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AI, Robotics, and the Machine Economy

Creative Problem-Solving in the Inevitable Machine Economy

April 7, 2021

By 2030, according to PwC, 70% of the growth of global GDP will come from the combination of AI, automation, and robotics.

PwC has argued that, by 2030, 70% of the growth of global GDP will come from the combination of AI, automation, and robotics. But the world's population is not going to grow by 70% by 2030; the current estimates are from 7.5 billion to 8.5 billion people, which is a 13% growth rate. Furthermore, the population of those aged 60 years or over — what we could call the retired workforce – is projected to grow by 56%, from 901 million to more than 1.4 billion. So more of us will be retired, fewer of us (proportionally) will be working, and yet we expect growth to be sustained or improved.

The world we live in is also inherently more complex, environmentally threatened, and in need of mass creative forces to push the transformations necessary to drive equitable changes. We need more humans to focus on these challenges, not fewer of us.

Data Will Be Crucial

That Gordian knot is not one that we can avoid or try to gently untangle. The vast array of data, the capacity of systems to deliver constant feedback, and decision-making on the edge combine to make a very different world. The question is, how to take advantage of this development?

The volume of data in the new world goes far beyond the human capabilities that exist now. The zettabytes of data will grow exponentially larger every thousand or so days as we increasingly rely on data-centric decision-making to drive near-instant decisions. Consider this simple example: Amazon now gives you multiple choices for delivery. Not just in terms of cost and speed but also in bundling, pickups, and types of environmental packaging. This simple modification — to increase choices based on demographic shifts in attitudes about the trade-off of urgent need compared to potential environmental harm — is something that just a few years ago would have been a complex issue involving logistics, every supplier on Amazon, and the company's complete infrastructure. Yet we now look at those simple new choices at the shipping stage as part of the Amazon experience that we all expect in everything we do, as consumers and as business leaders.

Seamless, intelligent, connected, sensing, and predictive. We need our systems at every level to incorporate these same capabilities, plus the ability to act, learn, and adjust. It's this combination of activities that will drive the machine economy to become far more than just the automation of mundane tasks but to actually create business value.

The Brookings Institution has argued that global changes in productivity are a mere slice of what they once were. For companies, industries, and whole economies to grow we will need to embrace the idea of machines being a vital part of the new intelligent systems world. More humans doing more work is not the solution to future growth imperatives.

A Moment of Transition

The machine economy requires a different set of thinking variables than before to be successful. If a company wants to ride the engine of economic growth that will drive success over the next 10 years or more, it will not succeed by doing the same things as before and expecting to get different results.

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We are at a moment of significant transformation as a global economy. The capacity to innovate, differentiate, and deliver is less and less dependent on geography or history and more and more dependent on the ability to bring tools, devices, and environments (such as the edge) into constantly connected interplay to create value.

The machine economy will create new value chains for companies, if they are able to recognize in near real time how they can deliver the level of rapid, highly customized experiences that customers in business-to-business environments will expect. It might not be as simple as Amazon's shift to packaging choices for consumers, but it presents the right engine for economic growth that connects the enormous amount of data being created with the increasing desire of businesses to deliver new forms of economic value and customer experience.

When we run out of human resources but still want to deliver extraordinary growth levels in a world of data centricity, a machine economy offers a new way to approach the issue. It could free up billions of human hours that can be used to change the world. Welcome to the inevitable machine economy; it should be compelling.

Robotics and Intelligent Systems

April 7, 2021

Up the Down Staircase

Imagine trying to drive your bicycle up a set of stairs — dozens of stairs. Unless you are a gifted cyclist, you likely imagined falling down and injuring yourself. Wheels work very well in a highly structured environment — on a flat surface, with defined sides for the surface you travel on and infrequent traffic intersecting your direction of travel.

Folks in mechatronics would say that the environment for wheeled robots would need to be relatively controlled with similar kinds of constraints. Within these constraints, wheels are great — they're efficient, they operate smoothly, and we have a supply chain of parts for wheels, axels, and steering components.

But stairs are less controlled environments and present a multitude of complexities. Stairs may have different heights within a single building. They may change direction; they can turn 180 degrees; and they can be straight, elliptical, or irregular. Stairs require more spatial intelligence and kinesthetic intelligence to navigate than flat surfaces do. They pose a host of challenges for mechatronics engineers to overcome as they evolve robots for a world that goes beyond flat, defined surfaces.

Compared to the Unimate #001, modern appliance mechatronics perform miracles in controlled environments — for example, your laundry room.

Flat Land

In 1961, Joseph Engelberger installed his Unimate #001 robotics arm at General Motors in Trenton, New Jersey, to pick up die-cast components. There were no sensors on this device. It had drum memory of almost 64K. It could only be safely used in highly controlled and repetitive open loop environments. ("Open loop" refers to the notion that the device is not sensing, as sensing constitutes "closing the loop.") The Unimate could only perform the one task it was programmed for.

Compared to the Unimate #001, modern appliance mechatronics perform miracles in controlled environments — for example, your laundry room. Modern clothes washers sense much more than the Unimate #001 did. They weigh the wash with strain gauges or by measuring the energy required to move the load. Dryers can sense how much moisture is evaporating off your clothes while they dry, so that they know when to stop.

New sensors (e.g., strain gauges, accelerometers, energy meters, and moisture and temperature gauges) and their processors interpret data to enable our everyday appliance to close the loop. These edge digital sensors and processors can be reliable, cost-efficient, and still accurate, because they sample the data infrequently, take small data samples, and use simple algorithms.

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High-Dimensional Space

We live in highly variable environments: different stair heights and room shapes, smooth floors and carpeted floors, wet and dry, noisy and quiet. For autonomous robotic machines to move within our environment productively, they will need the kinesthetic intelligence of a four-legged animal. To put this in context, the first vertebrate (the hagfish) is estimated to have arrived 450 million years ago. The first four-legged vertebrate was the tetrapod, 390 million years ago — so it took about 60 million years of evolution to navigate the unstructured environment of primordial earth.

Just 62 years after the introduction of the Unimate #001, Boston Dynamics created a $74,000 four-legged robot named Spot that can repetitively follow a path in a known environment. Because it is mobile, it requires enough onboard processing to remember the path and the instructions for walking (remember that Wi-Fi is not always accessible). This paragon of modern technology does not yet have the kinesthetic intelligence (KI) that the tetrapod had. It can flounder on smooth surfaces, has trouble navigating around moving objects, and still struggles a bit on stairs.

To be a valuable partner to a human worker, robots must either exceed the performance in narrow tasks, become much cheaper to own and operate, or be able to take on dangerous work that risks human lives.

How Much Is That Doggy in the Window?

U.S. organizations spend $300 billion annually on wages for 9.1 million employees working in production-focused occupations — i.e., doing tasks that require repetitive heavy lifting, moving equipment and materials (Bureau of Labor Statistics, 2016). The fully burdened cost to a company for each of these people is about $40,000–$60,000 a year.

Spot, at over $150,000 per year fully burdened, can only complete the most routine of tasks. And he's always at risk of being dognapped or damaged. To be a valuable partner to a human worker, robots must either exceed the performance in narrow tasks, become much cheaper to own and operate, or be able take on dangerous work that risks human lives. For example, think of a robot–human team in which the human teleoperates a robot in a dirty, dark, or dangerous environment, like the Sarcos Guardian S inspecting an asbestos plant.

Continued Intelligent Agent Evolution

Organisms evolve largely due to conditions, stimuli, and the ability to adapt and thrive in a given environment. In the case of robotics, the key factors for evolutionary success include environmental need, technology advancement, and system design that is commercially viable.

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The economics of hardware and mechatronic businesses do not improve at the rate of software or silicon. However, edge compute performance does bring decreases in costs and increases in parallelism, while deep learning brings increases in efficiency and more capabilities into the reach of commercial scenarios. As sensing AI and machine learning (e.g., object detection, pose detection, motion object identification) become commodities, these may drive interest in achieving economies of scale in mechatronics. Perhaps they will even inspire open source hardware mechatronics platforms.

Successful solutions will compete at price and performance points that that are viable in commercial markets such as retail, delivery, and security. As connectivity and edge computing evolve, the ability to connect these robots into larger networks will allow us to close business loops and achieve digital transformation.

Each cycle of automation in these markets reveals a cycle of evolution from research projects into financially successful businesses — and each epoch is marked by increasingly kinesthetically intelligent agents. Even those of us who were intrigued by coding in its infancy can now be more excited than ever about how technology can make our lives more productive, safer, and more fulfilling.

A Critical Piece of the Machine Economy: The People

May 1, 2021

Seventy percent of GDP growth in the global economy between now and 2030 will be driven by machines, according to PwC. This is a near $7 trillion dollar contribution to U.S. GDP, based on the combined production of artificial intelligence, machine learning, robotics, and embedded devices. This is the rise of a new machine economy.

For those not familiar with the machine economy, it's where smart, connected, autonomous, and economically independent machines or devices carry out the necessary activities of production, distribution, and operations with little or no human intervention. The development of this economy makes Industry 4.0 a reality.

70% of GDP growth in the global economy between now and 2030 will be driven by the machines, according to PwC.

Visionary leaders will implement new technologies and combine them with capital investments in ways that help them grow, expand, diversify, and improve lives. These machine economy leaders will operate in a new intelligent systems world, where thousands of companies will drive new economic models globally. Sounds good so far. But all of that autonomous machinery isn't going to build and operate itself.

Not Enough People to Do the Work

While most people would agree that manufacturing is an important part of our economy, they aren't recommending that their children pursue that line of work. It's expected that 4.6 million manufacturing jobs created between now and 2028 will go unfilled. Key drivers for this trend include the fact that 10,000 baby boomers retire every day, without people to replace them. The workforce is quickly losing the second-largest age group, and millennials (the largest group) have so far not been widely attracted to manufacturing jobs. Instead, they tend to be drawn toward technology, engineering, finance. The underlying issue may be one of perception, as the future of manufacturing will in fact include a much higher degree of technology, engineering, and finance in order to function.

Different Skills Are Needed

Manufacturing jobs are changing. The number of purely manual, repetitive tasks is shrinking as technology advances to handle those jobs with robots and automation. Fifty percent of manufacturers have already adopted some form of automation, and now they need people with critical

thinking, programming, and digital skills. Tomorrow's jobs have titles such as Digital Twin Engineer, Robot Teaming Coordinator, Drone Data Coordinator, Smart Scheduler, Factory Manager, Safety Supervisor, and so on.

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Humans Can't Keep Pace with Productivity Shifts

An unskilled position can be filled relatively quickly, as the prerequisite qualifications are limited. It typically takes months to fill a skilled position, and much longer for an individual to develop the requisite skills before they even think to apply. One alternative is to lower requirements in terms of education, skill, and experience, but then companies must absorb the entire expense of training the new hires. Meanwhile, there is increased pressure to utilize existing teams' times and skills as much as possible, which can lead to burnout. This makes for a fragile cycle that needs to be fortified by a workforce that has the training they need, when and where they need it.

To thrive in the machine economy, we need to invest significantly in people. Focusing purely on infrastructure might lead to short-term and perhaps mid-term profits, but ultimately it is not sustainable, and everyone loses. One can't simply say, "We couldn't fill the positions" while there are people who need work.

Level up Our Workforce

The human capacity to learn is basically limitless when individuals are motivated and have access to something to learn. There are several ways to tap into that capacity.

First, we need to capture the knowledge and experience of the employees we have, so that their relevant skills can be passed on to the next wave of workers.

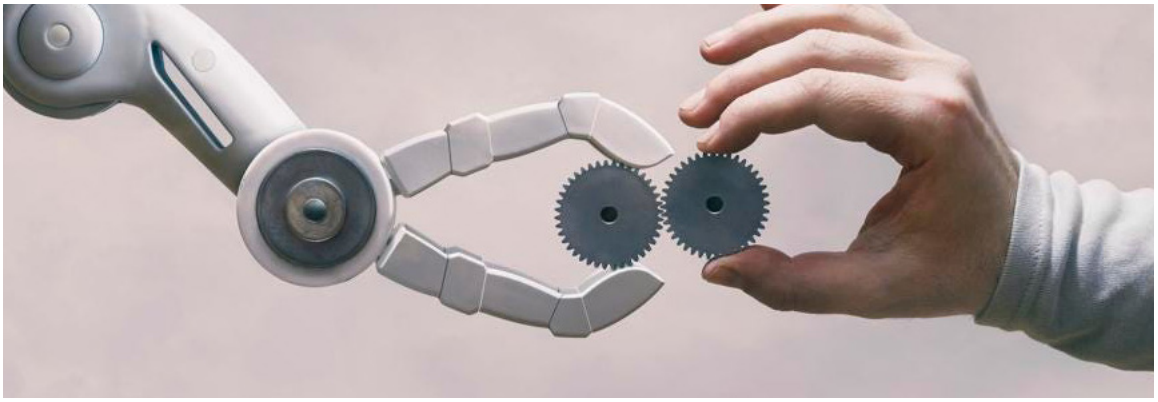
We also need to ensure that relevant training is available to people at every level of the company, so new people get up to speed and tenured employees don't get left behind. While some technologies need to be learned on the job, there is a level of foundational skill needed to understand in the machine economy, in addition to the technical and vocational skills required within a given field. An investment in, and possibly partnerships with, local schools could be a wise move for many companies.

Lastly, while college is a great path for many people, it's not the only form of higher education. Investments in vocational training and apprenticeship programs will be critical for our society to thrive in the machine economy.

Just as workers need to rethink and develop new skills, employers need to rethink and develop new ways of nurturing and attracting talent. To fully realize the promise of the machine economy, it is incumbent upon us to ensure people have access to the training and the tools they need in order to not only be successful but thrive. After all, what's the point of all this technology if it doesn't make life better for everyone?

AI, Robotics, and Ethics

March 1, 2022



The importance of ethics in artificial intelligence stems from the power of what can be accomplished with artificial intelligence (AI), especially when combined with machines: self-driving cars, robots coworking with humans in factories, remote surgery robots that allow doctors to operate on a patient across the globe, intelligent software systems that help pilots navigate, and so forth.

However, like earlier transformative technologies, AI is new and so arouses a fair amount of skepticism and even fear, giving birth to regulations and policies constraining the scope of its application. What's being done to promote the ethical application of one of today's most empowering technologies?

At Wind River®, we have more than 40 years of experience with delivering mission-critical, intelligent systems with the highest safety standards. We believe that it is our responsibility to constantly advance our technologies, while at the same time advancing the positive impact that such technologies will have on the world. In the case of AI-driven robotics, it means that we are proactive about delivering systems that meet — or exceed — the trust, transparency, fairness, and privacy that people expect from AI.

Where AI Intersects with Robotics

Auto manufacturers, according to McKinsey, will see 20% or more of their profits coming from software customization services in the vehicle.

Today's industrial robots are transforming radically, metamorphizing from rote machines limited to repetitive motions into cognitive collaborators.

AI applications ingest massive amounts of data gathered by robot-based sensors that require real-time interpretation and actions. That's why this data is not sent off to the cloud for processing but is analyzed at the edge — in the machine or close to it. Such edge computing gives machines real-time awareness and enables robots to act on decisions much faster than humans, who need to trust those decisions.

As robots become mobile, collaborative, edge resident, and connected to other IoT devices, the data-rich ecosystem opens itself to multiple access points for would-be hackers. Companies may find themselves vulnerable to malware, cyber ransom, production delays, and business disruption. What's more, cyberattacks targeting highly nimble, powerful robotic systems also come with some serious physical safety concerns.

What Are the Risks, Ethical and Otherwise?

The debate surrounding AI's potentially problematic aspects is ongoing, currently centered on a few key issues:

- **Privacy and security:** AI runs on data, so cybersecurity vulnerabilities may pose a threat to individuals and organizations.
- **Opacity/transparency:** How is the data processed and how is it used? The patterns recognized by AI systems may not be truly representative of the analytical decision output. Which data is selected and how is its quality ascertained? There needs to be transparency, community engagement, and algorithmic accountability built into the system to ensure confidence that AI-derived output meets ethical standards and is fair and free of bias.
- **Biases:** Bias can impact algorithms in a number of ways, especially via the use of flawed data or data sets unrelated to the issue at hand (statistical bias).

A proposed framework to ensure ethical AI implementation is coming into focus. The framework is built around four key pillars: trust, transparency, fairness, and privacy.

Regulating Ethical Considerations

As with other disruptive technologies that preceded AI, the formulation of laws and regulations to manage this area is playing catch-up. There are significant technical mechanisms to detect and remove bias from AI systems, but they are in early stages. And technological fixes have their limits in that they need to develop a mathematical notion of fairness, which is hard to come by.

Though little actual policy has been produced, some notable beginnings have been made. A 2019 EU policy document from the Center for Data Innovation posited that "trustworthy AI" should be lawful, ethical, and technically resilient, and it spelled out the requirements for meeting those objectives, including human oversight, technical robustness, privacy and data governance, transparency, fairness, and accountability. This has since been codified into proposed legislation.

Also, in the fall of 2021, top science advisers to President Joe Biden started calling for a new "bill of rights" to guard against powerful emerging artificial intelligence technology, according to the Associated Press.

AI can deliver substantial benefits to companies that successfully leverage its power, but if implemented without ethical safeguards, it can also damage a company's reputation and future performance. Developing standards or drafting legislation is not easily accomplished. That's because AI covers a broad, amorphous territory, everything from battlefield robots to self-driving cars to legal assistants used for reviewing contracts. Indeed, just about anything related to machine learning and data science is now considered a form of AI.

A Framework for Evaluating AI Applications

Going forward, and augmenting work that has come before, a proposed framework to ensure ethical implementation is coming into focus. The framework is built around four key pillars: trust, transparency, fairness, and privacy.

- **Trust:** The trustworthiness of an AI application is the threshold issue that needs affirmation. People need to know that the AI applications they are using come from a reliable source and have been developed with responsible and credible oversight.
- **Transparency:** Demonstrating transparency about how AI is being used and explaining its benefits in specific use case scenarios will go a long way toward reducing concerns and expanding adoption.
- **Fairness:** Developers need to show that AI is being deployed in a fair and impartial way. Since AI in its elemental state lacks the ability to apply judgment, and instead focuses primarily on pattern recognition, the algorithms need to be fine-tuned to remove biases. Processes should also be introduced to avoid the biases that we, as humans, inevitably bring to the table.
- **Privacy:** It's critical that developers consider how using AI may impact any personally identifiable information (PII) embedded in the data being processed. While AI processing does remove some privacy concerns, in that it bypasses human interaction with sensitive data, it raises others, such as the scope of information use, where it is stored, and who can access it.

A Proactive Approach to Ethical AI

AI is here to stay, and efforts to tame its power will surely follow. Thinking proactively, industry players in the technology community are trying to ensure that their applications follow the frameworks that call for AI to be trustworthy, transparent, and fair and to ensure privacy. One way to establish this assurance is to use a peer review system. In such a scenario, AI developers would submit their use cases for review by an AI community akin to the open source environments that have come before.

Another way to add clarity to AI applications is to develop an ad hoc organization that would allow companies to commit their projects and applications to a central AI registry. Unlike a formal standards body that is typically dominated by large organizations that control the agenda, the registry would be a self-reporting body for gathering feedback, advice, and affirmation.

Finally, one of the best ways to support ethical deployment of AI applications could be to embed ethics within computer science curricula from the very start.

The Second Wave of Digital Transformation

August 4, 2022

We are fast entering the era of the new intelligent machine economy. This is when machines are joining — not replacing — humans as intelligent participants in the software-defined and AI-driven environment.

For this era to flourish, we need to embark on the second wave of digital transformation. Many companies dove into the first wave when they invested in information technology. This first wave gave us the ability to search, shop, or perform business transactions using a browser or mobile device; it gave us access to collaboration tools that make remote work possible; and it enabled many other capabilities and functions. The first wave focused mostly on humans using technology to find information, connect with other humans, and do things more efficiently.

The second wave does something similar, but for machines. The second wave of digital transformation is the migration of the cloud-native and AI-driven application investments from the IT (information technology) world to the OT (operational technology) world. It applies to devices and machines in the physical world around us across multiple industries, including aerospace, automotive, defense, industrial, medical, and telecommunications.

The global industrial automation market is expected to reach USD326.14 billion by 2027 after a decade of CAGR at 8.9%, according to Fortune Business Insights.

After years of digital transformation associated with IT, focusing mostly on information flow in the digital ether, the focus has now turned to machines. McKinsey's Digital Manufacturing Global Expert survey reveals that most manufacturing companies (68%) consider connectivity, intelligence, and flexible automation to be their top priorities. The global industrial automation market is expected to reach USD326.14 billion by 2027 after a decade of CAGR at 8.9%, according to Fortune Business Insights.

Unlocking the Opportunities at the Intelligent Edge

Stand-alone devices — say, a heart monitor whose only function is to measure the heart rate without doing much else about it — are hardly state-of-the-art anymore. Today's devices gather and analyze data, communicate with one another, and act on the data.

A heart monitoring device can transmit a patient's data to a doctor or set off an alarm in real time when the results can be dangerous to health. Autonomous cars can talk to the road infrastructure in real time, sense other cars in the vicinity in real time, and act on this information by initiating accident avoidance. AI-driven power grids can automatically manage production and use across multiple, distributed energy resources.

To execute such connected applications, networks are heavily dependent on cloud computing, analytics, AI and machine learning, and 5G as a connectivity mechanism to enable them. And all of these new opportunities are at the intelligent edge.

Edge is a location, not a thing. It defines where the data sensing and processing happens. The edge of the network is at the farthest distance from the central data center, and within or very close to the relevant machines, such as cars, planes, or robots. Some of the processing of the data from the sensors embedded in machines needs to be in situ, at the edge — making it the intelligent edge — while other data can be pushed to the cloud for further processing.

Multiple machines and devices operating at the intelligent edge share information with one another and their data centers, forming digital loops. Such digital feedback loops are tied to Big Data systems to perform functions such as predictive outage avoidance, event correlation for operational faults across subsystems, software automation and oversight, and event detection and resolution.

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How to Develop for the New Intelligent Machine Economy

The complexity of intelligent systems means that embedded systems companies need to transform digitally to enable the development, deployment, operation, and servicing of such systems. To this end, they need to adopt tools, capabilities, and processes, including:

- **Cloud-native and edge-friendly development techniques and tools:** These are necessary to keep pace with time-to-market, system complexity, and resource shortages. As we move toward edge computing, cloud hosting platforms will need to adapt to become edge friendly or be revamped to be edge native. An edge-native platform will retain the capabilities of a cloud platform but will also address the new demands created by the edge. Wind River Studio provides a cloud- and edge-native platform for the development, deployment, operation, and servicing of mission-critical intelligent systems. Such cloud-native tools also allow developers to work anywhere, anytime, or anyhow (office, remote, PC, tablet, etc.).
- **High-level software automation:** With intelligent systems, deployment at the edge often means that payloads need to be deployed at scale over hundreds or potentially tens of thousands of geographical locations. It is not possible to deploy, operate, or service applications at the edge manually. Automation is key to reducing costs for deployed distributed-edge systems, for both device and cloud infrastructure installations.
- **DevOps is the key component to assemble complex embedded software at the intelligent edge:** Traditionally, embedded software developers wrote code. When they were finished, and the application had been through quality assurance, the embedded Ops (production) installed the systems. This sequential waterfall model is too slow for the intelligent edge, which is operating in real time. Under the DevOps banner, different embedded developer personas (e.g., platform developers, application developers, operators, data scientists, or DevOps engineers) work in scrums. They push out new software releases as part of agile teams and do it so rapidly that it's better to integrate the Ops and QA (quality assurance, testing) teams into the development process.
- **Continuous integration and continuous development tools:** CI and CD tools take new code and place it into a production application without stopping any functions from running. The pace of code release has grown so quickly — and many of the code releases are just small updates to existing applications — that it no longer makes sense to do a big uninstall/reinstall routine every day. To solve this problem, continuous integration (CI) and continuous deployment (CD) of code was introduced. This is like the old "change the tire while the car is moving" concept. But here, it works.
- **Certification:** Software development for critical infrastructure has moved to cloud-based, agile DevOps principles. However, the safety certification of such software still follows old-fashioned development paradigms and involves expensive manual work, which causes high costs per line of code, hinders fast adoption of new features, and slows down deployment and operation.

To decrease certification costs and achieve faster time-to-market, a novel certification approach is required. This new approach needs to be aligned with a modern DevSecOps methodology and integrated into the continuous delivery process using automation, AI/ML, and digital feedback loops. Releasing new code continuously creates security risk exposure, so development teams started to add security practices to the software development and delivery process to protect valuable assets during startup, runtime, and at rest. The result is a workflow known as DevSecOps.

The new intelligent machine economy promises not only to unlock economic value but also to make our lives easier and safer. To succeed, embedded systems companies must undergo the second wave of digital transformation and use modern, digital edge-friendly platforms, tools, and processes.

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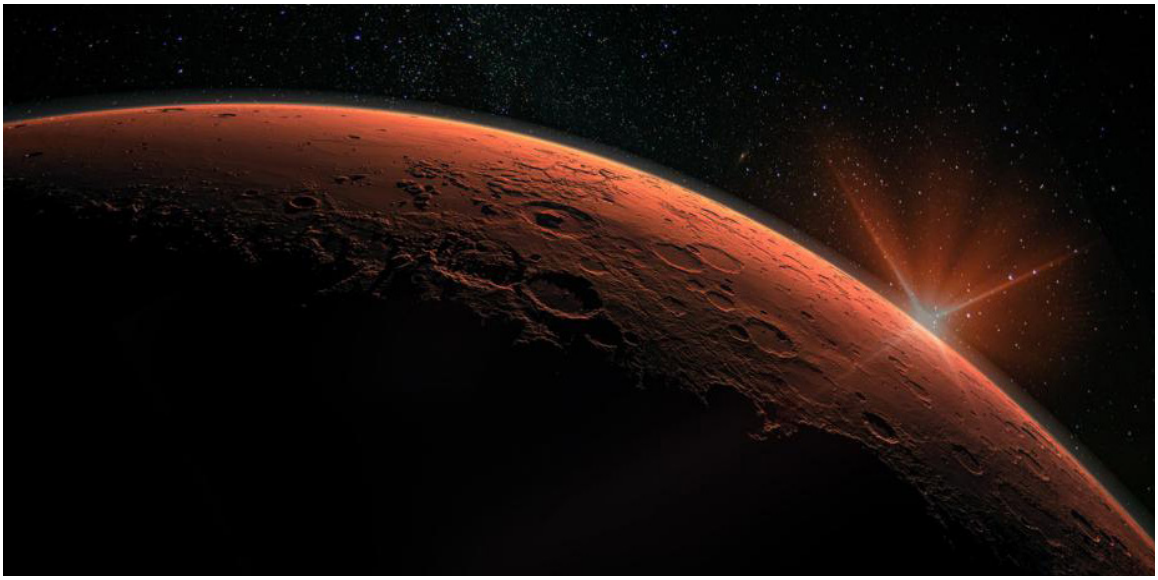
A&D

Perseverance on Mars

February 26, 2021



"We choose to go to the moon," said President John. F. Kennedy on September 12, 1962. "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard."

Inspiring as the speech was, the idea of a machine on Mars, thinking for itself and making a range of intelligent decisions in real time, was likely not part of Kennedy's thinking when he gave his address some 60 years ago.

In February 2021, the Perseverance rover successfully landed on Mars. Perseverance is the ultimate intelligent system. It's 130 million miles from Earth, so it has to make decisions and actions mostly on its own. The rover must use its "brains" to take photos and determine the best landing site based on image comparisons.

The idea of intelligent systems may in itself sound logical, but the conditions necessary for these systems to exist, thrive, and react to somewhat unexpected scenarios is what makes Perseverance the perfect example of an intelligent system.

This is not just an engineering feat but a dynamic system designed to monitor and choose its landing site on entry, calculating, assessing, and adjusting to a better spot. It has a second, internal robotic arm that acts as a "lab assistant" to the external arm, managing the samples and supplying the external arm with new sample tubes. It even has a remote helicopter.

According to NASA, "Perseverance generates constant engineering, housekeeping, and analysis telemetry; and periodic event reports that are stored for eventual transmission once the flight team requests the information from the rover."

The idea of intelligent systems may sound logical, but the characteristics that enable these systems to exist, thrive, and react to expected and unexpected scenarios is what makes Perseverance the perfect example of an intelligent system: It is computing, predicting, sensing, and eventually connecting from the very farthest edges back to Earth.

All these technologies working together are mission critical in nature. And being 130 million miles away makes it impossible to fix anything that breaks.

Our View into New Worlds

Perseverance is part of an even bigger story. It has a mission to look for signs of ancient microbial life. But it also has a mission to collect and seal samples of Martian rock and soil to return to Earth, as part of the MOXIE experiment that will determine whether oxygen can be produced from raw materials on Mars — perhaps paving the way for future human exploration.

Perseverance will do immensely more work over much wider distances, using its own intelligent systems. It might take more than 11 minutes for signals to travel the millions of miles from Mars to Earth, so Perseverance has to compute, sense, predict, and work intelligently on its own. That shows us the power intelligent systems can hold, as they explore new worlds and ideas.

Not Just on Mars

This is the fourth Rover (intelligent system) on Mars running with Wind River technology. Curiosity had been on Mars for over 3,000 sols (eight years).

Perseverance's gathering and transmission of scientific data can inspire the new machine economy here on Earth, focused on near-latency-free digital feedback loops to deliver value. Machines will help us see the possibilities of what is out there. Not just on Mars but inside cars and manufacturing plants; on farms with cobots; and in energy exploration and management in truck trains, on ships, and in the air. Not just way outside our atmosphere.

Perseverance is a wonderful example of machines working in mission-critical ways in demanding environments to deliver knowledge to advance mankind. And this is the fourth rover (intelligent system) on Mars running with Wind River technology. Curiosity had already been on Mars for eight years before Perseverance arrived.

Congratulations, NASA, well done. We look forward to the science to come, which will amplify the sense of possibility in the intelligent systems–first world we will all benefit from. Kennedy may not have fully imagined the power that NASA would bring to the world with its application and development of groundbreaking technologies. But Perseverance could be as inspirational to the idea of an intelligent systems world as NASA was to the idea of humankind leaving Earth's orbit.

Accelerate Change or Lose

July 1, 2021

We have the military to thank for some of the most important inventions that we use every day to increase productivity and innovation. One of those contributions can — and should — play a much bigger role than it does today, if we actually harness its potential.

During World War II, the mobile phone was invented when handheld phones came into use on the battlefield. In 1969, the first node-to-node communication went over ARPANET (Advanced Research Projects Agency Network), marking the birth of the internet. Between these events came another military invention with the potential to massively improve productivity and innovation, but until recently it lacked a key enabling technology needed for its full utilization. We're talking about the OODA loop, supported by today's intelligent edge.

In the mid-1950s, Colonel John Boyd coined the term OODA loop to define the process humans go through continuously every day as we react to stimuli. Boyd systematically detailed the steps in a way that lets us better experience the OODA loop on a much more conscious level, thereby enabling us to get better at it and achieve better results.

The OODA Loop

In the mid-1950s, Colonel John Boyd coined the term *OODA loop* to define the process humans go through continuously every day as we react to stimuli. Boyd systematically detailed the steps in a way that lets us better experience the OODA loop on a much more conscious level, thereby enabling us to get better at it and achieve better results.

The simple version of the OODA loop is: observe, orient, decide, act. When confronted with a situation, most of us instinctively go through the OODA loop, but perhaps not quickly or effectively. Often we are unable to process the information given, are rooted in a particular perspective, and/or are unwilling to change in a way that is needed — all of which can have dire consequences, depending on the situation.

This is why the *orient* piece is so critical. We often observe, decide, and act without orienting. Boyd discussed orientation in terms of the process of destructive deduction and creative induction. This refers to the ability to break our mental concepts into discrete parts, then recombine them as new concepts that better align with what is actually happening around us. Boyd illustrated this concept by asking what you might do with a tank's caterpillar treads, skis, the outboard motor of a boat, and the handlebars of a bike. Individually, they aren't of much use. But when put together in the right way, they form a snowmobile, which can be incredibly useful in snowy terrain. When you put the right pieces together to form a functional mental model, you are building a metaphorical snowmobile.

Accelerate Change or Lose

Air Force Chief of Staff General Charles Q. Brown published a set of action orders that center around the idea "accelerate change or lose" as a strategy for enabling change. Brown's report begins by observing that the idea "recognizes that we live in a world that is driven by rapidly changing technology and an environment that includes aggressive and capable global competitors. Therefore, if our nation's military is to remain the best in the world, we need to do our part to challenge the status quo and make necessary changes in our Air Force today so we are ready for tomorrow. For example, we cannot assume air dominance is guaranteed, and we need to recognize [that] good enough today will cause us to fail tomorrow."

Does any of this sound familiar? If not, replace "nation's military" with your company or regional industry and "Air Force" with "workforce and processes." Suddenly this statement applies to just about any business situation.

Bridging the Gap

Air Force Chief of Staff General Charles Q. Brown published a set of action orders that center around the idea "accelerate change or lose" as a strategy for enabling change.

Part of what the military is trying to solve is the information processing and communication gap between leadership and the boots on the ground. Often the leadership has the vision and/or buy-in regarding what needs to be done on a strategic level. The troops do what it takes to get it done because they are well trained and capable (and in some cases because it is a survival imperative). What doesn't always work as effectively is the coordination within middle management. As a result, those troops tend to work in silos, which usually leads to suboptimal solutions and limited cross-pollination of best practices.

Interestingly, the missing piece typically isn't lack of data. Often there is too much data that's either sitting in an information silo or is too cumbersome to be useful for decision-making. Again: Does this sound familiar?

This is where the OODA loop and the intelligent edge (or "tactical edge," as it is sometimes referred to in the military) comes in. Moving to a cloud-native infrastructure with more processing at the edge enables the military to be much more efficient, because that data can be parsed and analyzed near the source for rapid decision-making, as well as in the cloud for longer-term trend analysis.

Time to Rethink

When you introduce the ability to orchestrate workloads at the edge, you enable capabilities that were previously inconceivable. But it requires some imagination and reorienting.

It's a tanker, it's a transport, it's a … real-time node in a network?

Let's look at aerial refueling. The first generation of refueling tankers had the sole mission of refueling other planes. However, the military quickly realized that they could often carry troops and equipment as well, and the multi-mission tanker transport was born. Looking forward, what if a tanker transport could also function as an airborne data center that became a real-time network connection node? By putting a "cloud in the clouds" with subclouds on smaller manned and unmanned aircraft, you introduce the ability to connect, compute, and command systems at the edge as events are happening, where they are happening. This in turn enables the ability to turbocharge your OODA loop. And if the tanker gets taken out, a distributed cloud network has built-in resiliency with the ability to shift workloads and self-heal.

Whether with the tactical edge or the intelligent edge, the OODA loop has the power to help us gather data more effectively (observe); process that data using a variety of models, predictive analytics, and artificial intelligence (orient); visualize and recommend courses of action (decide); and ultimately give the operator the necessary tools to proceed in the most optimal way (act). Then the loop automatically begins all over again.

This could be incredibly effective in helping our military accelerate its transformation — and in enabling our businesses to achieve their directives and desired outcomes.

An Intelligent Systems Imperative for U.S. Defense

December 6, 2021

Nicolas Chaillan

Nicolas Chaillan was the first chief software officer (CSO) for the U.S. Air Force. He is one of the key players in the drive toward raising awareness of the threat and creating a more digital way, such as the U.S. Air Force's Platform One, that will counter the illusion of permanence created by military tradition.

The U.S. has the largest defense investment infrastructure in the world. It's a highly complex, intelligent, and agile environment driven by a historical and global imperative to protect democracy.

Concepts such as OODA (observe, orient, decide, act) and VUCA (volatile, uncertain, complex, ambiguous) have reshaped the combat mindset in transformative ways. In a world where "digital everything" increasingly dominates thinking, the need to transform behaviors to focus digitally is as important as — perhaps more important than — simply transforming in the physical world. Cyberthreats, the use of AI, cloud re-tasking, and cross-functional real-time collaboration are all part of the new intelligent systems world.

The situation is complex, global in nature, and increasingly seen as the Gordian knot at the center of global defense for the two most advanced military nations on the planet. One (China) has aggressively grasped that today's world centers around digital dominance. The other (the U.S.) has yet to fully grasp the magnitude of the changes, threats, and opportunities that AI and related concepts represent in this new intelligent-systems world.

We interviewed one of the key players in the drive toward raising awareness of the threat and creating a more digital way, such as the U.S. Air Force's Platform One, that will counter the illusion of permanence created by military tradition. Nicolas Chaillan was the first chief software officer (CSO) for the U.S. Air Force. His ideas about DevSecOps and a single, integrated delivery system have been thoroughly documented elsewhere (Nextgov.com). This interview takes the discussion into the multidimensional nature of change the U.S. faces in a cyberthreat-led world where AI and automation drive consistent competitive advantages.

Why, at this moment, are we moving away from hardware-only to intelligent systems defense?

Nicolas Chaillan: There is a tendency for large institutions to ignore the obvious, until someone doesn't just raise a flag but raises lots of flags and says, "Hold it, something's wrong here!" I think you have an interesting fulcrum of software for that new digital warfare space that's inevitable, which we seem to be ignoring in this country.

I think the future is going to be very different from what we've been preparing for. I think the U.S. government has been investing massively in hardware innovations and very little in software, cyber offense, cyber defense, and artificial intelligence. You see the U.S. government spending a lot

of money on fifth-generation fighters and war-fighting capabilities that are, quite honestly, probably now seen as old ways of fighting wars. I think you might realize pretty quickly that the next wars will be fought through a lot of ruthless automation, based on the ability to continuously update and deliver software and react to offense and defense issues.

