February 2021

Enterprise AR: Best Practices & Case Studies, Volume One

An ARtillery Intelligence Briefing

ARtillery Intelligence

Executive Summary

Though we spend ample time examining consumer-based AR endpoints, greater near-term impact is seen today in the enterprise.

This takes many forms including data visualization in corporate settings, or software to create customer-facing AR experiences for brands. But the greatest area of enterprise AR impact today is realized in *industrial* settings.

These industrial use cases include AR visualization to support assembly and maintenance in manufacturing facilities. The idea is that AR's line-of-sight orientation can guide front-line workers. Compared to the "mental mapping" they must do with 2D instructions, line-of-sight support makes them more effective.

This effectiveness results from AR-guided speed, accuracy and safety. These micro efficiencies add up to worthwhile bottom-line impact when implemented at scale in industrial operations. Macro benefits meanwhile include lessening job strain and the "skills gap," which can lead to preserving institutional knowledge.

For example, AR leader PTC reports up to **40 percent** improvements in new employee productivity, **30 percent** greater first-time fix rates, **50 percent** reductions in training costs, and **25 percent** reductions in materials scrap.

But it's not all good news. Though all of these advantages are valid, it's challenging to get to the point of realizing them. Practical and logistical barriers stand in the way, such as organizational inertia, politics, change management and fear of new technology among stakeholders like front-line workers.

The biggest symptom of these stumbling blocks is the dreaded "pilot purgatory." As its name suggests, and as you may have heard in AR industry narratives, this is when AR is adopted at the pilot stage, but never progresses to full deployment. It's the biggest pain point in industrial AR today.

In the past, ARtillery Intelligence has identified the sources and solution areas for pilot purgatory as the "3 Ps." Comprising *people*, *product* and *process*, they're the top areas where effective AR implementation strategies should focus.

With that backdrop, we continue the narrative in this report with an update on the enterprise AR opportunity, including new ARtillery Intelligence market sizing data. Moreover, we devote the bulk of this report to "show rather than tell." We'll do this through several case studies that demonstrate enterprise AR best practices and business cases.

To adequately represent these factors, we've reached out to leading enterprise AR players to collect their top case studies. We've then relayed these through our own lens and analytical rigor. We've prioritized case studies that have quantifiable results, actionable takeaways, and a wide variety of business verticals and use cases.

The goal in all of the above is to reveal the *why* and *how* of enterprise AR. Through the lens of industry best practices, *why* should enterprises invest in AR? And *how* should it be optimally implemented? The name of the game is to set up enterprise AR to succeed by deploying it from a position of confidence and knowledge.

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Key Takeaways

- **AR's benefits are being demonstrated in various enterprises, especially in industrial settings.**
- AR line-of-sight visualization breeds operational efficiency in areas like assembly and maintenance.
- Primary formats are remote AR assistance and automated pre-authored sequences.
- Recorded AR sessions are evolving to better capture and distribute institutional knowledge.

- **Enterprise AR advantages and ROI gains result from several micro and macro factors.**
- *Micro-benefits* include unit economics in production output (e.g., speed, accuracy and safety).
- Example: tasks can be completed faster by reducing reference to, and translation of, 2D instructions.
- *Macro-benefits* include profitability gains, job-strain reduction and institutional knowledge retention.
- Example: Lessening strain delays retirement, while recorded sequences distribute knowledge optimally.

- **Amplifying the value of successful AR deployments, bottom-line impact can scale up quickly.**
- When applied across large-scale operations, efficiencies can add up to millions of dollars in impact.
- The cost for AR implementation is often recouped quickly when it's applied effectively and at scale.
- The business case for these ROI gains will eventually overpower inertia and adoption impediments.

- **Meanwhile, several organizational hurdles and points of friction stand in the way of AR's benefits.**
- "Pilot purgatory" has emerged as enterprise AR's biggest pain point, diminishing real deployments.
- Causes are mostly organizational and cultural, such as inertia and natural resistance to change.
- Failure to reach deployment squanders the opportunity and sunk-cost investments in AR.

- **Pitfalls originate within three main areas we've identified as the "3Ps": *people*, *product* & *process*.**
- With *people*, industrial AR's value proposition should be customized to individual stakeholders.
- With *product*, the principles of product/market fit should be followed… just like consumer products.
- For *process*, AR product planning, deployment and communications require tactical precision.

- **Drilling down on one of the 3P's, *people* communications are critical to successful AR deployment.**
- After all of the investment in AR research and deployment, it will fail if end-users don't adopt it.
- Internal communications should therefore stress personal benefits like reduction in job strain.
- Medtronic achieved this by demonstrating to medical pros that AR can lessen time with paperwork.

- **Similarly, product fit includes deploying AR where it can have the most impact (not a silver bullet).**
- AR has proven effective with complex non-repetitive tasks such as heavy-equipment assembly.
- It conversely doesn't add value to simple repetitive tasks such as changing the oil in a car.
- AR can also add considerable value wherever there are current systems of guidance by paper instruction.
- Impact can be felt greatest where there are "high stakes" such as GE's use of AR in jet engine inspection.

- **The importance of following all these tactics is to set AR investments up to succeed.**
- AR investments can be protected rather than lost, if deployed with the right best practices.
- Points of failure are often within enterprises themselves (as opposed to AR vendors/providers).
- AR success therefore results from tactical execution around a set of common success factors.

- **In the near term, enterprise AR will continue to linger in early adopter phases.**
- Enterprise AR will reach a tipping point in the next 3-5 years, followed by rapid industrial adoption.
- ARtillery projects enterprise AR spending to grow from $2.77 billion in 2019 to $15.8 billion in 2024.
- Meanwhile, the opportunity remains with early adopters that can get a head start on reaping AR's rewards.
- Case studies throughout this report unpack and demonstrate many of the above principles.

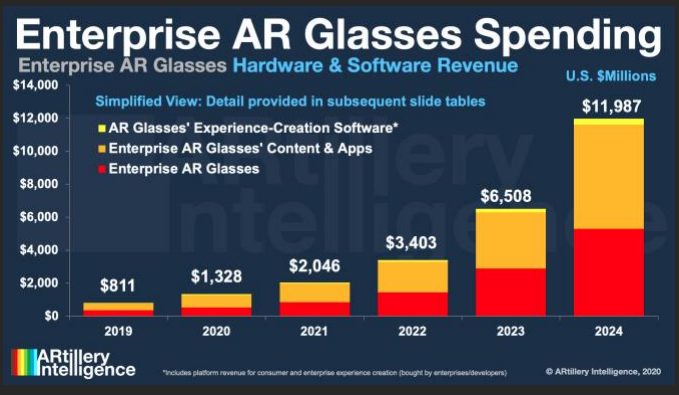
Introduction: Business Case

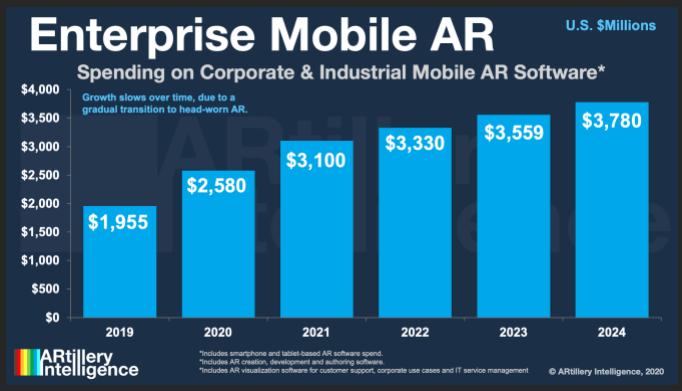
Last month's ARtillery Intelligence briefing examined the challenges facing consumer AR glasses. But as we mentioned at the time, many of those barriers aren't found in industrial enterprises. There, the technology's style crimes aren't an issue, and it demonstrates clearer ROI and adoption drivers.