You're going to see, for example, the rise of AI hackers — robots that will be used to get into U.S. systems. You're going to see AI used to make better, faster decisions and be able to compound information and gather more intelligence. (You see it with the adoption of TikTok, which is effectively just that.) I think that's going to be a very interesting and game-changing look at what we're going to be fighting in the next 20 years.

So there's a conflict in trying to fight the next war using the mechanisms of the old war. Why do we struggle to migrate to this new software-driven, AI, autonomous, highly agile environment versus relying on the traditional large blocks of pure hardware?

Chaillan: Just as Silicon Valley is a bubble, you also see a bubble of talent in the DOD (Department of Defense). What you see is people who are not coming from different backgrounds. Then, even when they leave the government, they end up working for some of the defense industrial base companies that are also part of the bubble. We don't invest in our people and we don't proactively drive continuous learning for better understanding of the importance of software, which is not just a "nice to have" but a core new competency.

"We need to find a way to bring talent into the government from industries that are outside of the traditional duty bubble. The other piece is investing in our people. We need to empower and then get out of the way of the talented people in our military."

We are starting to see a lot of near-real-time software innovations, such as what SpaceX is able to do, including updating software the day before the launch of a rocket. And they can reuse rockets, which is the de facto standard for any kind of new innovation. Today no company would try to build a launching capability that doesn't reuse rockets — that was not the case even five years ago.

How do we break that Gordian knot? Because at some point, doing the same thing and trying to get different results is not likely to succeed.

Chaillan: We need to find a way to bring talent into the government from industries that are outside of the traditional duty bubble. The other piece is investing in our people. We need to empower and then get out of the way of the talented people in our military.

We also must invest in their continuous learning. I was giving an hour a day to my people at Platform One to learn. This was essential so they could not only catch up but then keep up with the crazy pace of [change]. We need to do better there, and continuous learning will be the difference between becoming stale or leading.

Why does the intelligent systems world (cloud, AI, edge) force the need for change?

Chaillan: We need to find a way to convince 150 leaders to work together across all parts of our defense environment. We need to break those silos. We need to stop the Army, Navy, and Air Force from building things in a vacuum. We have to deal with cloud and zero trust and DevSecOps and data fabric and AI/ML layers.

We have 58 networks with all-mission partners, including NATO and Five Eyes. And for them to communicate with each other is just impossible. You end up having to copy and burn DVDs between devices.

I see change happening with JADC2, the U.S. Joint All-Domain Command and Control program. JADC2 is effectively supposed to be an "Internet of Things" connecting all weapons into a central capability to get better insights and more effective capabilities, which defeats the point of creating silos. Now you're paying them to integrate stuff that was designed to be siloed, built in vacuums. They're addressing issues such as basic networking; anyone would agree that we could have a transport layer bringing best-of-breed fiber-optic commercial internet, plus 5G satellite, plus the cloud service provider backbone into a single mesh, with crypto on top to access different classification levels.

Why is the pace of adoption elsewhere of ideas such as AI and automation so concerning?

Chaillan: We will not be able to catch up to the velocity and pace of China's adoption of AI, because they have 1.5 billion people and access to data points that we don't have the luxury to get access to. Add to this the velocity of delivery of these capabilities in production, which compounds over time. AI is going to learn and add more data and more training, with better algorithms, getting stronger over time — compounding upon itself. At some point, you just physically cannot catch up.

You're going to see a lot of what we do today with humans being completely automated. Take imagery, for example — looking at satellite data and being able to understand what's going on, having AI continuously monitor what's going on and give us a better picture of and insight into what's happening. A human cannot physically keep up with all this imagery, zoom at the right place and do all the stuff we need to do. But AI could potentially do that seamlessly across dozens of capabilities, aggregating data.

You look at Tesla: They open sourced their patents, because they're moving so fast that by the time other companies even start using them, Tesla's going to be five miles ahead. We should be in the same situation.

An intelligent systems defense-oriented world has to synthesize the physical and digital worlds' best attributes — automation, AI/machine learning — to be able to react and re-task through the cloud.

How Intelligent Systems Will Transform the Business of Flying

February 8, 2022

Commercial aviation has traditionally followed the ups and downs of economic cycles. Then, overnight, the pandemic halted air traffic and disrupted operations, devastating the industry. Since then, the volatility in passenger demand, coupled with shortages of crews, has made it increasingly difficult for airlines to align their schedules and resources to match where and when customers want to fly.

62% of technology leaders say that their organizations are putting into place strategies to become intelligent systems companies.

The industry cannot predict the next unexpected demand upheaval, whether it turns out to be medical, geopolitical, or driven by forces of nature. But the recent struggles have driven home the point that the aviation sector needs to be better prepared to respond to sudden changes in market demand. That means becoming much better at ensuring that aircraft and crews are ready for passengers at the right time and in the right place and can operate the planes more efficiently.

The Business Case for Intelligent Systems

The business cycles in commercial aviation will continue to compress, creating a more urgent need for more operational efficiency. This can be achieved by empowering airlines with software-enabled intelligent systems to manage in real time which assets need to be where, and to operate those assets most efficiently.

Wind River research finds that 62% of technology leaders say that their organizations are putting into place strategies to become intelligent systems companies.

Today, many advanced technologies that could make commercial aviation more efficient and safer are being used or tested by the military. Wind River is at the forefront of software-enabled intelligent systems and delivers the highest safety standards for the space, military, and commercial sectors. It is well positioned to facilitate cross-pollination of technologies among these sectors.

Data as Fuel for More Efficient Aviation Operations

The winning commercial operators will be those that will digitally transform to use data as fuel for efficient operations. The future of airlines' operational efficiency is in the software-enabled intelligent system of systems, powered by artificial intelligence, 5G, and edge computing. Such a system is fueled by data collected from sensors on board the planes, at the airports, at the maintenance centers and distribution warehouses. Some of the data will be processed at the edge, close to where it originates, to allow real-time localized actions.

Becoming reliable and efficient boils down to how well an airline can leverage software capabilities to extract more value from the data and to make better-informed decisions faster than competitors. An integrated operations center powered by an intelligent system of systems will be able to tie all the relevant data involved in the functioning of commercial aviation — from people to aircraft resources to maintenance equipment, spare parts, and weather conditions — and proactively manage it for optimal performance.

For instance, by having airplanes with health-monitoring sensors that can predict when certain parts are going to fail, the intelligent operations center will proactively place spare parts and mechanics with the right skill sets, to preempt any breakdowns and service interruptions.

Another efficiency improvement will come when new software capabilities are patched onto the planes' systems over the air, without having to take the aircraft out of circulation to update the software. If you have a Tesla today, you get software updates in real time. In the future, software-enabled capabilities for aircraft will be able to do something similar, without compromising the safety and security that is so paramount to the industry.

Wind River Studio for Intelligent Systems

The more volatile business cycles that commercial aviation will face with increasing frequency, and the accelerated technology insertion pace required to remain competitive in the marketplace, will require greater flexibility in how software is not only developed but ultimately deployed and integrated into aircraft as well as into airline operations and maintenance centers.

Technologies such as artificial intelligence and machine learning will need to work transparently and easily with edge devices. And, because needs continuously evolve, devices will need to be easily adaptable, upgradable, and reprogrammable with new software via over-the-air updates throughout their lifecycle.

Wind River Studio is the first cloud-native platform for the development, deployment, operations, and servicing of mission-critical intelligent edge systems that require security, safety, and reliability. Studio has been architected to deliver digital scale across the full lifecycle through a single pane of glass to accelerate transformative business outcomes. It effectively reengineers development workflows into solution sets that reduce development costs and accelerate capabilities for building, testing, and deploying on the edge.

To learn more about Wind River Studio, visit www.windriver.com/studio.

Using Intelligent Technologies to Manage the Highways in the Sky

Part of today's aviation inefficiency is caused by the air traffic management system, which is based on predefined routes — the highways in the sky. The paths that planes follow are well defined and relatively limited, forcing the planes to stay within specific parameters, which are not always the most optimal for each flight. Intelligent technology will deconflict air traffic, open up the skies, and provide the most efficient and safest route for each individual airplane.

Intelligent technology will deconflict air traffic, open up the skies, and provide the most efficient and safest route for each individual airplane.

Such enhanced traffic management systems are being tested today, but they are not yet used in commercial aviation. There exist technologies that are part of the mission-critical systems on the planes and within the operations centers that can enable such air traffic management, but the industry is not there yet in terms of the regulatory environment. The aviation community has to really push the envelope in terms of testing to collect enough data so that the regulators can be convinced that the policies and procedures can be changed, allowing more efficient route planning and operations.

Solving the air traffic gridlocks will be crucial for entering an exciting subsegment within commercial aviation — advanced urban air mobility, moving people (air taxis) and cargo (air delivery of packages) in time-critical scenarios. This entire new subsegment will require an air traffic management system that will enable air vehicles to self-deconflict and adjust flight paths as needed, while following optimal routes for each individual air vehicle.

Automating the Cockpit and Reducing Pilots' Workload

Ultimately, intelligent systems — which can sense, infer, learn, act, and adapt — will unlock the new machine economy across all industries.

Greater automation of the cockpit, enabled by the software-led intelligent systems, can reduce the pilot workload. Commercial flights require at least two pilots, who share tasks such as controlling the aircraft itself, voicing communications with the air traffic management systems, and running the checklists, which have to be done prior to departure, throughout the flight, and upon landing. Some of these tasks, especially the voice communications and the checklists, can be automated and performed by intelligent systems with a higher degree of reliability than a human.

In time, the automation of the cockpit can lead to reducing the number of pilots per flight. There is a high degree of automation that is used and being tested by the military, which can perform missions without pilots. On the commercial side, more automated cockpits may one day lead to reducing the number of pilots, starting on freight flights carrying cargo. Advanced urban air mobility companies are likely to take a page from uncrewed military systems and deliver goods such as medicines to remote areas via autonomous vehicles.

Ultimately, intelligent systems – which can sense, infer, learn, act, and adapt – will unlock the new machine economy across all industries. The aerospace and defense sector, to include commercial aviation, is recognizing the significance of this trend and investing in new capabilities to accelerate its own digital transformation journey and deliver a better travel experience for all.

Wind River Technology Helps the the NASA James Webb Space Telescope

July 12, 2022

To make its observations, the James Webb Space Telescope must remain as reliable as sunrise, as steady as a rock, and colder than the ninth circle of Dante's Inferno.

In early June of 2022, NASA announced that the James Webb Space Telescope had taken a hit from a micrometeorite, a dust-sized speck of rock traveling at high speed, a couple of weeks earlier. In fact, micrometeorites come with the territory and were anticipated by the telescope's designers. This was the fifth — though the largest — strike endured by the Webb so far.

In space, not only can no one hear you scream — the nearest repair service is literally a million miles away.

The micrometeorite left a dimple on one of the 18 beryllium-gold tiles that make up the Webb's 6.5-meter-wide primary mirror. The slight distortion in the tile is not expected to affect data collection. Still, this ding is a reminder that amazingly sensitive equipment like the Webb must operate reliably in an extreme, unforgiving environment, full of micrometeorites — not to mention high-energy charged particles that stream out from some types of solar storms and come zipping in from interstellar space, potentially wreaking havoc with electronics.

In space, not only can no one hear you scream — the nearest repair service is literally a million miles away.

Throwing Some Shade

The Webb is the largest telescope ever launched into space and an intricate marvel of engineering. The unfolding of its mirror tiles was inspired by origami. Each of the 18 hexagonal tiles is controlled by six actuators, tiny precision assemblies of motors and gears that flex the surface of each tile so they can focus together as one large mirror.

The Webb also deployed a sun shield the size of a tennis court, necessary to keep its sensors cold enough to detect faint infrared radiation, which is the telescope's specialty. The telescope operates at temperatures near absolute zero — the coldest it's physically possible to get — with the mid-infrared instrument (MIRI) operating at around 7 K (-266^0 C or -447^0 F).

Why infrared? It has several advantages. For one thing, because of the expansion of the universe, the most distant objects are receding from us the fastest, so the light from those objects is stretched out, the same way the pitch of a siren sounds lower as it speeds away from you. This moves the light toward the longer-wavelength, red end of the spectrum and is called redshift. In the case of the utmost distant objects — and the furthest back in time, snapshots from more than 13 billion years in the past — that light has shifted beyond visible red into the infrared. The Webb will be looking for the earliest luminous objects in the universe.

Another advantage: Infrared penetrates clouds of dust and gas better than other wavelengths. Since star birth and the formation of planetary systems usually happens in the middle of such clouds, we will get a better view. Moreover, infrared lends itself well to spectroscopy, which allows us to analyze the chemical composition of stars or planetary atmospheres.

The Delicate Dance

One month after its successful launch, the Webb achieved a metastable orbit at the second Lagrange point (L2) that trails the Earth–Moon system around the sun at a distance of about 1.5 million km (1 million miles). Sheltered in the shadow of its sunscreen, at a comfortable remove from any interference in the neighborhood of Earth, it will start the next exciting phase of its mission, from peering at the most distant galaxies in the early universe to taking a closer look at some exoplanets that are relatively nearby.

To reach this point, the Webb has already performed several delicate dances, including release and deployment of the solar array course correction burns and deployment of the sunshield and primary and secondary mirrors. All of these successful deployments are a credit to NASA and its partners, and of course to the expertise and dedication of their scientists and engineers. In space, there are no second chances, and mission-critical systems simply cannot fail.

Bringing Home Treasure

Safety, security, and reliability are part of the DNA of Wind River®, and this has driven the development and evolution of Wind River software, which has been successfully deployed on many space programs, including the Mars rovers Perseverance and Curiosity; the space telescope Kepler, which searches for Earth-size planets; and OSIRIS-REx, a spacecraft that reached near-Earth asteroid Bennu, obtained a sample, and is returning the sample to Earth. Wind River is proud of the role of its VxWorks® real-time operating system (RTOS) in the Webb's Integrated Science Instrument Module (ISIM). VxWorks provides the OS services layer for the science payloads applications (see Figure 21 in this NASA ISIM conference paper) and is running on a radiation-hardened processor.

Imagine that one day the James Webb captures a very clear spectrograph of the atmosphere of an exoplanet in its star system's habitable zone. A spectrograph that shows a significant percentage of oxygen — which suggests photosynthesis.

ISIM incorporates four main science payloads, including near-infrared camera and spectrograph and mid-infrared instrument, which can be used in 17 different instrument "modes." NASA has completed the process of checking out and verifying all of these modes and has released its first images.

One of these science payloads, the Near-Infrared Imager and Slitless Spectrograph (NIRISS), is especially useful for studying the atmospheres of exoplanets. For all the spectacular images and fundamental knowledge about the early formation of the universe we may gain, this comparatively humble topic could cause the greatest public stir.

Imagine that one day the Webb captures a very clear spectrograph of the atmosphere of an exoplanet in its star system's habitable zone. A spectrograph that shows a significant percentage of oxygen — which suggests photosynthesis. That could seize the imagination of even our own distracted species.

The whole point of this telescope is to look more deeply and more clearly into the universe than we've ever looked before. We will inevitably learn new things previously concealed from us. There is an Italian proverb: "I know of no difference between buried treasure and concealed knowledge." With the historic milestone of images now released from the Webb, surely we will continue to see unexpected wonders.

Software as a Defense Asset

August 16, 2022

This article comes from a Forbes *Futures In Focus* podcast interview with Hannah Hunt, chief product and innovation officer for the U.S. Army Software Factory. She discusses software's role as a fundamental asset in national defense and how the increasingly software-centric landscape will continue to evolve over the next decade.

"Imagine a military scenario in which there's an adversary or an issue, and you need to make a data-driven decision. How are you going to execute upon that mission?"

Software as a defense asset — this is an essential shift, impacting how we think about the world. Can you walk through your view of this and the idea of software as a defense asset?

Hannah Hunt: I see the ability to build and deliver software capabilities to support a quickly approaching future operating environment as a strategic imperative for the Department of Defense and U.S. Army. There's a big push to have a joint, all-domain, command-and-control methodology by the year 2030. This means that everything, from sensors to shooters to software to hardware, is integrated in a way that we can rapidly make decisions and be able to quickly resolve a situation.

Imagine a military scenario in which there's an adversary or an issue, and you need to make a data-driven decision. How are you going to execute upon that mission? What's unique about the Department of Defense's and the Army's needs is that it isn't about selling goods but about software becoming something that is a strategic priority, an imperative by which the Army will be able to develop the skill set within its own ranks to be able to build those capabilities. This will inform a much broader vision of how we as a country can rapidly iterate and build capabilities in support of new and different adversaries and challenges that arise.

That's why it's so critical for the work that we do within the Army Software Factory to ensure that we have soldiers who can build and deliver software.

There's so much to digest in that statement, including the idea that someone actually in the throes of conflict would be capable of orchestrating and reprogramming technical capabilities. It's unique, and to invest in an idea like this is complicated. What triggered this new thinking about army readiness?

Hunt: In the more traditional guerrilla warfare in Iraq and Afghanistan, we saw the [value in the] ability to have air dominance and access to networks on the ground and be able to quickly make updates, with government contractors on the fight lines and inside the operation centers.

But the future operating environment does not have that. You have contested environments, you have networking that will be jammed and go down. Our adversaries may have air dominance. They may have cyber dominance in certain respects. So having the ability for the Army to quickly make changes to the software or make new tools in an environment that is contested is incredibly important.

So we would need the ability to say, "I am a commander in the field and I'm about to conduct this mission, or I need to know if I can conduct this mission. Do I have the right assets? Are my sensors in the right place, or my tanks or my ships? Do I have soldiers who can be certain they can show up with this piece of software?" Instead of having to call or radio to confirm that, yes, these assets do exist in the places that need them to execute [the] mission.

It is incredibly critical, as we enter new warfare scenarios, [to prioritize] that capability.

It is an interesting shift, because you could argue that recent major conflicts were relatively traditional extensions of what we've seen before. But the nature of warfare going forward will be exponentially more agile, with contested environments on the edge. One's ability to respond quickly may become a greater asset than the size of the military force.

Hunt: Absolutely. The ability to code at the edge will be key. A lot of people don't put as much clout into it because of the cloud and the ability to have this kind of hybrid of cloud format. However, when you're in a disconnected environment, you need that capability, full stop.

And particularly as the edge increasingly comes into play, the capacity to function there — with the need for more resources in real time — becomes extraordinarily difficult. How have you been able to socialize this idea of future warfare when it's not being fully seen or understood yet by everybody?

"The ability to code at the edge will be key.... When you're in a disconnected environment, you need that capability, full stop."

Hunt: Within the department, we see senior leaders and general officers calling for these concepts and approaches. They see the data and intelligence gathered that show that this is a real need, something that must happen. However, it still can be very disconnected with what is being prioritized.

There's still a very antiquated acquisition process that takes anywhere from five to 10 years to deliver a certain capability. But we don't have the luxury of time. We need to be able to rapidly iterate and build software quickly and at scale and in an ad hoc fashion in those more austere conditions.

It's almost like saying to a racing driver, "We're going to build the car during the race. We're not going to build it before and test it." How are you starting to introduce this dynamic sense?

Hunt: There is value in having the Army Software Factory structured such that the soldiers themselves are able to build capabilities and deploy downrange and make those changes. That's our grand vision, the ability to have a future force designed so that they could say, "I need soldiers who can code and build solutions at the edge." This is of strategic importance for the Army.

Currently, many departments generally see software building as they would see building a tank or a jet — more of a waterfall approach. And largely it needs to be, because you're not going to have a half-finished aircraft fly in the sky. But you can come across pieces of software that are going to provide value, and so you iterate and improve over time until you have a full-fledged capability that can meet all the mission needs of that soldier downrange.

The way the Software Factory is structured, and what makes it a relatively unique concept, is that we have soldiers building that software. So instead of contracting out to a vendor to build this big system that may or may not meet the needs of the soldier, we have actual soldiers building capabilities and learning how to do that in an agile manner.

Is it easy to recruit within the ranks of current soldiers, or are you specifically having to find software developers who understand and buy into this exciting vision to become members of the Army? Are you reverse-engineering or are you going to recruit new people?

Hunt: Well, the original argument against the Software Factory was that you would have to recruit externally and bring people into the Army. However, we've found that there is immense talent within the ranks. We're actually in our fourth cohort of soldiers. There may be soldiers who code in their spare time, or were wrongly assigned to different career fields when they are in fact strong platform engineers or strong software engineers. Our organization gets around 300 applications per cohort for 30 slots. It's a very, very competitive process.

And we have every type of soldier, from your lowest enlisted to your field-grade officers from a variety of different career fields. We have medics, maintenance technicians, cyber officers, signal officers, and so on. We have ward officers from varying backgrounds, and many have the soft skills and some of the technical acumen to build software. We invest significantly up front in the level of academics and training through our tech accelerator, where soldiers gain a certain level of practical proficiency in software development, product management, UX design, and platform engineering. Then they are assigned different product problem spaces in the areas we want to solve.

It's a really interesting model, because there is a perception that there are no soldiers in the force who can do this, and we've been able to prove that is immensely wrong.

"We have every type of soldier, from your lowest enlisted to your field-grade officers from a variety of different career fields.... There is a perception that there are no soldiers in the force who can do this, and we've been able to prove that is immensely wrong."

How long does a cohort spend with you before they go on to other roles?

Hunt: Soldiers are here for a three-year assignment. They spend about the first 12 months or so in training status, where we front-load some academics through our tech accelerator. Then they are paired with industry partners that are enabling them to actually build software. They're working on real problems that my team and I evaluate and select. The intent is to reduce support over time, because then the soldiers are skilled to train future cohorts.

We've only been around for about a year and a half or so, and we're already seeing it pay dividends with soldiers who are getting a level of skill such that they no longer need that industry enablement. They can really start to drive themselves forward. Over time, I think we can imagine that we could reduce that industry support even further, and it really becomes something that is fully soldier led.

That's really exciting. Ten years from now, how big could you see this unit becoming?

Hunt: We believe that it'll be capped at around 200 soldiers, because after the three-year rotation we may still be working on what that future force design looks like, working with our counterparts across the Army and with our senior leaders. We still want to keep this somewhat of a small, compact unit. We want to be in charge our own destiny, be able to scale in a way that is sustainable. We want to keep it tight and focused.

There's also the potential for soldiers to finish their assignment with us and then go off to different operational commanders or different units or acquisition offices and build capabilities that way. So we're not necessarily holding them within the Software Factory itself but enabling different software development units that can be deployed to various organizations to help build software for their particular problems.

Let's imagine you've produced this focused group with a multiplier effect. You're not trying to produce a big, monolithic environment. How many more problems will you be able to help solve in five or 10 years' time, compared to what you're able to focus on now? Or is it difficult to calculate what that net impact might be a decade from now?

Hunt: It's difficult to calculate right now. We have 13 product teams that are building software across a variety of problem spaces. We focus on three key areas, including maintenance and logistics —

which is a massive pain point right now and definitely underfunded within the Army and tactical operations. This really comes back to the notion of having soldiers who can code and deliver capabilities at the edges of the battlefield.

In my role as the chief of product, I really care about delivering value with the product teams that we currently have. However, we're organizing ourselves in a way that, over time, we'll begin to have portfolios of products that are interdependent on one another. Instead of having a one-off product that delivers a particular capability, we operate in a sense like a G Suite or Google Workspace, with a wide variety of capabilities versus focusing on specific, tightly scoped implementations. That's where I really want to push us, because having a suite of capabilities is going to better enable that particular soldier or that particular operational commander to have a full breadth and depth of options as they're planning their missions and war-fighting needs.

Right. They're sort of like a quarterback. You start with a few plays, but at some point you want to give them access to 150 different plays so that they can make the correct situational decision. Have you seen ally nations do similar work?

Hunt: There's a large contingency within the British Army and the Royal Air Force that do something similar. The notion is to have their active-duty component upskilled to build software. I've also seen it with Australia. They have a very similar desire and need. And there is interest at the NATO level, to have that capability to have allied partners across NATO who are able to build software. So it is clearly something of real interest, not just with the Department of Defense and the Army but across all the services and even ally partners.

"My dad worked in Manhattan on 9/11 and he was actually supposed to go to the World Trade Center that day for a meeting. That really changed my perspective on how the U.S. interacts in the world."

You're on the Forbes list 30 Under 30. You're part of a generation for whom software is central to everything, where the commercial upside is obvious, and interest in the armed forces varies across the population. This is a very emotional, passionate mission for you; there must have been something in your background that said, "This is a major problem I want to solve for society." What was it?

Hunt: I've always had a passion for federal service, which sounds kind of cringey, but it's true. My dad worked in Manhattan on 9/11 and he was actually supposed to go to the World Trade Center that day for a meeting. That really changed my perspective on how the U.S. interacts in the world.

Seeing the early stages of the wars in Afghanistan and Iraq made me really interested in international relations and how we communicate. My degree is not in software; my background is in international affairs, with a focus on global institutions like the United Nations and global governance. However, I found myself really wanting to serve the government. My entire career at this point has been in the federal space, whether as a federal employee or as a government contractor.

I've been so passionate about helping and enabling the federal government and the Department of Defense to meet its needs and be able to support internally from a national defense perspective, but also to champion a lot of the goodness that we're doing here with soldier-led software development in a much broader sense. I have a strong, emotional response to being able to support and provide that level of service to the government.

We all tend to have heroes if we're on these mission-type journeys. Are there people that you've learned from and pulled experiences from to help you on this journey?

Hunt: I'm somebody who is always very growth-mindset focused. So on a personal level, I'm a huge fan of Brené Brown and her emphasis on vulnerability and shame and how you can be a leader and connect with people in a way that is much more in depth and not superficial. I have that mindset on life. And the way that we communicate with people is something that I very much value.

Also, I worked for the Air Force at a software factory known in the division as Kessel Run, which is how I got into supporting the Army Software Factory — seeing a group of people changing the way the Air Force builds software. Watching them fight the bureaucracy and the funding struggles and all the various pushbacks and still be able to deliver capabilities was very inspiring to me. I learned about how you can be resilient through immense stress and bureaucratic toil.

I'm a big fan of Gene Kim, Jez Humble, and all the DevOps work that they've done. Eric Ries and his ideas from *The Lean Startup* also fascinate me. I really try to tap into the best of breed of what the industry is talking about when it comes to software development. It's been incredible to see these concepts becoming operationalized within the Air Force and now here within the Army.

Recruiting for the Army is a huge challenge, but there are skills you can learn in the Army that you can also apply outside. Are there any projects where you've seen a solid soldier-coder become incredibly valuable?

"We've had soldiers who have [pitched us ideas] multiple times in their career. They understand the pain points because they're users of the application. You don't get that level of insight into the pain unless you've lived it, and these soldiers have."

Hunt: Absolutely. We have 13 product teams right now, and I've seen soldiers building solutions providing such immense value. Here is one example: Currently, the way that maintenance is done on vehicles and equipment is a paper process. And it's been the same paper process since the Vietnam War. Every Monday is "motor-pool Monday," when you and your unit go out and inspect your vehicles or inspect whatever equipment you have and make sure there are no issues or faults. If there are, you record them on a piece of paper and you look at a paper technical manual that instructs how to record the issue. Then you upload it into a system that will buy the needed part. It's an incredibly manual and brutal process. And it takes 12 to 14 hours to do every Monday, because you might not have the technical manual that has the information, as it may have been ripped or lost or gotten wet due to rain.

We have a soldier team that is building a digital solution to this so that a soldier on your unit can review technical manuals digitally and, in turn, be able to conduct your maintenance in a digital fashion. You'll then have an ability to quickly upload that into the Army system or record and begin to order parts that way. And the reason it's been so successful is because we had a soldier within our organization who pitched this idea.

We've had soldiers who have done this type of thing multiple times in their career. They understand the pain points because they're users of the application. You don't get that level of insight into the pain unless you've lived it, and these soldiers have.

They then engage with units across the country that want to use the software. It's currently being used not just within the United States but with Army units in Eastern Europe and in Korea, because there's so much value in it. It's been fascinating to me that what we're building is actually a joyful experience for a soldier to use.

What are the challenges you'd like to solve that would really benefit from this sort of mindset and technical capability?

Hunt: We're working on business systems and improving processes, making it easier for soldiers to do their jobs and meet their mission requirements. We need to move toward a world in which we're at the edges of the battlefield and actually ingesting data and making real-world, data-driven decisions around very intense operational needs. The Software Factory started piloting a lot of this already, but that's something that we really need to jump-start more over time — this vision of a future operating environment that's operationalized as soon as possible.

I'm very optimistic about that, because I see how well the soldiers are doing right now and how they're able to build capabilities in a way that is user centered, that is lean and focused on business value and mission impacts — things I have not really seen in my time in the federal space. So it gives me a lot of hope.

But it also means there's a lot of work to do to connect all these different systems, from these data points and data feeds, to actually make informed decisions at the edge.

The way you are thinking about problem-solving is not something that, frankly, has been part of the historical method of technological problem-solving in the Army. How much of this could you argue is a generational shift? Or is there something different driving this?

"I would hope that 10 years from now you'll be seeing soldier coders actively engaged in advancing operating environments and building and delivering capabilities."

Hunt: I think there is definitely a desire to change the way the Army does business. I do see it from the younger generations, but there is even a push to change the mindset coming from higher levels of senior leadership. I think that having grown up with technology certainly enabled us to realize how easily accessible it is, and that it is in the realm of possibility. I think that is part of it.

But I also think that Army senior leaders and general officers who are Gen-Xers and above are seeing that they don't necessarily know how to code something, but they know that there is a strategic imperative to have that skill set within the force.

If there is another unfortunate conflict happening in the world some years down the road, how different do you imagine the reporting of that situation would be inside Army Command?

Hunt: I would hope that 10 years from now you'll be seeing soldier coders actively engaged in advancing operating environments and building and delivering capabilities, because that was really not a thing in previous conflicts. Again, you had a lot of contractors who were brought onto the flight lines or operation centers, and soldiers were just kind of overseeing them but didn't have significant influence into what was being built.

I'm optimistic that that's changing, because I'm seeing a strong push within our organization. As I said, even Army senior leaders are recognizing this need. We need to give the Software Factory the opportunity to demonstrate that this is something that has longevity.

How much faster will we be at building software situationally in that type of environment than we are now?

Hunt: It would require a massive amount of cloud adoption within the Army, and a hybrid cloud model that doesn't particularly exist right now. But there's a big push for it. A couple of years ago, the Army realized the need to have enterprise cloud capability and set up an office whose sole job is to provide that enterprise cloud offering, a multi-cloud offering, and hybrid cloud offering across the department. That is what's going to enable us to get to that place.

The Future of Regional Flight

October 27, 2022

This article comes from a Forbes *Futures in Focus* podcast interview with Neil Cloughley, CEO and founder of Faradair, a U.K.-based company developing a hybrid electric aircraft concept for sustainable regional flight. He shares his perspectives on the evolving landscape of air travel.

The dynamics of travel are changing. The delivery of low-cost capability with regional capacity using different types of engine systems changes the way we think about the environmental footprint of travel. How is Faradair, based in the U.K., approaching the shifting nature of air travel?

Neil Cloughley: Throughout aircraft and aviation history, a number of people have come through the ranks and proposed big ideas. Those who haven't fulfilled or followed through have seen their ideas die. If they'd just taken a slightly more staggered approach and looked at what exactly they're trying to solve, things could have turned out differently.

If we look at new technologies that are coming from automotive, aerospace, and various other sectors, we can take what has been done before and improve it. And we have to. I say that because, having spent 15-odd years in the commercial aviation market, I think it's fair to say that about the regional aviation market — the way we get from city to city.

"I'm talking about regional airfields that are close to your town, a 15- to 30-minute curbside-to-airside experience. That is an infrastructure asset that we simply are not making good enough use of right now."

Why is it that, more than 100 years since the Wright brothers flew, I cannot use my regional airfields? I'm not talking about going to major hub airports like JFK or Heathrow or O'Hare. I'm talking about regional airfields that are close to your town, a 15- to 30-minute curbside-to-airside experience. That is an infrastructure asset that we simply are not making good enough use of right now.

So, having been in that commercial aviation environment, having repossessed lots of regional aircraft and seen what wasn't working, we combined that experience with the new technologies that are available. And we combined it with our desire and need to do things more sustainably going forward. Then it made sense that we figured out the core problems.

And the reason we don't fly regional is down to three simple problems: cost of operation, noise, and emissions. These are the three core problems, with cost of operations probably being the biggest one. We realized that in order to fly people from point A to point B, it is currently an extremely expensive process.

If we can put a major dent in that, while not upsetting all the local people who are living in and around these regional airfields, and we can do it more sustainably — that was a light-bulb moment for me. I decided to form Faradair in 2014 with the specific goal of solving those three problems. I wanted to design and come up with an asset solution that would attack those three core problems and go about it with technologies that we knew we could deliver, that we knew we could certify, that we knew we could make safe and grow. And all the while, we're hoping that some of the new technologies that come along are going to be able to improve that model even more.

When considering the list of existing technologies that can be applied, how are you going to handle that development? This is a unique and intriguing part of the business, that capacity to synthesize between past and future.

Cloughley: Let's start with commercial aviation. In commercial aviation, less is more. That's the simple logic. Now, what do I mean by that?

Back in the day, to go transatlantic, to go across the Pacific, we were looking at things like the 747, four-engine 707, etc. Airbus came forward with the Airbus A380. But what we've now discovered is that less is more.

If you can make the same flight distance with two engines, that's less fuel burn, less cost, less complexity, less maintenance. It makes more sense to be doing that if you can get the regulator comfortable with the fact that now you've got two engines instead of four. If one flames out, you've now got to be within a certain strike range of putting the aircraft down with one-engine power.

As we improve over time, we try and improve the metric, the economic model. We try and improve the opportunity. And we looked at this from the same perspective, saying, "OK, most regional turboprops are twin-engine aircraft or regional jets. Can we get to the less-is-more approach on this?" If we could go to a single turbine, then we need to get the regulator comfortable enough with "What happens in the event of X?" Because if we can use one turbine, instantly we're reducing fuel burn compared to what's out there today. We're reducing maintenance costs compared to what's out there today. And we're obviously reducing emissions.

That is a great way to break down that cost-of-operations problem. But how do you do that sensibly and without overpromising? We can use new technologies.

This is where the automotive link comes in. If 10 years ago I had said, "There will be a car that's going to out-accelerate a Ferrari or a Lamborghini, except you can put four adults in it," you'd probably say, "That's nonsense." However, look at where the industry is today with Tesla. It can be done.

"Let's compare it to a turboprop. You buy a new turboprop for over a million dollars, for 1,800 hours of use, and you're going to do a hot-section inspection, which is about $40,000 or $50,000. Then you're going to do an overhaul after 2,000 hours."

So, basically, what we've seen is that new technologies emerge.

I remember talking to the Prodrive guys about why they put solar panels on the roof of the Aston Martin at Le Mans. And it was so that they could take the air-conditioning unit and power it from solar, which meant that they got a little bit more horsepower off the engine, which gave them a little bit more grunt down the Mulsanne Straight.

This is where new technology can come into an existing field and environment and make it better.

Let's think about an electric motor. This is a no-brainer, a single moving part. Let's compare it to a turboprop. You buy a new turboprop for over a million dollars, for 1,800 hours of use, and you're going to do a hot-section inspection, which is about $40,000 or $50,000. Then you're going to do an overhaul after 2,000 hours. And that's going to cost you about half a million, to do that overhaul.

You're then going to do that three times before you do a heavy overhaul for about $800,000. So, over the period of 30,000 hours of use, you're going to spend 7 to 8 million just in maintenance costs alone on that turboprop engine — and on a two-turboprop engine, that's $16 million spent just in maintenance.

Consider the same 30,000-hour period with the electric motor. You don't have to crack the case open, because you have that single moving part. It gets inspected at 30,000 hours, and you have no cost in that period. That's putting a huge dent into that cost-of-operation model.

Let's look at electric cars, now becoming more common. Can you talk through why or why not that idea can be leveraged in an airplane?

Cloughley: First, automotive batteries are built for production volume and cost. The safety standards required for aircraft are significantly higher than for automotive, for obvious reasons. If something happens in a vehicle, you smell smoke or whatever else, you can pull over and be out of the car within seconds. If you're at 10,000 feet and something goes wrong and smoke starts pouring out, you're in real trouble.

It is absolutely imperative that when it comes to transporting people in a commercial environment, it has got to be as safe as possible. Therefore, there have got to be certain technologies that reach a higher level, a higher capability than what we're using in cars. So these technologies have got a little way to go yet in order to reach that standard in terms of power, density, weight, range, capability, etc., for us to mimic in aviation what has been done so incredibly successfully in automotive.

So, then, how do we power those electric motors? As discussed, it's a low-cost way of propelling the asset through the air compared to using a single turbine, which is used every day of the week in commercial jets today. Some background: When you start up a big commercial aircraft, you plug it into the terminal in order to get the power to fire up these engines.

If you don't have a ground power connection — for example, you're parked out on a stand on the apron — then you have a thing in the tail cone called an APU, an auxiliary power unit. It's a mini jet turbine, and all it does is turn on and create electrical power. It's a generator. That allows you to fire up your big engines. And once they're running, you can turn the APU off.

So what we decided was, well, what we need is a little turbine generator. We need something that doesn't handle the entire flight cycle. It doesn't do the takeoff, the landing, or that big fuel burn. It just turns on and creates power at a reduced fuel burn rate for the entire flight cycle. We do not have a flight cycle — a cycle is a takeoff and landing — to add to the maintenance mix. It's literally just our usage alone.

If we can use that to power the electric motors in a hybrid electric configuration while the technology is becoming mature — be it all battery or hydrogen fuel cell or ammonia fuel cell — then this is the starting point. This enables us to reduce fuel burn. We're definitely reducing maintenance costs. We're definitely reducing emissions.

"If you're at 10,000 feet and something goes wrong and smoke starts pouring out, you're in real trouble."

This is a more sustainable starting point. And as these technologies mature, we start introducing them. And so what we see in our turbine generators (for example the Honeywell APU that sits in the tail cone of an Airbus A350 today), when future technologies are available we can simply take out one box of power, replace it with a different box of power, and our aircraft still remains an electric aircraft.

The Faradair BEHA is an electric airplane. But today, we use a jet fuel power generator, which could use sustainable aviation fuel to reduce the emissions footprint even further. And then, at a point in the future, we take that box out, put a different box in, and the aircraft carries on as a full net-zero asset. That's our rationale. That's our logic to how we're approaching things.

It's sort of similar in some ways to Formula One and Formula E: The basic construct is to use compatible technologies from the past but change out the power units over time, when those power units are able to deliver the appropriate performance level.

Let's revisit the economics of the regional airports.

Cloughley: There are something like 5,700-odd regional airfields in the U.S., of which I think only about 570 — basically 10% — have scheduled daily services. Now, out of those 570 airfields, you're looking at $134 billion, if I recall, of economic activity value from just that group of airfields.

We're talking about cargo as well. We live in an age in which online demand means I order something today and I want it tomorrow. Well, the fairy godmother doesn't bring it to your front doorstep. There is aircraft involved, generally, when something is on the far side of a country. And it will then

have to go to a major airport or a major cargo logistics hub, and then it gets put onto a great big truck, and taken out to regional distribution centers, and blah, blah, blah.

Wouldn't it be interesting if we could use an aircraft asset — what we've done with our aircraft is make it utility–passenger capable, so you can fly passengers by day and then take the seats out and fly cargo by night. So what you're doing is driving up the utilization of the asset, which increases its economic model and makes it more viable to use. It means that people will be getting their product faster from their regional environment.

We can take trucks off the road, because what would have been done by a great big articulated lorry can now potentially be distributed locally by a regional electric van from the local distribution hub. As long as you've got a 500-meter lot — and we're saying 300 meters or less for a short take-off and landing and runway requirement, which is very short on all surfaces — then we can start using those regional environments for the movement of both people and of goods. But we can do it quietly, sustainably.

Quietly indeed, like electric cars.

Cloughley: A funny story: As one of the instructors for AMG Mercedes, I was in an electric smart car conducting a corporate demonstration. There are people in the road ahead of you, and you're moving from one point to another. And nobody could hear this thing, it was so quiet.

"It may become as easy as taking a bus. And as the network grows, it becomes a standard form of transport."

I'm leaning my head out the window and saying, "Excuse me, can you just step out of the way? We need to come through." Of course, with an ordinary vehicle, they would normally hear you coming.

It would be nice if we can get to that point in aerospace as well. For places like Santa Monica, where you have such a huge furor over the aircraft noise for local residents, there's that constant battle between aircraft owners and people who use airports and the local environment. If we can remove some of that, where people get the benefit because the service is cost-effective enough for everybody to use, then we are going to see a monumental boom in aviation and aircraft usage in the regional environment.

Let's step forward about 10 years from now — and, obviously, be pragmatic — let's say it's 2033. How might this conversation be different? What might have changed around us if we head toward the landscape you envision?

Cloughley: Probably one of the biggest and most interesting factors is the integration of technology into our lives. Let's take a really extreme example: COVID. Videoconferencing has been around for many years. Yet in the space of six months to a year, everybody from a four-year-old to a 94-year-old suddenly had to get their heads around videoconferencing as a means to speak to loved ones, carry on business, etc. It was a forced technology push on people of a technology that had been around for a long time.

Aviation's been around for a long time. Regional flight's been around for a long time. Say you have a meeting coming up or realize you haven't seen family members in a while. Imagine that, via the use of smartphone apps, you decide to make a spontaneous visit. It could be a very simple process: You can pull up the app, look at the schedule, and decide, "OK, there's a flight leaving at 5:30. It's going to go from here to here, and it's going to cost me $30 to jump on it. Great." And you give your mates a call.

Or you fancy visiting an event. Yep, it looks like there are six seats available. Great. Let's book it and jump on that and go.

It may become as easy as taking a bus. There are set schedules, running every hour between point A, point B, etc. And as the network grows, it becomes a standard form of transport.

We may look back and wonder, "You drove in a car in congested traffic for five hours? What were you doing with your life?" It's like when you talk to people now about what it was like to dial up to the internet on a Spectrum 48K computer back in the day.

We are going to have to become far more collective in how we use our transport. I think it's just going to be a different environment. We've seen that in science-fiction films. When you look back at the film *Blade Runner* with its scenes of aircraft with vertical takeoff and landing all around cities, we are heading there now.

What a fantastic thing it will be if we can go between cities from regional airfields, journeys that would ordinarily take three hours to drive, and we simply do it in half an hour.

Cloughley: Yes. When we're looking at this issue of operating from regional airfields, we decided to have an asset that's going to move people as well as cargo and goods, the ability to lift that heavy payload but also handle a range of jobs and opportunities.

For example, if it's taking on a humanitarian role, going where an earthquake happened or a volcano has erupted and the local regional airfields have been cut off by lava flow, and now you've got a 300-meter piece of tarmac rather than a 600- to 1,000-meter piece of tarmac. Then that short takeoff and landing capability, that super high-lift capability, is really important. This is an aircraft that's been designed to handle this situation.

"The opportunity, if we get this right, is absolutely enormous."

It also does not need to be particularly high. We don't want the cost base of pressurizing the aircraft. It's beneath pressurization altitudes and goes from point to point in a very effective manner.

And we designed it with noise in mind. If you go with open-propeller architecture, that's great when you want to go faster than 230-odd knots. But if you're only going up to 200 or 230 knots, then various university studies have proven that the thrust efficiency is much better with a ducted fan.

We've worked through many design considerations and, yes, it does look different. We've had to overcome the naysayers of the world. But we've got the evidence that proves what it does. And that's the core thing. You always have to base whatever you're doing on surefire evidence.

The final design hasn't been revealed yet. We hope to do that within the next six months to a year. When people see it, I think they're going to be surprised.

We're aerospace guys. We haven't come from oil and gas or technology or whatever. We're people who've been there and done it within the commercial aviation environment. We understand what the market needs and we understand the difficulty of certifying new assets.

The opportunity, if we get this right, is absolutely enormous.

Building Software-Enabled Armored Vehicles

November 17, 2022

Military armored vehicles have come a long way since their early days. The first tank designs appeared in World War I and were designed to cross trenches, which required long, large vehicles. You could include good armor, good speed, or good firepower, but not all three, which led to a proliferation of specialized tank types. During World War II these specialized tanks proved less than useful, and improved technology enabled the widespread adoption of all-purpose tanks.

Transforming the Land Battlespace

Today technology including faster processors, artificial intelligence (AI), compact and energy-efficient computers, and scalable cloud computing enable autonomous and semiautonomous vehicle operation. Currently, the U.S. Army is testing its first autonomous vehicle: The Autonomous Multi-Domain Launcher (AML) modifies a High Mobility Artillery Rocket System (HIMARS) with hardware and software that lets it be controlled remotely and driven autonomously.

Today technology including faster processors, artificial intelligence (AI), compact and energy-efficient computers, and scalable cloud computing enable autonomous and semi-autonomous vehicle operation.

The development of new types of vehicles, especially those as transformative as software-enabled vehicles, requires new methodologies. Modern design practices such as DevSecOps have automated the consistent development of secure, highly maintainable systems in a cloud-native environment. Simulation software lets suppliers design and test components without the need for expensive hardware.

The term *software-enabled armored vehicle* encompasses a range of vehicle types, from infantry combat vehicles to armored personnel carriers, to battle tanks and mobile command stations. Vehicles may have weapons or not, be tracked or wheeled, and be manned or optionally manned. Software-enabled means that functions, and in some cases even hardware, can be manipulated, enhanced, created, and managed by mechanisms based on software control. Such a vehicle's capabilities can evolve more easily and affordably over its expected lifetime.

The main differences among light, medium, and heavy armored vehicles are the type and amount of armor and the extent of engineering devoted to resisting damage from hostile fire. Otherwise, they all tend to be equipped with essentially similar systems. In a software-enabled vehicle, these systems can be enhanced dynamically to provide new capabilities relevant to the current mission, even

as that mission is being executed. This could handled be through local communications or through a tactical cloud platform.

The deep experience Wind River brings to large-scale systems for space exploration, avionics, industrial automation, electrical grid substations, and hybrid cloud deployments provides an ideal foundation for building next-generation software-enabled armored vehicles.

Open Standards

NATO's Generic Vehicle Architecture (NGVA) aims to provide interoperability across NATO vehicle fleets.

Open standards–based architectures simplify platform design by minimizing the need for integration of components, making upgrades easier during the lifetime of a vehicle that may extend 10 to 40 years. This can eliminate or minimize key problems:

- Crew control and displays can be more uniform, streamlining training and maintenance and making important vehicle functions more accessible to the crew.
- Power conflicts between platform components can be minimized.
- Data generated by the system can be analyzed more effectively.

NATO's Generic Vehicle Architecture (NGVA), for instance, aims to provide interoperability across NATO vehicle fleets. In the U.S., two open standards — Future Airborne Capability Environment (FACE™) and Vehicular Integration for C4ISR/EW Interoperability (VICTORY) — that provide guidance for weapons system development and procurement are becoming more closely aligned. The U.S. is also pushing for sensor standardization via Sensor Open Systems Architecture (SOSA).

Autonomous Military Vehicles

Autonomous, semiautonomous, and optionally manned armored vehicles each have a role in digitally transformed defense. Not far in the future, military armored vehicles may perform missions such as reconnaissance, supply runs, and terrain surveys without a crew on board, eliminating risks to personnel. In addition, the increased autonomy of an optionally manned vehicle can reduce the number of crew members necessary to complete a mission.

The recent partnership between Wind River and Aptiv, which supplies electronic parts and safety technology to the auto industry, brings a wealth of experience around autonomous vehicles that dovetails with Wind River experience in software-enabled architectures.

Rethinking Vehicle Design with DevSecOps

The principles of DevSecOps dictate that designers focus on security at the very earliest stages of design to mitigate vulnerabilities and develop systems at each level that protect against hacking threats. Wind River has adopted these underlying principles into toolsets for use by developers. This cloud-native toolset integrates new software releases into the main body of code systematically and with rigorous automated testing available at each stage of the pipeline.

Once vehicles are active in the field, the DevSecOps environment is invaluable in managing security patches and software updates to various mission systems. The status of each vehicle in the fleet can be monitored to ensure that security is up to date and systems are functioning well.

While aircraft equipped with an internal cloud server can use containerized applications for updates and maintenance, this same software architecture can also be used in military ground vehicles. Technology developed by Wind River and Aptiv could make it possible to have a central management computer in a mobile cloud configuration that could update, on the fly, other computers on different vehicles.

Optimizing Flexibility

One of the attractions of software-enabled systems is the possibility of adapting a system or machine to multiple uses. A single configuration of an armored vehicle can be tailored to one mission, then reconfigured as needed to adapt to changing field conditions, new requirements, shifts in mission priorities, or unexpected situations. Rapid field updates are possible through a traditional cloud network or through a mobile tactical cloud in environments where communication is sporadic or nonexistent.

One of the attractions of software-enabled systems is the possibility of adapting a system or machine to multiple uses.

Speeding up Development and Maximizing Security with Simulation

Wind River Simics® allows teams to build and test simulations of systems within a cloud-native environment. By automating the processes for integrating and deploying components in a simulation of the final system, much of the difficult development work can be done without hardware prototypes. Geographically separated developers can work together on a final design, validate components for interoperability, confirm software compatibility, perform regression testing, and verify that requirements have been met. This can shorten development cycles by eliminating hardware supply chain delays and detecting design problems before investing in hardware prototypes.

Simics also lets teams put components and systems through multiple forms of security testing. In a simulated environment combined with the latest container technology, the discovery of vulnerabilities — whether new malware, a newly uncovered cybersecurity threat, or weaknesses in applications or operating systems — can lead to quick action. Patches can be made using containers, often without taking the deployed system out of service.

Electric and Hybrid-Electric Vehicles

The U.S. Defense Department, in collaboration with the auto industry, plans to introduce electric and hybrid-electric drive technologies into large segments of the military. Fueling electric vehicles in the field, of course, presents a significant hurdle.

Armored vehicles tend to be heavy and often need to travel fast, so their engine requirements are demanding, even when considering hybrid-electric drives, whose engines can supply much of the needed charging. Yet military planners are beginning to prototype. The potential exists for vehicles that not only have a high-efficiency energy source but also operate with minimal noise and low heat signatures.

Rolling Fast into the Future

Autonomous and semiautonomous vehicles are within reach, and Wind River is partnering with companies that are focused on realizing this promise. Edge computing and cloud networking have been advancing quickly. The solid benefits and versatility of software-enabled machine technology will likely hasten its adoption by the military as increasing numbers of next-generation armored vehicles are built worldwide.

Automotive and Autonomous

One in Five Automotive Industry Leaders See Intelligent Systems as the Future

October 1, 2021

While the idea of the automobile arose in the late 1800s in Germany and France, the true commercial revolution of the industry occurred in the 1920s in the U.S. There were 40+ years of experimentation between 1880 and 1920, with different form factors such as steering sticks, drive systems, and even names (such as the Stanley Steamer). Brands and technologies were secondary until the true mass production of one common form, and with that development in the 1920s came the exceptional volumes and growth rates that led to the tripling of registered drivers in the U.S. between 1920 and 1930.

Where Are We Now?

The question now is this: Are we in a 1920s-like stage of an EV (electric vehicle) world that will usher in new economic models for a future defined not by the combustion engine but by software? Or are we still in an age of experimentation like the one that stretched from the late 1800s to the product revolution of the 1920s?

Today, technology including faster processors, artificial intelligence (AI), compact and energy-efficient computers, and scalable cloud computing enable autonomous and semiautonomous vehicle operation.

New EV companies such as Tesla, Rivian, Polestar, Waymo, Uber, Piaggio Fast Forward, Envoy Technologies, Hyliion, Ztractor, ChargePoint, and Revel or companies such as SAIC, BYD, FAW Group, Geely (they owned Volvo), BAIC, or Dongfeng could become the new leaders in this world, changing the way we think and experience the automobile. Or it could be the list of traditional vendors, from GM to Ford, Volkswagen, BMW, Mercedes, Nissan, Toyota, and Hyundai who revolutionize the economic models and experiences we all (humans and machines) have with automotive products and services.

Ford certainly put its name in the hat in a big way with its recent announcement of an $11.4 billion investment in new vehicle and battery plants.

The current automotive industry sees razor-thin (sub 5%) net margins, and the industry has a growth rate of less than 3% per annum. That is not a good formula for vibrant success, unless something changes. The traditional automotive industry might be worth just south of $6 trillion by 2025. The EV market might be valued at over half a trillion by that time.

Intelligent Systems: The Future's Predominant Business Model

This new EV number may sound small, a mere 12% of the total by 2025. But when we joined Forbes to talk to leaders in the automotive industry about the new business models that would be driven by the EV revolution, 19% of them said they believe that their future isn't just EV but will likely be a predominantly intelligent systems world. This means a world driven by constant interactions between the consumer, the company, and the product, with whole new economic models from the supply chain perspective (software led), constant innovation with digital feedback loops, and the capacity for automotive vehicles (in whatever form they take) to self-heal and be reprogrammable through the cloud.

The third rail in this driving force is the environment. Moving away from the combustion engine is a mandated requirement, so the race is on for the next set of business models that will dominate a multitrillion-dollar industry.

One in five executive leaders are convinced that this is the future. For comparison, consider the manufacturing industry. We talk a lot about intelligent manufacturing led by facilities with few if any humans in them, or the idea that 85% of all manufacturing personnel will have cobots as their work partners. Even in this industry, just slightly more than one in four leaders (27%) believe intelligent systems are going to be the predominant business model of the future. The automotive industry is undergoing a similar revolution in terms of where it believes value will be created. There will be winners in this period, but there will be losers too, because while growth could be substantial with new platforms and ideas, not every automotive vendor will be rewarded in the same way — or will even survive. Who remembers Studebaker or Packard in the U.S. or Jowett in the U.K.?

This is not just a technology revolution. It's also a reaction to how we increasingly see the automotive vehicle as a platform for transportation (humans and products) and as a workhorse in new roles (autonomous vehicles in warehousing, long-distance applications, campus transport, delivery, etc.). The third rail in this driving force is the environment. Moving away from the combustion engine is a mandated requirement, so the race is on for the next set of business models that will dominate a multitrillion-dollar industry. These three forces will drive a deep and wide change in how we see not just the automotive industry but, most important, the product and the services we all experience, from truck trains to autonomous home product delivery.

Peter Drucker, one of the founding fathers of management consulting, often argued that the future is already written; it's just a case of how we get there. The auto industry is inexorably heading toward a completely different future: EV; new revenue streams; software-centric development and management models; and highly connected experiences between customer, product, and company. Will there be a role for dealers? Will there be gas stations? How will we think about insurance in a world of near-instant data feedback?

All these questions present a remarkable set of moments for transformation, centered around the idea of a fully intelligent industry where software-centric experiences for manufacturers, customers, and ecosystems are the norm.

Ground-up Design and the Future of Transportation

May 2, 2022

This article is the first in a three-part series that comes from a Forbes *Futures in Focus* podcast interview with Jesse Levinson, CTO and founder of Zoox. Here Levinson discusses the current state of the automotive industry and the importance of a "ground-up" approach to making a meaningful impact.

The automotive industry is roughly 130 years old. Please share your vision of where it's going and specifically why "ground up" is so important.

"The benefits of using autonomous technology are so much better than features that you can add onto cars that you sell to people. Electric cars can be much better — faster, smoother, and quieter — so that's a wonderful evolution of the automobile."

Jesse Levinson: We have over two cars per family in the United States right now. At some point in the not-too-distant future, that's going to sound kind of ridiculous. It's not that nobody ever needs to own a car. But imagine that you could own and operate a fleet of electric, autonomous people movers, so that when you wanted to go from somewhere to somewhere else in the city, instead of having to drive your own car and look for parking, you could just hail it from your phone and take it to wherever you wanted to go. And if that experience could be safer and cleaner and more enjoyable and even cheaper than ride-hailing is today, a lot of people will not only switch from ride-hailing to that but even start switching from driving their own car to that much, much better model.

Zoox is unusual in the autonomous industry in that we started the company with a fairly ambitious product idea, business idea, and scope. And the insight there was that the benefits of using autonomous technology are so much better than features that you can add onto cars that you sell to people. Electric cars can be much better — faster, smoother, and quieter — so that's a wonderful evolution of the automobile.

Fundamentally, though, they are still cars, and they're very similar to the cars of the last 100 years. That's OK to an extent, but what we realized is there's an opportunity with autonomous technology to remove the requirement that everybody needs to own a car or even multiple cars.

We decided to build a ground-up vehicle, because today's cars were not architected to be fully autonomous. They don't have the shape, they don't have the interior experience. They don't have the safety features. But there are really dozens of reasons why the traditional automobile is not

well suited to being a taxi that's operating 16-plus hours a day, seven days a week, moving people around cities all day and all night long. That's why we took this approach when we started the company in 2014.

It's unusual and it's expensive to build a company that can get all that technology working together, let alone building the vehicles and deploying them and scaling them. But we knew that the opportunity was so vast — not just economically but in terms of what it can do for our cities and the safety and comfort of people who used ground transportation every day — that we figured it was worth a shot, and we were going to give it our best. We're seven-plus years into it now. It's incredibly exciting that we're so close to getting these things on public roads and that we've been able to show the world a little bit of what it's going to look like.

What are some trends you've seen in attitudes toward car ownership and openness of transportation — particularly in America, where automobile ownership has historically been seen as a symbol of success?

Levinson: I think car ownership is definitely part of the American story, but it's really amazing to see how quickly consumer sentiment is shifting, and that's even before autonomous technology is widely available. I think ride-hailing has already made people realize that in a lot of situations, you don't need to be driving your own car. The trouble with ride-hailing is that it's an inconsistent experience. It's a little bit odd if you think about getting in the back seat of a stranger's car, and it's actually very expensive because you're literally having to pay somebody else to drive you around. But even with those caveats, it is changing consumer sentiments.

"The iPhone is one of the inspirations for the way we approach autonomy at Zoox, because what Apple realized was that the opportunity to transform the phone industry could not come through software or hardware alone."

We're excited that when we get this technology out there and we're able to scale it, it'll become less and less compelling for people to own and drive their own cars. Again, we're not looking at replacing the idea of car ownership, and that's certainly not going to happen overnight. But when you look at the industry over decades, there's a real opportunity for a very significant kind of phase change in the way the landscape looks over the next couple of decades. And we're excited to help accelerate that transition.

At what point do you think we'll see critical mass toward this transition?

Levinson: One of the interesting things about that is that I don't think you can necessarily pinpoint a single year. Consider smartphones. The adoption of smartphones was actually a fairly gradual process. There were lots of smartphones in the early 2000s. They were not good, but for people who needed the ability to read and send emails on the go, they were a godsend. They were very clunky. They were very slow. By today's standards, they were a joke. But they still enabled a certain type of use case that was very helpful to many folks. The iPhone came along in 2007 and really shook things up, because it completely changed the concept of what a smartphone could be and how you could interact with it.

The iPhone is one of the inspirations for the way we approach autonomy at Zoox, because what Apple realized, in 2005 and 2006 when they were developing the first iPhone, was that the opportunity to transform the phone industry could not come through software or hardware alone. If Apple had written a new operating system for a Blackberry phone, maybe it would have been better than the Blackberry operating system. And it maybe would have been a slightly better device. But it still would have been fundamentally a similar kind of thing.

The insight there, of course, was that you needed a custom form factor, a custom user interface. The idea was making the most of the device's screen and adding multi-touch with capacitive, touch-sensing technology, basically making a computer in your pocket that was easier to use than existing smartphones but vastly more capable, vastly more powerful. It was the first time you were able to experience most of the web on a phone. It's the hardware and software integration that enabled that.

Our view is very similar with autonomy. Trying to take a regular car and make it autonomous is like taking a Blackberry phone from 2007 and writing a new operating system for it.

The analogy is maybe even stronger than that. Because on top of the integration of the hardware and the software from a functionality and user experience perspective, we also have to consider that we're building a safety-critical device. Driving is a dangerous activity. More than forty thousand Americans are killed every year in car crashes. When you also add the safety layer, you think about how much more you can prove that your entire platform is safe. And when you own the hardware, the software, and the vehicle platform itself, it becomes all the more compelling to build from the ground up what's now called a robo-taxi, versus trying to shoehorn some autonomous technology onto cars that were never designed for that purpose.

Sensors, Steering Wheels, Intelligent Systems: Your Vehicle Doesn't Need All Three

June 1, 2022

This is Part 2 in a series featuring a conversation with Jesse Levinson, CTO and founder of Zoox, from an interview from the Forbes *Futures in Focus* podcast. In the previous installment, Levinson discussed the importance of a "ground-up" approach. Here he details some of the specific design elements this approach has enabled, as well as the role of intelligent systems and mission-critical AI in autonomous vehicles.

"One of the reasons we're so excited about our approach to solving this problem is that when you get inside a Zoox vehicle, there is no 'missing' steering wheel."

One obvious difference in your ground-up approach to designing your vehicles is the lack of a steering wheel. What has been the response to that choice?

Jesse Levinson: What's interesting is that when you tell people there's no steering wheel, they think that's strange because they're so used to thinking about cars. They imagine a car missing a steering wheel and think, "That's a little bit odd." Some of the companies in the space either put people in the back seat of a car that has a disembodied steering wheel, or the steering wheel is turning all by itself. That's kind of cool, from a nerdy perspective, but it's not a good product experience. There's something rather disconcerting about seeing the wheel turn itself. It makes the rider wonder, "Where is the driver?" One of the reasons we're so excited about our approach to solving this problem is that when you get inside a Zoox vehicle, there is no "missing" steering wheel.

There is no place where there is supposed to be a driver. We simply deleted the steering wheel. When you get inside a Zoox vehicle, it's obvious that it was designed for the rider because that's all we have. We only have the rider. We never had drivers. Although it's a surprising experience for the first few seconds, one of my favorite aspects of seeing people's reaction to getting into a Zoox is that after somewhere between 10 and about 30 seconds, in a very interesting way, that novelty wears off and it becomes the most natural thing you've ever experienced. When you're in one of our vehicles, you shouldn't be focusing on the fact that there's not a steering wheel. You should

be focusing on the fact that you're not having to worry about steering wheels or pedals, or who is driving or who isn't driving. You're in a device that was designed from the ground up to move you safely and comfortably around cities. That's what we're building in Zoox, and I love seeing people's reactions to that.

Please give some examples of other design elements, such as the pronounced sensors, that you've included to help people get comfortable with this new approach.

Levinson: The primary reason why we have our sensors where they are is that it's the best and safest way to perceive the world. And there are many, many ways in which our vehicles have considerable advantages over humans. Not that humans aren't amazing — it's just that we have certain limitations. We're able to put a camera, lidar, and even long-wave infrared thermal sensors on all four corners of the vehicle, way up at the top, which is the best possible way to see things. And that gives us a 270-degree field of view on every corner, which means not only do we get a 360-degree total field of view but we have overlapping 360-degree fields of views across all of our sensor modalities.

"We're able to put a camera, lidar, and even long-wave infrared thermal sensors on all four corners of the vehicle. And that gives us a 270-degree field of view on every corner, which means not only do we get a 360-degree total field of view but we have overlapping 360-degree fields of views across all of our sensor modalities."

That makes it much easier to track and predict the future locations of objects, particularly in dense urban environments, where you have objects behind other objects. The more perspectives you can see them from, the more consistently you can track them. And there is a side benefit of that, which is that if you are a pedestrian or another road user, as long as you can see one of our sensor pods — which are the pods on the four top corners of our vehicle — then that means the vehicle can see you. So you never have to really wonder, "Hey, does this vehicle perceive me or not?" As long as you can see any of those corners, you can rest assured that the vehicle knows exactly where you are. And I absolutely think that is comforting.

Do you see this intelligent system, mission-critical AI world limited to the current design construct or do you see it stretching into different form factors?

Levinson: Currently we're really focused on moving people around cities, specifically with the vehicle that we've shown publicly. Obviously, we're working super hard on it, and we're making hundreds of very, very small changes and improvements to it, but you won't notice most of them. It's still going to look almost identical to what we revealed in December 2020. That vehicle, though, doesn't do all things for all people.

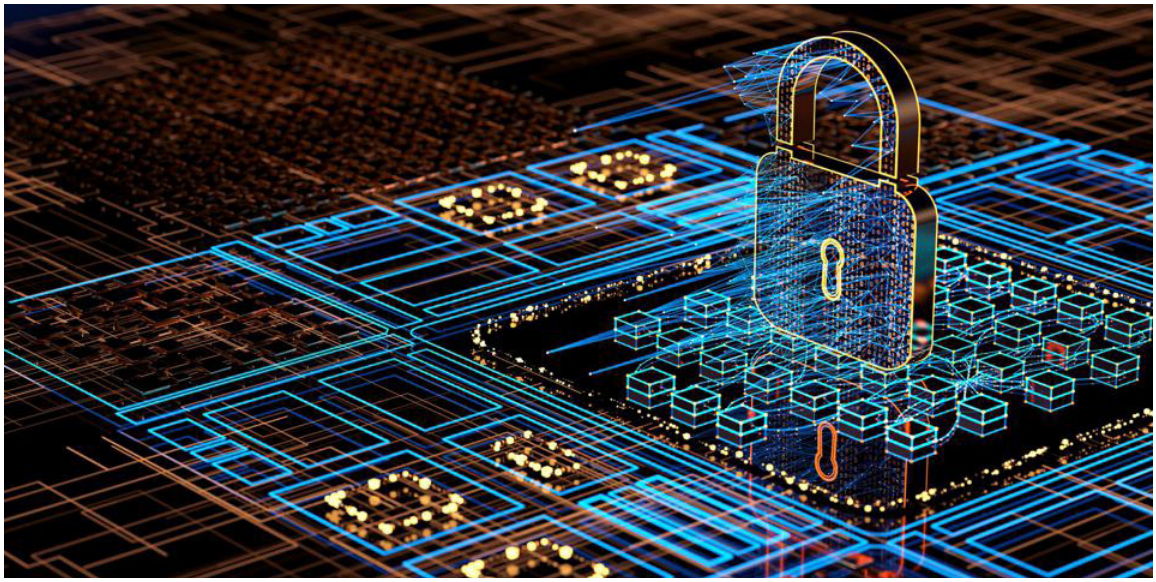
It's not that we're not interested in adjacent areas. Actually, one of the reasons why we like our approach with the sensor pods is that as long as the vehicle design supports that kind of architecture, then a lot of what we're building can carry through, especially if the vehicles have a similar underlying architecture all the way down to the firmware, the drive train, the four-wheel steering, and so on.

So we are definitely excited to eventually explore adjacent areas and different form factors, but I think a lot of companies potentially make the mistake of getting a little bit overaggressive about how many things they are trying to do at the same time. At Zoox, we are very humble about how hard a problem this is, and how much hard-core systems engineering and safety work there is to do to get these vehicles on public roads and then scale them. Fortunately, the market opportunity is absolutely massive. This is one of those products that could be worth hundreds of billions of dollars all by itself. The iPhone is another one, but there are not many examples of that in any industry.

We are very fortunate to be working on a problem that has such a big impact. And what that means is that we aren't feeling any type of pressure to do five other things at the same time. We want to get this product really right. We're taking the time to iterate on it, perfect it, make it safe, and scale it. Once we start doing that, absolutely we'll work on other platforms and bigger and smaller vehicles and all sorts of things. You can assume that we have some people already thinking about some of that and working on early ideas and concepts — but know that we are very focused at Zoox.

The Role of Government in Autonomous Vehicles and Expected Behavioral Changes

July 1, 2022



This article is the third and final in a series from an interview on the Forbes *Futures in Focus* podcast featuring Jesse Levinson, CTO and founder of Zoox. Here Levinson discusses some of the dependencies and impact on cities that adopt robo-taxi technology. He also addresses some of the expected challenges.

"There are all kinds of wonderful things for cities that this technology can improve over time. But we're not waiting for that."

How do you work with local and national infrastructure? What do cities need to do for your technology to work? Will this shift require a new road bill?

Jesse Levinson: One thing we've always been consistent about is that we aren't going to wait around for cities to change.

Working with cities and states and the federal government — it's slow, right? And it's hard because they have so many different stakeholders, and it takes a lot of time to do these kinds of projects. We made the decision very early on that we aren't going to rely on any infrastructure changes. We're going to build a vehicle that works perfectly well with existing roads, existing infrastructure. And we're going to do the work that we have to do to make that really plug and play with cities as they are today.

That doesn't mean we wouldn't love cities to evolve over time and get greener so we can start replacing parking lots. There are all kinds of wonderful things for cities that this technology can improve over time. But we're not waiting for that. We knew if we came around and said, "Hey, Cities, just do these 17 things that will cost you $10 billion," we'd never get off the ground.

Looking beyond America, which geographies do you see that, by 2030–2032, might have comfortably adopted this idea from you?

Levinson: I would hope that, by 2032, most major urban areas across the world would have adopted this type of technology. Certainly we do have global aspirations. We'd love to bring our technology to many, many countries on many continents.

That will take some time — we do have to actually get these vehicles built. We won't be able to scale at the rate that, let's say, Uber and Lyft did, which is fundamentally with an app that the customer and the driver need to download, plus the backend infrastructure to make it all connect and run seamlessly. That's not easy at all. But fundamentally they were not limited in their rate of scaling in the way companies that have to make physical things are.

Having said that, 2032 is nearly a decade from now, so it gives us lots of time to have several iterations of the vehicle and manufacturing strategy.

My expectation is that Zoox won't be the only company that's building this type of technology, especially a decade from now. My expectation is that if you live in a major city almost anywhere in the world, a decade from now this will be a primary way of getting from point to point. And again, it doesn't mean that nobody will ever own a car, but I strongly believe that a decade from now this is going to be a very significant form of transportation in all major cities, or almost all major cities, across the globe.

"Cars were an amazing invention that helped connect people, and we're grateful for that history, but they also have a lot of drawbacks and they've definitely not been strictly positive for cities or society. We think we can do better."

Some of the more obvious benefits of our technology are the safety aspects, and of course we're deeply excited to help save lives. There's not much that's more inspiring than that. But getting people access to safe, affordable, and clean transportation is powerful, because there are so many segments of the population that just don't have that today. In some cases it's due to accessibility, and in some cases it's due to financial considerations.

If you look at cab drivers, for example, they do discriminate based both on people's appearances and on what parts of town they're going to in order to pick people up. If you're in one of the parts of the town that is a little bit less privileged and you're looking for a safe way to get around the city at two in the morning, it can be really scary for folks — to the point that people maybe make bad decisions or don't go places.

One of the great things about our technology is it doesn't have any of those biases. There's no person you have to interact with. You don't have to wonder about who your driver's going to be. And we're going to be able to significantly lower the cost of transportation, because today the largest portion of your Uber or Lyft bill is paying the driver.

Our driver is an artificial intelligence system, and we're really excited about the societal implications. We're also mindful of the fact that we're not going to solve all things for all people right away. This is a journey. Our first vehicle has some great accessibility features, but it doesn't do everything for everyone. Similarly, while we expect our costs to be lower due to not needing human services, it's going to take some time to be massively less expensive. But that will happen. We're very excited about that.

Do you foresee alleviating the issues just discussed, potentially changing behavior and having an impact on area businesses?

Levinson: Very much so. I think there are dozens of subtle and not-so-subtle changes we can look forward to in our cities over the coming decade and beyond. Sometimes it takes time to change an entire city. But it is really going to be wonderful for people to see just how much clean and empty space there is to congregate and then bike and walk in. It's kind of remarkable when you think about how many cities are designed around people owning cars and driving them. Cars were an amazing invention that helped connect people, and we're grateful for that history, but they also have a lot of drawbacks and they've definitely not been strictly positive for cities or society. We think we can do better.

Again, we're not confused; this is not a panacea. It doesn't solve everything for everyone, and any new technology creates some new challenges as well. We want to be very mindful of that, and respectful of all of the dynamics there. But overall, we're just tremendously excited about the way cities will evolve over the coming decades as a result of this type of technology.

"We're creating a whole bunch of new types of jobs that didn't even exist, for example remote teleguidance of the vehicles. We're very optimistic — but again, we do need to be mindful of all these different societal impacts of what we're building."

What do you think the biggest problems are going to be?

Levinson: I don't know that there are going to be problems so much as just that it takes time to perfect and then scale the technology. For example, when you think about operating in a city, there will probably be certain intersections that are particularly poorly designed. It might make sense, from a safety perspective, for robo-taxis to avoid some percent of those intersections. The cool thing about that is that I don't actually think it will fundamentally limit the quality of the service. Worst case: Maybe you get picked up or dropped off one block away from your ideal location. I do foresee there being some issues like that.

Similarly, we may see some impact from certain types of extreme weather. There could also be some scenarios when, in the early deployments — we might say for 1% or half of that in the year — we might just not operate our fleet for those few hours. I think that's a lot better than saying we're going to wait to deploy this until the vehicles can handle 100% of everything. We're not going to deploy them anywhere that's not extraordinarily safe. But I think the fact that we get to own and operate the fleet gives us a lot of control and agency over our path to market and allows us to bring this technology quite soon to people in a measured and safe way. That's something we're going to have to deal with as an industry. But anytime there's a new technology, there are always some things you have to think about.

People also ask about the displacement of workers who are currently driving vehicles around. This is going to take a long time. We're talking many years before the actual macro trends change meaningfully. So there's lots of time to prepare. We're creating a whole bunch of new types of jobs that didn't even exist, for example remote teleguidance of the vehicles. We're very optimistic — but again, we do need to be mindful of all these different societal impacts of what we're building.

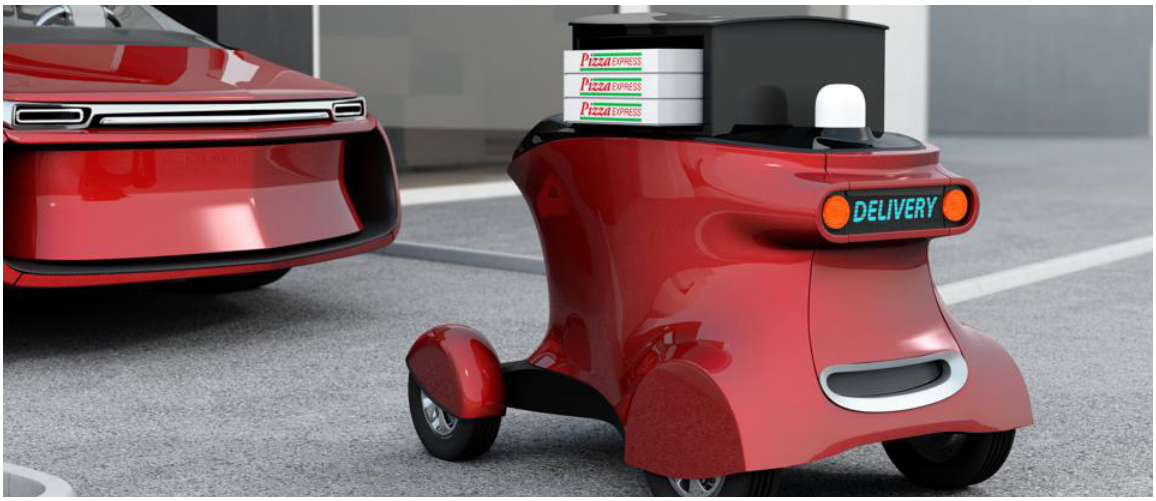
How does that work when you present the idea to a local government? Do they want to fund it? Do they want to use it? Are they there to enable it?

Levinson: It really depends on whom you're talking to. Some folks are excited, and they ask us, "What can we do to make us one of your first cities? What can we do to make this easier for you, whether it's funding investment or changing the rules of the road so that there's easier access for autonomous vehicles?" Then sometimes you talk to folks who are more like, "This sounds cool, but I don't know if I really believe in it yet." There are a lot of considerations that make this a city-by-city conversation. I will point out that our primary business model is not to sell to cities. It's to sell rides directly to consumers.