These drivers include operational efficiencies that result from line-of-sight visualization. In areas like assembly and maintenance, AR can expedite task completion and reduce errors by lessening cognitive load from "mentally mapping" 2D instructions to 3D space.

For example, industrial AR leader PTC reports up to **40 percent** improvement in new employee productivity and **30 percent** improvement in first-time fix rates. The latter prevents the expensive problem of dispatching field technicians for a second time.

Speaking of cost savings, **PTC** likewise reports up to **50 percent** reductions in training costs and **25 percent** reductions in materials scrap that results from inefficient assembly. We'll break down such figures in the case studies to come later in this report.





Macro Scale

Joining these micro-benefits and unit economics are macro-benefits. They include optimal distribution and retention of institutional knowledge. This is all about mitigating knowledge loss from seasoned personnel (such as baby boomers) retiring en masse — another "expensive problem."

AR can allay such detriments in two ways. By turning seasoned pros into subject matter experts who support field staff through remote AR guidance, it can delay retirement given a "cushier gig." On another level, AR guided instructions help novice workers train and upskill faster. As a bonus, all of the above supports social distancing in the Covid era.

For all of these reasons, ARtillery Intelligence has estimated that enterprise AR spending will grow from **$2.77 billion** in 2019 to **$15.8 billion** in 2024, a **41.6 percent** CAGR. This includes head-worn AR[i] (hardware and software spending) as well as mobile & tablet-based AR[ii] (software spending).

The Dark Side

Though AR carries all of the opportunities and advantages outlined above (and detailed later in this report) it's challenging to get to the point of realizing them. Practical and logistical barriers stand in the way — such as organizational inertia, politics, change management and fear of new technology among key stakeholders.

These barriers exist even in a pandemic when social distancing measures compel AR's ability to facilitate remote assistance, as noted above.

These Covid-based drivers could accelerate AR adoption to some degree and expose the technology's benefits... but organizational inertia persists.

For example, the biggest stumbling block for enterprise AR is the dreaded "pilot purgatory." This is when AR is adopted at the pilot stage, but never progresses to full deployment. It's the biggest pain point in industrial AR, and there are many reasons for it…most of them cultural.

Image Source: Microsoft

The 3 Ps

One key question that stems from the above is how can enterprises alleviate cultural deterrents? The best way is to go straight to the root of the issue. These focal points are what we call the 3Ps: *people*, *product*, and *process*. These were the focus of a 2019 ARtillery Intelligence report, which we'll revisit here before diving into our case studies.

People

Internal messaging around AR's benefits should be customized to individual — and sometimes selfish — needs. Conversely, AR implementation fails when companies sell front-line workers on AR based on its unit economics, or financial ROI for the company.

The story should instead be spun to their advantage, such as reduction in job strain from reduced cognitive load. Or it can extend their longevity by turning seasoned workers into subject matter experts who support field workers remotely — a "cushier gig," as noted.

Product

Beyond the people that represent barriers to AR success, there's also the product itself. To get straight to the point, AR should be deployed where it can have real impact. Because AR isn't a "silver bullet," it should be carefully implemented and set up to succeed as a function of *where* it's applied.

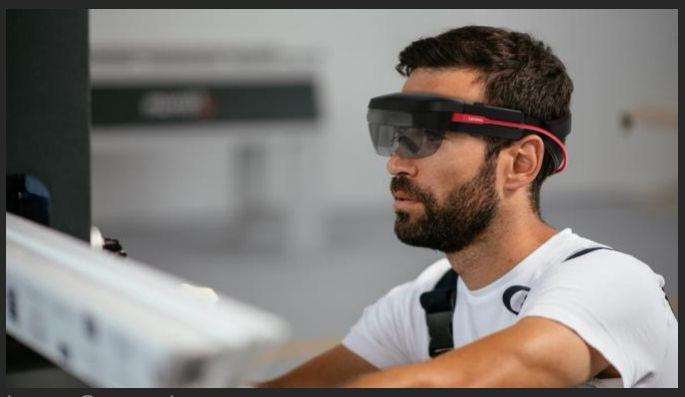


Image Source: Lenovo

Image Source: Microsoft

For example, AR visualization can be most effective in jobs that require *guidance* for complex and non-repetitive tasks such as large-equipment maintenance. It's less effective in jobs that involve *repetitive simple tasks* — such as assembly line work. Muscle memory already guides such tasks.

Process

All of the above is meaningless if AR isn't implemented methodically. Here the common trap is top-down implementation from executives or corporate innovation centers. These stakeholders are sold on AR's business case and are so excited that they fail to solicit the input or buy-in of front-line workers.

This results in failure to address true pain points or achieve commitment from end-users. Bottom-up product planning conversely breeds success by involving front-line workers. That not only pinpoints features that will solve real operational issues, but it gives front-line workers a sense of ownership... which leads to effective adoption.