Of course, we're not going to just show up and not talk to the city we're operating in. To our earlier point, we're not actually asking for changes from the city. We've tried to design the vehicle and our service and business model in such a way that we don't really need much from the city. That said, we want to be good stewards. Of course we don't want to surprise anybody. We're obviously going to comply with all of the local laws and regulations. But our perspective is that we should make cities more desirable by being there and really not ask too much of the cities in return.

The Future of Autonomous Delivery Bots

September 23, 2022



This article comes from a Forbes *Futures in Focus* podcast interview with Alastair Westgarth, CEO of Starship Technologies, an autonomous delivery vehicle company based in San Francisco. He shares his perspectives on the new autonomous machine economy.

The autonomous machine space will head into interesting places, from everyday deliveries to more complex, high-value applications. Let's start with a practical understanding of what is happening today. Walk us through some of Starship's use case scenarios so people can start imagining what life with cobots might look like 10 years from now.

Alastair Westgarth: Consider a university campus. There is a plethora of food and meal choices that students encounter every day, multiple times a day. People go to various locations and they get in a very, very long line. The line could be 45 minutes long. Often they are bound to specific timetables and are trying to get to a class, a lecture, an appointment with another colleague or member of the academic staff. They are pressed for time. It made sense that if you could bring those foodstuffs to the individual in a convenient and economical manner, people would be interested.

"The merchant can put food or groceries in the delivery robot, and it will go to wherever the student or faculty member wants it delivered. It took a lot of conversations for people to be convinced that it might be possible, but when we turned it on, almost immediately there was massive demand."

The merchant can put food or groceries in the delivery robot, and it will go to wherever the student or faculty member wants it delivered. It took a lot of conversations for people to be convinced that it might be possible, but when we turned it on, almost immediately there was massive demand. Near the end of class, students would order their lunch. We saw that people in dorms would want a delivery for dinner. If there was an event on campus that weekend, all of a sudden we had hundreds of robots running around multiple areas of the campus, delivering thousands of orders a day. You'll often see a robot or two rolling down the sidewalk, or a handful sitting outside of a merchant location ready to take orders. An order will come in on a tablet, it will be identified as having to be put in a robot, and a staff runner will leave the merchant and go outside to a loading area and pick any robot. They load the item in there and the robot will head off and deliver that food.

The system works like a mesh. The robot doesn't need to go back to a central location. A robot doesn't need to go back to one merchant. It could go to another merchant and deliver to a different student. It's a mesh that's constantly evolving over time, depending on the demand and ability to fulfill those orders.

"We aim to be a good partner in an environment. That is essential to success in making this hybrid ecosystem of human beings and robots work together seamlessly."

A campus is a perfect place to try this idea, as it is an enclosed ecosystem. Also, younger generations will typically be much more comfortable with new forms of technology. What sort of resistance or confusion have you encountered?

Westgarth: The resistance has been relatively modest. Some people will point to pizza delivery services via bike being no longer around. Well, unfortunately the reason that is no longer available is likely due to the economics or reliability or viability — it was not sustainable. We were able to put in something that was economical and scalable.

Some also thought we might cause congestion on a campus or blockage on sidewalks. While those opinions were the minority, there were legitimate concerns about parking the robots and things like that. We had to evolve and grow our system and learn, because after we were actually deployed on campus, there were many things that we had a much deeper knowledge about, such as the dynamics of parking or the dynamics of robots in idle areas.

We spent a lot of time and effort making sure that robots were parked neatly and tidily, out of the way so as not to create obstacles for foot traffic or personal mobility devices. When the robots are in a loading area, that area is designated for loading. All those refinements and enhancements came as a result of the learning that we did on the campuses.

As we've done that, any resistance has tended to fall away relatively quickly. If we get concerns expressed about blocking crossings or not being tidy in our operation, we immediately address it, because we want to be sure that we coexist as a good neighbor. We aim to be a good partner in an environment. That is essential to success in making this hybrid ecosystem of human beings and robots work together seamlessly.

How do you reprogram these robots — is this done in a central station? Do you implement 5G or an edge network when reprogramming is needed? Or do they have to come back to a central repository where they're physically handled?

Westgarth: We have a massive software system of millions of lines of code, both in the robot and in the cloud. In simple terms, each robot has an awareness system. It can see what's going on, avoid objects, detect objects, brake, accelerate, turn corners. It identifies where it is and signals to central locations if there's a problem with the device.

And the cloud software handles things like payments, route planning, fleet orchestration. It monitors the robot health and energy charge and ensures that the correct number of robots arrive at the right time at the right location. It's a choreography of things in the cloud as well as things on the ground.

Nearly all the time — 99.9% of the time — the robots have a data connection. That could be a cellular connection or a Wi-Fi connection. If there's Wi-Fi on the campus, it'll take advantage of that. If there isn't, it will go to a cellular connection. If we lose a connection, the robot is smart enough to know where it is and continue to navigate down its allowed path until it can reestablish a connection. It won't just freeze up in the middle of nowhere.

With respect to reprogramming, we send commands from the central location to the robots to say there's an issue and the robot needs assistance. Normally we don't have to do that. Likewise, we can send telemetry information, such as location or visual information, for steering and navigating up to a central location if needed. But, more than 99% of the time, that's all handled by the robot.

If we wanted to reprogram the robot with a fix or an update, that is done in the hub, which is basically a robot garage where they're housed overnight and their batteries are charged. They're plugged into a system that includes a data connection whereby we can extract diagnostics and telemetry or download new software images, new software fixes, or anything else that's needed.

Taking this beyond universities, how do you see it working in commercial campus environments, such as major companies that have significant campus environments but few nearby facilities or resources?

Westgarth: We have a handful of deployments in Germany where we are on an industrial campus, usually a heavy industry campus where we're delivering spare parts or samples. A fleet of three to six robots may be moving around this industrial environment to get supplies, parts, or samples that are requested from other parts of the campus. We've experimented a little bit with it with these commercial environments, but their demand curve is very different.

If you look at a school campus, you'd be surprised how relatively constant the activity is throughout the entire day. Some of the busiest times are breakfast and late in the evening for students. Compare this to a business campus, where you might see the majority of activity focused on lunch or dinner times.

There are some interesting elements to consider moving forward, such as human capital. Machines could play a role as increasingly economically viable alternatives for what are relatively low-skilled but high-sensing jobs.

Westgarth: It is a very, very nuanced and tricky topic. The environments where we provide service today were partly compelled by the pandemic. Initially because of social distance requirements and nobody wanting to be within two meters of each other, and also because many merchants were either closed or only available for pickup. These factors accelerated the demand for our technology. Our experience also spotlighted some of the challenges with respect to a delivery economy.

One of the things that we've seen over the course of 2021 and 2022 is that all of these college campuses struggled to hire staff. So providing a service that didn't require a massive amount of additional human capital was extremely valuable. Then, over time, it became very attractive, just because it was a valuable service that provided time savings, convenience, or lower costs for merchants versus hiring a human.

"When we posted job openings for staff — technical staff, project management staff, or whatever — we would have no trouble hiring them. They would come to us."

It becomes sticky now, in the case of cities and neighborhoods where we do deliveries today. While there's competition between us and the delivery services using human-powered delivery, those services can still be impacted by labor availability challenges. In addition, there are the moral and ethical dilemmas surrounding pure gig-economy workers and how they're compensated for the labor and the services they provide. We believe that if you can insert value into the economy overall, whatever jobs the economy provides will be of higher value.

One of the interesting dynamics that we saw in some environments was that our partners and customers would have a hard time hiring staff. However, when we posted job openings for staff — technical staff, project management staff, or whatever — we would have no trouble hiring them. They would come to us. It is because they saw more opportunity to be involved in an evolving economy. To them, it was more attractive working with robotics than making food or delivering food themselves.

Both are extremely valuable. But at the end of the day, if we could raise the value of what the human being does versus what this automated machine does, I think that's a good change in society overall.

It's not going to be completely smooth. It may get messy sometimes. However, consider the automotive industry: Even as technologies that temporarily displace some work are introduced, there are more people involved in the automotive industry today than there were 20 or 30 years ago. This is despite the fact that automation technologies in the automotive industry are exponentially many times more prevalent today than they were then. So at the end of the day, it's a nuanced situation.

Let's talk a little bit about autonomous vehicles. You're in the "things" business, while the automotive industry is in the human-moving business, and there are anxieties about fully autonomous vehicles. Humans are unpredictable; machines are programmable. Although you're dealing with the more controlled universe of a contained campus, you're still managing it in the real world, interacting with real humans. Do you see the interaction between your machines and humans becoming an increasingly comfortable part of everyday life?

Westgarth: About three or four weeks ago, I was in Phoenix attending a wedding. My wife was downtown with a friend of ours and they went to the Arizona State University campus, on which our technologies are deployed. She saw some of our robots making deliveries. One of the merchants had placed a table and chairs in the middle of the sidewalk as an extension of their eating space, and the robot came along and stopped at the table and was working to figure it out. My wife approached the individuals sitting at the table and asked if the robot would be stuck or confused. And they said, "Oh no, don't worry about it. It'll figure it out." And sure enough, after doing a bit of a robot dance, the robot figured it out and reversed and navigated around the table.

"It's a never-ending journey to make sure that this human–robot dynamic is maintained, fostered, and improved. When the robot makes an error or does something unexpected, we try to take in all the points of feedback to make sure that it gets better and better."

It's interesting when you see that dynamic, where a community has become comfortable with the interaction with those robots. They're not threatening, they're not banging into people or causing accidents. They're providing value in that society, and the community has become accepting of them in that environment.

We spend an awful lot of time looking at robot behavior. We've tried to make them as polite and as nonthreatening as possible. This influences the shape of the robot, with its rounded edges, and the soft perspective that they seem to communicate. If they come upon a people on the sidewalk, they'll say, "Excuse me, I need to complete my job. Can I please get by? Thank you very much for moving out of the way." We try to make sure that they interact in a manner that communicates intent but also acknowledges assistance. Through that, and being seen to actually add value, in almost every single instance we get a positive response from people in the interaction.

It's a never-ending journey to make sure that this human–robot dynamic is maintained, fostered, and improved. When the robot makes an error or does something unexpected, we try to take in all the points of feedback to make sure that it gets better and better, because the bar gets raised as well. We can't assume the bar is static. I am of the opinion that if you're going to automate something, it not only needs to be as good as but it needs to be better than a human being.

There are about 4,000 campuses in the U.S. This activity in a small, enclosed ecosystem like a university campus is a good place for us to recognize that learning economies are where we're heading. Constant capacity for learning is key. What could the year 2035 look like, in hospitals, manufacturing, or other areas?

Westgarth: Automated logistics as a sort of big box is never going away. There is more and more automation being poured into it all the time.

Now, a robot is never going to replace a special sit-down dining experience that requires a certain ambiance, or going to the farmer's market to smell and pick fresh produce yourself with your own hands. Those are experiential activities that a robot cannot replace.

However, when you talk about things that are repetitive, things that are related to convenience or will help you in everyday life, it makes sense to make the activities cheaper, faster, more efficient, and more environmentally conscious. The demand for delivery and convenience will never be satiated, so more and more of that economy has to be more sustainable. This can be helped along with green, efficient, autonomous options.

Also, it's not just on us to address the issue of the last mile. It will be multimodal. There will be people on the road making deliveries or deploying drones. There is zip line method in West Africa making delivery of medical supplies across hazardous or rugged terrain. So, with other modes deployed — whether that's drone delivery for urgent, very light packages or being on the road for long distances with large, bulky items — all those things will come into play, and probably at some point they will start working together.

Yes, ecosystems will lean on multimodal approaches. Be it truck or train, it is still the concept of delivery — but there is a fundamentally different way of managing it, depending on the mode.

"We spend a lot of time working on public affairs. We never ever go anywhere where we don't have permission. Creating new problems or not addressing potential issues in advance with the right stakeholders will only slow down adoption and slow down learning as well."

Westgarth: The interesting thing about campuses is that they're like mini cities, as a complete ecosystem, and they're very difficult to operate in because they're extremely crowded. This is good, because we learn very quickly. But to your point, you can see the construct of an ecosystem in a city or a campus, versus just a niche application of delivering groceries. That idea that you've got all these things working together, the whole community of users and suppliers — it gives you a glimpse of what's possible.

That's why this is interesting, because it is a complex ecosystem and an incredibly good learning environment. What concerns do you have that we all need to sort out now to make this a more widespread reality?

Westgarth: There's always going to be the dynamic of many competitors emerging, and there will be some creation and some destruction in that process. You have a rush of people, the land grab, and then you have a sorting out. That might be occurring now in quick delivery around the world, though it has yet to occur in the robotic world. The other thing — and this is a constant in any autonomous vehicle environment — is both the opportunity and risk around getting the public affairs matters right.

We spend a lot of time working on public affairs. We never ever go anywhere where we don't have permission. We work with the university and the university transit organizations. We work with the town. We make sure all those constructs are in place so that everybody knows where we're operating. Creating new problems or not addressing potential issues in advance with the right stakeholders will only slow down adoption and slow down learning as well.

As part of an industry of autonomy, evolving and helping develop those public affairs frameworks is important so that we don't slow deployment. We want to speed deployment and lay a common framework. That's both safe and beneficial for everybody. I've seen people do the opposite, and it has bad results at the end of the day.

The construct of safe, secure, and mission critical becomes important, not just on the practical engineering level but also on the level of cognitive and societal acceptance. And if, through more automation, we could have a much lower carbon footprint as we consume more, that will improve our situation.

Westgarth: Exactly. We did some modeling around our Milton teams in the U.K. and determined that doing a delivery of up to three kilometers on a Starship robot uses the equivalent amount of energy as boiling water for a cup of tea. While it would be difficult to be completely energy neutral, we're trying to do our best.

Whether it's green-sourcing energy into a hub or making sure that we work on closed-loop recycling for batteries, we're thinking in those terms versus just doing it and spewing out something that's not beneficial for society in general. If our footprint is smaller by a long shot, and if we can make that footprint as green as possible, then we're really making a difference.

WNDRVR

Edge, Cloud, and Intelligent Systems

World of Intelligent Systems

January 27, 2021

15-Year-Olds Are Showing Us the Way Forward

My children expect the world to be centered around their technology needs. They expect to receive services how and when they want them. Transport is their own car or Uber, and products come to them when they want them. They see everything as a service highly connected to their needs. This is a radically different view of the world than previous generations held, amplified by events of 2020 and the shift to millennials — and those even younger — as the core of the world's workforce. We expect our systems to sense and measure everything, from taking blood oxygen levels from the wrist to predicting when you should refill your refrigerator.

Your car may be able to drive itself and, in near real time, deliver ongoing data from the driver and vehicle to the manufacturer, who then updates settings, based on feedback from your most recent drive, about best adjustments to the suspension or handling. This won't make you the Formula One driver and world champion Lewis Hamilton, but it does show where the synthesis of human and machine learning and near real-time updates can take us. Driving will soon be a different activity than our parents engaged in. The car, the human, the manufacturer, other cars, and even highway infrastructure will interact in a seamless experience. Roads will be safer and most of what you care about while driving will be enhanced by the customization of your whole-car experience.

Auto manufacturers, according to McKinsey, will see 20% or more of their profits coming from software customization services in the vehicle. The same will be true for commercial trucking, with self-driving truck trains in Australia reducing human workloads and also increasing safety and the volume of cargo carried. Telematics technologies and other connected devices and sensors will make sure the vehicle is performing as expected and connect to various drop points on the journey to check whether the inventory on the trucks is needed. Imagine a virtual, moving supply chain, crossing a continent for near real-time matching of supply and demand.

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Intelligent Systems at the Edge Become the Expected, Not the Unexpected

The idea that products will increasingly need to be intelligent to be useful, not just intelligent as a value-added experience, is the catalyst to an intelligent systems world. These systems are a pathway to build digital scale and competitiveness for organizations where embedded machines, software, and intelligence work together in near real time to do tasks, pass information, or deliver services through the cloud. And these systems are found at the intelligent edge where data is being collected, analyzed, or sensed — rather than at a centralized server.

To seamlessly connect the driver, the vehicle, and the manufacturer in near real time has obvious and exciting possibilities for the user, the vendor, and the completely revised set of expectations that this new generation will have for transportation. This is as true for personal autonomous vehicles as for autonomous transportation — for each of us as well as for those truck trains in Australia.

And it's true across industries. Just imagine being in the elevator business and recognizing that the elevator is a sensor, gathering data on usage and movement patterns of people in the building, and that it is even a potential addition to the building's security capabilities. If sensors can monitor and prevent expensive and highly inconvenient repairs by anticipating possible parts failures and conducting predictive maintenance, then the economics of the elevator business and the nature of conversations about the value of the elevator go far beyond the past 100 years of highly focused expectations. Imagine connecting that data securely from one elevator to others in the city (or other cities). Then imagine being able to look for similar patterns in near real time to enhance knowledge for new product or service design, or even to lower ownership costs for users across tens of thousands of similar elevators. Turning this from a capital cost for a user to an operating expense, with the promise that the application of that intelligence will be used to lower ongoing costs and that perpetual updates will be deployed over time, is going to be the norm.

By making the elevator a service (transport, security, and insights), by focusing on machine and software to deliver services never before imagined possible, we enter the world of intelligent systems at the edge. Now think about your industry and how you can turn your company into a thriving intelligent-systems business.

Whereas digital transformation has been a steady process since 2013, the growth of intelligent systems at the edge is likely to be faster and deeper.

- What outcomes could your intelligent systems at the edge (human, machine, and software code with near real-time analytics and automation) radically optimize for your customers right now?
- What other outcomes does the customer need you to deliver on in an intelligent systems approach?
- How could intelligent systems at the edge reengineer the dynamics of your industry?

Since KPMG's 2017 research into CEO mindsets, we've known that 65% of company leaders believe that disruptions to their industry sectors present opportunity.

Intelligent systems allow leaders to go beyond choosing one of the tenets of Michael Porter's five-forces model of strategy frameworks, giving you the potential to address all of them: You can compete by changing the nature of your relationships with existing customers and suppliers, protect against substitutes, and enhance components or experiences you might have relied on for decades.

Whereas digital transformation has been a steady process since 2013, the growth of intelligent systems at the edge is likely to be faster and deeper, because as enterprises become software driven to deliver on the needs of systems and customers, the intelligent systems world becomes the expected norm. We could call this the Teslafication of industry.

Teaching Diversity and Inclusion to Autonomous Intelligent Systems

April 7, 2021

The idea that diversity and inclusion should be core drivers of the new economy and the emerging global society is fairly well understood and accepted. The more people who are part of one system, being offered the same opportunities regardless of their gender, race, ethnic origin, and many other diverse variables, the higher the water level rises for everybody. But even with that intrinsic understanding that diversity and inclusion will generate a different and better world, significant barriers still exist to making this human truth a practical reality in our daily lives.

Digital companies talk about the power of the individual or the customer to be the center of the service. Since 2014, McKinsey has been measuring diversity and inclusivity as drivers of business value creation. The intent is to show every year that companies that live and deliver diverse and inclusive strategies outperform their industry peers. The gap between diverse and inclusive leaders and the poorest performers has gotten bigger year by year, growing from 33% percent in 2018 to 36% in 2019. Even with clear and longitudinal data, however, we still struggle against inherent biases to accept and act on the fact that diversity and inclusion widen the lens for viewing ideas, thinking, processes, and customers in an increasingly global market.

The gap between diverse and inclusive leaders and the poorest performers has gotten bigger year by year, growing from 33% percent in 2018 to 36% in 2019.

Diversity Isn't Going Away

The world will get more diverse over time. It is projected that, by 2044, more than half of all Americans will belong to a minority group. We will, in effect, be a collection of diversities, with one in five of us not having being born in the U.S. Multiply this American future by the nuances of each of the 195 countries in the world, and the planet will host a huge collection of diversities.

Now imagine a world of not just 7 billion people, but 40 billion devices computing, connecting, sensing, predicting, and running autonomously in an intelligent systems world. PwC estimated that 70% of all global GDP growth between 2020 and 2030 will come from this machine economy (which includes AI, robotics, and IoT devices). The U.S. GDP is expected to grow by $10T between now and 2030.

If 70% of that is from these machines sensing, predicting, computing, and connecting on the intelligent edge, then that is a $7T economy. Will these machines be more capable than humankind has been to think about diversity and inclusion in the way they work with data, humans, and other machines?

These devices don't have a McKinsey to explain to them where and how inclusion and diversity will drive a better result. They make decisions in milliseconds, based on the programming instructions they receive, and they learn as they execute their many, often complex and intelligent, tasks. How these machines learn to think is driven by rules set by humans, and by other machines that were in part or wholly programmed by humans. How can the right behaviors be instilled in these intelligent systems?

Teaching Intelligent Systems

There are two basic dynamics we must pay attention to in an increasingly intelligent systems world:

Human Experiences Drive Diversity and Inclusive Design

Learning (and applying) an awareness of the needs of diverse groups has more value than ever before. This acquired knowledge will act as the codex for how we program the devices that live and work with us globally by 2030 and beyond. There is a narrow time window in which to take our own personal experiences and the experience of others around us into account in the design and programming process for intelligent systems that will manage autonomous vehicles, medical devices, and manufacturing environments where robots will be working alongside humans.

All machines might look and behave in the same way, but the humans around them do not, so what machine biases will exist in the intelligent systems world?

All machines might look and behave in the same way, but the humans around them do not, so what machine biases will exist in the intelligent systems world? Understanding how to design and program for inclusive and diverse thinking without bias means intelligent systems need to have a progressive learning ability (through machine learning and digital feedback loops) as well as mission-critical capacities that mean they can safely and securely function around humans who may look, sound, move, or think differently from those whom the machines have been designed by or have operated around.

Machines Will Also Be Diverse and Will Need to Be Inclusive of Each Other

Once we live in an intelligent systems world, we will need intelligent systems to recognize each other in near–instant time. These systems might be doing completely different tasks, but they will need to share data, space, or compute capacity within milliseconds (for example, consider the operation of autonomous vehicles in crowded cities).

Knowing when, where, and how to have that network effect in an intelligent systems world requires a capacity for inclusiveness and even a clear comprehension of the power of diverse data sets from different devices to create value far greater than the sum of all the parts. Nurturing that capacity to create systems for a diversity of design and operations, as well as for an inclusiveness to allow constant learning, is a challenge that will be essential in an intelligent systems world.

We will not be able to make the right world for these intelligent systems and all that they can bring to humanity if we do not design, operate, and build them to be inclusive, diverse, and without bias in their operations. While not suggesting that there should be a soul to an intelligent system, we should recognize that the moment in our own human world to encourage as much diversity and inclusion in our thinking is right now. How well we do it will have major consequences for how we teach our intelligent systems to thrive in a world dominated by a diversity of machines and humans.

How to Achieve Success in Five Years

April 14, 2021

In 2021, Wind River interviewed more than 500 executives and leaders about their vision, processes, and investment models for their own intelligent systems futures. The idea of embedded devices, machines, and applications computing, sensing, predicting, and connecting on the far edge of the cloud may sound abstract, even niche. But to these leaders it wasn't niche or abstract. Eight in 10 of them were aggressively pursuing strategies to develop intelligent systems into a core competency in the next five years.

These are not executives in retail or healthcare (which together comprise 22.1% of the U.S. economy). These executives lead very large companies in automotive, industrial and manufacturing, energy and utilities, medical technology, aerospace and defense, telecommunications, and technology hardware. They represent over 46% of GDP in the U.S. The one thing they have in common is their near-total belief in the power of intelligent systems.

Consider that traditional product and service development can take three to five years. Success then is going to be partly defined by how you architect for that success now.

Where the World Is Going

It is easy to say these executives are leaders with incredible vision. And it is true that 26% of them (across 16 dimensions) did see themselves as being visionaries ahead of their peers. Yet a full eight in 10 of these executives are clearly set on developing an intelligent systems–led company. That means nearly three in four of them are pragmatically recognizing the inevitability of this idea for themselves and their industry peers, since not only visionaries but also those pragmatists who see where the world is going are accelerating their build-out for that intelligent systems world.

The bottom line is that the time to build your intelligent systems capabilities is now. Consider that traditional product and service development can take three to five years. Success then is going to be partly defined by how you architect for that success now.

Think of it this way: The most successful organizations across 15 metrics outperformed their less successful peers by a ratio of four to one. Yet only 16% of them fell into this "most successful" category. Remember, we just saw 26% of them measured as industry visionaries — so even if your organization has a visionary leader, there is no guarantee it will succeed. This suggests that the 16% that are now succeeding at that level of magnitude are architecting the right type of intelligent systems future. They are committed and performing because they have figured out what intelligent systems characteristics work: the infrastructure elements that are needed to set you up for success. The foun-

dational characteristics that will deliver success now and in the future. And the characteristics that, while not available or maybe even appropriate now, will have substantial value in the future based on the characteristics that are built in now. These leaders also hinted at additions they might like to see once they have architected correctly.

We modeled 13 characteristics for intelligent systems success over 4,000 times in order to build predictive models for success.

The Foundational Characteristics

We modeled 13 characteristics for intelligent systems success over 4,000 times in order to build predictive models for success. Facts gleaned from these leaders, based on these 4,000-plus simulations of alternative approaches to investing in intelligent systems, should spark discussions with your colleagues, especially if you are one of those eight in 10 executives looking to build for your future success now.

For example, the number-one characteristic that the most successful organizations are investing in right now is a real-time collaborative workflow process or platform that enables everybody to share, collaborate, and work together. Now, this most successful group is not unique in this investment.

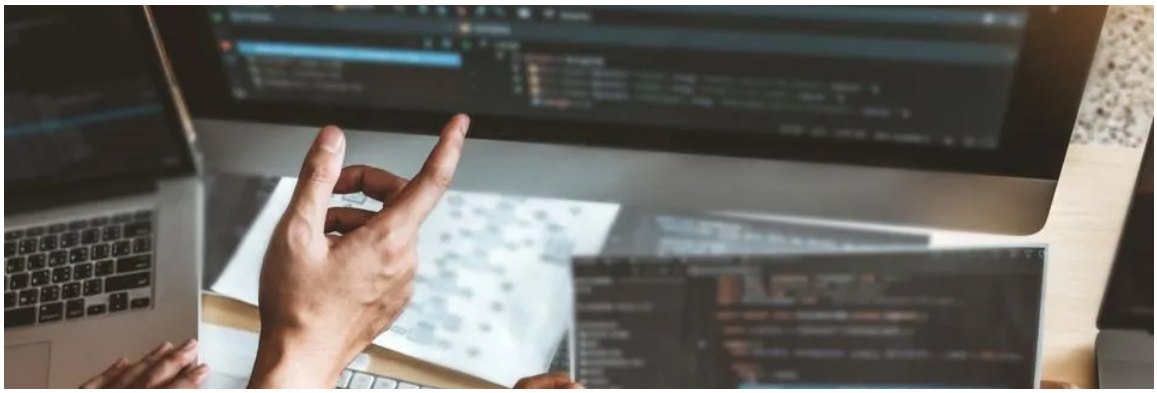
However, their almost singular focus on it illustrates their understanding that the intelligent systems world of machines they want to work in will be predetermined by their ability to have people, artificial intelligence, machine learning, and digital feedback loops all working together in near real time. To them, this is not a lofty goal but an essential platform for success. They see their ability to compute on the far edge of the cloud as a foundation of their immediate and longer-term success; it gets built on top of that workflow platform.

The research uncovered 20-plus characteristics for success for this most successful group, as well as characteristics for the success achieved by those still on their journey, or experimenting, or those who are only just starting to explore the potential of the intelligent systems world. Wind River has shared these results to help you architect your own success on the path to this intelligent systems future.

One conclusion is clear: The path to success is not a matter of luck or happenstance but can be defined in an unambiguous way — not with small steps, but with giant, connected leaps. The promise of what intelligent systems can bring should be enough to entice most corporations. The challenge is blueprinting the right sequence of investments in characteristics that will drive success.

Open Source Brings Collective Creativity to the Intelligent Edge

May 7, 2021



The idea of open source is not new. Ideas around the power of collectives to share, iterate, and effectively innovate together in near virtual space arose in the mid-eighteenth century, during the heyday of the age of enlightenment, with groups like the Lunar Society in the U.K. The Lunar Society met roughly once a month in Birmingham, at the epicenter of the industrial revolution, as a collective of great minds, including both of Charles Darwin's grandfathers. They explored, shared, and broke barriers across disciplines together because they had the space in which to do it, and as a byproduct they gained great energy from discovering the possibilities of the world around them. For anyone who has attended an open source event, this description may sound familiar.

The Lunar Society of the 1790s is in many ways the very essence of open source community: getting the best ideas, working together, reacting and sharing together in real time. One major difference, though, is that the Lunar Society was exclusive by nature, while today's open source community is not. It is truly open. We live in a vastly more complex and expansive world than Birmingham in the 1790s; the power of the opportunities today is global, and mostly still forming.

Only an open source strategy can work in this environment: millions of people, tens of millions of ideas, maybe billions of combinations of code.

With billions of devices running autonomously, computing, sensing, and predicting zettabytes of data, there are endless possibilities for what business ideas and technologies will thrive on the intelligent edge. Only an open source strategy can work in this environment: millions of people, tens of millions of ideas, maybe billions of combinations of code.

Open Source for the Intelligent Edge

An effective intelligent edge will require a robust infrastructure that can handle low latency, high availability, and bandwidth demands. This infrastructure will include three key components: a cloud platform for running applications, analytics to monitor the health of the platform and services, and an orchestration layer to deploy and manage services across a distributed network.

There are five basic ways for companies to obtain this infrastructure: build it themselves from scratch, buy a proprietary solution from a vendor, build it starting with open source, buy a vendor-supported open source solution, or use infrastructure as a service (IaaS).

In a recent survey we administered across 500 respondents in France, Germany, Spain, the U.K., and the U.S., a relatively small percentage selected "build your own from scratch," and a few more selected "vendor proprietary." The majority selected an option where open source plays a role, whether in IaaS, do-it-yourself (DIY), or vendor-supported options. IaaS was the #1 choice for all three elements (cloud platform, analytics, and orchestration). The rest were split between one of the other flavors of open source (DIY or vendor-supported).

It seems most people aren't interested in building and/or managing their infrastructure themselves. Thirty-four percent of businesses in the U.S. cite "lack of internal skills or knowledge" and "bandwidth constraints on people's time" as the biggest barriers to adopting intelligent edge technologies, followed closely by "additional investments in associated technologies are unclear" and "lack of internal business support or request." Open source options give these companies the benefits of the solution without having to shoulder the burden all on their own.

If building and supporting your own infrastructure is core to your business, then building from scratch might make sense — but even then, chances are you may still use open source components. With 180,000 open source projects available with 1,400 unique licenses, it just doesn't make sense not to use open source to some degree.

With open source projects you get to leverage some of the smartest people on the planet, and they don't have to be on your company payroll.

Why Open Source Is So Pervasive

The popularity of open source is not surprising. For one thing, you get to tap into a technological hive mind. There is some debate, and many variables, but estimates put the number of open source developers worldwide somewhere north of 20 million. Open source communities attract a wide variety of people who are interested in participating in a particular piece of technology, with communities and projects running the gamut in terms of size and scope, depending on the focus and maturity of the project. The common thread is the community of people who are contributing and reviewing code in an effort to make the project better. Generally speaking, the more applicable the code is to a variety of use cases and needs, the more participation you might see in the community. So with open source projects you get to leverage some of the smartest people on the planet, and they don't have to be on your company payroll.

The second reason for such widespread usage of open source — related to the first — is the fact that you don't have to do it all yourself. It's a pretty common scenario for a development organization to use open source code as a component of a larger solution. By leveraging that open source component they can save hundreds if not thousands of work hours by not having to develop or be the sole maintainer of that piece of code. It also allows the organization to focus on their value-add.

Not Just a Groovy Codefest

Open source derives its success from community, and just like in any community, some boundaries and agreed-upon rules to play by are necessary in order to thrive. It's one thing to download a piece of open source code for use in a personal project. It's another to use open source code as a critical component of your company's operations or as a product you provide to your customers. Just because you can get open source code "for free" doesn't mean you won't make an investment.

In order to get the full value from the community, one must be an active member of that community.

Open source projects need focus, attention, and nurturing. In order to get the full value from the community, one must be an active member of that community — or pay someone to be an active member of the community on your behalf. Being active requires an investment of time and resources to give a voice and listen to other voices on a steering committee, discuss priority features to work on next, participate in marketing activities designed to encourage more participants, contribute quality code, review code from others, and more. Leaning in is strongly encouraged.

Open source technology offers a tremendous opportunity for collective creativity and innovation. When like-minded people gather together for a focused intellectual purpose, it's energizing to the individual and can be hugely beneficial to the organization. Whether the open source code is part of an IaaS, a component of something you build, or part of a vendor-supported solution, it is a tremendous asset you can use to push your company's value-add forward to better meet your customer's needs.

Characteristics of an Intelligent Systems Future

August 10, 2021

By 2030, $7 trillion of the U.S. economy will be driven by what we might call the machine economy.

53% of leaders and executives see their organizations putting strategy, experiments, and plans into place right now for intelligent systems success in the next five years.

AI, robotics, automation, and autonomous machines will drive 70% of GDP growth between now and 2030 globally (PwC). This may be the most vital period of the next industrial age, as machines, humans, and data exponentially increase the volume, range, and depth of the work we achieve, discover, and even create. We will all become data-driven software enterprises in this process.

How we get there, and how successful we are, is already part of the thinking and action of executives and leaders in organizations dependent on these ideas for business success. Here are 12 points to consider.

1 Sixty-eight percent of leaders land in the mainstream-to-positive range concerning digital transformation; only 9% see themselves as already fully moved to an intelligent systems future.

Digital transformation has reached a mainstream or better state inside these organizations. The ideas and practices behind intelligent systems are at the same stage that digital transformation was in by 2015 (Michael Gale, *The Digital Helix*). Current giants of digital business models — Amazon, Google, Netflix, Facebook — have grown by at least two and half times in the years since then, because the world has evolved to where they were going. In other words, in a mere half dozen years, companies committed to a dominant new business model were significantly rewarded in terms of size, growth, and profitability. A commitment to intelligent systems will show similar rewards by 2030. The patterns are being set now.

2 This is the next wave of the digital economy. Already, 62% of leaders are moving toward their own intelligent systems futures.

Nine percent of leaders and executives see their organizations as fully moved to an intelligent systems digital business model.

Fifty-three percent of leaders and executives see their organizations putting strategy, experiments, and plans into place right now for intelligent systems success in the next five years.

Thirty-eight percent of leaders and executives are just talking about the idea of intelligent systems success in the next five years.

3 Thirteen interwoven meta-trends form the components of intelligent systems.

Fewer than 3% of executives and leaders believe that one or some of these 13 meta-trends are not important or relevant. Ideas about AI and machine learning, the power of real-time data, agile methodologies, 5G, connected systems, cybersecurity in the cloud, cloud-based design, and the mission-critical importance of embedded devices have all permeated the decision-making process.

	Behind Peers	In Line with Peers	Ahead of Most Peers	Not Applicable to Our Business Right Now
The idea that AI and machine learning are or will be critical for future success	17%	55%	25%	2%
The idea that using real-time data to drive decision-making will be key for success in our products and services	17%	55%	25%	2%
The idea that agile versus waterfall development ideas are critical for how we will develop and deploy embedded devices and services in the near future	18%	54%	27%	1%
The ability to deliver services and products inside other business sectors we have not worked in traditionally	18%	53%	27%	2%
The idea that embedded devices are mission critical for the future of our company	19%	52%	27%	3%
The idea that embedded devices are mission critical for the future of our company	19%	51%	27%	3%
The idea that all the systems from customer to supplier, product, and services used are highly connected in real time	19%	51%	27%	3%
The idea that the intelligent edge and 5G are the future	19%	49%	31%	1%
The idea that cloud-based design and delivery is the dominant way our business will work moving forward	22%	49%	27%	2%
The idea that business models are at our core	23%	49%	28%	1%
Cybersecurity in our products and services are critical as building blocks for all business success	21%	48%	30%	1%
The ideas that real-time digital and data feedback loops will drive our ongoing decision-making	21%	47%	30%	3%
The idea that our embedded systems can run themselves mainly autonomously	2%	20%	46%	31%
The idea that companies are increasingly becoming software companies at their core	3%	22%	46%	29%

4 There is a clear business imperative served by the idea of intelligent systems technologies.

Only 12% of these leaders believe that technology leads their overall strategy. Yet 61% of them are leaning into the processes to build intelligent systems for themselves. This is a business imperative and shows an awareness of meta-trends. Software-led enterprises, the edge, and data-centric decision-making are driving leaders' desire to push their organizations to become intelligent systems companies.

5 The depth of buy-in and actions varies by industry — but the race is on now, with $1.1T in play in the six industries we researched.

When these executives and leaders talk to us about where they are and where the potential could lie for intelligent systems inside their industry, we see that there are different patterns. But leaders in up to 27% of sectors (such as manufacturing) and 10% of industries (such as energy) believe they will be following a predominantly intelligent systems business model. Using 2020 GDP contributions for these sectors, we see that a combined $1.1T+ of GDP in these sectors could be affected by intelligent systems.

	Some Core Intelligent Systems Changes Already	Could Be the Most Dominant Business Model
Aerospace & Defense	27%	6%
Automotive	13%	19%
Energy	17%	10%
Manufacturing	19%	27%
Medical Technologies	14%	22%
Telecom & Technology	32%	20%

6 Four thousand simulations of the 13 characteristics show the power of one particular characteristic: true compute on the far edge.

After using discrete choice models to simulate 4,000 possible combinations of characteristics for intelligent systems success, we were able to rank what matters (priorities) and when it matters (now, the near and/or further future). Forbes researched the opinions of 506 executives and leaders in the following industries: automotive, medical technologies, aerospace and defense, energy and utilities, telecommunications, technology hardware, and industrial manufacturing. In six of the seven industries, the ability to compute at the far edge is the number-one priority. Their systems would be sensing, predicting, computing, creating, and connecting using digital feedback loops to run autonomously or with machine learning and automation. The capacity to do this 24/7/365 on the far edge will be essential for the machine economy that will be working in the same 24/7/365 in thousands or maybe millions of different ways.

7 Barriers and drivers to success are at times obvious, and some are very human.

If this transformation were easy, every organization would be there now. But currently, 57% of leaders believe that integrating the necessary workflows will be challenging; 37% believe that needed skill sets and common approaches are not fully available. Thirty-six percent believe that their industries are so highly regulated that adoption of intelligent systems is restricted. Only 15% believe that their industry will not easily embrace moving business to the cloud from the intelligent edge and devices to the customer.

8 Mission-critical capabilities dominate the pathway for success.

Mission criticality is defined in a number of ways, from certification of codes to safe, secure, cyber-protected, and near-latency-free compute times. One in 5.5 of the embedded devices on that far edge will need to be mission-critical capable. Eighteen percent to 24% of all embedded products and services will need to be mission-critical capable across seven dimensions for success.

9 Building a foundation is an absolutely vital stepping stone for measurable success.

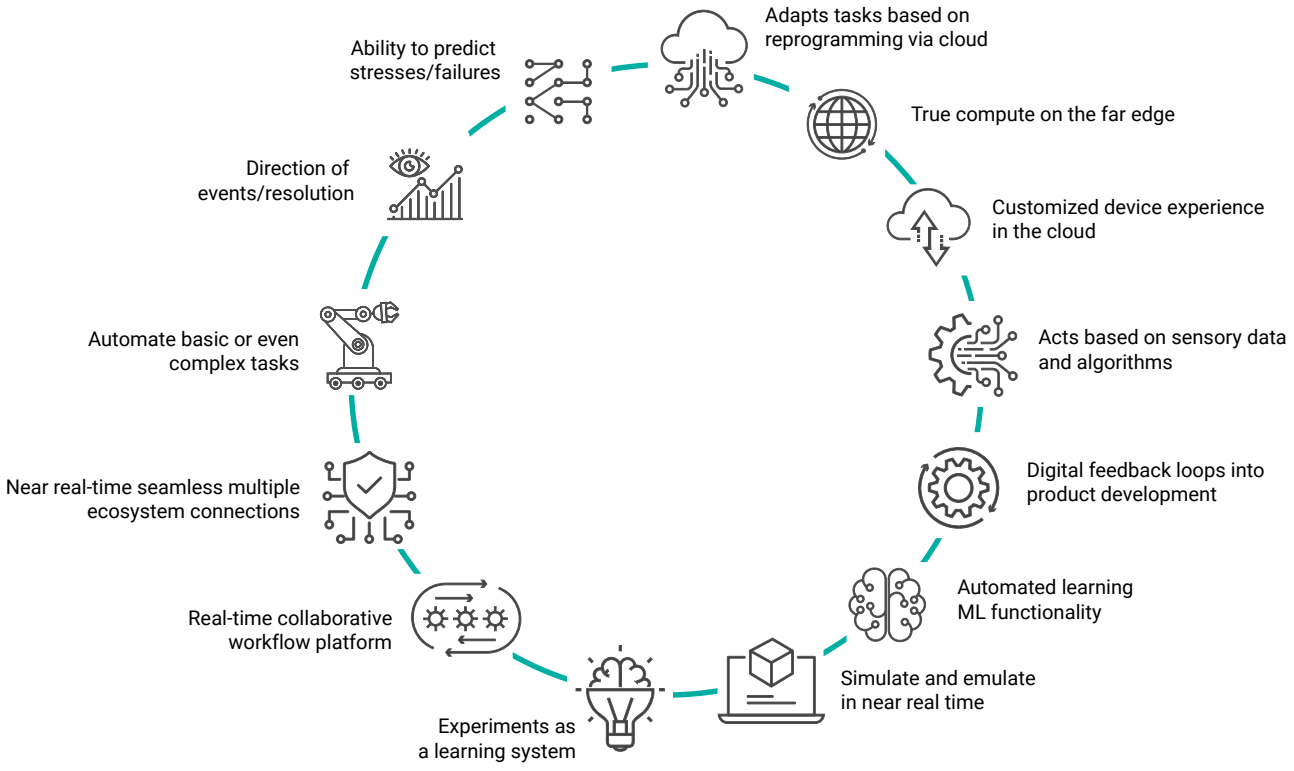
Executives told us how they rank the 13 key characteristics in importance over the next three to five years. Viewing the ranking, we see that 18% of their focus is on infrastructure needed now, 41% is on foundational elements that build for longer-term success, and 22% is on characteristics they will need in five years' time. The rest of the focus is on nice-to-haves, not essentials.

10 In five years' time, two of the most important characteristics overall will come into play.

Two of the three tier-one characteristics from the list of 13 are the ability to utilize real-time ecosystems of applications and AL/ML learning. In effect, embedded devices and the digital feedback loops they are creating or interacting through in near-latency-free time can be infused with AI/ML as well as with a wider array of application capabilities. We might call this a sign of true intelligent systems.

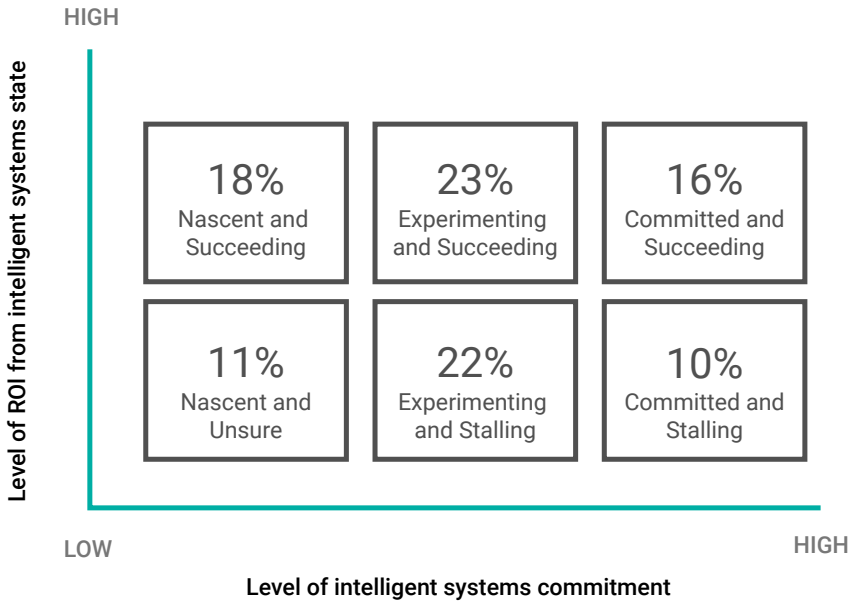
11 Industry-specific road maps are important for success.

Each industrial sector places a different emphasis on each of the 13 intelligent-systems characteristics in order to build a solid infrastructure, lay a foundation for growth, and ultimately show growth by the end of five years' time.



12 Your next steps will drive where you end up. Can you be part of the 16% who are committed and succeeding?

When we modeled commitment to the idea of intelligent systems plus a clear acceptance that a level of highly authentic reengineering of certain business processes is required, and then correlated that across 15 ROI metrics models, we found that only 16% of leaders interviewed are committed and succeeding. They outperform their committed peers by 4:1 across the combined metrics. To see why they are succeeding in the creation of their own intelligent systems future, we defined 200 distinctive flags that highlight the way they think, design, measure, and orchestrate each of the characteristics for intelligent systems success.



To learn more about how to become a leader in intelligent systems, download the overview and industry-specific booklets below:

Intelligent Systems Overview

Aerospace & Defense

Automotive

Energy & Utilities

Manufacturing

Medical

Telecommunications

Cloud Convergence

March 1, 2022

Most of us can no longer imagine living without doing things that are possible thanks to cloud technology — performing business transactions from a browser or mobile device from any place in the world, using a phone camera to take a picture that gets stored somewhere in the cloud, interacting with a business via natural language processing when calling the toll-free number of a company. All of these activities require on-demand computing power and storage, which cloud technology provides.

The popular perception has been that the cloud is useful mostly in the IT world for tools, email, or web searches. The devices that most people associate with cloud technology are mobile phones, fitness trackers, and smart watches.

The cloud is part of the critical infrastructure. Machines and the cloud are now part of the same technology continuum that spans the traditional world of physical assets and the digital information flow.

From my vantage point, having worked for more than 15 years with businesses making robots, planes, medical equipment, manufacturing controllers, and many other machines, the cloud — just like those machines — is part of the critical infrastructure. Machines and the cloud are now part of the same technology continuum that spans the traditional world of physical assets and the digital information flow.

To fully embrace this concept requires a new, broader perception of what the cloud can help us accomplish. Then we need to think about how this new perception can be brought to life with packaging of software and cloud-native development processes. These are the three P's: perception, packaging, and process.

Changing the Perception of What the Cloud Can Do

After years of digital transformation associated with IT, focusing mostly on information flow in the digital ether, the focus has now turned to IoT. McKinsey's recent Digital Manufacturing Global Expert survey reveals that most manufacturing companies (68%) consider Industry 4.0 manufacturing initiatives to be their top priority. The global industrial automation market is expected to reach USD326.14 billion by 2027 after a decade of CAGR at 8.9%, according to Fortune Business Insights.

Critical infrastructure players are connecting their devices to get data out of them and offer new services, provide functional and security updates to the software, introduce net new features, or integrate the devices in a larger system. Devices are not alone anymore. They are part of a global cyber-physical system that spans hyperscale clouds, edge clouds, and the electro-mechanical edge.

As part of this continuum, products are no longer simply physical things; they become services as they continuously generate data and provide insights for performance management, remote control or equipment, predictive maintenance, and many other uses. Consumption and production converge as autonomous, AI-driven power grids automatically manage production and use across multiple, distributed energy resources. Mass and custom production become increasingly meaningless differentiators as software-driven manufacturing enables mass customization and assembly lines give way to modular assembly.

The devices themselves are not moving to the cloud. Even though one may argue that 5G is introducing high-bandwidth, low-latency connectivity, the fact is that it is still not enough when one expects a response time in the single-digit microseconds. Some of the processing of the data from the sensors needs to be in situ. Agreed, a lot of the data will be pushed to the cloud for further processing, but 75% will still be consumed right there, at the edge — thus making it an intelligent edge.

Software Packaging That Can Handle the Intelligent Edge

Containers were introduced to solve specific problems. Just as ships carry specific cargo for different customers in their onboard containers, so do cloud-based containers carry specific code for different applications, independently from other containers.

Beyond connectivity and data, a key component of any system today is its software, which delivers instructions for the edge applications. Cloud technologies have driven a lot of innovation that make it easier to manage software. One such technology that has enabled a significant amount of scale is the container, which can power what we at Wind River envision as the edge cloud.

Containers were introduced to solve specific problems.This definition from Google is perfect: “Containers are lightweight packages of your application code together with dependencies such as specific versions of programming language, runtimes, and libraries required to run your software services.” Just as ships carry specific cargo for different customers in their onboard containers, so do cloud-based containers carry specific code for different applications, independently from other containers.

As we look at the intelligent edge, our vision at Wind River is to enable our customers to build better software faster, and — equally important — to enable the management and operation of the software in the field once it’s deployed. A fighter jet is a good example, but the same principles apply to self-driving cars, automated factories, and any number of other scenarios.

The fighter jet has a lot of computers to do a variety of tasks such as running the flight management system, weapons system, or radars. Each of the jet’s computers runs on a platform with a potentially different operating system. The question is, how do we accelerate the deployment of software on such large systems? The answer that we envision is a containerized local infrastructure — or edge cloud — in the plane, car, or factory, ready to serve the software for the various subsystems. That edge cloud connects in turn to another cloud, which allows you to push information and software updates in order to manage and orchestrate your heterogeneous software subsystems.

With these capabilities, aerospace and defense organizations, energy providers, large-scale manufacturers, and medical organizations can take advantage of low-latency, high-bandwidth performance for the most challenging applications.

Processes That Enable End-to-End Cloud-Based Edge Infrastructure

One of the most direct benefits of container technology is that it provides a solution to the software management conundrum of mission-critical systems. Bridging container technology, which is cloud-native, with the embedded applications development requires a new cloud native–inspired workflow.

Fully embracing cloud convergence — what it can help accomplish and how to evolve to get it done — is the next step in digital transformation.

Container technology is fundamentally changing how systems are being developed, tested, deployed, and managed. People are most familiar with containers as part of cloud-native architectures in which applications are decoupled from the infrastructure — including hardware and operating systems — on which they are running.

However, traditional embedded application development/deployment has significant differences compared to a cloud-native architecture, one of which is that it is tightly coupled to specific hardware and also requires specialized development and management tools.

The requirements of embedded systems introduce many new issues compared with a typical cloud-native application. For example, edge devices might be physically accessible. They might need to operate in constrained, unreliable networks. Devices could go offline for long periods of time to conserve battery life. It can be difficult to determine whether a device has failed or has simply been moved out of network range. Devices can be stolen. And a device may be the only one serving an area, so it cannot fail over to another device if there's a problem or it needs to go offline for an update.

To bring container technology to embedded applications, Wind River has created a container engine for its real-time operating system, which can be used to accommodate the real-time needs of embedded applications. It can be managed by the same standard tools that cloud-native developers are already familiar with, and it also supports services, giving teams tremendous flexibility in how systems are deployed and managed.

Cloud convergence brings to bear savings by leveraging standards, existing infrastructures, and, most important, human knowledge and experience. Fully embracing cloud convergence — what it can help accomplish and how to evolve to get it done — is the next step in digital transformation.

Agile, Intelligent, and Green?

April 4, 2022

Do *agile, intelligent, and green* all describe a real outcome in an intelligent systems world? Sixteen percent of leaders in intelligent systems are living the dream right now.

What Does the C-suite Believe?

A famous quote comes from Michael Robinson, a Superbowl-winning fullback for the Seattle Seahawks: "Believe, behave, become." This saying rings true among companies that believe that technologies can improve their environmental impact. The key questions are: What behaviors do C-suite executives believe will make a greener world? And are those behaviors delivering on that promise?

Any physical product company must take into account a complex work formula that includes raw materials, the processing and fabrication of products, and then the power to make them work or to transport them.

We are heading toward a world that should be more carbon negative, for the simple reason that we are collectively realizing that we are damaging the planet. At the same time, we are living in an increasingly software-centric world. We can surely reduce the damage to the environment every day if we develop and deliver more experiences and even business models through the lens of software and not just physical product. Software products have a profoundly smaller environmental impact.

We can surely reduce the damage to the environment every day if we develop and deliver more experiences and even business models through the lens of software and not just physical product. Software products have a profoundly smaller environmental impact.

Imagine a Cleaner Future

Research from 2015 indicated that consumer household products and services generated some 60% of all greenhouse gases. In the U.S., the EPA calculated in 2019 that 23% of greenhouse gas emissions come from industrial production. A recent *Harvard Business Review* article entitled "How Green Is Your Software?" covered the impact of software on the environment and showed that, in 2007, software was believed to deliver 1.5% of all environmental emissions. By 2040 that number might hit nearly 16%.

Even so, if by 2040 we are a fundamentally more software-centric and intelligent systems–oriented world, we will be radically reducing our carbon footprint.

Imagine a reality in which more intelligent systems (machines, edge compute AI, automation) deliver evolving services. Seventy percent of GDP growth in 2020–2030 is positioned to come from such changes. Given this, the interplay between being green and/or carbon neutral and being exponentially more intelligent becomes truly interesting. Instead of rebuilding new products

or capabilities, we could be using software to re-task, re-vector or even redesign a customer experience. There will be a constant capacity to connect a customer, the product/service, and the company in near real-time.

New intelligent edge–based business models will radically shift companies, helping them embrace the vision of delivering a greener future as a genuine possibility.

This software-centric world sits at the heart of intelligent systems ideas, driving new business models, experiences, and innovations at the edge. This becomes clear as we see telecommunications carriers use 5G services to focus increasingly on a software-driven network, and it is also at work in the energy, aerospace, automotive, and industrial robotics and controls industries.

What the Research Shows

In our recent work with Forbes, we delved deeper into possible correlations between intelligent systems and new business models. Traditionally, industrial systems evolve slowly. Being intelligent requires a level of adaptive learning. To be a true intelligent systems company, do you need to be more agile? We also asked whether the combination of these two elements, agility and intelligent systems, could produce greener products. Here are three simple conclusions, which include some optimistic elements:

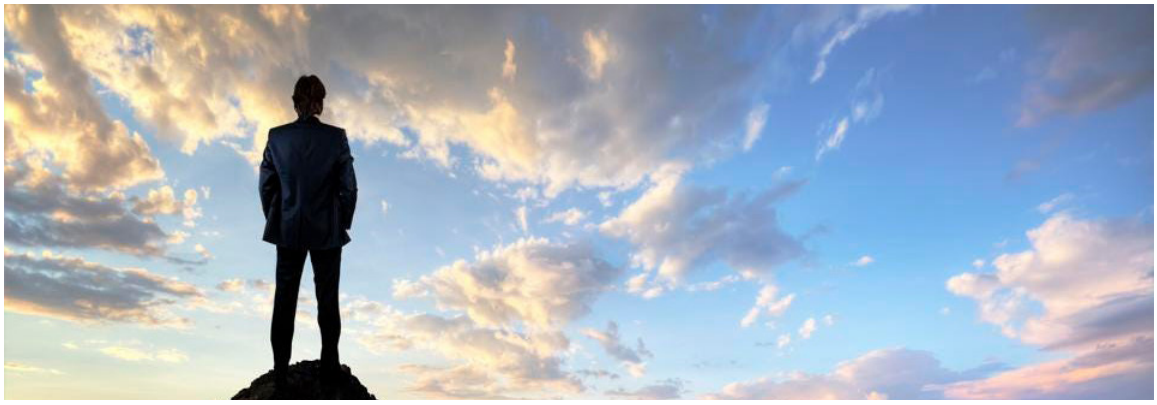
- Of the eight industries we researched, 35%–46% of their C-suite and executive-level leaders were completely committed to the idea of intelligent systems as dramatic influencers of their new business models. Intelligent systems will support an important business model going forward, creating a major economic impact.
- When comparing agile working methods versus delivering greener products, agile working methods won out as more important in six of eight instances. We are still working on how to positively apply agile working methods to change the world around us.
- When we find the intersection of a high interest in intelligent systems and a clear understanding of what it takes to be more agile, then add the desire to get greener products out of the process, we find that three industries lead the way: automotive, manufacturing, and energy/utilities. Together, these sectors generate more than 50% of the world's carbon footprint. The 16% of these companies that are currently intelligent systems focused, who are adopting agile work methods and also have a strong understanding of green products and services, are the ones we should learn from. Read the two-part interview with Schneider Electric on the power of the grid in an intelligent, distributed world (pp. 91–94) and see how that company is delivering according to this concept.

Back in 2009, research determined the greenest technology brands worldwide, looking at 3,500 IT leaders in 11 major economies. Dell fared extremely well due to its attitude about green recycling. That was the tip of the iceberg; green business practices have evolved greatly since then. In IT products, for example, power consumption in networks and services from telecom carriers has moved to cloud-based networks. Similar investments would not have been as likely or as public back in 2009.

New intelligent edge–based business models will radically shift companies, helping them embrace the vision of delivering a greener future as a genuine possibility. Maybe this is the formula that delivers on the promise: not greenwashing, but applying a deep understanding of how intelligent systems, agile work styles, and the promise of greener products for the planet can move us from the abstract to the norm.

Open Source: Innovating at the Intelligent Edge

June 1, 2022



Conquering the next frontier in technology will take all the brainpower the technology community can muster.

That frontier is the intelligent edge. That brainpower can be mustered with open source systems.

The intelligent edge is built on AI-driven software systems, which are embedded in everything from the energy grid to thermostats, smart watches, insulin pumps, industrial robots, autonomous vehicles, aviation systems, and much more. These devices are part of a global cyber-physical system that spans hyperscale clouds, edge clouds, and the electro-mechanical edge. We probably can't yet imagine all the ways in which the intelligent edge will change how we live and work, but we can already see that the complexity and innovation it requires are unprecedented.

Open source will play a critical role in supporting and powering the intelligent edge, because it allows developers access to a distributed collaborative environment, shared vision, reciprocity of findings, and great tools — leveraging the full brain trust of the technology community.

The experience Wind River has amassed with Linux and open source over nearly two decades across mission-critical industries is well known throughout the industry. In fact, according to VDC Research, Wind River is ranked as the market leader in commercial embedded Linux global revenues. We are right in the middle of the action. By 2028, 63% of the global infrastructure edge footprint will be for use cases supporting applications in vertical markets such as healthcare, manufacturing, energy, logistics, smart cities, retail, and transportation.

Cloud and embedded computing have ushered in a completely new era, with digital transformation now involving the creation of a connected society and a machine economy.

Digital Transformation Is Moving to the Edge

Digital transformation has been among the top priorities for more than a decade, with business growth dependent on how well companies use technologies to streamline work processes, improve customer experience, or target their digital marketing. But cloud and embedded computing have ushered in a completely new era, with digital transformation now involving the creation of a connected society and a machine economy — the world in which critical infrastructure players are connecting their devices to retrieve data, offer new services, introduce new features, or integrate the devices into a larger system. As a natural extension of cloud computing, the intelligent edge cloud is a key enabler for the so-called Fourth Industrial Revolution, or Industry 4.0.

The infrastructure investments to support the growing demand of device and infrastructure edge will amount to a cumulative capital expenditure of up to $800 billion between 2019 and 2028. These expenditures will be relatively evenly split between equipment for the device and the infrastructure edges. The global IT power footprint for infrastructure edge deployments is conservatively forecast to increase from 1 GW in 2019 to more than 40 GW by 2028, with a compound annual growth rate (CAGR) of 40%.

The verdict is in about how technology leaders are planning to go about creating a machine economy: 79% of technology leaders expect to increase their use of enterprise open source software for emerging technologies such as artificial intelligence, machine learning, edge computing, and the Internet of Things. The relationship between edge computing and digital transformation pulls in enterprise open source as well. The majority (54%) of technology decision makers now say that digital transformation is an important use of enterprise open source.

Succeeding with Open Source at the Edge

As a greater percentage of compute workloads move away from data centers and to the edge, the companies most able to leverage the vast amount of powerful, real-time information will be the ones that have effectively sought out digital transformation.

While digital transformation is tough, and only 28% of the Global 2000 are actively succeeding in digitally transforming, it will become increasingly essential to change how teams develop, deploy, and operate embedded devices and infuse them with capabilities such as AI in order to build greater levels of automation, autonomy, and knowledge. As a greater percentage of compute workloads move away from data centers and to the edge, the companies most able to leverage the vast amount of powerful, real-time information will be the ones that have effectively sought out digital transformation.

Mission-critical embedded systems have some of the most demanding requirements and the longest lifespans, and teams must plan to build, manage, and maintain them over years or decades. This is especially challenging in an intelligent systems future that demands increasing vigilance around security and compliance.

As an example, Wind River Studio Linux Services directly addresses the evolving market needs of developing, deploying, and maintaining embedded systems and helps with challenges around security, defects, compliance, and the ongoing management of mission-critical intelligent systems when using community-based open source software. By helping developers build and deploy robust, reliable, and secure Linux-based intelligent devices and systems, Studio Linux Services can remove the burden of monitoring and maintaining platforms, leaving developers able to focus instead on developing innovative and differentiated intelligent edge systems that maximize return on investment.

We understand that some organizations may want to start their Linux journey somewhere other than Wind River Linux. Perhaps they want to leverage a board-specific Linux from a semiconductor provider such as NXP, TI, or AMD. Regardless of how an organization sources its Linux platform, there are common challenges everyone must overcome.

At Wind River, we approach the intelligent edge believing that we can get further by becoming part of an ecosystem, learning from one another and contributing to the open source community.

The New Era of Edge Computing

September 26, 2022

This article comes from a Forbes *Futures in Focus* podcast interview with Ron Martino, executive vice president of global sales for NXP Semiconductors. He discusses the edge economy and what edge technology may need to look like moving forward.

We're entering a new age, in which we will experience a dramatically different world of compute ushering in new experiences and economic models. How would you define the edge compute world and what it looks like?

Ron Martino: Edge computing goes beyond the traditional type of computing, such as existing mobile phones or personal computers. It involves small, distributed computers embedded in all the devices around you. Those devices are sensing local environments; they're establishing and understanding the context of that environment. And then we're enabling those devices to perform actions that are independent of human interaction or command, but consistent with what you desire. These devices also interact to build a collective intelligence among themselves and then take action based on how they understand the world in which they exist — whether that's your home, work environment, or even your car.

"We're enabling embedded devices to perform actions that are independent of human interaction or command, but consistent with what you desire."

Can you work through some examples and where you think we will be in the next decade or so?

Martino: Let's consider agriculture. Farms around the world use about 70% of our fresh water, in terms of annual consumption. It's estimated that half of the water is used for irrigation — this was determined via devices placed out in the field. You can use that data to get insights in terms of the conditions of the crops and the needs around irrigation, specifically for a given field or crop. You could apply the data to determine whether what's needed is water or fertilizer or pesticide, and it can be applied in a much more efficient way. These are just a few examples of how we can dramatically eliminate waste and also improve the productivity of farming.

The ability is there today to collect the data. It can come in via more very efficient small devices that can run on different energy sources, whether that's the sun or extracting energy from the soil through a photosynthesis process. Or it could be part of equipment that is used to actually do the farming, integrated into the sensors in the larger compute inside those vehicles. And all of that can then be leveraged through a different type of local compute, as well as combined with cloud computing to determine and optimize the productivity and efficiency of that farming operation.

How far is this from the chalkboard to actual practical examples? Have you seen applications in large-scale agriculture where this is now happening, or is this still mostly on the whiteboard?

Martino: This is happening today. The majority of farming is done in an autonomous way. And the data is being fed in from tractors and other farming practices into a cloud. There is a local capability that efficiently operates the vehicles, and then there's a collection of data that can be preprocessed locally and then sent for higher compute analysis or more complex analysis of the data. This is in play today.

It's in play in your home as well. Not from an agricultural point of view, but in terms of placing more compute capability in your thermostats in your home or in controls for your lighting, and looking at how to operate those at more efficient times in terms of power consumption and cost. The data can help determine when to shut off lights and use energy when the environment is not active.

What are other applications where a very small-footprint, high-powered processing skill that uses AI — which we may not see with our own eyes — can start making a substantial difference to our daily lives?

Martino: Let's talk about it at a very high level first: this type of computing and how its evolution will enhance productivity. In automotive, injuries and fatalities can be reduced when you're mapping the environment and taking action when dangerous situations are identified.

Let's also consider the improvement of your personal health when optimizing sleep quality of the air, as well as the overall conditions of the environment that you're living in. The biometrics or the data you collect monitoring your body conditions — that data can help lead to making better choices.

It can also provide another meaningful impact on society around the achievement of sustainability goals, such as creating a greener world with more efficient use of power. All of this can be done through the proliferation of these billions and billions of connected devices and managing new sources of information. We can take all this data and collect and process it to be able to leverage new insights and take action.

"There are different forms of security, and we've been working with financial and banking industries and governments to protect data and ensure secure transactions."

These are independent devices functioning on the edge in the cloud, super intelligent and better at managing data in real time than human beings are. These billions of devices will engage with all of us in various ways. What sort of societal changes do you think could arise, say in 10 years, when this becomes a common process?

Martino: Current forecasts estimate that there will be 75 billion connected devices by the next decade. An interesting fact: Today we generate about 64 zettabytes of data — that's 64 followed by 21 zeros. It's a massive amount of data, and it's only going to increase by orders of magnitude in the next decade.

When you think about the amount of information this makes available, and the desire to not waste it and to extract valuable information, you're going to need compute devices that operate locally where the data's generated, not use significant energy, and then transfer the information most efficiently. In terms of its impact to society and how it will be deployed, it's going to come into play in meaningful ways. For example, it can help reduce your energy bill. Or you may interact with media and sound in environments in a way that is more enjoyable.

Let's dive into the issue of security. For example, would blockchain technology play an important role in the solution? It would require cloud-to-device interaction and integration.

Martino: There are different forms of security, and we've been working with financial and banking industries and governments to protect data and ensure secure transactions. The types of security discussions that are critical include enabling system protection under different conditions. It becomes very important to be able to securely bring up a system so it doesn't have vulnerabilities and can identify that a device is secure and has an identification that's unique. We must also think

about how you provision it, then how you commission it into an environment that is targeted for the use of that device — be it your home or work environment — and then how you manage its security on an ongoing basis.

For example, how do you protect from physical attacks or remotely connected attacks and enable updating these devices over time, or effectively remove them from an environment so they can't be used to gather information?

Then there are concepts around confidential computing that come into play, on collecting data from multiple sources and not losing privacy but getting the benefit of processing the data to extract valuable information to protect your personal information. A great example of that could be personal health data — looking for information to help society or a community but not revealing the personal information of a specific individual.

Yes, for example things like orphan diseases, where there is a vast array of some very harmful but disparate, low-incidence diseases. If you could share some of that data blind, between one patient to the next, you could create a large and beneficial database of knowledge around a particular orphan disease. It's currently tough to measure unless you're in a particular institution database.

Martino: Absolutely. Medical applications around the tracking of disease, as well as other aspects of sharing information that could be useful for a community, clearly come into play when you're looking at that type of processing of information. It's a capability that exists today, and it is evolving to higher levels of energy efficiency and ease of use.

Management of these devices plays a key part in growing broad adoption. People have to trust the devices, trust the security, and find it easy to deploy without the challenges of managing a high-tech environment.

As you think about the lifecycle process, safety, security, and all the things that really matter, what are the triggers that are going to turn this into an endemic norm?

Martino: I've touched on a few of them. First is examining the meaningful end result of, say, putting a device into your home or your work or your car. As the benefits of having these different devices around you become clear, they're going to be more broadly adopted. If I tell you I can cut your energy bill in half, you're going to be very interested. And if it's easy to deploy, you will have little reason to not deploy it.

"Half of global waste is caused by manufacturing inefficiencies. If you combine devices with sensors and machine learning at the edge, you have more energy-efficient devices.... You can significantly reduce waste and improve the output of the factory."

What will make it even more attractive is the ease of putting the device into your home and the interoperability of that device with other devices in a simple interface. And when an issue occurs, having the ability to resolve it in a simple way or have the system identify what needs to be fixed.

When it comes to industrial applications, it's going to be about enhancing the output of the factory through automation. Improvement of the safety of your workers, which will make your workplace a more attractive place to join, are other examples of addressing economic and social motivations.

This puts that data accumulation into practical or contextual action in an environment. In a factory environment, for example, there must be some unique outputs, because organizations are using insights not only for safety but also for productivity. It must be opening windows of opportunity for companies to see the data as being as valuable as the actual product.

Martino: Yes. Specific to industrial applications, industrial control and automation are important areas for us. Half of global waste is caused by manufacturing inefficiencies. If you combine these devices with sensors and machine learning at the edge, you have more energy-efficient devices and you can conduct a real-time reaction. You can significantly reduce waste and improve the output of the factory.

We're working with many different industrial customers to put scalable platforms of computing in place that can automate and control their manufacturing environments in a much more efficient way. That's done through a range of different computing capabilities, combined with other capabilities to make the computer more intelligent.

And what do I mean by that? It's applying machine learning. And that machine learning is basically a model that will allow the machine to understand the scenario, what activities are taking place, who is in the environment, whether they are in a distracted condition or in danger — and then take action. Those are just small examples of where industries are looking to either improve efficiencies or improve safety and leverage this to drive enhancements for their company.

You can already see this type of ability with the distraction mode in cars. If you take your hands off the steering wheel or there's a sudden motion, there's a warning that you might be distracted. There's a natural extension of that experience into a more complex industrial landscape.

"Machine learning is basically a model that will allow the machine to understand the scenario, what activities are taking place, who is in the environment, whether they are in a distracted condition or in danger — and then take action."

Martino: Yes. Another area of significant growth is the way you interact with machines. The human–machine interaction and interface is an area of significant growth. It is relevant to health and being able to interact with different systems and machines without touching them — having a cleaner environment and ease of interaction, whether it's using a voice- or a camera-based system to achieve new efficiencies. If you're hitting buttons or using interfaces through more of a natural human interaction that the machine can understand, you can work with them in a much more effective way.

That's another significant aspect of investment in innovation: enhancing that human–machine interaction so that it feels natural and creates a safer and healthier environment.

Right. People have a lot more sensing capability than just trying to use fingers on a keyboard, which is a really limited way of interacting with the machine.

Martino: Absolutely right. There's a lot that you can do to make it a seamless experience. You can easily detect where an individual is staring, for instance, and you can adjust the environment to make it more effective and comfortable for that person to use, or make it safer to use. You can combine a vision-based classification of who you are and the fact that you're speaking, so that the machine can not only understand the words that are being stated but who's stating them. And conveying your state in terms of emotion — are you happy? Are you laughing? This can provide context for what you're saying, in addition to the words themselves. It's really understanding the context of the environment by using more data so that the interaction becomes more effective.

It's a fascinating new world. In the next decade or so, what may be some interesting surprises that are not readily obvious to us now?

Martino: To build on the idea of human–machine interaction and the experiences you have today, here's a fun one: You have a multimedia experience where you're immersed in sound. You hear it in three dimensions, so you can place sound in specific locations with certain technologies today. That's usually optimized for a point in a room. Well, future technology will allow that to adjust for your location and give you that environment at many points as you move. Same thing with lighting. So the ability for an experience or an environment to adjust based on your physical location, even to where you're looking, becomes an interesting capability.

In the case of modifying your environment with sound, if you have a child sleeping, perhaps you shift the sound away from that area. You only target the sound in areas that are relevant to the listeners, and you keep a quiet environment for the sleeping child. You can also use it for safety reasons, say in a car when you want to direct the driver's attention to a source of possible danger, which could be a car in the blind spot. Or imagine being alerted to a security issue occurring in your house as windows are being broken: The sound is directed toward the point of the security issue, as opposed to your going to a panel and interpreting a code to understand where you should pay attention.

Another example is how we efficiently obtain energy to run these devices. One of the demonstrations that we provided at an industry convention showed the use of plants and photosynthesis to harvest energy and convert it to a current in a voltage that can operate the device. We are literally extracting energy from the soil to operate devices, using a natural process that occurs all around us.

Creating sustainable devices to perform tasks in a way that is consistent with the environment — build from that, and we can create many different and exciting applications where this local computing and access to information can be meaningful to the individual or the business.

There's an interesting paradox here. We talked about about 70+ billion devices in the near future. What percent of those devices could effectively be run using alternative energy sources?

Martino: That's an interesting question. While I haven't really come up with a percentage, many if not all of those devices will need to have energy efficiency factored in. The effective use of energy to achieve sustainability goals and help drive a greener world will be an additive effect of efficiency through the devices we enable. Alternatively, energy can involve solar, it can involve wind. It can also involve techniques like those I mentioned previously, such as extracting energy from the soil through photosynthesis. A broad set of applications can be driven through alternative energy.

At the end of the day, it comes down to efficient operation and efficient systems. You don't want to send all the data to the cloud, because you're spending energy going from a local environment to a remote environment and then sending information back. That is inefficient. The more you can do at the source of the data, the more you save energy as a whole. That really ties into the sustainability focus that we have as a company and what we are doing in terms of enabling these devices to operate in the most efficient way.

To what extent does this vast new edge environment replace the existing data center/PC business in terms of compute? There must be some sort of transition point at which the edge, not the core, becomes the prime place where compute occurs.

Martino: Edge internet economies are projected to reach 4–5 trillion by 2030, and this is a somewhat conservative estimate. When you talk about the edge and the deployment of all these devices, it's transforming how computing is done. There will be all sorts of new data sources, and we'll need to efficiently process that data locally and then send information appropriately.

"At the end of the day, it comes down to efficient operation and efficient systems.... The more you can do at the source of the data, the more you save energy as a whole. That really ties into the sustainability focus that we have as a company."

This computing is complementary and additive, and it is not replacing what you would typically do with your PC. More use cases and an increased need for higher compute levels in a data center will be needed, but efficiency is important as we scale massive amounts of data. We need to think through how to do that efficiently from the perspective of energy usage and management, how to process it locally and then use the other forms of computing in a more targeted way that is effective from the perspective of cost of ownership. These use cases will also require us to handle real-time local tasks for specific applications that need quick response.

In this future we're discussing, there will be a fundamental shift from what used to be compute or gather and sense centrally, to what will be gather, adjust, and compute locally and in the moment.

Martino: The way that I always talk about this is that the central compute model and the edge compute model are complementary. They build on each other. The optimization or end goal is how to use the combination of those two in the most effective way.

At NXP, we work in partnership with all of the cloud businesses to enable these many devices to securely connect to the cloud. Then we let our end customers, as well as ourselves, look at different ways to optimize that balance between the two for a particular application. Not all applications will have their own optimization. Not everything will be the same. Some will benefit from a heavier cloud usage, some will benefit from local usage.

The other important aspect of this is where you need to use a cloud environment. When you get disconnected from that environment, you want to also have local capability that allows that experience to continue, that allows the operation of your environment to continue without disruption. The local environment capability also allows for the backup or the continuation of the local capability. Consider your home and, say, security monitoring. You want that to occur whether you're connected to a cloud service or not. It's the same thing with factory automation and operation — you can't have disruption locally even if you have a cloud connection. So that becomes a key complementary aspect of how edge and cloud together make the strongest solutions.

NXP is on a fascinating journey, and we'll be eager to see what develops now and through the next decade.