The Gatekeepers

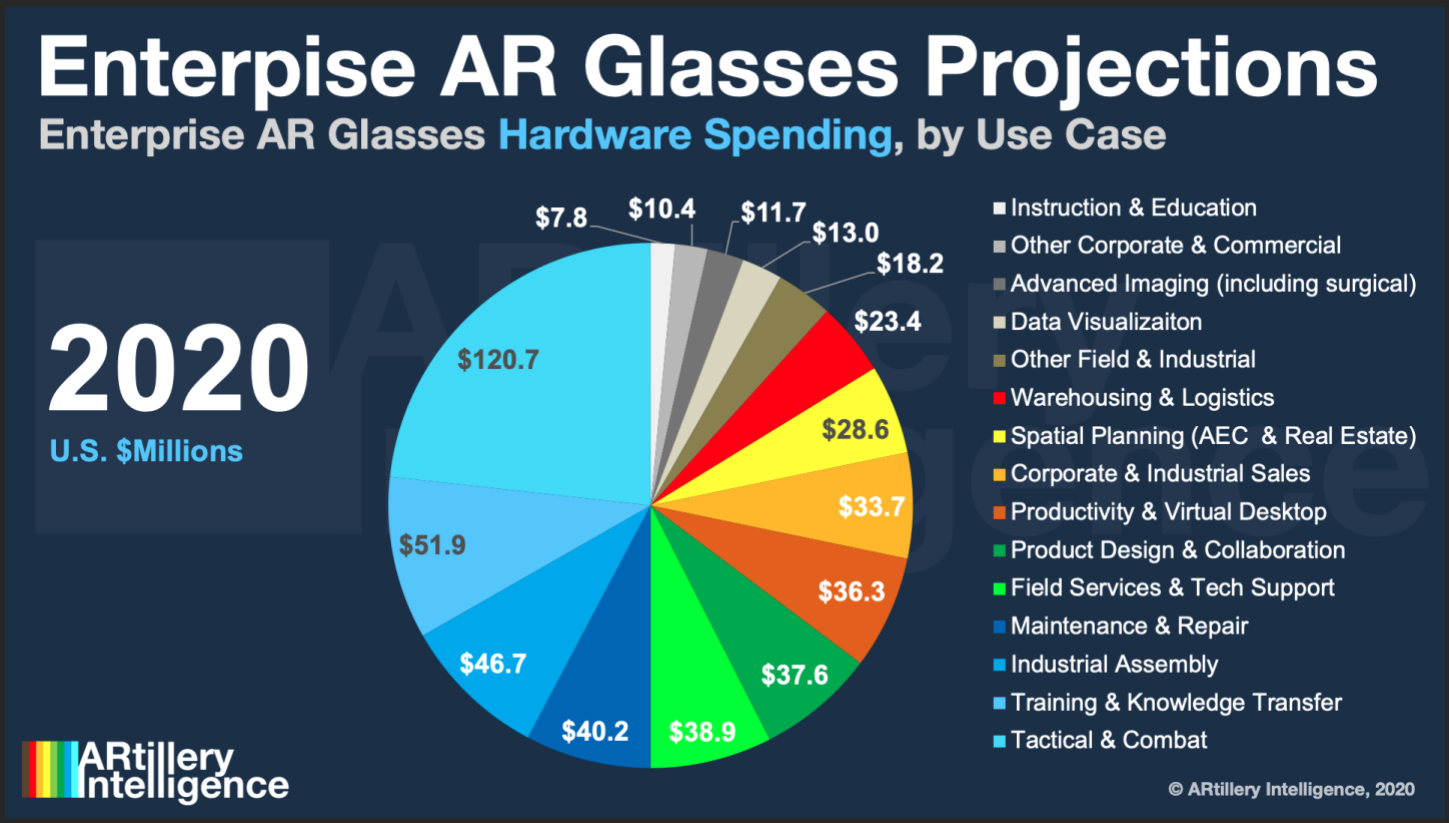
As an addendum to the 3 P's, it's also important to remember to apply the same principles to many stakeholders, not just front-line workers. The IT department for example can be a powerful friend or foe. Involve them early in order to get the same input and ownership espoused above.

Another way to lessen resistance is to start with proven hardware. If the use case aligns, consider deploying AR through smartphones and tablets before headsets. There can be less resistance from risk-averse IT and comfort-driven workers when trusted hardware is the vessel.

Marketing Play

With all of the above, targeted communication and education are key enterprise AR success factors. And that communication is more about marketing than technology. Communication and education to proposed AR end-users should therefore follow the best-practices of marketing.

Bringing this back to an earlier point about solving the pain points of AR's proposed end-users: speak to them and speak their language. Devise scripts and narratives for "objection handling" using carefully devised and plain-spoken language. And use that language consistently.



Case Studies

Building from the above background and high-level “state of the union” for enterprise AR, we’ll now “show rather than tell,” in spotlighting selected case studies. These case studies were selected based on their variety. That includes representation from various AR use cases as well as business verticals.

Case studies were also selected based on value. For example, we’ve only selected case studies that have a quantifiable outcome that indicates a concrete return on investment. And we’ve selected cases that have discernable and transferable lessons for tactical execution.

With that backdrop, let’s dive in...

Image Source: Microsoft

Porsche

To return to and drill down on a figure we've examined in the past, **Porsche** has reduced service resolution time by **40 percent** by equipping its mechanics with AR glasses for guided maintenance

This includes line-of-sight instructions and reference material for complex maintenance procedures like replacing a transmission. Given the costs of dispatching high-end mechanics, this service-time reduction added up to meaningful savings at scale.

Now a few years later, it's evident that **Porsche** has internalized this ROI boost and taken real action to invest in AR. It has tripled down on the technology by boosting its AR usage **3X** according to **Atheer**, which is Porche's AR supplier of record.

Image Source: Porsche

Think Like a Marketer

Porsche's follow-on investment holds a few key lessons. First, it's a notable indicator that AR is working. But beyond that fact — which we mostly know from several case studies — **Porsche** got over the hump of the dreaded pilot purgatory outlined earlier, and was able to move on to full deployment.

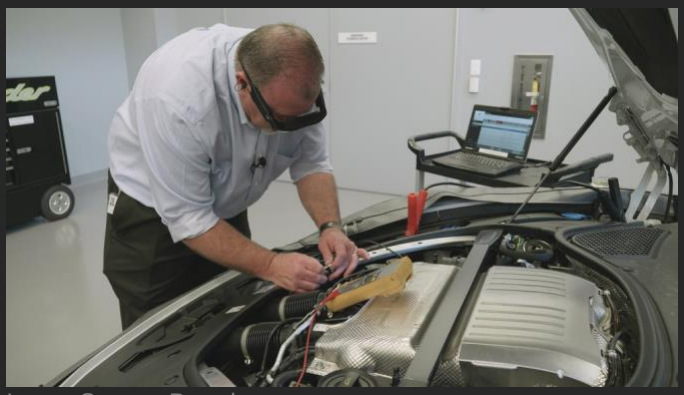


Image Source: Porsche

As a reminder, pilot purgatory happens when enterprise "innovation hubs" bring in AR but then fail to achieve a critical mass of organizational adoption. It's usually a function of top-down planning, and poor communication to tech-averse front-line workers, as noted.

Atheer overcame this challenge by internalizing the lessons espoused above in the "Marketing Play" section. The way **Atheer** puts it, it's all about "thinking like a marketer" in internal communications. This can help enlist and excite stakeholders at all levels.

"Porsche brands everything as 'Tech Live Look'" said **Atheer** CEO Amar Dhaliwal at AWE Europe. "So everything they do — every press release, every analyst briefing — they talk about the program. Internally, the posters and packaging… when glasses go out… everything is branded."


Image Source: Porsche

Not a Silver Bullet

The other best practice that can be attributed to **Porsche's** increased AR spending is to deploy AR where it can have the most impact. Though that sounds obvious, AR isn't a silver bullet: it follows the dynamics of any market sector in requiring good *product/market fit*.

In that sense, **Atheer's** playbook stresses the need to find areas where AR's strengths align. For example, it reports that AR is great for guidance but not for training (though VR has proven ability to boost knowledge retention in training). This validates a point made in the previous section and speaks to the second "P" In the 3 Ps (product).

In other words, AR doesn't add value in jobs that involve repetitive, simple tasks like changing your oil. But it can have lots of impact in jobs that need guidance. That includes complex, non-repetitive tasks like — again — replacing your transmission. It's all about aligning goals.

"We'll start by asking 'what is it that you're trying to do?'" Dhaliwal said at the AWE conference. "If they're trying to do something that sounds better for training, we'll say 'we're not the right partner for you, because deploying this technology to solve this problem will not have the ROI that you're looking for'."

Image Source: Porsche

GE Aviation

Mistakes can be costly when building aircraft engines. For that reason, aerospace companies put a tremendous level of emphasis on quality control. **GE Aviation** is one such company, subject to lose millions of dollars each year to errors in engine assembly and maintenance.