Martino: We work with many customers and industries and applications, both consumer and business, as well as connecting information with the cloud. We are leaders in the automotive industry in terms of supplying electronics for all functions in the car. And so we are present in a variety of environments and have a worldwide footprint that engages with many types of customers.

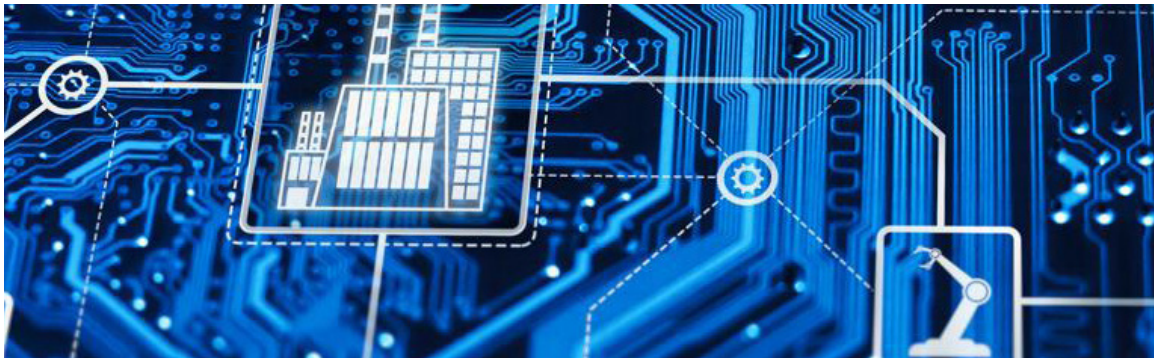
There are multiple ways to connect with NXP and multiple forums where we're talking about new developments. We look forward to continuing to share our work around edge computing and the proliferation of this capability.

WNDRVR

Energy/ Industrial

Crossing the Chasm for Industry 4.0

January 27, 2021



Geoffrey Moore's seminal book on the migration of technology usage from early to mainstream, *Crossing the Chasm* (1991), is widely seen as the bible for broadly marketing cutting-edge products. The book provides the perfect framework for viewing the moment we're about to face with Industry 4.0. For those unfamiliar with the work, we're talking about the moment when use of a technology or product moves from the early adopters, who are often interested in technology simply because it is novel, to the early majority, who are interested because they are able to see practical benefit.

Some 30 years after the book's first edition, it is clear that we are about to see Industry 4.0 "cross the chasm" because of the following five factors:

Factor One
The Advent of 5G

It's important to note that 5G isn't "just another G." Historically, factory automation was fixed function and connected via cable. A step in the right direction toward autonomy was 4G connectivity, but its basic bandwidth and latency issues prevented it from being a viable solution.

COVID-19 has served as a technology accelerator. In the COVID-19 industry impact survey we sponsored in mid-2020, we found that COVID-19 put 70% of 5G projects in the U.S., and 98% of 5G projects in China, on a fast track.

As Verizon's Srini Kalapala said in a recent interview, "[In previous generations,] the technology focused on a single vector, either delivering more data in a better-quality voice or delivering voice across the nation. But when you look at 5G, we are not looking at delivering a single vector but actually looking at delivering across multiple vectors. And that is in a high throughput, [with] lower latency, better security, and higher reliability — and all of these dimensions are delivering a service on demand within a matter of minutes. Now, to do that, it requires us to rethink the way we build the networks and actually transform on the way."

Kalapala then discussed how 5G millimeter wave technology "allows us to deliver gigabytes' worth of bandwidth to a single user." Imagine gigabytes of data (about 10x what is available today), wirelessly flowing to a single device with ultra-low latency security and reliability. Apply these ideas to the factory floor, and 5G is a game changer that will enable robots to unplug and run not just with automation but autonomously. This can create a smart factory with a level of flexibility that previously would have been considered only in science fiction.

Factor Two
COVID-19, Accelerating the Inevitable

COVID-19 has served as a technology accelerator. In the COVID-19 industry impact survey we sponsored in mid-2020, we found that COVID-19 put 70% of 5G projects in the U.S., and 98% of 5G projects in China, on a fast track. As we looked to a broader selection of industries in the U.S. and China, we found that 39% and 43%, respectively, were in "COVID-19 survival mode," while 35%

If we're being honest, everyone went into survival mode in 2020. The real difference is the outlook on the future. Surviving 2020 is one thing; surviving and thriving going forward now will require investment.

and 33% reported that COVID-19 was prompting them to transform. (The priorities of the remainder were unchanged.)

We then compared investment between the factions. Using 100 as the index for those in survival mode, we found companies focused on transforming invested in these areas at the following rates: 5G as an accelerator (179), container-based development (173), digital transformation initiatives (159), artificial intelligence (134), cloud-native app development (133), and IoT development (122). If we're being honest, everyone went into survival mode in 2020. The real difference is the outlook on the future. Surviving 2020 is one thing; surviving and thriving going forward now will require investment.

Factor Three
New-World Approaches in Need of a Chasm Crossing

According to Fortune Business Insights, the global Industry 4.0 market is projected to reach USD 260.71 billion by 2026, with a 16.3% CAGR during the forecast period of 2019 to 2026. The manufacturing leaders who are making these investments by adopting new technology have high expectations. In a second post–COVID-19 survey by Wind River titled "5G and Industry 4.0," U.S. and European manufacturers noted the adoption of new technologies leading them to a lift of 50% or more in customer satisfaction, internal confidence, competitive advantage, and profit margins. To realize these gains, 50% of respondents expected to adopt 5G this year, and 81% within three years, in order to leverage these technologies in priority order: analytics, artificial intelligence, autonomous collaborative robotics, machine equipment diagnostics, cloud computing/cloud-native applications, cloud-to-edge PaaS, industrial automation, machine learning, digital twins, edge computing. These technologies need an intelligent edge to be effective.

Factor Four
Adaptive, Smart Manufacturing, Amplified by the Power of the Intelligent Edge

Gartner expects that, by 2025, 75% of enterprise-generated data will be created and processed at the edge. Industry 4.0 and 5G are key drivers in this statistic. Part of the reason for this shift is that it is much less expensive to process data nearer to the source, since that avoids backhaul transport costs, but a key part of the value arises because the power of data often lies in or around the moment it is created, computed, or sensed. For example, 5G edge could help a manufacturing plant that deals in heat-sensitive materials wirelessly monitor and adjust as needed across the entire production line to ensure optimal production, as well as alerting and adjusting to avoid costly failures.

The intelligent edge is the nexus of Industry 4.0 and 5G — the point where the processing will happen that leverages all that comes with 5G connectivity to enable the technology of Industry 4.0 to achieve our goals.

Factor Five
Generational Expectations, from Boomers to Zoomers

Pew Research determined in 2016 that Millennials had become the largest generation in the labor force.

The last factor has to do with where we are in technology's demographic shift. Pew Research determined in 2016 that millennials had become the largest generation in the labor force. Most millennials don't remember a time without cellphones or the internet. Consider how commonplace it is to be able, by spending a few minutes on your phone, to conduct transactions that previously might have taken days or months using mail, telephones, or in-person visits. As this and every other generation become more accustomed to convenience and personalization in their personal lives, they will also expect it in their work lives. The ability to adapt and personalize for your customers will undoubtedly be a success factor for the future, and pre–Industry 4.0 processes simply won't cut it on their own.

Moore's book was intended as a model, with strategies for bringing new products to market driven by a company or entity. In this article, we've discussed what is really a chasm crossing that has been driven by the emergence of the intelligent edge, which is a convergence of multiple products and technologies. As the intelligent edge concept and its actual infrastructure take hold, it will grow and spread exponentially, making this the time to be building intelligent systems at the edge.

Manufacturing and the Intelligent Edge

April 14, 2021

Industrial manufacturers tend to be conservative when implementing new technologies, a stance which has historically made sense. They typically want to ensure that they maximize the functional life expectancy of their equipment in order to extract the maximum value, with some equipment in use for 5, 15, or even 30+ years. In addition, the equipment they use is often highly specialized and purpose built, which can make it very expensive. This combination of pressures makes companies reticent to introduce changes until they've squeezed every last drop of value from their system.

A Mindset Shift

But as technology evolves, this conservative mindset appears to be shifting. Manufacturers are starting to embrace digital transformation and intelligent systems because they are realizing what a new approach, and new technologies, can really do for them. This development could be called the "Teslafication" of modern manufacturing.

Tesla has demonstrated the benefits of using technology to collect customer feedback, understand their needs, adapt their offerings, and deliver updates to improve the customer experience — all very quickly.

Tesla has demonstrated the benefits of using technology to collect customer feedback, understand their needs, adapt their offerings, and deliver updates to improve the customer experience — all very quickly. Personalization and the ability to adapt quickly to your customers' needs are becoming more valuable in all sectors, and manufacturing companies don't want to be left behind.

So how are companies making this shift? We asked industrial manufacturing leaders in Germany, Spain, the United Kingdom, and the United States how they are adopting their facilities to meet modern demand. These are the top five things these industrial leaders are doing to get ahead of the curve.

1. Maximizing Bang for Buck

Understanding the return on investment (ROI) is always important, but just focusing on equipment cost and longevity isn't enough, which became clear when we looked at which technologies are being deployed and why. We first determined the key initiatives our research subjects were most engaged in (optimizing the supply chain, innovation, enhanced time-critical control, remote control/operations, and optimizing non–time-critical control, in that order). We then sought to understand which technologies they were deploying now and which they expected to deploy in the future. Not every technology applied directly to each initiative, so the ranking was determined by the number of

times selected per the number of times presented. The top technologies were:

- Analytics: 5/5
- Artificial intelligence: 4/4
- Autonomous/collaborative robotics: 4/4
- Machine/equipment diagnostics: 4/4
- Digital twins: 4/5

Clearly, the ability to gather and process intelligence from your systems is a good place to start when selecting technologies.

2. Choosing Their Connectivity Carefully

There is a lot of buzz about 5G these days, and considering some of the features 5G will provide, it's easy to understand the enthusiasm. With ultra-low latency, high bandwidth, and enhanced security, a 5G-based intelligent edge has the potential to provide the infrastructure for a fleet of modern, connected industrial robots that can deliver flexibility and agility that legacy equipment could never achieve. When we asked survey respondents about connectivity preferences, 5G was the clear choice above other options such as Private LTE and Wi-Fi 6.

When we asked survey respondents about connectivity preferences, 5G was the clear choice above other options such as Private LTE and Wi-Fi 6.

The rollout of 5G wireless technology, with its strong focus on machine-type communications and support for the Industrial Internet of Things (IIoT), is expected to have an outsized impact on automation and control applications. Unprecedented reliability and very low latency add to the basic potential of industrial 5G in manufacturing, even though the main technology building blocks and implementation challenges haven't been fully resolved. For example, one concern is the difficulty of ensuring that 5G will work inside buildings where signal drop can be significant. But for every problem identified, solutions are being quickly developed. Some interesting "in-building 5G" solutions are emerging that use small cell millimeter wave (mmWave) technology and combine the ultra-wideband of 5G with private multi-access edge computing (MEC) and a private network core. These solutions are being deployed in office facilities now and can be deployed in other settings where robots may live, such as manufacturing facilities, fulfillment warehouses, and so on.

3. Optimizing for Their Technology

Our respondents told us what they think are the most important measures for the technologies overall, and #1 was security. We have yet to see a survey that doesn't rank security as the most important factor for just about any category. Connectivity ranked a close second (see the preceding section), followed by high availability. So: Secure it, connect it, and keep it running. Pretty straightforward. After these basics, the next priorities are bandwidth, as those connected machines are going to need to collect and process a ton of data; scalability, to allow them to adapt to the ebb and flow of processing needs; and low latency, in order to keep those machines responsive.

4. Put the Pedal Down and Don't Let Up

Fully reaping the benefits of a highly available, ultra-low-latency intelligent edge is going to come in phases over the next five years.

More than 70% of our survey respondents are engaged in all five of the process improvement initiatives listed earlier. Their transition is happening now; it's already begun. But fully reaping the benefits of a highly available, ultra-low-latency intelligent edge is going to come in phases over the next five years.

Since 5G is the most anticipated technology and people seem to have the highest expectations for it, we inquired about the current level of adoption and upcoming timelines. Thirty-six percent of respondents are "adopters" who plan to use 5G in the very near future as a connectivity solution across the programs they implement; 35% fall into the "tester" category and expect to use 5G on a handful of technologies; and 29% don't intend to use 5G across their technologies at all in the near term.

Of those respondents who see 5G in their future, 50% say they expect to adopt 5G-enabled technologies within the next 12 months, 60% in the next two years, and a full 81% expect to adopt 5G within the next five years. The fact that such a high percentage of this typically conservative crowd expects to adopt this new technology so quickly suggests the degree to which they are looking to accelerate their digital transformation.

5. Preparation Is the Key To Success

It's one thing to anticipate a fully automated factory with connected autonomous robots driving increased production and lower cost; it's another thing to actually implement one. There are considerable barriers. Of the leaders we spoke with, 35% understand the need to upgrade or re-engineer legacy systems, while 33% identified their companies as lacking internal skills or knowledge. Business leaders need to invest in both areas in order to succeed. Re-engineering of tools, processes, and people drives the need to start planning sooner rather than later — the barriers are surmountable with proper planning.

It's one thing to anticipate a fully automated factory with connected autonomous robots driving increased production and lower cost; it's another thing to actually implement one.

In contrast, the barriers that ranked lowest in the survey — i.e., they were least likely to be perceived as barriers — included "none of our competitors seem to be using these technologies" at 18%, which tells us that competitors are using these technologies, so it is not the case that they are seen as risky due to being unknown quantities. "Too high a risk" came in at 17%, so fear is not an obstacle. And, actually, 12% selected "None of the above" (no barriers expected).

It's Happening Now

Technology advancements in manufacturing are happening now and building up a new intelligent edge. Manufacturing leaders are aware of this shift and are taking steps down the path of digital transformation. They know it's just a matter of how much and how soon more technology will be deployed in order to fully realize the benefits.

Energy Must Transition

July 1, 2021

The first millennials started to turn 40 in 2021. (Indeed, we consider ourselves a millennial company, since we turned 40 that year too.) As they move beyond being consumers into roles as corporate executives, senior government officials, and societal leaders, millennials' worldviews will increasingly influence the direction of our global future. For example, around 76% of older millennials, ages 33 to 40, think climate change poses a serious threat to society, according to a survey conducted by the Harris Poll on behalf of CNBC.

That opinion will make a difference in how leaders think about many connected issues, such as energy and Bitcoin mining. Cambridge University researchers have shown that the consumption of energy by Bitcoin mining will be more than the annual consumption of electricity by Argentina, a country of more than 44 million people. Every new form of innovation will have its energy-use component, and the interconnections will become more and more complex — producing both opportunities and challenges.

Around 76% of older millennials, ages 33 to 40, think climate change poses a serious threat to society.

Energy and Innovation

Consider these four sets of facts:

- While we consume more for new business models like Bitcoin mining, we are also wasting (in the U.S.) at least 58% of the energy that is being created (2019).
- The rate of transition in how we source our energy is also painfully slow, putting increasing pressure on resource models, management models, and the need for an intelligent systems approach to energy. Take Germany, for example. Its economy is both highly advanced and also focused on innovating new business models and technologies, all while doing it more efficiently than ever before. 2020 was the first year that wind-powered production of electricity equaled the production of electricity from coal (20%). This was after a nearly 40-year program initiative. The average annual consumption per capita in Germany has fallen from 53,000 kWh to 44,000 kWh. But that shift has taken 39 years to achieve (1980–2019).
- In the U.K., by 2030 (bought forward from 2035) you will not be able to buy a new diesel or gasoline-driven vehicle. In the largest car market in the world (China), 9.4% of vehicles sold were electric — compared to 2.4% in the U.S. (Canalys). By 2030, electric vehicles could make up 60% of the market in China. There are more than 140 million vehicles sold in China and the U.S. each year, which creates a whole new combination of energy management needs over time. The networks necessary to recharge and store electricity will need to be completely reengineered to service these vehicles. How they manage, deploy, and adapt themselves across the landscapes they work within will demand new points of connection and connected compute. GPS will become just one small sliver of how these vehicles will manage their experiences as they learn to interact with varying ecosystems of applications through the cloud.

- In Cameroon, only 60% of the population has access to electricity. Shifts in global demographics may also dramatically shift needs for better production and far more thoughtful management. The Brookings Institute has calculated that if we were able to lift the world to the standard of living experienced in the U.S. by 2100, we would need to produce four times as much energy as we do today.

From wind turbines to energy-efficient factories, with 85% of the human workforce having a robotic copilot, by 2030 we could potentially have 125 billion devices computing, predicting, and sensing in the world.

Energy Must Support the Machine Economy

In a machine-led, software-centric, digital-feedback–led future, energy becomes a vital component not just during the development stages for devices and applications but also throughout the lifecycle of re-tasking these machines — especially with devices, applications, and nodes on the far edge. In our recent research, executives told us they believe that 50% of their embedded devices will be functioning on the far edge, through the cloud, and often in far-off places. From wind turbines to energy-efficient factories, with 85% of the human workforce having a robotic copilot, by 2030 we could potentially have 125 billion devices computing, predicting, and sensing in the world. Energy will be at the very center of this machine economy, so it should be the recipient of its new intelligent systems insights.

Those insights will be needed to solve the challenges that come with an increased focus on machines to handle vast arrays of automated roles. Energy systems will be under more pressure and managing an increasingly complex new grid or infrastructure of users (both humans and machines). They will need more intelligent systems designed to develop, deploy, and operate adaptive systems, many of which will live on that far edge, working and powering machines doing millions of different near-real-time jobs.

Our research has shown how the energy and utilities industry is building the foundations and key infrastructure for its own intelligent systems right now, and which of the 13 key characteristics of intelligent systems they believe will have the most impact over time. Read more about it here.

Intelligent Warehousing in the New Intelligent Systems Era

October 1, 2021

Warehousing plays an important role in new intelligent systems and the machine economy. Think: artificial intelligence/machine learning (AI/ML), digital feedback loops, constant connection with customers, the company using 5G technologies on the far edge and engaging with its users in near real time — all from the warehouse.

It's difficult to imagine a relatively sterile-looking building, devoid of the typical meeting rooms and offices and with no real centers of innovation or product design, as a potential epicenter for growth. However, the new intelligent systems world will elevate the role of the warehouse from logistics center to a more intelligent and innovative core business environment.

Four trends are driving this change:

1. Warehousing Is Becoming Adaptive

The new intelligent systems world will elevate the role of the warehouse from logistics center to a more intelligent and innovative core business environment.

Warehousing has long been about moving things around. In recent years, however, warehouses have become increasingly dynamic. They've had to. Two thirds of consumers have chosen an e-commerce vendor based on delivery options, and 54% consider fast shipping to be two days or fewer. These sorts of expectations necessitate efficiency. Today's warehouse must be smart, and that can only happen by working with the data that sits behind the moving of things. This includes Big Data; machine learning optimization for robots and routes; information about package weights, shapes, sizes; and more. All this affects the interactions of shelving, carrying systems, robots acting as copilots, and other warehouse processes. The combination of examining every aspect of the warehouse and using intelligent techniques (visual monitoring, image analytics, automated robotic storage enhanced by augmented reality) to optimize operations not only improves the supply chain but also increases supply chain visibility.

And while package delivery is the goal, what happens when products are returned? The ability to easily return an unwanted item has become a buying criterion for many. Pitney Bowes found that 54% of consumers are unlikely to purchase a product if the retailer has a poor or unclear return policy. Returns must be easy, and retailers should expect consumers to take advantage. To keep operational costs under control, the return process must be as automated as possible so that the inevitable product returns can happen as often as necessary, without killing margins. This is why warehouses are using automated sort-and-store systems connected to their logistics software.

2. Warehouses Are Evolving Products and Packaging Design

Packaging, an industry in its own right, is much more sophisticated than it used to be and has become a critical component of the supply chain. It's not enough to just put your product in a box and send it along. Companies that care undergo significant design and testing before they ship anything. Then they continue to use packaging data as a key element in their feedback loop.

Fundamentally, packaging needs to protect the item during storage and shipping. Increasingly, it also needs to positively communicate the brand to the customer. Other optimizing elements to consider include weight, durability, size, storage needs, and environmental impact. This has led to the use of myriad materials including cardboard boxes, moldable plastics, and flexible materials. Depending on the product, different optimizations may be needed, such as packaging that optimizes the product's structural integrity. It might include changing the package design so the consumer's item is not blemished or broken by the secondary packaging. That secondary — and sometimes tertiary — packaging can smooth the process of shipping numerous items. It involves larger boxes, pallets, plastic wrap, and crates of all sizes, and it includes options such as stacking, nesting, and folding for easy product return and reuse.

Then there is the issue of keeping track of these packages. Options for identification and tracking with barcodes and radio frequency identification (RFID) tags help buyer and seller know where their items are at every point along the shipping journey.

Considering that package delivery by Amazon, UPS, and FedEx combined is estimated to have reached nearly 15 billion packages per year, according to Morgan Stanley, optimization of the package itself, along with tracking, becomes critical to ensure that packages reach their destination and are not lost or damaged somewhere in the warehouse.

3. Robotics Provide Infinite Personalization and Efficiency

Much of the above is being made possible by employing robots. Alibaba (whose robots carry out an incredible 70% of tasks), Amazon, and Ocado are setting the standard for effective robotic use. This includes robots of many types: Collaborative robots (cobots) have arms designed with multiple sensors so that they operate safely when a human is nearby. Exoskeleton robotic suits can increase a human's capacity to lift items by 20 times or more. Automated guided vehicles, or AGVs, smooth transport of items within the warehouse. With layered-in intelligent systems, these technologies can become infinitely flexible, with the ability to reprogram on the fly by implementing updates over the air.

Warehouses are becoming active participants in creating value moments. They are centers of knowledge for determining which products or combinations of products are working for customers and how to automatically order and ship spare parts.

Warehouses and robots can also enable customization or late personalization. The manufacturer can ship its products or product components in bulk, and the warehouse can provide customized configuration or assembly that is best suited for the customer's needs. It could be a matter of combining the desired set of flavors for a selection of consumer goods going to different retail chains or perhaps combining different components (power adapters, for example) as required for the region to which the product is being shipped.

This means warehouses are becoming active participants in creating value moments. They are centers of knowledge for determining which products or combinations of products are working for customers and how to automatically order and ship spare parts.

4. Smart Warehousing Takes Advantage of Edge Infrastructure

Smart warehousing integrates new physical and analytical technologies to realize a host of benefits, including faster problem resolution, improved labor efficiency and operational scalability, better safety, cheaper and faster delivery, supply chain visibility, the ability to predict and better adapt to business demands, and more.

At the core of smart warehousing and related technologies is edge computing, the necessary component for enabling automated, real-time control of all of these new technologies. Done properly, operation of this network can be handled within a single pane of glass with high levels of automation, which reduces costly human errors.

Warehouses have become their own ecosystems within a supply chain that serves our modern world. They are sophisticated exchange stations that store, track, customize, and ship our products. Next time you pass a big box by the side of the highway, perhaps you won't see it as "just a box" but rather as a hot spot of technology that enables our modern world.

Four Truths About Intelligent Systems in Energy and Utilities

November 3, 2021

Energy is one of the most controversial third-rail discussions around the globe. Fossil fuel consumption is still set to rise exponentially over the next 10 years, while at the same time we are heading toward global mandates for carbon neutrality. Companies such as Amazon, Brooks Running, Frog Bikes, Ikea, Inditex, Michelin, Patagonia, Tchibo, and Unilever have pledged carbon neutral shipping by 2040. Wouldn't it be smarter if every company in the world could make that carbon-neutral promise because we are managing our energy creation, consumption, and management so intelligently that it's just the norm? What if carbon neutral was not the exception?

Despite the fact that in 2020 we saw the largest decline in energy consumption since 1945 (4.5%), projections indicate consumption will nonetheless rise at a rate of 1.8% per year for the next three decades. Less than 2% per year might not sound bad. But can the planet really sustain a 50% increase in energy consumption by 2050 when what we really need is a radical *reduction* in energy consumption?

The pressure of the promise of carbon neutrality for companies, as well as the fear of an Anthropocene disaster, is driving more than 80% of major energy and utilities companies to take on an intelligent systems view of the world: a world where energy creation, distribution, and management all feed intelligently from utilities — and maybe even from consumers — back into the grid.

Despite the fact that in 2020 we saw the largest decline in energy consumption since 1945 (4.5%), projections indicate consumption will nonetheless rise at a rate of 1.8% per year for the next three decades.

The 16% of companies that are doing this successfully — and seeing 30% or greater changes in their margins, OpEx, CapEx, and even revenue growth models — are illustrating that there are four distinctive behaviors that all companies in this sector should be adopting.

1. The Future Is Unknown — but the Patterns Are Clear

In the energy sector, 81% of leaders believe that embedded devices and applications will increasingly be used in innovative ways yet to be discovered. There is a clear acceptance that changes are coming. These same energy leaders say that more than 50% of their embedded products and services will be designed for use on the far edge — a far edge used to manage and operate increasingly complex and interconnected systems.

2. Adopting Intelligent Systems Is a Gating Measure to Success

Forty-one percent of energy sector leaders believe that intelligent systems can transform how we use resources in the environment. Software-centric business models for devices and applications that are computing, learning, and adapting through the edge are inherently logical in an industry that must constantly adjust system performance. Remember that 58% of all energy produced in the U.S. is lost, and that there must be a driving economic reality to push change of the required magnitude. So it is significant that 59% of executive leaders in the sector actually see the potential for positive ROI from these ideas.

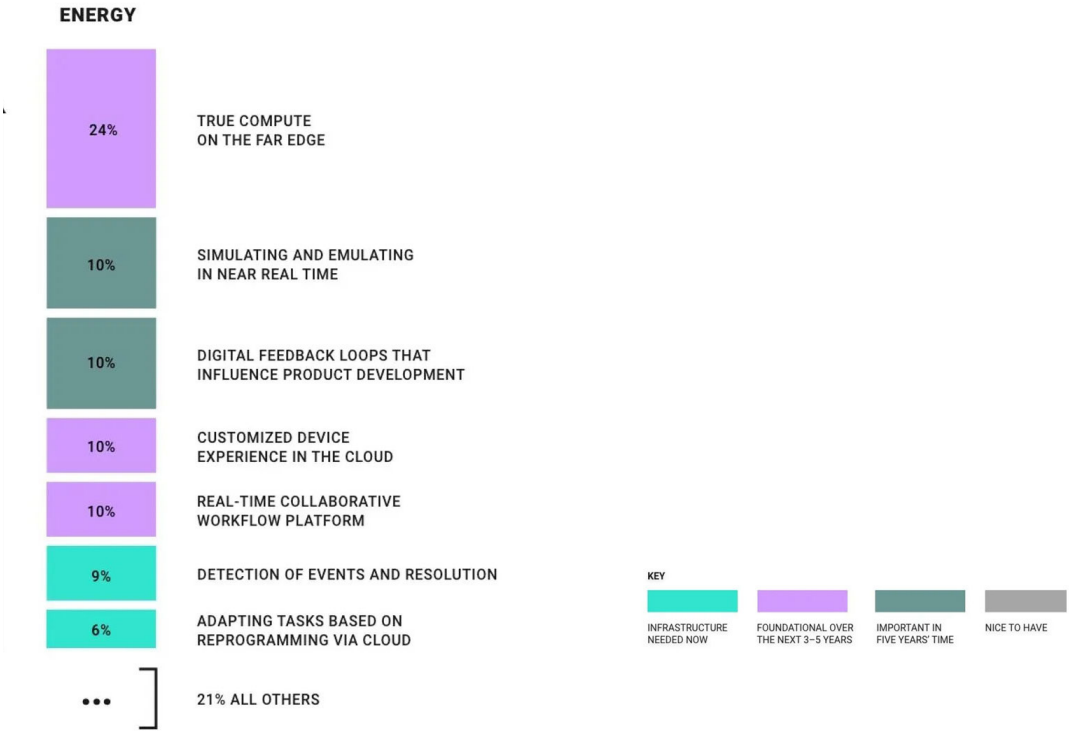
This framework has a transformative capacity to make us all carbon neutral by 2030.

When those leaders are indexed with leaders actually succeeding economically (as measured across 10 independent metrics), we can see that 80% of those who believe in the world-changing potential of intelligent systems in energy and utilities management are getting 30% plus shifts in OpEx, CapEx, margins, and more. With these results, this framework has a transformative capacity to make us all carbon neutral by 2030.

3. The Foundations for This Future Will Be Built in the Next One Thousand Days

Intelligent systems are complex interactions of data, devices, customer, product, and companies, all of which are connected in near real time to deliver complex, invariably mission-critical and latency-free services. Four in 10 leaders in the energy and utilities sector believe that intelligent systems could fundamentally shift the direction of the industry.

Among all the characteristics for intelligent systems success in this industry, 63% of their impact and power will be put into place in the next three years. The chart below shows both the timing necessity and the net impact of each of these 13 intelligent systems characteristics.



The intelligent systems future is going to bring together characteristics that traditionally have not worked in unison in one real-time environment.

4. Solving the Paradoxes Inside Traditional Thinking Is Critical

If we want to change the direction of energy management on the planet, we need to do things differently. Intelligent systems offer a new formula for success for an industry traditionally measuring success over many decades.

The basic foundational needs for success include the ability to detect, manage, and resolve events and the ability to reprogram devices in the cloud. These characteristics may ultimately offer only 15% of systems' total impact, but without them the other characteristics cannot be put into place.

The intelligent systems future is going to bring together characteristics that traditionally have not worked in unison in one real-time environment. The DNA of this process for the most successful 16% in energy and utilities is distinctively different from the 84% of energy and utility companies struggling to reinvent themselves for a carbon-neutral world.

To download the report on how successful leaders are starting to thrive with intelligent systems in energy and utilities, visit www.windriver.com/intelligent-systems.

The Power of the Grid in an Intelligent Distributed World

February 1, 2022

This first article in a two-part series comes from an interview with Gary Lawrence, president of Power and Grid at Schneider Electric. He shares how the energy industry revolutionized itself over the past decade and continues to do so now. He also discusses the critical role intelligent systems will play in meeting the demands of growing energy use.

When you think about being able to reimagine the world of energy, how is the idea of intelligent systems transforming the energy sector, in terms of how we design and operate with our environmental resources?

Gary Lawrence: Intelligent systems, powered by data, are substantially transforming the world of energy for the better. It's not about reimagining the future at this point, because we've already got all the technology and expertise required to achieve even the most ambitious energy efficiency, reliability, and decarbonization goals. It's about taking the intelligent systems and technologies we've already developed and deploying them widely.

"Intelligent systems, powered by data, are substantially transforming the world of energy for the better."

And by widely, I'm talking about total industry transformation. Not only the power grid, but all energy players. Especially those that use lots of energy. Doesn't matter if it's a data center, an offshore platform, a semiconductor fab, or a big office building. Intelligent energy systems are greatly improving the way we plan, design, build, operate, and service our infrastructure and all the businesses that power the economy. And regarding our environmental resources, that is a very good thing.

For example, say you're a grid operator and you have companies and consumers who want to connect new windfarms or rooftop solar to your network. This introduces a lot of technical complexity to the grid. But today's digital grid technologies make it possible for utilities to integrate and manage far more renewables than ever before, and to prepare their systems to accommodate even more. Or say you are a steel manufacturer, and you want to increase your operational efficiency, reduce your process downtime, and cut your carbon footprint. Intelligent digital systems make it possible to achieve those three goals simultaneously today.

What are the factors that have changed this view compared to 10 years ago, and how do you believe they will evolve 10 years from now to shape the industry even further?

Lawrence: Ten years ago, we knew we were in trouble with the environment. But today the problem is far more salient. When the Intergovernmental Panel on Climate Change issued the first chapter of its sixth assessment report last year, the U.N. Secretary General called it a "code red for humanity." We know that the bulk of emissions come from energy. So every energy player is on the hook to help fix this, which is still possible if we zero our carbon dioxide emissions by 2050 and reduce them 30%–50% by 2030.

Today we also have new insights. If we look at the history of energy, we notice that what drives energy transitions is the way energy is used and consumed. Energy transitions happen because new energy resources change consumption patterns, or because new consumption patterns call for innovations in energy use. In other words, energy demand is in the driver's seat, and energy supply is following along. What this means is the only way we can achieve successful energy transition on a huge scale is to design a transition that makes sense for the consumer, driving much faster adoption of the intelligent, digital systems we talked about.

Regarding the future, 10 or 30 years from now, there are two points: how and where. Regarding the "how," we know that electricity and digital technology are the two keys to a sustainable future. That's because electricity makes energy green and digital technology makes energy smart. So together, electric and digital are unstoppable.

Regarding the "where," I believe the future energy landscape will be heavily shaped by prosumers of all kinds. Those who are both producing and consuming energy on the residential, commercial, and industrial scales. I believe that three major prosumer revolutions, in buildings, mobility, and industry, all supported by a grid of the future, will be where successful energy transition happens.

Do you think a lot of the change, or at least the signal, may be what we're seeing from shifting demographics?

"Electricity makes energy green and digital technology makes energy smart. So together, electric and digital are unstoppable."

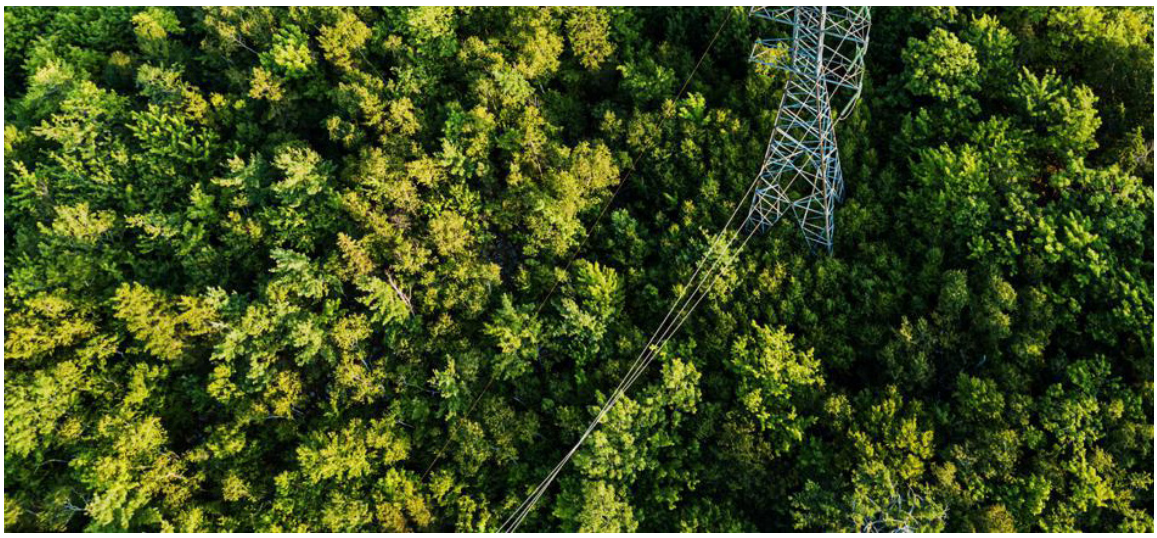
Lawrence: Population or demographics can have a certain influence, but I think it's technology that's driving the overarching direction. It's really interesting. Technologies often drive changes to the way we use energy, and other technologies support that changing energy use. Since my company is developing and deploying energy technologies every day, we see exactly how the energy industry and all large energy consumers continue to revolutionize themselves.

Look at how utilities are undergoing a data-driven grid overhaul that's bringing intelligence to their systems so they can solve a bunch of technical, environmental, and business challenges all at the same time. For example, take asset performance management in distribution utilities. These businesses are some of the most asset-intensive in the world, as they operate hundreds of thousands of pieces of equipment in the field — a giant, geographically dispersed machine that everyone relies on. Traditionally, they take a calendar-based approach to inspection and maintenance for all this field equipment, conducting maintenance visits whether the equipment actually needs it or not. To support this, they'd use the irreplaceable career knowledge of in-house experts and rudimentary, homegrown tools.

But now they are shifting to an evidence-based approach, thanks to intelligent digital systems including software and smart equipment. It means they can conduct condition-based maintenance, get insights from advanced analytics based on real-time operational data, and make risk-based decisions considering actual asset health. From a sustainability, network reliability, and cost efficiency perspective, this is a whole new world.

The Power of the Grid: Making It Happen

March 1, 2022



This is the second article in a two-part series from an interview with Gary Lawrence, president, Power and Grid, at Schneider Electric. Here he shares his observations from COP26, the U.N. Climate Change Conference in Glasgow in 2021, along with his view of the future of a bidirectional and connected grid that will drive electrification, resulting in a healthier planet.

When we talk about governments and how they think about the new infrastructure needed, where is this heading? Is it going to come from business-led innovation or from legislative imperatives?

Gary Lawrence: It's both. Successful energy transition is powered by the technologies developed by companies and corporate innovation, the massive amounts of R&D taking place in the private sector. My company alone invests 5% of our annual turnover in R&D.

"Modern policies for a modern world would go a long way toward getting our act together."

But the speed of deployment of the green and digital technologies, which is what really matters now if we want to stay under the 1.5 degree scenario, depends greatly on policy and legislation. Especially in highly regulated industries, like the grid. The policy side is crucial for removing barriers to adoption of intelligent systems, making deployment move fast enough to achieve our environmental goals, and in some cases even incentivizing solutions that help us transition to a better energy future.

If we look specifically at COP 26, we can at least recognize growing commitments globally. But 2030 is the key milestone and we are way off track, as most COP26 improvement relates only to the long term and is not backed up by policies. What we need to do is innovate ourselves out of the deadlock.

This is still doable, but it requires the right focus on three things: First, we need to disrupt the inertia. That means everything new needs to be low carbon. Second, we need to repair the existing. Here I mean we need to boost renovation rates, looking at modernization as an investment and not a burden, because today's technologies make it cheaper and faster. Third, we need to build the platform for grid decarbonization. Modern policies for a modern world would go a long way toward getting our act together.