Those losses result specifically from lost productivity, time to fix mistakes, and delays throughout the process. You can think of aircraft engine work as a very complicated assembly line where any hiccups in one part of the process can have ripple effects on interrelated operations and processes.

Beyond cascading delays, a potentially more costly factor occurs when assembly errors aren't detected until customers (think: aircraft manufacturers) receive them. In these cases, repair costs are elevated due to the need to dispatch professionals to the customer's location, not to mention the intangible hit to customer satisfaction.

Image Source: GE Aviation

Verifying Torque

One error-prone area for **GE** is with B-nuts. These provide the necessary seal in aircraft engine-fluid lines to ensure proper flow and containment. This seal requires a specific level of torque: If it's too loose or too tight, it can lead to many of the above costly scenarios.

Given this ongoing pain point, **GE** went in search of technology that can empower mechanics to get it right the first time. AR became a logical answer given its line-of-sight annotations that could guide mechanics in various ways. Working with **Upskill**, it devised a system.

Specifically, **GE** used **Upskill's** Skylight AR platform in tandem with **Google** Glass Enterprise Edition. These tools were then integrated with standard Wi-Fi-enabled torque wrenches. Altogether, the result is that mechanics get guided and intuitive instructions to help them verify torque levels.

For example, as mechanics move through standard processes, they come to the step when they need to use the torque wrench. The **Skylight** software – through **Google** Glass EE – then verifies the torque level in real time. Once the correct torque is matched, the mechanic can move on to the next item.

Image Source: Upskill

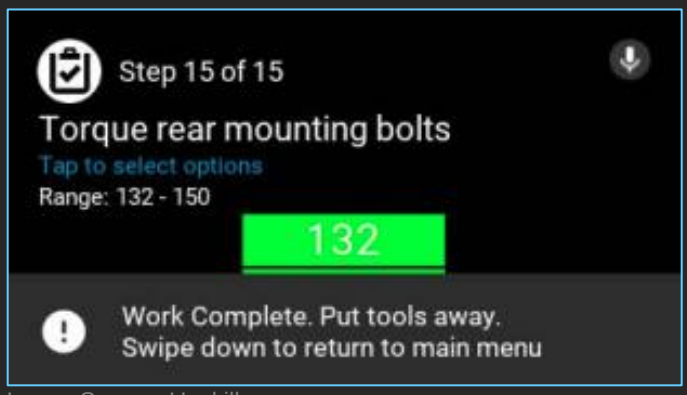


Image Source: Upskill

As shown in the images on this page, red indicates that there is either too much or not enough torque. Green conversely indicates that the torque is within the optimal range. In addition to color-coded values, explicit notifications signal that mechanics can move on to the next task. They can also swipe to the next task with gestures or voice.

Beyond torque optimization, AR supports **GE** mechanics in a broader sense. For example, common FAA-approved assembly procedures tell mechanics to leave the engine and walk to a table or monitor to check how their work lines up with corresponding instructions. That usually involves paper manuals or a computer.

AR line-of-sight instructions and videos conversely put the information closer to its relevant location. That not only means less cognitive load and more accuracy, but greater speed and efficiency. Mechanics can also utilize **Google** Glass's camera to get live "see what I see" support from remote colleagues.

Speaking of the camera, this provides another point of value: tracking. By tracking mechanics' work (such as torque accuracy), **GE** holds greater analytics and reporting. That can be for its own ongoing systems optimization or to keep detailed engine maintenance files for the chain of custody.

Proof Points

All of the above AR-guided actions are good examples of the *training vs guidance* principles outlined earlier. To reiterate, AR is successful when applied to areas that align with its strengths. Complex guidance such as aviation assembly is a good example of that – reducing "cognitive load" and therefore mistakes.

Beyond theoretical benefits, there are also quantifiable results in **GE's** work. Initial deployment in its Cincinnati OH facility involved 15 mechanics who each spent one day testing the new system against existing procedures. The results were clear differences in speed, productivity and error reduction.

One mechanic showed a **38-minute** task completion time with AR, compared with **51 minutes** with the standard procedure – a **25 percent** improvement. The collective result for all mechanics tracked was **8-11 percent** efficiency improvements.

Mechanics are also importantly "on board" to use AR. **60 percent** of participants indicated that they preferred using AR to traditional methods. As examined earlier, this end-user buy-in is a critical component of any enterprise AR deployment. Without that, it's doomed.

As for bottom-line results for all of the above, **GE** analyzed the efficiency and accuracy gains in light of its full-scale operations, and deduced that it can save **several millions of dollars**.

"We believe that Skylight with Glass has the potential to be a real game changer in terms of its ability to minimize errors, improve product quality, and increase mechanic efficiency," **GE Aviation** Manager Ted Robertson told **Upskill**.

Image Source: GE Aviation

Toyota

*Guest authorship by **Unity's** Nick Davis*

One of the core principles of **Toyota Motor Corporation** is *Kaizen*, which translates in English to *continuous improvement*. In production equipment and work procedures, Kaizen seeks to drive maximum quality, efficiency gains, and eliminate waste.

Toyota often turns to technology to deliver these improvements, which is why the automaker was an early adopter of 3D data and AR-guided processes. This includes digital engineering, assembly and all stages of the automotive lifecycle.

Unpacking that a bit, **Toyota's** virtual pipeline starts by importing vehicle data into **Unity** using **Pixyz**. This process quickly converts **Toyota's** large computer-aided design (CAD) assemblies into lightweight content suitable for real-time 3D.

The company then develops applications tailored to its needs and deploys them to various platforms. That can include training sessions in VR, creating realistic car configurators for its luxury Lexus brand, or condensing inspection workflows from days to hours with HoloLens 2.

Image Source: Toyota Motor Company

Driving Continuous Improvement

Drilling down, here are some of the many ways **Toyota** is saving time, reducing costs and driving efficiencies with mixed reality.

Enabling remote assistance in field service

As a global company, **Toyota** needs to connect field support engineers and experts across various locations. This presents numerous challenges and hinders effective collaboration and training.

With HoloLens 2 and Dynamics 365 Remote Assist (Microsoft's mixed reality distance collaboration tool) two or more participants can share the same view, communicate, and collaborate wherever they are. This allows remote staff to inspect work, educate, and train field engineers, while saving considerable time and money, and improving overall results.

Improving design reviews for CFD analysis

Computational fluid dynamics is a critical but arduous step in the automotive lifecycle. It involves testing things like aerodynamics and how an automobile channels liquid such as rainfall. This is another place that **Toyota** integrated Hololens 2 into its workflows.

Image Source: Unity

Equipped with the device, technicians can navigate around a stationary vehicle to simulate and analyze how its design affects aerodynamics. Using multiple HoloLens 2s, they can share views to better communicate and collaborate during the review process.

Increasing understanding of vehicle functionality

Once a vehicle is assembled, it's challenging to explain the functionality of mechanisms that are out of view. This is made more difficult when the function requires the vehicle to be in motion.

Using HoloLens 2, that motion state can be simulated. Users can move around and inspect the inner workings of a "moving" vehicle – making a task that was once impossible not only doable, but easy and safe.

Reducing mistakes in field service

Proper electrical wiring configuration is crucial for ensuring that vehicles operate as intended. In a finished vehicle, however, inspection of connector positions and pin assignments is a sizable challenge.