Things are moving genuinely at the speed of electricity. Do you see different ways that people are going to have to work together in development teams and operations?

Lawrence: We continue to see many convergences over the course of the energy transition. Electricity and digital, IT and OT, electrification and automation. There's also a big shift in the way we work as people, with important convergences, as you suggest, between the technology developers and technology users. More transparency, more data sharing, and far more meaningful collaboration than ever before. You cannot do energy transition in isolation.

"There's a big shift in the way we work.... More transparency, more data sharing, and far more meaningful collaboration than ever before. You cannot do energy transition in isolation."

At my company, we see this kind of unification of traditionally separate entities in lots of industries, and we're even driving that unification. For example, our customers uncover huge value in the convergence of electrical power and process automation. This is true across sectors, all the way from mining to airports.

One example from my business, which is the grid: Traditionally at utilities, you'd talk about "behind the meter," which is the retail/end user/consumer space, and "in front of the meter," which is distribution and transmission. These two rarely meet, except when you got the electric bill in your mailbox.

Now that's all changing. With data and intelligent systems, those silos are disappearing. This lets us treat the whole picture and improve the entire lifecycle across every part of the value chain.

Do we hire different types of people going forward, or do you think re-skilling is fundamentally where we're going to hedge our bets on the transition of skills and knowledge?

Lawrence: As the energy industry and all energy players grow and change to meet the challenges of energy transition and decarbonization, it's definitely going to require some new skill sets and profiles alongside the types of roles we already have. Sometimes it's new hires, other times it's upskilling the existing workforce. It's a data-driven energy revolution, so we'll continue making big investments for experts in software, analytics, and AI.

For example, in energy, one place where data will form the heart of the solution is EV to grid. If we look at France, today they have about 600,000 electric vehicles. But in about 10 years, there will be many, many millions of EVs in that country. Evolving the grid to be flexible enough to support the necessary charging infrastructure for all those EVs is a challenge that will be solved by data and intelligent systems.

How Intelligent Systems Can Help Save the Planet

April 5, 2022

"Human-induced climate change is causing dangerous and widespread disruption in nature and affecting the lives of billions of people around the world, despite efforts to reduce the risks," according to a report from the Intergovernmental Panel on Climate Change (IPCC) released in February 2022. To avoid mounting loss of life, biodiversity, and infrastructure, states the report, ambitious, accelerated action is required to adapt to climate change while simultaneously making rapid and deep cuts in greenhouse gas emissions.

At Wind River, we strongly believe that intelligent technology systems are an integral part of the urgent action needed to increase energy efficiency.

The IPPC report calls for urgent action to deal with increasing risks. This involves a relentless focus on energy efficiency, as well as easing energy service demand through materials efficiency and behavioral change. The global economy's energy intensity [a measure of the energy inefficiency of an economy] drops by more than 4% per year between 2020 and 2030 in the International Energy Agency's Net Zero Emissions by 2050 scenario — more than twice the average rate of the previous decade. Without this reduction in energy intensity, total final energy consumption will be about one-third higher in 2030, boosting the cost and difficulty of decarbonizing the energy supply.

At Wind River, we strongly believe that intelligent technology systems are an integral part of the urgent action needed to increase energy efficiency. Delivering software for cloud-based intelligent systems, Wind River allows companies across multiple industries to deploy and operate systems that sense, predict, and compute using digital feedback loops to run autonomously or with machine learning and automation.

The information that flows through these digital loops is collected by sensors embedded in the machines — such as elements of the power grids, cars, airplanes, construction cranes, or robots on the factory floor. Where, then, is the most cost-efficient and environmentally friendly location to place the processing of this increasing amount of collected data?

Consider the technical aspects of having to transport the data. And from an environmental perspective, consider the real cost when comparing an edge to a cloud deployment. The data the sensors collect is processed close to the edge of the network, where the machines operate. This allows for real-time information to affect real-time operations, which transforms how resources are used and minimizes the need for transportation. In this sense, the use of intelligent systems could well provide the key to delivering a clean, affordable, and data-driven new reality.

Becoming Intelligent About Energy

The bulk of greenhouse emissions come from energy. In fact, energy demand has a strong connection with almost all the United Nations sustainable development goals (SDGs). Thus every energy player, whether producer, distributor, or consumer — from the energy sector through transportation and manufacturing — needs to focus on sustainability. Becoming a digitally intelligent organization would help all these players achieve greater energy efficiency and better contribute to the reduction of greenhouse emissions.

Let's take a close look at how intelligent systems are currently taking hold in the energy sector. A Forbes and Wind River survey of more than 500 executives across different industries revealed that to 59% of energy leaders, the idea of intelligent systems is highly appealing. Forty-one percent of them also recognize the opportunities of intelligent systems for lowering greenhouse emissions, as they believe that we can become more adaptive and that such systems can positively transform how carefully and efficiently we use environmental resources.

Every energy player, whether producer, distributor, or consumer — from the energy sector through transportation and manufacturing — needs to focus on sustainability.

However, the energy sector needs to speed up its intelligent systems journey if it wants to answer the call for urgent climate action. The Forbes and Wind River research finds that currently just 16% of energy companies already see themselves as intelligent systems digital businesses.

In the context of the energy and utilities sector, digital transformation relates to the rollout of a smarter grid with smart meters and energy plant sensors and the need to autonomously monitor resource consumption patterns, learn baseline behavior and detect anomalies, build stress models, and enable proactive maintenance patterns.

Blurring the Lines

Critical infrastructure players are connecting their devices to get data out of them and offer new services, introduce new features, or integrate the devices into a larger hybrid system consisting of physical nodes and digital twins. They become part of a cyber-physical continuum connected by the flow of data made possible by intelligent systems. One of the outcomes of creating such a continuum is that consumption and production converge as autonomous systems, as AI-driven power grids automatically manage production and use across multiple, distributed energy resources.

In one example of blurring the lines between a producer and a consumer, a neighborhood of some two dozen homes in a western state of the U.S. shares energy, thanks to its connection to a microgrid, which in turn connects to the main grid. Within each home, every smart appliance and energy resource is controlled to maximize energy efficiency. All those assets are monitored and can be controlled by an autonomous energy grid (AEG). Houses within the neighborhood can rapidly share power, creating reliable electricity for everyone, since solar energy generated at one house can be used to charge the electric car next door.

The autonomous energy grid offers a vision for a future of energy defined by resilience and efficiency. In theory, power systems of any size could be covered in a patchwork of microgrids, layering regions and even an entire country in smart grids to automatically manage energy production and use across millions of controllable distributed energy resources.

AEGs will create at least as many benefits for utilities as they do for customers. With AEGs monitoring distributed energy resources such as rooftop solar and household storage batteries, a utility's control room will become more like a highly automated air traffic control center. The result is that energy generated within an AEG is used more efficiently — it's either consumed immediately or stored, according to *IEEE Spectrum* magazine.

Heavy Industries, Planes, Trains, Automobiles … and Robots

Clean electricity can undoubtedly provide significant help in the quest for achieving carbon neutrality. Heavy industries and transport, however, present different sorts of challenges.

Clean electricity can undoubtedly provide significant help in the quest for achieving carbon neutrality. Heavy industries and transport, however, present different sorts of challenges, and it becomes more difficult to bend the emissions curve from steel, cement, other energy-intensive industrial sectors, and long-distance transport.

Seventy-seven percent of greenhouse emissions — which are the reason for climate change — are produced by industrial sectors such as energy generation, transportation, and the above-mentioned manufacturing. Intelligent systems can help reduce emission by making energy use more efficient across many of those different industries.

In the aviation sector, intelligent systems are the backbone that improves operational efficiency, including energy efficiency. Many planes have sensors that gather data on engine use and hundreds of other variables to monitor and control fuel consumption.

Looking more futuristically at how intelligent systems will one day make flying more efficient: They'll enable planes to follow the most optimal and safest route for each flight, instead of managing air traffic based on pre-defined routes, the so-called "highways in the sky." While such traffic management systems are not yet used in commercial aviation, if the aviation community pushes for more testing, regulators may get enough data and one day get on board with the idea.

Heavy industry, such as steel manufacturing, has inherited historical knowledge and dependencies on "gut-feel" operators and, as a result, lags behind on digital maturity. There are considerable benefits in adopting an intelligent systems approach, and there is a need to combine new technology and processes with domain knowledge in order to achieve breakthrough innovations such as improving product quality and energy efficiency to achieve the best price per ton. Further advancing artificial intelligence and machine learning (AI/ML) with the use of digital twins and digital feedback loops with physical devices is an example of a cyber-physical continuum enabled by intelligent systems.

As industrial IoT adoption continues to grow, it will spread into robotics energy consumption. IoT sensors within robotic systems will provide workplaces with wirelessly accessible, real-time data about their power usage. Workplaces will come to expect these features as more companies take an IoT-driven, granular approach to resource optimization, according to *Robotics Tomorrow*.

Interoperability will be a crucial consideration for these sensors. If all IoT devices in a facility could interconnect, some robotic systems could consume more power to increase output if levels in another area are low. Smart energy monitoring with this level of interoperability would help maximize both energy efficiency and productivity.

Increased data from embedded sensors and the ability to utilize this data to optimize energy use are among the benefits of intelligent systems. For many companies across different sectors, their effective contributions to the reduction of greenhouse emissions will depend on where they are on their intelligent systems journey. With the world heading toward a more intelligent future, it will be increasingly urgent for companies to accelerate their transformation.

The Power of XaaS in Manufacturing

August 2, 2022

Industrial equipment, like an earth-moving machine or a manufacturing robot, is no longer simply about big-muscle strength or mechanical prowess. With embedded software-driven sensors, these machines now operate at the intelligent edge, making them part of the digital information flow.

The intelligence that these machines can gather, process, or react to generates insights and actions that help with performance management, remote control, predictive maintenance, and many other uses. A series of robots cooperating on a factory floor can communicate about their capacity with the control tower so that the workloads are distributed efficiently among the machines, in real time. An earth-excavating machine can sense the physical dangers around it and prevent the breakdown of equipment or harm to humans. Data analysis collected by embedded sensors from multiple operational scenarios can lead to more sustainable and efficient production parameters. This physical–digital flow continuum creates new business opportunities for equipment suppliers and their customers.

Solutions businesses are poised to be key contributors to revenue growth of industrial automation companies by 2030.

Manufacturing is increasingly software driven, blurring the lines between the physical world of machines and the cyber world of data. The traditional portfolio mix of heavy hardware orientation with associated software is transitioning to application and non-control software. The move to solutions combining hardware, software, and services is real. Bain & Company estimate that leading machinery companies with more mature portfolios of solutions have delivered a 32% total shareholder return from 2019 through 2021, compared to 4% among the laggards. Solutions businesses are poised to be key contributors to revenue growth of industrial automation companies by 2030.

In conversations with industrial equipment manufacturers and suppliers, an average of 95% of software engineers focus on applications versus underlying platforms and tools. Sitting at the higher layers of the technology stack, software offers more attractive margins and differentiation opportunities — starting with the product-as-a-service model.

According to Manufacturers Alliance, nearly one in three manufacturers is deploying a products-as-a-service IoT model, where the company remotely monitors data from and about the product and sells analysis of data for the customer in the form of alerts, performance data, maintenance, etc. It is exciting to witness the positive impact of the software-driven approach, especially in mission-critical industries such as industrial manufacturing.

There is big potential here. Per McKinsey, successful technology enablement can unlock up to $2 trillion for the industrials.

Data-Driven Models Create Better Outcomes for Equipment Suppliers and Operators

The manufacturing sector is heeding the call of digitalization. Fifty-five percent of manufacturing companies are actively pursuing becoming intelligent systems digital business companies, on top of the 11% who already see themselves as such. The leading companies consider themselves significantly more able to deliver new business models with intelligent systems, including seamless connections between suppliers and customers and connecting business processes with new forms of sensors, than all their peers.

Fifty-five percent of manufacturing companies are actively pursuing becoming intelligent systems digital business companies, on top of the 11% who already see themselves as such.

Traditionally, industrial equipment suppliers have sold hardware as one-off products, which entails a significant up-front CapEx for their customers (automotive manufacturers, semiconductor foundries/fabs, aerospace manufacturers, and so on). But this way of selling and purchasing industrial equipment is no longer an optimal solution for either side of the transaction.

With the advent of software-driven intelligent systems, manufacturing supply chains are becoming more agile and smart, quickly transforming into autonomous, self-learning, and interoperable ecosystems. In this environment, equipment operators increasingly need more customization of operational environments, as well as timelier data-driven insights from their heterogeneous assets and complex operations. For them, it is about outcomes related to productivity, equipment availability, and lifespan, limiting or eradicating unplanned downtime, decreasing operational expenditure and service cost, and ensuring safety and a faster time-to-market.

On their side, suppliers are facing these new software-driven expectations from their customers on top of challenges around intensifying global competition, increasing hardware commoditization, rationalizing offering portfolios, and talent issues.

As in other industries, data — in this case generated by intelligent systems embedded in the machines — is key for monetization. Among some of the data-driven business models in manufacturing are services that can be delivered thanks to intelligent software systems, such as product performance monitoring, data analysis diagnostics from the manufacturer, or IoT-driven field services.

These intelligent systems are enabling the shift toward outcome-based software and services, precipitating the move from a one-time transactional business model to an anything-as-a-service (XaaS) delivery model.

Anything-as-a-Service, or XaaS

XaaS is the delivery model of a hardware, software, and/or services offering. The offering is owned, delivered, and managed by a supplier. The supplier provides the customers the ability to consume the offering on a pay-for-use basis or through a subscription based on use metrics.

Industry 4.0 and Industrial IoT technologies enable the XaaS model by supporting capabilities such as telemetry and digital feedback for asset usage and performance, turning sensor and exogenous data into insights, and frequent over-the-air updates via super-fast networks. These capabilities power outcome-based services, provide crucial operational insights, and give transparency into equipment, machine, or asset usage.

Power-by-the-Hour is a well-known monetization example of XaaS. Invented by Rolls-Royce in 1962 to support its Viper engine on the de Havilland/Hawker Siddeley 125 business jet, it is a complete engine and accessory replacement service offered on a fixed-cost-per-flying-hour basis. It aligned the interests of the manufacturer and operator, who paid only for engines that performed well. Similar customer-focused business model reconfigurations are evident across different verticals.

In the healthcare vertical, digital surgery-as-a-service offers medical robots to hospitals and healthcare professionals using a pay-per-use model. In energy, sustainability-as-a-service and energy-as-a-service give customers access to energy management services without up-front costs. In the mining sector, earthmoving-as-a-service sells tons of earth moved. And rocket and spacecraft manufacturers offer astronaut transportation-as-a-service.

If you are rethinking business models and evaluating delivery models of EaaS, RaaS, MaaS, or any other permutation, then understanding the basics of business model reinvention and assembling the right operating model is table stakes.

The *X* in XaaS can be many different things, including:

- **Technology:** Infrastructure, platform, software
- **Medical device:** MRI, radiosurgery, cardiac rhythm monitoring
- **Machinery and factory system:** Robots, control systems
- **Utilities system:** Digital substations, advanced distribution management systems
- **Heavy assets:** Semiconductor lithography equipment, gas turbines, aviation engines, mining trucks
- **Operations:** Factories, cities, grids, hospitals
- **Societal goals:** Sustainability

Benefits of XaaS

Both suppliers and customers reap benefits from XaaS models.

Benefits for suppliers include:

- Strengthened and expanded customer relationships through outcome-based services
- Ability to give customers choice, freedom, and flexibility regarding what and how they consume
- Availability of consumption-based pricing so customers pay for what they use
- Predictable, renewable, recurring, and expandable revenue streams
- Scalable and profitable revenue as more customers are served from a common platform
- Continuously optimized and enhanced offerings based on product insights

Benefits for customers include:

- Increased productivity
- Reduced downtime and OpEx
- Ability to forecast business planning with more predictable costs
- Higher satisfaction and support from suppliers
- Outcome-driven investments with aligned costs
- The most up-to-date offerings

Getting Started with Business Model Innovation

If you are rethinking business models and evaluating delivery models of EaaS (equipment-as-a-service), RaaS (robots-as-a-service), MaaS (machines-as-a-service), or any other permutation, then understanding the basics of business model reinvention and assembling the right operating model is table stakes. The following four-step framework will help you design your XaaS models:

1. Research: Gain more insights into the outcomes that matter to your customers and their customers. Are your customers open to discussing performance as a shared and continuous responsibility? If so, that is a promising start.
2. Learn: Understand which data from your products/operations and the ancillary equipment around them can be collected and used to give outcome-driven insights and improve performance for your customers. That becomes the control point for the offering.

3. **Identify:** Determine the suitable key performance indicators (KPIs) to track, measure, and communicate the value.
4. **Model:** Using the unique value, derive the revenue model for the XaaS offering. Test a minimum viable XaaS offering, deliver promised value, and scale.

Using this framework to implement your XaaS models will help align your software-driven capabilities with your customers' needs and expectations amid fast-changing customer and supplier environments. It will make you more competitive, able to deliver the outcomes that provide your customers with measurable business value. And it will lead to close integration with your customer, as you share responsibility and innovate together.

WNDRVR

Medical

The Future of Healthcare Is Intelligent

February 1, 2022

The human body contains many mysteries. We still know relatively little about how our bodies work or do not work in certain situations. We sit on billions of pieces of information moving around our bodies at every minute.

The human body is complex but not yet fully tapped for its intelligence. For example, only 43% of the body's total cell count is recognizable; the rest is comprised of the microbiome or microscopic creatures. Imagine if we could extract more intelligence from and about our bodies at a cellular level, and what that could do to help us combat illnesses. Imagine the opportunities that exist for medical technologies that measure, share information, and change the way we manage the human experience.

That is the promise for intelligent healthcare. The application of intelligent systems for preventative health maintenance and innovation opens a world of new possibilities for every person on the planet.

In our research conducted with Forbes, 78% of executives in medical technology companies indicated that they understand the power of intelligent systems to deliver quality services, OPEX reductions, and revenue growth. They understood they needed to get going and invest in this concept now. However, a third of them — by their own admission and by calculation across 10 economic measures — are not succeeding. The journey to success will be difficult and complex if you cannot get the DNA of it correctly sequenced.

Looking at those who are succeeding, let's consider how they are getting it right. There are three key drivers in the development of intelligent systems for medical technology:

1. Thirty-Six Percent of What Needs to Be Done Must Happen Right Now

Given the 13 characteristics that constitute an intelligent system, medical technology companies were the most committed to building intelligent systems as part of their infrastructure right now. This is partly due to the enormous opportunities to apply intelligent systems to the healthcare industry.

The healthcare industry is one of the largest in the U.S., at over 18% of the GDP (CMS, 2022). So its opportunities to save money, act faster, and deliver better quality experiences to medical professionals, healthcare systems, and patients could have immense impact. For example, Accenture estimated that the use of AI in healthcare could easily save the U.S. healthcare system $150B every year. That's roughly the size of Cigna or Cardinal Health, two of the biggest U.S. healthcare providers.

The application of intelligent systems for preventative health maintenance and innovation opens a world of new possibilities for every person on the planet.

2. The Software Factory Has to Function Immediately

When looking into the 36% up-front investment required for success, the most critical characteristics to invest in right now are output needs (sense and detect); automation of key functions that would otherwise overload pure human resources; creation of a common workflow platform enabling cloud-native development; and deployment and operations with DevSecOps, digital twin, simulation, digital feedback loop, OTA, and security and safety capabilities.

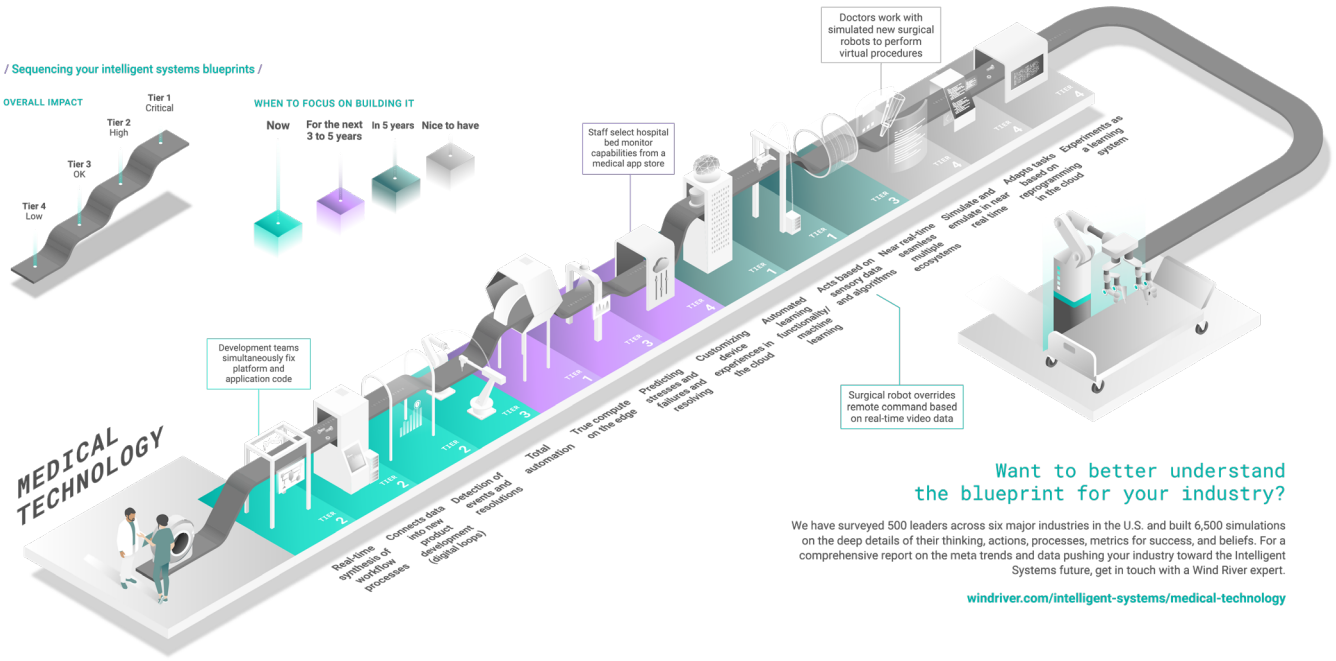


Figure 1. The intelligent system technologies and capabilities most needed in the medical industry

COVID-19 showed us the importance of being able to monitor and manage our health inside our own homes.

The ability to have people working together to create exponentially better ways to sense and detect intelligence and then automate key functions or outcomes in order to get scale would be tremendous. This is all part of the virtuous cycle for a software factory (constant feedback, collaborative workflows, a focus on automation, and the ability to sense and resolve issues on the fly). And the core DNA of that software factory model must be built now.

3. True Compute Edge Is the Key

The single most impactful and necessary characteristic for successful intelligent systems, according to our research, is their ability to work on the intelligent edge. Nineteen percent of the total possible impact from all key characteristics come from just this one. This is logical, given the need for devices to work wherever humans and data engage and exist.

COVID-19 showed us the importance of being able to monitor and manage our health inside our own homes. In the U.S., millions of homes are not near a hospital or doctor's office. Consider the extraordinary power of data if it could be properly and regularly collected and utilized in real time for medical purposes. The boom in wearables, increased mobile medical professional services, and growing diseases such as type 2 diabetes all require home-based healthcare management as the norm, not the exception.

Where we have traditionally seen the invention of new pharmaceuticals as the panacea for better healthcare, we now envision a future driven by a more holistic approach. Intelligent systems will give us more power to prevent, manage, and resolve healthcare challenges, based on the information we will be able to collect, monitor, and act upon.

For the companies developing the billions of embedded devices that are part of this intelligent systems approach, the key will be accessing a level of capabilities far beyond traditional design and operational parameters.

To view our research conducted with Forbes for the medical technology industry, including implied recommendations from peer executives, visit www.windriver.com/intelligent-systems/medical-technology.

Security

Mitigating Cyber Exposure with Threat Modeling

May 6, 2022

"If you know the enemy and know yourself, you need not fear the result of a hundred battles," said ancient Chinese military strategist Sun Tzu. Fast-forward some 2,500 years, and he could have been referring to cyberattacks and threat modeling.

Threat modeling is an organized approach to documenting components of your systems architecture, then assessing the security threats to the assets that you're trying to protect and the resilience of the systems to these threats. It is a set of methodologies that security experts and software developers use, starting at the design stage.

It requires end-to-end analysis of the architecture design, which includes considering every entry point, every exit point, and all known threats. This analysis serves as the basis for prioritizing and implementing the long-term security controls in your system.

Companies that successfully navigate cyber-threats are twice as successful in their segments as others.

Threat modeling enables informed decision-making when assessing cyberattacks, providing you have actionable insights about what needs fixing. It is an essential component of building, deploying, and managing secure software. Organizations that embrace threat modeling gain a security advantage through their ability to protect sensitive data, to implement preventative measures to mitigate the risk of a data breach, and to enhance their overall security posture.

They also win the economic battles. According to Forbes, companies that successfully navigate cyberthreats are twice as successful in their segments as others.

Select Your Strategy and Your Tactics

There are three common approaches to threat modeling. The software-centric approach evaluates the system that is being modeled to determine the risks and how to mitigate them.

The attack-centric approach requires taking on the mindset of the attacker. The goal is to examine the threats against a system from the perspective of an attacker, including the attacker's motive, approach, resources, and identity.

And finally, the asset-centric approach identifies the assets to be protected, classifies those assets based on sensitivity and valued potential, and goes about threat modeling from that perspective.

There are also different methodologies, including STRIDE, developed by Microsoft. It identifies threats based on the following categories, which create its name: Spoofing, Tampering, Repudiation, Information disclosure, Denial of service, and Elevation of privilege.

Other methodologies include PASTA (Process for Attack Simulation and Threat Analysis) and VAST (Visual, Agile, Simple Threat modeling). The latter is unique because it is founded on the idea that threat modeling is useful only if it encircles the entire software development life cycle (SDLC) throughout the whole enterprise.

These approaches and methodologies are not prescriptive. Even when you take an existing methodology, there is work for you to do in defining how you're going to implement this in your company — which methodology, or hybrid of methodologies, will be your best defense. A group of threat modeling leaders put together a threat modeling manifesto to use as a guide to develop or refine the methodology that best fits your needs. It is well worth examining. If you would like to dig deeper into the subject, threat modeling approaches and methodologies are discussed in this webinar.

The Attack Surface Broadens

We're living in a connected society, in a machine economy. Critical infrastructure players are connecting their devices to get data out of them and offer new services, provide functional and security updates to the software, introduce new features, or integrate the devices into a larger system. Devices are not alone anymore. They are part of a global cyber-physical system that spans hyperscale clouds, edge clouds, and the electro-mechanical edge.

You need to know that the underlying operating system is secure before you can even worry about the data flow. When you threat model the intelligent system, you must consider the entire connected continuum.

Statista estimates that there will be almost 30.9 billion active IoT connections — such as connected cars, smart home devices, and connected industrial equipment — by 2025, up from 3.6 billion in 2015. In comparison, non-IoT connections, which include smartphones, laptops, and computers, will rise to 10.3 billion by 2025, up from 9.7 billion in 2015. That's 750% growth for IoT connections over the 2015–2025 decade, versus 6% growth on the non-IoT side.

And with that surge in connectedness come the risks that can shut down a business or even take down our most critical infrastructures. In most cases, devices are now all over the place, so the physical layer of protection around our systems that we use to rely on has been removed. Consider the restrictions and protections around accessing physical data centers. And now consider our servers and devices that are processing data at the edge, while communicating to and from sensors, actuators, microcontrollers, and other components that drive the vast array of intelligent systems connecting our lives. These are easily accessible and could be tampered with if not effectively protected.

The loss of physical access control has greatly impacted the attack surface of the intelligent edge, which now extends far beyond the data center. Protecting the attack surface also entails knowing what the devices connect to, and what happens if we connect them to something else. You need to consider the threats when someone has access to a system in your car, or to your key fob.

The data flow within a design is the basis of threat modeling. However, it's not just about the data that's flowing — we also need to know that the device is secure. When you have critical infrastructures or critical systems, whether they are missile systems, nuclear plants, or healthcare devices, you need to know where your threat is. So you need to know that the underlying operating system is secure before you can even worry about the data flow. When you threat model the intelligent system, you must consider the entire connected continuum.

Don't Procrastinate

Critical decisions made at the design phase about infrastructure, design components, and data flow, all of which could be vulnerable to threats, are not easily reversible. If we don't make the right security decisions at design time, we risk an expensive fix later. Finding defects, especially security defects, then repairing them and deploying patches can cost as much as 100 times more in deployed systems versus during the design phase. We also risk not finding a vulnerability in a deployed product before an attacker does.

Threat modeling must align with the organization's development practices and follow design changes in iterations that are each scoped in manageable portions of the system. One big reason why organizations put off doing threat modeling is because it becomes overwhelming. You will never be perfect, so you need to prioritize.

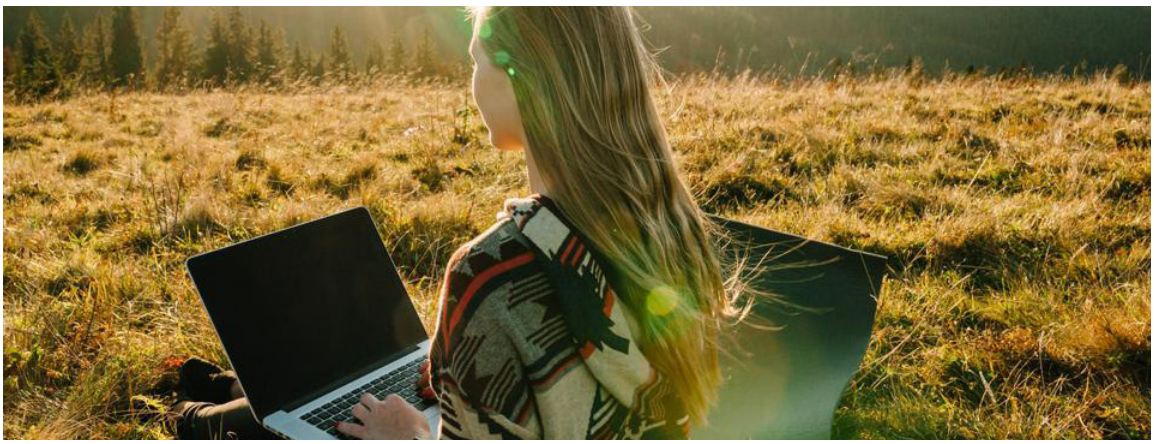
You're not doing threat modeling just to point out problems with the system. The outcomes of threat modeling are meaningful when they provide value to the stakeholders, and when you are clear on your objectives. For this reason, you need to start by brainstorming with your team and the whole organization about your threats and the best way to mitigate them, and then carry on this dialog to make sure you continue learning about your product and your potential cyber enemies.

WNDRVR

Telecom

Three Changes That Will Make Rural 5G Access a Reality

February 22, 2021



In 2018, Global Workplace Analytics estimated that 3.6% of U.S. workers worked fully at home, five days a week. Then 2020 arrived, and suddenly 85% of us were working at home, by choice or necessity. The U.S. economy shrank by only 3.5% in 2020, even although 8 in 10 of us were in vastly different work surroundings, with dogs barking and kids (rightly) needing constant help, support, and entertaining.

Something actually went right.

One of the logical reasons why the GDP was not so severely damaged was the availability of high-speed internet (HSI) to provide a fast, digital office space at home. But consider:

- Forty-eight percent of applications run on the cloud, according to IDG, so access to those applications requires bandwidth no matter where you are.
- The average amount of time the American worker spends on the phone each day is 56 minutes. Access to a quality connection has increasingly become a barrier or a differentiator for employees.
- Kids in remote classes (and maybe grown-ups as well) are spending five to six hours a day on Zoom. The lack of bandwidth (cell phone or laptop) again causes a problem in places where students or employees cannot express, collaborate, or present their ideas in the best ways.

Of the 15 million people who can't access HSI, roughly 80% of them live in rural areas. Why should people who are able to do identical work not have access to the same essential infrastructure?

If you live in an area where the speed of internet access is slow (defining HSI as having download speeds of at least 25 Mbps and uploads of at least 3 Mbps), how much of a disadvantage are you, and your children, dealing with? How much could your opportunity and income be affected, or existing gaps amplified?

Consider this disparity: The 2021 FCC Broadband Deployment Report shows that 98.8% of urban dwellers have access to HSI. Only 82.7% of rural dwellers can say the same. Stretch that to tribal areas and we are down to a low 79.1%. Of the 15 million people who can't access HSI, roughly 80% of them live in rural areas. Why should people who are able to do identical work not have access to the same essential infrastructure?

5G and the Intelligent Edge Create a Radical Shift in Economics

To create a rural network that enables all citizens in the digital economy means investing in 5G technology for both wireless and fixed networks. The 5G standard empowers a broader scope of use cases than ever before, with faster speeds, wider coverage areas, and improved security compared to the previous 4G networks.

When building the intelligent rural network, keeping costs under control will be a key factor in making it affordable to everyone.

But it's no use building this new network if people can't afford it. And that's where the intelligent edge comes in. It moves real-time computing power close to where it's generated, meaning easier deployments and lower operational costs. Combining 5G with the intelligent edge can provide the same workload performance with less overhead, resulting in significantly lower cost. And when we're building the intelligent rural network, keeping costs under control will be a key factor in making it affordable to everyone.

The Promise of Open RAN for Rural Networks

RAN (radio access network) is the "last mile" of a network, the visible link from the network to a mobile phone. Operators have been working to open up RAN protocols and remove dependency on single-vendor systems. Already, large operators such as Orange, Vodafone, and MTN are planning to use virtual (vRAN) and Open RAN to bring coverage to new markets, because it provides more choices for equipment providers, has lower TCO, and it is easier to upgrade parts as needed.

For rural networks where cost is a large factor in deploying new networks or upgrading outdated ones, Open RAN provides the opportunity for competitive bidding and frees CSPs to choose the best technical solutions for the situation, rather than being tied to single-vendor offerings. When talking about rural connectivity, Open RAN plus 5G create a promising combination.

Leveraging the Intelligent Edge and AI Analytics to Reduce Costs

Past projects have shown that the costs involved in standing up networks over a large physical area have been considerable. Intelligent rural networks can leverage powerful new technology, such as distributed clouds and edge computing, to bring down the cost.

Rural networks will also require remote, large-scale management and monitoring. End-to-end automation and AI-based analytics as integral parts of the network design and implementation can help lower ongoing costs while keeping networks up and running efficiently. Given the large geographical areas involved, these management and monitoring tools also need to work remotely so that when issues arise, they can be handled quickly by technical staff.

Increasing Opportunity for Everyone

In the age of information, digital access is an imperative to ensure that every citizen has an equal opportunity to thrive. If we fail to act now, we are failing a future generation. Imagine a broadband network that covers every single village, town, and city of America. Imagine fast, secure, and reliable internet at an affordable price — no matter where you live. Imagine the power of connecting fully wired smart cities to the "clever countryside," building a nationwide economic network that provides a wide range of opportunities for everyone.

Opening New Economic Realities with Open RAN

July 6, 2021

As Jack Welch famously stated, "Change before you have to." We live in a dynamic world where opportunities should exist on a level playing field for everybody, not just for certain groups. COVID-19 has leveled that playing field in many ways; one that stands out is the move toward hybrid work.

The New World of Hybrid Work

A hybrid work world is an inevitability for us all, regardless of whether we live in dense urban environments or more scattered rural communities. Forty-six percent of the workforce is looking to move because they can now work remotely, and employers are responding with five times more remote job postings on LinkedIn than before the pandemic began. Eighty-seven percent of American workers who found themselves working from home during this period wish to continue doing so at least one day per week. Most agree that some form of hybrid workplace is ideal.

A hybrid work world is an inevitability for us all, regardless of whether we live in dense urban environments or more scattered rural communities.

Our work product and our working environments should both be driven by fair access to the internet infrastructure we all use. This is especially true as new forms of working together and creating together will be amplified in a post–COVID-19 working world. What has revealed itself clearly is that collective capacity has immense potential to evolve rapidly, given a level playing field for access, collaboration, and creation.

The hybrid workforce is going to require infrastructure to support that collective collaboration. Much of the urban U.S. has access to high-speed internet, but initiatives are needed to give the same advantage to rural areas.

Recognizing the power of a fair shake to create better economic conditions, the U.K. government has set specific targets to provide at least 85% of U.K. premises with gigabit broadband by 2025, with the intention to "get as close to 100% as possible." At the same time, the U.K. also chose to discontinue installing new 5G telecom equipment from Huawei. For years, the telco model has been to design the system to work with propriety equipment bought from traditional equipment manufacturers such as Huawei. However, by removing a key manufacturer from the equation, new possibilities have emerged, with Open RAN playing a pivotal role.

Enabling the Change with Open RAN

Without getting too far into the technical details, Open RAN allows for the disaggregation of the key pieces of the radio access network that connect that network to your phone. These pieces include the radio unit (RU), the distributed unit (DU), and the centralized unit (CU). From there, Open RAN helps to "open" the protocols and interfaces between the radios, the compute platform, the software infrastructure, and the applications. Breaking these components apart gives telecommunications companies many more choices about how and with whom they build their networks. They aren't stuck with one box that does everything. Rather, they can pick the best-of-breed providers of each component. Furthermore, they gain the flexibility to swap out components when they are no longer needed, rather than replacing the entire integrated system. This choice drives competitive innovation and pricing from the vendors of each component. The result: the best technology and fast time-to-market, at the best price and with flexibility for change.

Open RAN was pioneered by Vodafone to drive greater innovation through a diverse and open vendor ecosystem. This year Vodafone and its recently selected vendors will start work to extend 4G and 5G coverage to rural South West England and most of Wales. The company is also planning to launch Open RAN in other areas of Europe and in Africa.