Instead of relying on 2D diagrams, **Toyota's** team now has the ability to visualize the entire three-dimensional electrical wiring diagram inside the engine, doors, dashboard, or any other part of the car.

This allows **Toyota's** field service engineers to gain contextual understanding and to visualize the location of the wiring systems without the labor and time needed to remove physical parts.

Making it easier and faster to create field-guidance applications

Step-by-step tutorials are critical for service engineers to make repairs effectively. But creating these manuals is time- and resource-intensive. In the past, a digital version of a work procedure app would take up to ten days and require an onsite computer graphics engineer.

With Dynamics 365 Guides (Microsoft's virtual training, performance and instruction software) the same task now takes **90 percent** less time – just one day. This automated process allows anyone with basic training to create necessary applications through detailed instructions and guidance, freeing up programmers to focus on other tasks.

Reducing human error during inspections

The possibility of human error is always present, even among expert technicians. Simple errors such as a loose coolant cap carry consequences if not detected and corrected immediately.

With the help of machine learning, digital models, and HoloLens 2, **Toyota** engineers are given guidance to recognize and remedy inconsistencies that are easily missed by ordinary inspection.

To do this, **Toyota** creates 3D models of the vehicle and the body parts under the hood. It can then vary the model's position in 3D space, and automatically capture a large volume of labeled images to train its machine learning models.

By comparison, previous processes involved training machine learning models on Microsoft Azure to recognize mistakes. To build that training set, **Toyota's** team needed to take **20,000 photos** and spend **200 hours** annotating the photos manually.

The end result in switching to an AR-based approach was reducing this time to **30 minutes** – a **400x** speed improvement. And there was notably no reduction in accuracy or quality.

For **Toyota**, this kind of time and cost savings is an ideal example of Kaizen in action.

Image Source: Unity

U.S. Air Force

Spatial computing's benefits in industrial settings continue to be demonstrated. This is a critical step in the technology's early lifespan as ROI signals are required by enterprise buyers. We've seen several proof points so far, but ongoing evidence is needed to reinforce that ROI story.

With that backdrop, another example comes from the **U.S. Air Force**, which reduced errors in aircraft maintenance to almost **zero**. It applied **Taqtile's** Manifest AR assistance software and **Unity**-created content to help Air Force recruits gain expert-level knowledge through line-of-sight annotations on aircraft parts.

As noted earlier, this is a key principle in that AR can automate knowledge transfer and alleviate the dreaded "skills gap". This could represent a shift in thinking about how industrial assembly and maintenance is done with "just in time" or "on-demand" knowledge, replacing rote preparation.

"One of the things that's happening with AR is that we can rethink the training model from 'in-advance' and 'just-in-case' to 'in-the-moment' and 'just-in-time,' said **PTC** CEO Jim Heppelmann at an AWE conference.[iii]

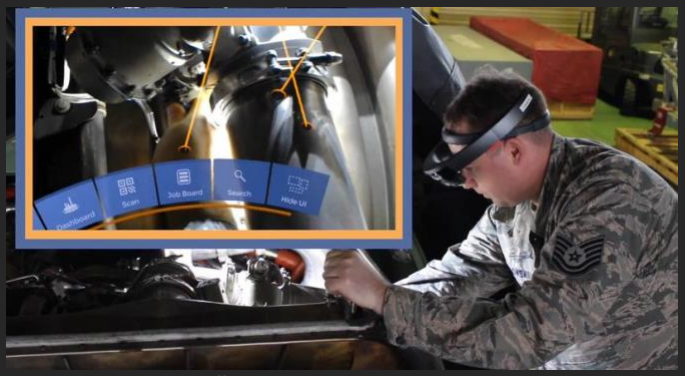


Image Source: Taqtile

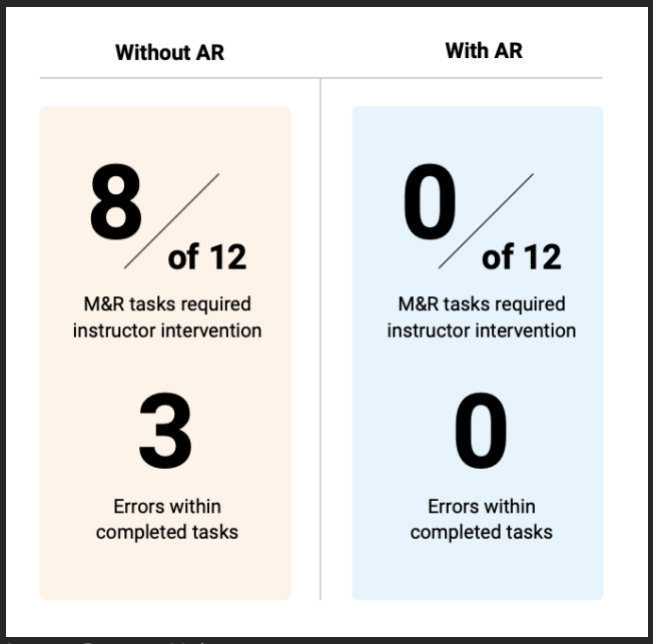


Image Source: Unity

Beyond the C-Suite

These results, again, are important to continue to validate the ROI story. This is especially true considering slower than expected enterprise adoption. Industrial AR, for one, is still far from ubiquity despite strong ROI signals. That disconnect signals the need for continued education.

As espoused in the third P in the 3 Ps (process), education will extend beyond executive levels to other stakeholders that can make or break AR's success. That includes the IT department (risk averse) and front-line workers (tech/change-averse).

The lesson plan in this educational journey should involve financial ROI and *individual ROI*. For front line workers, that's education on how it eliminates job strain, makes them more effective and accurate, and trains them for the next era of industrial work.

KPN

KPN is the leading telecom provider in the Netherlands. Serving **33 million** subscribers in the country (and throughout Europe) there's a good chance that anyone you call in the Netherland is picking up the call through a **KPN** connection.

This operational scale means – like several large telcos – that there's a perpetual challenge in maintaining network equipment and uptime. The company's **3000** field technicians do everything from routine maintenance to repairing base stations.

For the latter, the process traditionally involves field technicians receiving work orders by phone, which prompts them to drive to the location, locate the equipment in need of service, diagnose the problem, then execute the repair work.

Throughout this process, technicians require guidance based on the complexity and variability of the equipment they're servicing. So they often have to locate equipment manuals, retrieve diagnostic data or call a central office for expert guidance by voice.

These low-tech ways to solve high-tech problems leads to inefficient operations, wasted time or, worse, ineffectiveness in repairs. Like we examined in several of the previous case studies, ineffective repairs can be an expensive problem as they require dispatching technicians for a second visit.

With an eye towards improving operational efficiencies and success rates, **KPN** enlisted Accenture to devise an AR-based solution to guide field technicians in more streamlined ways. The result was a customized combination of **Google Glass** and **Upskill Skylight** (similar to the previous GE study).

Goals for the new program included improving speed, safety, repair quality and first-time close rates. **KPN** also wanted to stretch the value of its scarcest asset: seasoned technician expertise. It wanted to give new hires seamless access to this senior talent so that they could "inherit" advanced skills.

The result of the program was a connected and hands-free process. Equipped with smart glasses and AR software, field technicians were able to gain line-of-sight access to the same repair instructions, diagnostics and live remote help mentioned earlier.

But rather than the traditional workflow, new orders are automatically pulled from the **KPN** queue and delivered to smart glasses in the field through the Skylight software. Technicians can then be guided to the right on-site equipment using Bluetooth beacons.

Through the smart glasses, they could also receive live data feeds of network diagnostics, which gives them an immediate feedback loop of their work status as they're performing it. This step alone saved considerable time versus stopping to check analog and physically-separated diagnostics.

Image Source: KPN

Results Oriented

To quantify these results, **KPN's** AR adoption led to **5 percent** faster job completion, **11 percent** lower operating costs and **17 percent** improved work error rates. These are meaningful improvements when applied across **KPN's** operational scale.

Adding to these benefits, field techs using the Skylight/Glass combination could initiate live video calls with experts in a central location to then be guided with the benefit of "see what I see" support. The technician can also use voice to close the case when they're complete.

The remote support feature is particularly valuable, due to the above-mentioned goal of stretching the value of **KPN's** seasoned experts. By turning them into centrally-located experts, they can cover more ground through the telepresence of remote AR.

Repeating a common thread seen throughout this report, this AR program was also able to gain the loyalties and buy-in of field technicians, as they saw its benefits to their day-to-day work. This is a key component, as the technology is meaningless if front line workers don't adopt it, as noted.

"I wasn't very familiar with smart glasses before this project," a **KPN** field technician told **Upskill**, "but after using them with Skylight, I found it simple to use and helpful for my job. It is exciting for us to get this new technology"

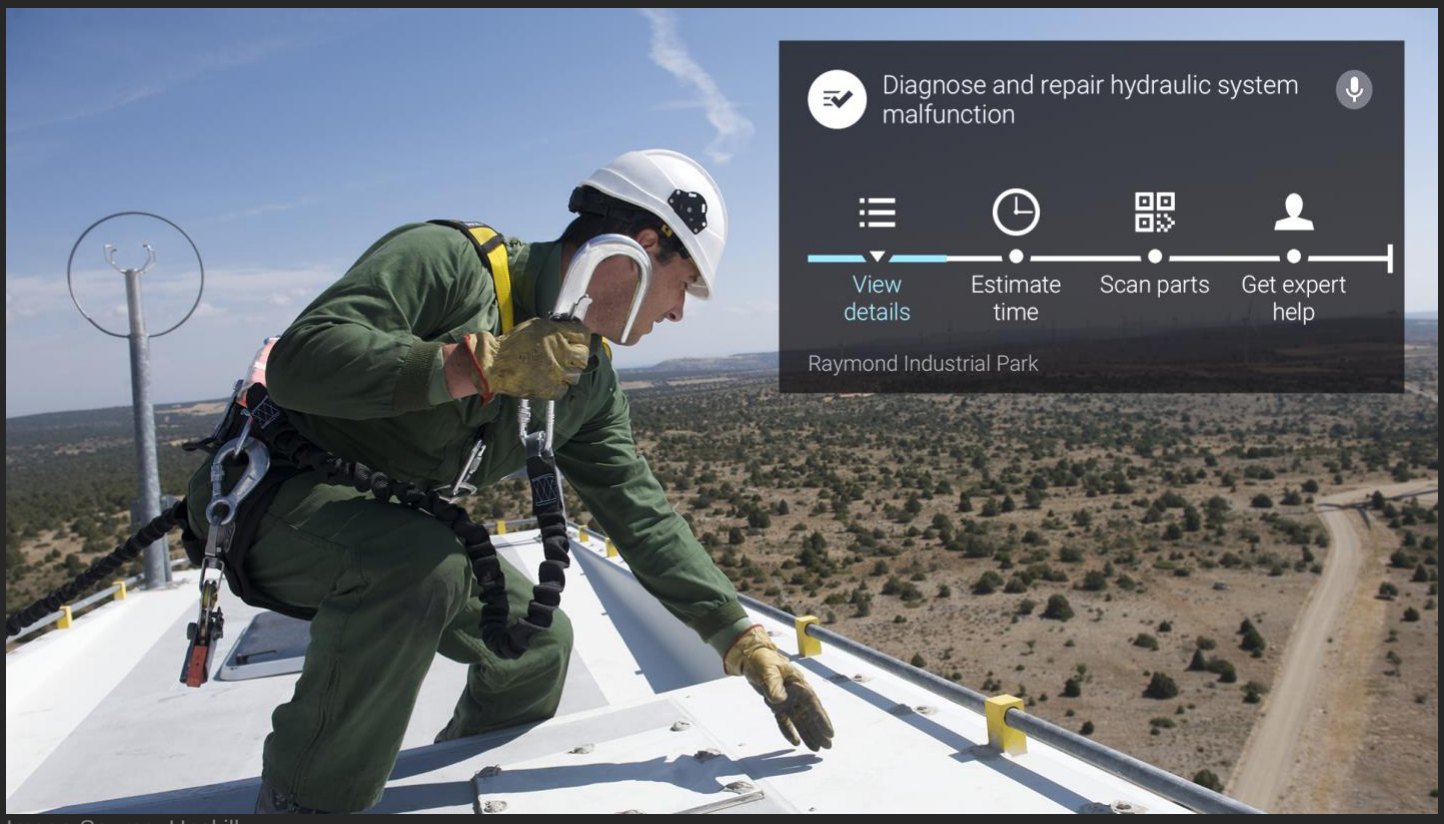


Image Source: Upskill

Medtronic

One area that's ripe for AR guidance that we haven't yet covered is healthcare. The healthcare vertical is of course quite expansive and so are the opportunities and points of entry for AR. That can include everything from guiding surgeons through line-of-sight instructions to medical device manufacturing.

These use cases are where the next case study comes into play. Medical device manufacturer **Medtronic**, with the help of **Re'Flekt** and **Unity**, has implemented AR into operator training. This allows operators such as surgeons to improve their acclimation to and mastery of medical equipment, which has high-stakes outcomes

To provide some context, a sizeable challenge facing device manufacturers like **Medtronic** is human error due to ineffective training. After spending years in product design, optimization and manufacturing, a "weak link in the chain," can be the human that ends up operating the equipment.

This challenge has gained impact over time as the rate of medical device technology accelerates. That means the cycles of innovation render previous equipment – and the expertise to use it effectively – obsolete at shorter intervals. In other words, training needs to keep up with product cycles.

In other cases, it's the opposite problem: Technology deployed in healthcare settings is outdated and doesn't integrate with the latest solutions. Lastly, an issue that **Medtronic** tracked was that the attention and time required by medical records were taking valuable time away from patient care.

Based on these challenges, **Medtronic** technical fellow William Harding sought to find tech-driven answers. Among other technologies tested and implemented, AR came to the rescue for each of the above challenges, which speaks yet again to the technology's breadth and versatility.

Image Source: Re'Flekt

Brain Encoding

To address the above issues, **Medtronic** has implemented digital simulators for surgical training in a minimally-invasive way. This involves real patients, but without actual surgery. Instead, Microsoft HoloLens guides surgeons while they're using the equipment.