While COVID-19 has been unpleasant for most and tragic for many, one silver lining is that it has forced us to look differently at the way we work and communicate. The choices we make now are informed by a new perspective that could give us all an opportunity to collaborate and grow together.

6.5 Reasons to Pay Attention to Open RAN

October 1, 2021

The radio access network, or RAN, is a critical component of our daily lives, although most of us don't give it much thought or even know what it is. The RAN is the access point, the place where our cell phone signal gets on the network. It then typically travels through a regional data center, through the network core, and back out again.

With 5G deployments coming online and the introduction of Open RAN, the RAN is becoming much more interesting. There are 6.5 reasons why.

Before we get into those reasons, it's worth taking a moment to introduce Open RAN as well. Open RAN allows for the disaggregation of the key pieces of the RAN. These pieces include the radio unit, the distributed unit, and the centralized unit. Open RAN helps "open" the protocols and interfaces between the radios, the compute platform, the software infrastructure, and the applications. Breaking these components apart gives telecommunications companies increased choices about how they build their network and with whom.

With 5G deployments coming online and the introduction of Open RAN, the RAN is becoming much more interesting.

Now, why you should care:

Reason #1: It Opens a New World

Open RAN unlocks a new world on the far edge of the network for communications service providers (CSPs) — and that's not hyperbole. 5G is heavily focused on low-latency, high-bandwidth, high-availability use cases, and you simply can't get to the new world with old world thinking. New consumer and enterprise use cases require a much more flexible model than can be supported on today's equipment. Open RAN provides that flexibility. More on that in a moment.

Reason #2: It Will Lower Costs

5G will need many more cell sites than the preceding technology due to its relatively short range, and those sites are coming online quickly. A recent report from CTIA found that 67,871 new cell sites were added between 2018 and 2020, which is more than during the preceding seven years combined, and there are no signs of a slowdown. Considering that many of these sites will be very small, CSPs are focused on getting the most from them with the smallest footprint possible, as the cost of every additional resource required will be multiplied across all of the sites.

Open RAN provides the ability to select the component pieces that provide the greatest performance per watt, ensuring that compute power is being used at its greatest efficiency to provide the needed coverage — and keeping costs for CSPs, and their subscribers, under control.

Reason #3: It Will Answer the Demand

Open RAN gives the ability to address demand more efficiently. By virtualizing the RAN, you can bring up infrastructure, applications, and services as they are needed. Once the physical hardware is in place, you can provision the software infrastructure and allocate resources to the services needed in that area. This capability is coming into play as CSPs provide 5G coverage for sporting venues, for example.

Open RAN provides a flexible framework to enable adding coverage quickly, then scaling back when not needed. In the past, any area would need to be over-provisioned to ensure coverage, even though most of the time the equipment would be sitting idle.

Reason #4: It Encourages Collaboration

Open RAN fosters community and collaboration. The O-RAN Alliance was founded in February 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO, and Orange, and it has since grown to include 32 of the top CSPs globally, along with some 200 members and contributors. Then there is the Telecom Infra Project, whose hundreds of members are working to "accelerate the development and deployment of open, disaggregated, and standards-based technology solutions that deliver the high-quality connectivity that the world needs — now and in the decades to come."

These two organizations bring together people and companies, which might otherwise compete, to collaborate in building a better network.

Reason #5: It's Already Here

The future is happening now. Verizon has deployed a disaggregated virtual RAN solution, and Vodafone has begun to deploy Europe's first commercial Open RAN network, starting in the U.K. and then extending to other countries in Europe and Africa. NTT DOCOMO has created its 5G Open RAN Ecosystem to accelerate Open RAN to operators globally. Open RAN isn't just a neat idea or a lab experiment anymore; it's actually being brought to commercial life by Tier 1 CSPs.

Reason #6: It Will Enable the Future

Open RAN isn't just a neat idea or a lab experiment anymore; it's actually being brought to commercial life by Tier 1 CSPs.

It will power the future economy. Seventy percent of GDP growth in the global economy between now and 2030 will be driven by connected machines and intelligent systems, according to PwC. This is a near $7 trillion contribution to U.S. GDP.

Of the 13 key characteristics we've found to be critical for success with these intelligent systems, compute at the far edge is a technology that connects and enables them all. Open RAN will provide the framework for much of this compute.

And That Last Half Point

There is a general shift toward disaggregated and open systems, away from traditional, monolithic systems that may have been completely provided by one vendor. Calling this a half point is meant to be ironic: This is a massive change in how CSPs are conceptualizing, designing, and deploying their networks, not to mention the concurrent changes to their business models. Rather than selecting one equipment vendor and creating a purpose-built appliance for the life of the network, CSPs are working with many vendors to select best-of-breed components for their systems, which can be changed as the network demands.

Open RAN is the way of the future. It's complicated, no doubt, but the flexibility, cost-effectiveness, and performance it will provide will enable us to do far more with future technology than we've yet dreamed of.

5G Ushers in a New World of Customization

November 3, 2021

Sadayuki Abeta, PhD, is vice president and general manager of NTT Docomo's Radio Access Network Development Department. Docomo is the largest mobile phone operator in Japan and a leading innovator in the era of 5G. Abeta is responsible for the development of the company's LTE, 5G, X-haul, and satellite communications, and he has worked on the research, development, and standardization of 5G. In this interview, Abeta explains his vision of 5G as a highly customizable network that will help transform companies and their impact on the new digital world.

What is NTT Docomo's vision for 5G, and how it is transforming the industry?

Sadayuki Abeta: 5G is not just an extension or another generation of network capabilities. We at NTT Docomo see this as a whole new world where we can actually directly affect and help solve social issues with 5G services.

"5G is not just an extension or another generation of network capabilities. We at NTT Docomo see this as a whole new world where we can actually directly affect and help solve social issues with 5G services."

Back in February 2018, we set up a network of partners across industries, local governments, automotive, medical, construction, and retail companies in a 5G open partnership program to create new services and solutions. We did this because for 5G to drive innovation in industry as well as help effect social change, the parties delivering those new services and ideas had to be involved at the very start.

5G will clearly bring far higher speeds of connectivity, but how 5G will be used in a more open environment for innovation is even more interesting to us. For example, AR/VR, the support infrastructure for the evolution of the autonomous driving industry, is an important new area for innovation, and 5G — more than any other generation — can help in the design and delivery.

What is 5G going to do that's so different that it will motivate people to think about this in a new way?

Abeta: Businesses and social services can be designed and transformed to take advantage of the network from the very first moment these ideas are thought about. In an open partnership, 5G allows our partners to design their businesses in new ways that are customized to their needs. This means we have worked for a long time with each of our partners to build the network, designed and deployed, that suits their own needs.

In the past we built a network — for example, 3G and then 4G — and tried to fit the customer's needs into it. This is a different, open, collaborative approach across a vast array of different customer needs.

What is the significance of the 5G Open RAN Ecosystem?

Abeta: We launched the 5G Open RAN commercial service in March 2020. Our network was fully multi-vendor interoperable, using an O-RAN interface. With an open network, we have the benefit of being able to take a best-of-breed approach that is customized for a particular scenario with each customer. For example, we can choose the best radio unit for indoor or outdoor or a rural area. As a result, we could reduce the costs of multi-vendor selection and reduce supply chain risks. Many operators want to introduce Open RAN, but they face challenges. Some of these challenges can be solved only through interoperability testing that will bring better performance with Open RAN.

To accelerate 5G Open RAN and also help operators enable flexible network deployment, we announced the creation of an Open RAN ecosystem with partners, including technology leaders such as Wind River, in February 2021. Our Open RAN ecosystem is not just integrating equipment but realizing fusions of technologies through working with partners. Also, we provide a remote open test environment for the Open RAN ecosystem so that operators around the world can access the lab with our support. We share our experience in Open RAN with operators, and they can reduce costs and save time.

The idea of 5G is really exciting, but it can be complex from an operational perspective. Where do you see your biggest operational advantages, compared with traditional approaches to running a network?

"To accelerate 5G Open RAN and also help operators enable flexible network deployment, we announced the creation of an Open RAN ecosystem with partners, including technology leaders such as Wind River, in February 2021."

Abeta: Deployment is getting more complex in the 5G era. Use cases are more varied, and communications network parameters and configurations are diverse. Under these circumstances, it has become increasingly difficult to manage RAN deployment and operation and to achieve optimization with a traditional operation.

To solve this problem, using "intelligence" in RAN will be inevitable to enable automated management and control. The important benefit of using intelligence is to reduce OpEx through digital transformation in RAN operation. Also, it is important to improve RAN performance by automating optimization of radio resource management and control, as it will contribute to increased customer satisfaction and create new business. So intelligence is key in Open RAN.

What is NTT Docomo's vision for 5G use cases such as digital feedback loops and other technologies that are needed to realize digital transformation at the edge?

Abeta: All the operators in the world can access these capabilities with Docomo for test bed works, remote control, and more. That is the inherent power of a cloud-native approach for 5G: using this type of Open RAN ecosystem across the globe. This structure is the way forward for carriers who have been concerned about the differences between the older world and the needs of the newer world.

In 2016, NTT Docomo developed the world's first NFV [Network Functions Virtualization] technologies in the 4G era. Now we are extending that from the edge to RAN and MEC [multi-access edge computing]. This is a global opportunity for partners in an Open RAN world.

Because the deployment operations for a carrier are getting more complex, with use cases, applications, geographies, and a diverse set of network parameters and configurations, it has become increasingly difficult to manage in an optimal and effective way. Open RAN enables that digital transformation capability for carriers and their customers.

We are accelerating digital transformation on both the service and the network sides. We have introduced new technologies covering all areas of digital transformation. We're gathering, using, and analyzing data. In the future, some will be with closed-loop control and some will be open. But we know that increased AI and machine learning will make feedback loops increasingly important.

We are changing the role of the network to be highly customizable in a digital world by adopting new technologies. And we will continue to cooperate with various industry partners through the 5G Open RAN ecosystem to accelerate wide adoption of open networks that can cater to diverse needs.

How Advancements in 5G, Edge, and AI Can Impact Food Production

November 3, 2021

This first article in a two-part series comes from a recent interview with Cristina Rodriguez, vice president of Intel Corporation's Network and Edge Group and general manager of the Wireless Access Network Division. Here she shares her vision for a 5G-, edge- and AI-empowered world that has the potential to make significant positive impact on underserved communities.

Let's start with your view of the world of technology. Where is it heading and what needs to happen?

Cristina Rodriguez: If I look into the future, I see data. Tons of data. Billions of things connected — sensors, devices, phones, computers, you name it. By 2025, more than half of the world's data is going to be generated by these devices and sensors outside the data center.

"By 2025, more than half of the world's data is going to be generated by these devices and sensors outside the data center."

So the world has to be prepared. We need an infrastructure that is prepared for many new use cases. And what's making this possible is the ramp-up of 5G, the build-out of the edge and artificial intelligence, or AI. All of these come together to unleash all types of innovations.

What does the world look like with the combination of edge, 5G, and AI?

Rodriguez: Think, for example, about some of the use cases that we want to address, like autonomous driving and remote surgery. These use cases are truly mission critical and require a very low latency, because the response in the network is critical.

So when you have use cases that require millisecond and less-than-millisecond response, you can't afford to send the data all the way to a data center and back. And that's why you need to build the edge closer to where the data is generated, so you can process the data right there and make decisions right there. That's where the edge comes in.

5G enters with faster speed and high bandwidth with ultra-reliability and low latency. And now you add analytics, AI, and machine learning. Analytics goes on the edge, where you can apply AI to that data to learn and make better decisions. You put all that together and now you have the ability to address requirements and support use cases that weren't possible before.

Autonomous driving is an example that I always talk about, mostly because I don't like to drive. I can't wait to not have to drive. But take another example: agriculture, which has the potential to open new opportunities for underserved communities across the globe. How many things could you do in agriculture when you introduce technology at the edge, such as sensors for water, sensors for health of the crops, for energy saving? Think of the amount of waste we could reduce — but also the ability to have more food available for people.

The interesting thing is that the confluence of these three phenomena — 5G, edge, and AI — are going to touch every single part of our lives. And every single part of society is going to change. The way we live, the way we work, the way we play. It's going to completely touch our lives, and I think it's going to do it for the better. It's going to give us a much better society.

Describe how the edge works with agriculture.

Rodriguez: The number-one thing we need, in general, is connectivity. And we're not talking about just here in the U.S., but in the entire world. It starts there.

But it's not just connectivity. It's also important to consider how we build that connectivity. At Intel we bring cloud-native architecture into the network that allows us to lower the cost to make a stronger, bigger ecosystem that is going to be able to reach and help bridge the digital divide, going to every corner of the world.

Now you can introduce humidity sensors, temperature sensors, all kinds of sensors that are going to help you, depending on what crop or what kind of agricultural product you have. This helps you determine what you need. More water? Less water? Fertilizer?

This connectivity and intelligence help you have better productivity and be more efficient, because you are able to farm how much you actually need. You can have applications and services that make sense for your specific crop. You can have drones delivering supplies or tools that you need. You can have applications running and managing your warehouse. There are all kinds of possibilities that, at the end, reduce your costs, give you better productivity and better efficiency, reduce energy consumption, become more sustainable, and just have a better outcome for your business.

"How many things could you do in agriculture when you introduce technology at the edge, such as sensors for water, sensors for health of the crops, for energy saving? Think of the amount of waste we could reduce — but also the ability to have more food available for people."

We actually did some very interesting work with the Snohomish County 5G food resiliency project. Intel was a founding member of the 5G Open Innovation Lab. A project with this lab, with support from Intel and other partners, resulted in the first application development field lab for the agricultural industry, and it was a fantastic outcome. That's just the beginning; there is tremendous potential there. And that's just one example.

So this is about precision farming for better production?

Rodriguez: Yes. You are able to put more food on the table for the people who need it. Technology innovations will enable us to be much more efficient with the soil we have. Examples like I just gave enable food producers to reduce waste and at the same time find economic goodness. You have a good business on your hands. It's the perfect combination where you are creating economic value — and that's important — and, at the same time, you are giving consumers what they need and you are not wasting. It's perfect.

This is what gets me so excited and makes me believe in the mission. And I will say, the Intel mission is putting the technology that we have and the advancements that we have toward good. We're solving the questions, "How do we have a better world, how do we have a better planet, how do we help and reach more people?" It's very exciting.

Network Footprint, Proximity, and Efficiency

December 6, 2021

Cristina Rodriguez | ADAM BACHER

This second article of a two-part series covers a recent interview with Cristina Rodriguez, vice president of Intel Corporation's Network and Edge Group and general manager of the Wireless Access Network Division. Earlier she shared her vision of a 5G-, edge- and AI-empowered world that has the potential to make a significant positive impact on underserved communities. Now we move to the importance of footprint in the network.

Footprint is a big issue in the network environment. Why?

Cristina Rodriguez: Everything used to sit in a data center, and those data centers just grew. Now they are essentially moving to the edge, and we need to think differently about how to achieve low latency with a small edge footprint. What we have been working on for 14 years now is how to transform the network with architecture that is capable of being future-proof and gives us all the flexibility and scalability that we need.

"When you have a software-driven environment and architecture that is flexible and agile, we are talking about easier and much faster software upgrades and updates of software features."

One of the things we've worked on with the ecosystem is how to abstract network functions that used to be implemented in hardware. There is all this purpose-built hardware that was part of the network, that made the network. We took some of those functions, some of those workloads, and made them work in software. That's what we call virtualization. We started at the core of the network, and now we've extended that into the radio access network (RAN) and, of course, to the edge.

What we're talking about here is applying software-defined network, Network Functions Virtualization, cloud-native network functions to the network. We're also applying a little bit of the architecture that has been used by the cloud for a very long time, using server architecture built on Intel Xeon scalable processors. That means you have a common platform from the core to the edge to the access. That gives you a common platform that is cost-effective, allows you to use open source, and allows you to build your application on top of it using many of the components that the ecosystem provides.

Now we're talking about a network that has a very strong, very vibrant ecosystem providing different pieces. It's a software-driven environment. When you have a software-driven environment and architecture that is flexible and agile, we are talking about easier and much faster software upgrades and updates of software features.

Every single vertical, every single industry can take that platform and have an abstraction or a standard interface that they can program to. And they can develop their whole stack or specific applications and then bring the use cases to reality for their specific industry. And again, it's just going back to the cloud architecture, where you have all the cloud benefits — the observability, the resilience, the agility, the flexibility, the scalability, the security, all of it — but now in your entire network.

This is what we say is a "future-proof" architecture that can evolve with us as we get new requirements, new use cases, new services, new experiences.

What are the barriers we have to overcome?

Rodriguez: The good news is that's already happening. The technology is ready. For years we did proofs of concept, lab trials, small trial sizes, small deployments. But now we're seeing companies like Verizon and companies like Rakuten operating in Japan. They, along with others, are commercially deploying on this type of virtualized network at scale.

If you look at what the operators are stating, they're definitely embracing the virtualization and cloud network. They say they "would not be deploying it if it wasn't as good or better than what [they] have in place today." So I think the fact is that the technology is proven. There's no more proof of concept. We now need to scale and make it happen.

What we're trying to do now, with this network based on a cloud RAN architecture, is aggregation of the hardware and software where there are multiple members of the ecosystem providing different components and different solutions and innovation. I think the biggest, most exciting thing about all of this is the amount of innovation it is bringing. There has to be collaboration. These components have to be integrated.

"I think the biggest, most exciting thing about all of this is the amount of innovation it is bringing."

We need to get to a point where we agree on standards, agree on interfaces, collaborate with each other, do integrations, and make sure it all comes together. I'm very much engaged in it, and Intel of course has a long history of having a strong ecosystem. We have programs that have tremendous participation — the Intel Network Builders, for example.

Then we need to make sure the solution meets the performance per watt required and that all the orchestration and all the management is there. This is happening, and it's very, very exciting. And again, what's especially exciting is the amount of innovation. You see companies that are figuring out the analytics, figuring out how they steer traffic, figuring out how to be more efficient with their spectrum, figuring out how to reduce power consumption. This is fascinating, absolutely fascinating.

Can you touch on the economic formula needed?

Rodriguez: Yes. It's about giving access to more people on the planet to things that were not available before. And it's about making life better, having a better experience. But it all has to make sense economically, too — there has to be an economic value created. There has to be better production. And I think what is happening is that every industry we could pick will be touched by these technologies, and there is a mix of paths they could take. That is to say, either you can do the same for less or you can generate more value and you can generate more services and offerings for your customers.

A Vodafone Perspective on Key Market and Technology Trends

April 4, 2022

Santiago (aka Yago) Tenorio is a Vodafone fellow and director of Network Strategy and Architecture. In this interview, he discusses the expected evolution of network infrastructure over the next decade. He also examines the transformational capabilities of Open RAN, edge compute, and 5G, which will deliver low latency and high throughput to fulfill the needs of future services.

"Through Open RAN, we enable a new ecosystem of RAN software providers supporting competition (reducing costs), innovation (driving performance), and flexibility (reducing time-to-market) for mobile operators."

By 2030, what should the network infrastructure look like?

Yago Tenorio: It is an exciting time for innovation in the world of network infrastructure. As the world modernizes and digitizes, there is increased need for more capacity and performance from our communications infrastructure, while we ensure that we control energy and costs.

Let me start with Open RAN, which is an essential enabler to drive openness and innovation into access networks. Through Open RAN, we enable a new ecosystem of RAN software providers supporting competition (reducing costs), innovation (driving performance), and flexibility (reducing time-to-market) for mobile operators. At Vodafone, together with our partners such as Wind River, we are building toward 30% of our European sites being Open RAN by 2030.

In addition, our fixed network is also evolving through deeper distribution of fiber (FTTx), and our cable network is evolving to give fiber-like experiences (the evolution to DOCSIS 3.1).

We also deployed a network exposure platform that is growing to enable enrichment of many enterprise and consumer services through greater direct interaction with mobile and fixed networks.

Finally, obsolete technologies such as 3G, DSL, and, to a degree, 2G will have been removed, simplifying our network and allowing more spectrum for 5G services.

What new innovations can we expect in five years, and what role will software play in these advancements?

Tenorio: Software and digitalization will play a key role in bringing the network closer to our customers. We are building edge sites that will bring app/API-rich environments for developers to use to create new ultra-low-latency applications and software, unblocking new sources of revenue. Utilization of APIs developed and exposed via network as a platform (NaaP) will drive additional services and build greater engagement with our customers.

From a radio network perspective, mmWave will increasingly be deployed, offering multi-gigabit rates for advanced industry and machine-to-machine and consumer services.

From a service perspective, augmented reality (AR) will evolve toward extended-reality capabilities, enriching visual appeal and offering advanced mixed-reality experiences. Virtual reality (VR) will have developed to offer metaverse capabilities, enabling the beginnings of a new service and communications economy.

"5G, with its lower latency and higher throughput capabilities, will enable edge compute to support many more advanced consumer and enterprise services at substantially lower cost."

In hardware, compute capabilities will evolve through advanced hardware accelerators, improving the ability to use common general-purpose hardware across multiple use cases, such as Open RAN and video processing. It will also provide further developments in cutting-edge compute, such as quantum computing.

What are some of the benefits of 5G that most people might not have considered but that will impact their daily lives?

Tenorio: 5G, with its lower latency and higher throughput capabilities, will enable edge compute to support many more advanced consumer and enterprise services at substantially lower cost. For example, AR for connected workers will aid the resolution of issues in the field and enable the automation of digital twin creation. Cloud gaming will leverage low latency and compute to drive improvements in gameplay and support across devices.

5G can also enable revolutionary capabilities. For example, Vodafone engineers teamed up with the specialist software firm Canonical to demonstrate, at MWC22, how a prototype smartphone operating system can run on powerful cloud servers. This allows users to access their apps and data from any internet-connected screen (or mirror), without the need for powerful hardware.

5G network slicing can enable instant high-performance slices for mobile private network use cases, such as automated guided vehicle control or smart grid management, which improves energy management and reliability.

The 5G future is exciting!

Leadership Lessons and Opportunities from Unpredictable Times

June 15, 2022

This first article in a two-part series comes from a Forbes *Futures in Focus* podcast interview with Tami Erwin, the CEO of Verizon Business. She discusses lessons in leadership growing out of the COVID-19 pandemic as well as the promise of 5G and beyond.

"I remember distinctly the day on which we said we had to move people home for what we anticipated would be a short couple of weeks. There was one thing that I will always remember, and that is that we made a distinct decision."

From the pandemic over the last couple of years to the recent turmoil in Ukraine and Europe, dramatic changes in business leadership and work environments have taught us all lessons. You manage a large organization. What are some of the lessons you've learned from this time? How might those lessons become amplified in the current climate?

Tami Erwin: Thank you for the question and for the opportunity to talk about the human component of the world in which we live and operate, and how that plays out from an overall business perspective. With COVID coming into Asia, then Europe, and then into the U.S., it became real for Verizon, a large U.S. employer but a large global employer as well. I remember distinctly the day on which we said we had to move people home for what we anticipated would be a short couple of weeks.

There was one thing that I will always remember, and that is that we made a distinct decision. We needed to determine it then and there: What was the single most important element to how we would deal with the crisis? And we decided that the care and well-being of our employees and their families had to be our number-one objective. That has made everything else that much easier as we've worked through the last couple of years, to be clear on the fact that we serve four stakeholders: our employees, our customers, our shareholders, and society at large. But we were clear that the safety and well-being of our employees had to be our first priority.

We've also had to drop our masks — and I'm not talking about the ones we wear in public now, a couple of years into the pandemic, but the masks that we used to wear as employees. We've had to really reveal the whole of who we are. We've all had to come together in a humanitarian way and get to know one another and demonstrate kindness for one another. And for me, that will be the theme that carries through from the last couple of years: learning to allow kindness to guide our actions, because there's been a lot of loss.

"For me, that will be the theme that carries through the last couple of years: learning to allow kindness to guide our actions, because there's been a lot of loss."

I think kindness and the ability to show up on behalf of one another have been key themes for what we've been through over the last two years. I think nothing could have prepared us for what we're all watching play out in real time in Ukraine right now — the incredible humanitarian crisis that's happening there. So I think there's this theme of "how do we drop the masks?" to expose the whole of who we are and how we show up with kindness and compassion and move forward as a society with the blend of private and public partnerships. And I believe — I hope — technology will be at the core of helping us solve some of these big problems.

We've encountered levels of virtual intimacy we could have never planned for as a society, because the separation of home and work was so crisply delineated. It's a lovely analogy of taking down the mask as we come out of COVID. How do you think employee-stakeholder relationships will be changed at a more physical, practical level?

Erwin: I think there are a lot of changes that are being anticipated or tested as we speak. A hybrid work environment is one that can be very effective. I think we're finding that some jobs can be done remotely, and you never need to come into the office. The idea of aspiring to have a career that grows into something that must end up at corporate headquarters — I think those days are gone.

How does life change when you recognize that there are different ways to work? We don't have to get up and move our families and disrupt our lives just because that's a thing we used to do. I think we've been given permission to reexamine and redefine work as what we do and not as a place we go, and that will forever transform the way we work. I'm super excited, because technology advancements give us permission and give us a platform to work anywhere, at any time.

Now, there are some upside and downsides to that — I don't want to be connected as an employee seven days a week, 24 hours a day. We'll have to make choices about where and when we work and how we work. How can I create the most effective version of myself to bring to work, regardless of where that might be, and feel free to be the true me? And I think it goes back to the conversation of dropping the masks. I'm a mom. I have two kids. I am a daughter. I'm a wife. I'm all these things that define who I am. If I can bring the best of me to the work environment that I'm working in, then I bring the whole of that to unlock the full potential of who I am as an employee. And that's what I believe we will get out of this hybrid work environment. We'll find new and different ways of doing our work that will give us the ability to really feed back into being part of society, being part of the communities in which we live and work.

"I think we've been given permission to reexamine and redefine work as what we do and not as a place we go, and that will forever transform the way we work."

As we encounter some of the societal challenges that we face, from an education standpoint and around closing the digital divide, we'll need to think through the things that require presence and different ways of working.

This is an interesting trigger for the movement from a monolithic model to a highly personalized one. Before the pandemic, we'd long talked about how a growth mindset can push people to become the best version of themselves. It may well have taken a crisis to force this theoretical discourse to become an actual reality for every one of us.

Erwin: Absolutely yes. It used to be that you could define work by the job description. Consider 20,000 people meeting the same job description with the same set of the standards around how the work got done and where the work got done. I think we're now talking about: How do I unlock the individual talent against the opportunity?

I was speaking with one of our top performers, someone with big career aspirations, and he said to me, "I can rethink and reimagine the balance I have between work and my family because I now have a different set of choices, and those choices are personal." For many, we're getting to that place where people believe they have permission to think about the whole of who they are rather than separating work and home so the two don't intersect. But of course, these things do intersect — it's called life.

Great leaders must understand the personal one-on-one element and create a fair environment, where you are consistent with how you operate and yet flexible enough to customize to the individual person. That's how to really attract and retain top talent.

Let's look ahead to 10 years from now. 5G, 6G, the edge — the promise is incredible. True ubiquity of these technologies to realize availability when, where, and how you want it, whether it's in a sports stadium or a shopping center looking up a product on your phone. Can you talk to us about the trends you're envisioning in communications 10 years from now and beyond?

Erwin: Absolutely. I love to imagine in that space, because I spend a lot of time in that space.

Going back to the previous conversational thread, as we talk about defining and managing the individual, let's touch on an idea that is important to employees, and that is the concept of self. Consider the ideas around diversity and inclusion, around belonging from the standpoint of gender, race, or background. I bring that in because I think it is an important part of how we serve customers. If you think back over the last couple of years and what we've all been through, we've had this awakening, I think, of humanity. To recognize that we need to find a way to unlock the true value of and respect for different backgrounds, genders, and experiences in the work environment.

"If we fast-forward to a reality of ubiquitous connectivity, anywhere and everywhere, one of the things I'm most excited about is creating a path to help anyone and everyone affordably access that connectivity."

How do we do that in a way that people feel not just accepted or represented but feel as though they belong? I raise this because I think it plays into how we think about ubiquitous connectivity and how you serve different customer segments. All groups belong at our table. I think this is such an important point regarding ubiquitous connectivity.

The pace at which the world is changing is giving us permission to reimagine everything about the way we live, work, and play. When I think about the products and the platform and the technology that we at Verizon unlock, it really does start with connectivity.

I will always distinctly remember the very first time I made a wireless phone call. It was probably 35 or 40 years ago, and it was on one of those great big brick phones. It was scratchy and you could hardly hear, but wow. Wasn't it cool? It was so cool, because all of a sudden you had wireless connectivity. Fast-forward now, 35 or 40 years, and think about how you use your wireless device. Occasionally you make a phone call, but think about the power of data. Who knows you better than your device? It knows whom you call, what you communicate, how you communicate, which apps you engage with and interact with, who your friends are, etc.

If we fast-forward to a reality of ubiquitous connectivity, anywhere and everywhere, one of the things I'm most excited about is creating a path to help anyone and everyone affordably access that connectivity.

When thinking about the world in which we live today and COVID, I think about kids who struggled with education during this time. Many tried desperately to find core connectivity, to be able to watch their teacher in front of a video camera. Depending on where in the world you lived, some had unstable, awful connectivity. We have to solve for the digital divide.

When we think about closing the digital divide and having people have core broadband connectivity, it's part of the reason why we're so excited about the work we're doing with 5G. It's not just mobility, it's a fixed wireless access solution. Consider also our spectrum holdings, and the ability for us to deliver coverage across the U.S. in both small and large communities. How awesome is that? It's a little bit like plumbing coming to every household in America. You and I never lived in a time when that wasn't the case, but now we live in a place where not everybody has access to broadband. Think about how our worlds have changed because of that.

Ubiquitous Connectivity and an Immersive Future

July 1, 2022

This is the second article in a two-part series from an interview from the Forbes *Futures in Focus* podcast featuring Tami Erwin, CEO of Verizon Business. Here she discusses 5G, 6G, and their ubiquity in the next decade, as well as her thoughts about an immersive digital future driving transformative outcomes.

Connectivity is becoming an essential part of living, and everybody should have equal and constant access to it. It shouldn't be something that's privileged by geography or income or infrastructure.

Tami Erwin: I completely agree. That's why we're so excited about the spectrum holdings that we've acquired. It allows for the ability to serve every customer. It also allows us to serve in segments — like our TracFone segment, which has traditionally been a prepaid segment — to bring that segment up to the performance of our network. We can scale to serve high-end premium customers, and we have the ability to serve up and down the spectrum of customers and give them all access.

"Consider the possibilities, 10 years in the future, for a medical student engaging with lessons via augmented reality."

We think that's a game-changer for everybody. Consider some of the vertical applications. Think about being immersed while in your kitchen, receiving a history lesson where you're standing in the Coliseum in a virtual classroom environment and your instructor is showcasing the different pieces of the Coliseum and teaching with real examples, right there — instead of you merely reading a textbook.

Immersive education can change the way kids learn. Imagine if every child could have access to that. Consider the possibilities, 10 years in the future, for a medical student engaging with lessons via augmented reality. At Arizona State University in Tempe, Dr. Michael Crow has done some spectacular work. If you're a Biology 101 student today, you can come in and work in a 5G environment with edge computing. You learn in an augmented reality or virtuality reality (AR/VR) environment where information is served up to you in highly engaging way, instead of via rote memorization.

I think education is on track to be radically disrupted by technology, from elementary learners all the way through university learners — and, quite frankly, business learners also, especially as things are changing so quickly around us.

Step ahead to the year 2030 or so. How much education do you think is going to be delivered this way, throughout the economic and social chain? Will it be a much more common experience for everybody?

Erwin: Yes, I believe it will become much more common by the time you get to 2030. As of early January, we now cover a hundred million people in the U.S. with 5G. We've announced that we'll take that number up to closer to 160 million by the end of 2022, pulling forward our schedule and accelerating the deployment. The deployment of 5G key capability is quickly being rolled out across the country and around the world. We're certainly leading the charge. We were first in the world to deliver 5G mobility, first in the world to deliver 5G fixed wireless access, and first in the world to deliver edge compute. The U.S. is leading the way in how to use 5G to create great change.

"It's important to create a model that focuses on affordability for everyone. And it's key to have the innovation of partners. We are extremely excited about the partnerships that we've forged."

It's important to create a model that focuses on affordability for everyone. And it's key to have the innovation of partners. We are extremely excited about the partnerships that we've forged. We're still the only telecom in the world to have partnerships with all three of the big hyperscalers — AWS, Azure, Google. Think about having a million developers who now can develop applications and solutions, recognizing that you'll have this ubiquitous coverage across the U.S by 2030. Consider the applications that everybody uses. Now envision creating applications and use cases that work in a private network using private edge compute, but then they are transferable and available to a public environment. This is happening as we speak.

By 2030, we'll see driverless cars. Today in a 4G world, the clearance to the car in front of you is about four inches. In a 5G world that supports low-latency applications, you could be enabled for a four-foot clearance to the vehicle in front of you. I don't know about you, but I would much rather be in a driverless vehicle with four feet of clearance as a buffer.

The industry is advancing tremendously with 5G. Think about the possibilities when you really unlock the ecosystem and achieve nationwide coverage. Think about the developers who are innovating and the power of the devices we're carrying. Let's consider how businesses have responded to the COVID crisis. Everyone has come out of COVID reimagining. How do they conduct their work differently? How do they serve their customers differently? How do they build product capability differently? How do they unlock and tap into the potential of their employees using technology?

Unlocking new possibilities is exciting particularly for the medical sector. There are tens of millions of people who do not live close to a major hospital or medical facility. Consider those without readily available access to a specialist. However, then imagine being able to connect and work with a specialized doctor with actual experience, regardless of their location. They could create diagnostic and prescriptive pathways in a way that was never previously available to someone in a rural area.

Erwin: Yes. There can be breakthroughs in accessibility for diagnostics and treatment protocol. I grew up in a small rural community north of Seattle. My father was a physician. I remember going out and doing house calls with him. Consider a rural community that can have access to the world's best oncology specialist. That can be enabled for a small rural community, like where I grew up. Imagine having access — not just for the wealthy — to physicians around world who are experts in their field. This is exciting because the scenario is not imaginary.

I live in the East Coast. Someone emotionally close to me who lives on the West Coast recently had some heart issues, and I was able to be part of her discussion with her physician via a virtual visit for both of us. It changed the outcome for her because of the availability of telehealth. This would not have been possible just a few years ago. Due to her advanced age, it was important that I be

part of the discussion to help translate the details. I didn't have to fly across the country to be present in order to help her.

I was speaking with the head of innovation for the Mayo Clinic recently, and he was talking about some of their innovations. He said, "Tami, I participated in three different consults in three different parts of the world, because we have expertise here that everybody wants to have access to. Technology gives us that kind of access. And we're just getting started."

This becomes a new medical and educational construct. And now with the tragedies in Ukraine, the world is going through another crisis of a different dimension.

Erwin: The world is responding differently to what's happening in Ukraine because we're watching it in real time. Technology is also playing a big role in terms of communication within the region. It's impacted what we know about the conflict. Technology is enabling the world to do that in an accelerated fashion.

I remain hopeful that we can use technology to solve some of the world's biggest problems — to educate, to reform, to really resolve some of the issues that we might not otherwise be able to address quickly. It gives me a lot of hope that we can use technology to make the world a better place.

"I remain hopeful that we can use technology to solve some of the world's biggest problems — to educate, to reform, to really resolve some of the issues that we might not otherwise be able to address quickly. It gives me a lot of hope that we can use technology to make the world a better place."

Without it, we have no capacity to lean into the future with confidence. The metaverse idea is an interesting discussion. You've touched on it around education and healthcare. What do you think it will look like by 2030?

Erwin: I think it looks pretty exciting. I remember when the internet was starting to become popular, and it was amazing to have access to all this information. Now think about being part of an immersive experience in a metaverse. The power of our network capability unlocks the potential of making that real. When you have the ability to take the compute that happens today on your smartphone and put it into the cloud, you can be in an immersive environment.

I've participated in it in some of the early testing, and it feels real. It feels like a world in which you can better imagine coming into a hybrid work environment, very different than the world of today.

We're just getting started. We're now building the platform and capabilities to have that kind of ubiquitous network capability that unlocks low latency, sensor densification, and lower power consumptions. It's a playground, it's a sandbox for innovation. The innovation that will happen in augmented reality in a virtual environment, because of the ability to offload that compute capability into the cloud, will deliver incredible and radical transformation across every vertical that we operate in.

I am excited because it will give us more choice in how we live in our world. Do we live in our world in an analog way? Do we live it in a digital and immersive world?

Think about a world without the internet. You can't imagine it. I think 10 years from now we'll say, "Imagine a world without the metaverse," because it will be that commonplace.

That's interesting, because people can immerse in various formats, but the ability to transverse what historically has been physical versus digital will open perspectives that many of us can't even calibrate right now.

Erwin: I think things that we can't even yet imagine will be possible. And they're probable because of the 21st-century technology infrastructure we're building. Plumbing was cool 150 years ago — and, by the way, it's still cool. But imagine now the 21st-century infrastructure, which includes mobility, broadband, and cloud. As we tackle the complex problems the world is trying to solve, when you have that kind of new infrastructure and people who can innovate on that in a technology sandbox, we'll see transformational change and outcomes. You can afford to have the compute live in the cloud as opposed to having it live on hardware. It will change and drive radical transformation. I believe it will do so in a way that will be available for everyone, and that is super exciting.

If everyone, everywhere, has the chance to be the best version of themselves using technology in an immersive way, we're going to bring out remarkable things in human beings.

Erwin: I completely agree. Having access to information transforms the way we think about the world. Being immersed and surrounded by a different environment, a digital environment, could give you the ability to not only hear it but to see it, to feel it, to be part of it. It will really give us a different view of the world — and perhaps give us a more equitable view of the world, as we begin to think about how we use technology to solve some of these problems and really innovate and deliver different kinds of outcomes.

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