Harding reports that surgeons who practice in the simulation show an error rate of **15 percent** in real surgery, compared to an **82 percent** error rate for those who didn't train in the simulator. This success rate results from the effective brain encoding that a highly visual medium like AR can instill.[iv]

Another area that AR adds value is further upstream: the manufacturing process. **Medtronic** has implemented AR at that stage, including effective production. Here the complex process of assembly line "changeovers" (modifying equipment for a different product output) can benefit from AR.

"In manufacturing, we have various stages of manual, semi-automatic, and automatic processes," Medtronic's Harding told **Re'Flekt**. "Those processes must be transferred across many facilities where there is a lack of standardization around the data. If I add a new process to a production line, many questions need to be addressed: How do I get the process to integrate seamlessly? How do I accomplish that without using paper-based systems? The goal is to speed up efficiencies and reduce scrap while also reducing human error. When we create a new process in lean manufacturing, we need to establish the most ergonomic way for an operator to perform their tasks within a sterile environment. We also want them to complete these tasks in the most efficient way possible, while delivering a high-quality product. There are many factors to be considered."

One example of the principles that Harding references is how **Medtronic** trains employees on assembly processes. It has begun to use simulations in AR versus cardboard models. Similar to surgeons' error reduction, manufacturing front-line workers can use AR in simulated environments to save money. That happens to the tune of **$30,000** per training.

"It used to take us two and a half weeks to build a cardboard set-up with five process stations," said Harding. "For one training session, we also needed at least eight to ten people off the production floor, who then weren't engaged in manufacturing products while they were in training. It would cost us about **$30,000** for one training effort with the cardboard set-up. We usually require five sessions in total to get everything right, and by the time we decide that everything is ready, we're making changes five minutes later. In contrast, creating AR content to train my colleagues took me less than two hours. They can access it individually whenever required (including in the manufacturing floor cleanroom environment), and we can easily adapt it if changes occur in the set-up."

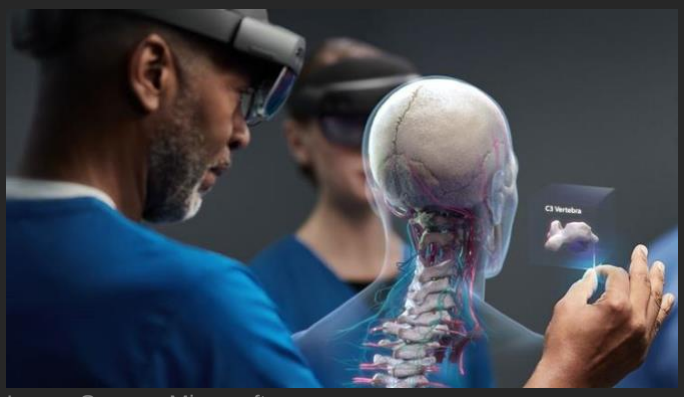


Image Source: Microsoft

Where It's Needed...

Speaking of saving valuable time, we mentioned earlier the challenge of doctors and nurses getting diverted from patient care due to the processing of medical records. Here too, AR has come to the rescue by streamlining the transfer of records to a doctor's field of view where it's needed.

" EMRs (Electronic Medical Records) and EHRs (Electronic Healthcare Records) were built to improve billing," said Harding. "Any attempt to digitize these records and integrate the information with other solutions was simply a digital version of the paper-based format. This makes the management of medical records for medical staff very time consuming as they transcribed the manually collected data or transferred the data between dissimilar systems. I found that doctors spend around **52 percent** and nurses around **47 percent** of their time transcribing health-related data from one system to another, which uses valuable time and skills that they could be investing in the patient. To truly connect devices and digitize our data, we need a transformative approach. That's what XR technology offers."

This circles back to a key concept introduced earlier when examining the 3Ps. As validated in a few other case studies above, a key success factor in enterprise AR deployments is to create benefits that are felt by the front-line professionals who are proposed to use it. The medical professional time-saving benefits outlined above not only help **Medtronic** and medical institutions, but they have tangible quality of work-life advantages for doctors and nurses. This should be a key lesson for AR's success.

"There's no better way to prove that your solution provides value than if the users change their habits and use your tool instead of what they had before," **Re'Flekt** CMO and president Dirk Schart told ARtillery Intelligence. "The clearest path to success is to have clear goals, business-side buy-in, and most importantly to prove value to end-users."

"Through the use of AR/VR/MR technology, I know that Medtronic will be able to more quickly understand patient, healthcare professional, and payer needs, such that the life cycles of innovation are reduced in addressing those needs."

- William Harding, Distinguished Technical Fellow, Medtronic

Elekta Medical

One foundational concept in enterprise AR that we haven't yet covered in this report is *digital twins*. These are digital replicas of real-life equipment. The benefit of having this digital counterpart is that activities such as product design, testing and monitoring can happen in simulated environments.

Much like the previous **Medtronic** case study, operating in simulated ways can bring several benefits. In that case, it was all about surgeon training in non-invasive ways. But it can equally apply to industrial settings, where expensive machinery can be optimized through digital twins.

Backing up, digital twins were first used in experimental engineering for **NASA**. Here it wasn't a matter of cost (though that plays in), but practicality. Because physical systems can't be easily tested in space, digital twins can help engineers get a better sense of material properties.

This particular use case for digital twins dates back to the Apollo 13 mission, but digital twins have since blossomed into several areas. Though the stakes aren't often as high in a manufacturing facility as in an aerospace mission, there are meaningful benefits and financial outcomes.

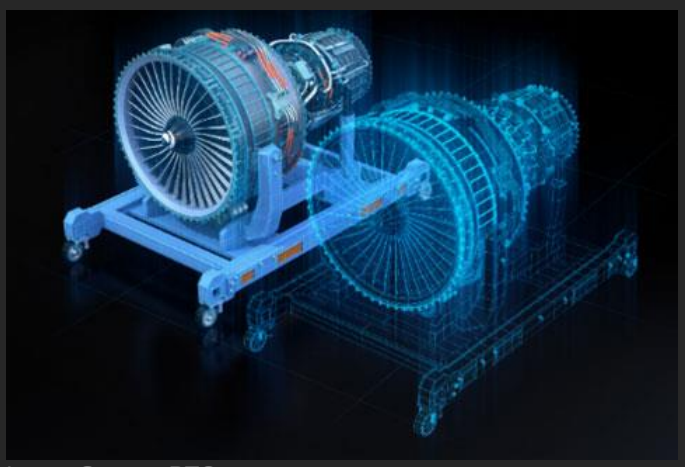


Image Source: PTC

The way this often works is through industrial internet of things (IoT) technology, whereby equipment is embedded with several sensors. This creates a sort of living, breathing digital replica of not only a device's physical orientation but its real-time performance readings or threshold anomalies.

Knowing this data can unlock several advantages such as proactive maintenance or optimizing workflows. Beyond diagnostics, digital twins come into play when a machine needs maintenance: AR-guided line-of-sight instructions can overlay digital twins on physical equipment.

Other advantages include a set of digital records for the lifetime stats of a given piece of equipment. These stats can be delivered to AR glasses in the aforementioned maintenance scenarios to layer in additional intelligence about a given piece of equipment. This can boost first-time fix rates.

Putting some of these use cases into practice, Cancer-focused medical technology provider **Elekta Medical** launched a digital-twin based program with the help of PTC. Known as the Connected Field Service program, it works with remote digital twins of its deployed medical equipment to monitor behavior.

By doing so, it increased equipment uptime and resolved **20 percent** of service issues remotely. It also achieved uninterrupted treatments for more than **14,000** patients in the program's first year. It was also able to use digital twin data to optimize logistics such as its delivery network.

Boeing

One of the themes seen throughout this report is that AR can have outsized value when the stakes are high. In other words, AR's ability to make work faster and/or more accurate is especially valued when the products being assembled are "high-ticket items."

As examined in the earlier GE case study, nowhere are these stakes higher than in the world of aerospace. This is the case for leading commercial aircraft manufacturer **Boeing**, which has dizzying levels of complexity in the construction of each plane – everything from engines to wiring.

In fact, 130 miles of wiring go into every new aircraft. And laying that wire requires high degrees of precision, and little margin for error. Things get even more complex when you consider that each **Boeing** aircraft – from the 737 to the 787 – has unique wiring configurations.

This adds up to tens of thousands of hours of work each year. And the traditional method for guiding wire placement involved paper manuals packed with diagrams. Technicians would repeatedly shift attention to compare diagrams and schematics.

To reduce that cognitive load – a leading cause of mistakes – **Boeing** implemented **Google Glass** with **Upskill Skylight**. By eschewing the cross-checking method in favor of line-of-sight instructions for its wire harnesses, the goal was to speed up and improve assembly.

Specifically, the AR-based method let technicians move through multiple instruction prompts using voice commands, gestural taps (standard on Google Glass Enterprise Edition) and a head-tracking interface. Voice commands could also summon a particular sequence of schematic instructions.

This voice-based approach is particularly additive to wire assembly, given that it's a process that requires maximum dexterity and freedom of movement with all ten fingers. Additionally, bar code readers and Google Glass cameras helped technicians identify and confirm specific wires.

Beyond these automated line-of-sight features, technicians have the option to call in a remote expert who can assist in a "see what I see" manner, given Google Glass's built-in camera and voice input. Technicians can also stream how-to videos directly in their field of view without looking away.

And the result of these AR implementations? **Boeing** was able to reduce error rates effectively to **zero**. It also cut its wiring production time by **25 percent**. The former is important when talking about passenger jets given the importance of safety. And the latter breeds bottom-line savings.

"Rather than picking up seconds or minutes, a step function change gives us an opportunity to cut the build time by **25 percent**," **Boeing's** Electrical Strategic Fabrication Center Senior Manager Randall MacPherson told **Upskill**. "Wearable technology is helping us amplify the power of our workforce."

Image Source: Upskill

Streem

AR's proposed use cases are often divided between enterprise (B2B), and consumer (B2C). But there's a third category we're monitoring that's somewhere between the two: *B2B2C*. In other words, AR is being applied to help consumer-facing businesses better serve *their* customers.

This is where **Streem** lives. It brings the industrial AR concept of remote assistance (a.k.a. "see what I see") to the much larger market of customer support. Picture a cable company phone rep visually walking you through a router setup versus disjointed – and often painful – voice-only instructions.

But an even better area to reduce pain and cost is home services like plumbing. Homeowners can be the eyes and ears of a remote pro, via upheld smartphone. The latter can then diagnose issues and, depending on the issue, instruct homeowners with voice and positionally-accurate on-screen annotations.

The real value here for service providers lies in in reducing costly technician visits. Streem has been able to accomplish this to the tune of **42 percent** fewer visits. Otherwise known as a "truckroll," this includes preliminary home visits to scope and price a given job. The result is cutting two visits down to one.

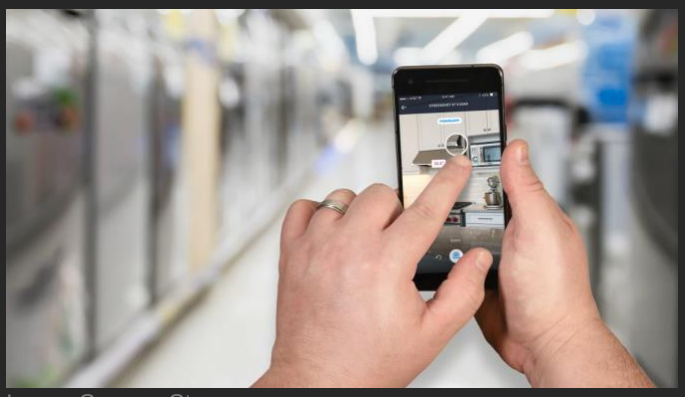


Image Source: Streem

Doubling Down

This was all validated when home services giant Frontdoor acquired **Streem** in late 2019. The acquisition amplified **Streem's** installed base of home services customers, while Frontdoor gained directly-integrated remote support functionality to boost its own value proposition and customer retention.

And they've barely scratched the surface. A sizeable B2B2C market exists in other technician-oriented services. The largest of these is telephony services, where technical support reps can benefit from AR remote assistance to help you set up your Wi-Fi router.

All of the above opportunities tap into a long tail of consumer markets, especially demographics and psychographics who are comfortable with a smartphone but not technically savvy enough for in-home tech troubleshooting. This could be a sort of Geek Squad 2.0, with greater potential scale.

And it extends to other home-oriented business verticals. In fact, **Streem** has recently expanded into real estate. The idea is that it can help real estate agents offer live virtual showings by appointment, where they walk homebuyers through a given house and answer their questions.

Underscoring the opportunity further, **Streem's** value proposition is amplified in the Covid era by supporting socially-distanced home services. Even when the world returns to normal, Covid-19 has instilled a sustained demand for remotely-fulfilled and operationally-efficient services.

Final Thoughts

One of the takeaways from this report is AR's breadth of applicability. It demonstrates value in everything from aerospace to medicine. Though these sectors vary in their goals, AR delivers common value points.

For example, several of the case studies in this report demonstrated cost savings that are associated with reducing time to task completion. Those time savings often result from AR's inherent line-of-sight visualization. This can eliminate the need to shift attention to reference and compare physical instructions.

Beyond time, these attentions shifts create "cognitive load" as front-line workers must mentally translate 2D instructions to 3D space. This is an issue because it can cause mental fatigue which in turn negatively impacts both worker morale and costly errors.

Joining these common advantages are common best practices. As shown in case studies throughout this report, AR shines when applied to jobs that require complex and non-repetitive tasks, such as inspecting jet engines.

Another common success factor we'll reiterate is to ensure AR's value is internalized and appreciated by the end-users proposed to apply it on a daily basis. This can be achieved by emphasizing worker-centric benefits such as lessened job strain, or reducing time spent with rote tasks in favor of higher-value work.

These traits and others continue to be validated in the examination of enterprise AR deployments. As time goes on and more enterprises adopt, the playbook for enterprise AR best practices will continue to develop. It will be an opportune – but moving – target.

Image Source: Microsoft

Just the Beginning...

To address that moving target, the story doesn't end here. This report represents the first volume of an ongoing series for ARtillery Intelligence. Following this first volume, we'll circle back semi-annually for subsequent collections of case studies, each carrying a different theme or strategic thread.

Like this report, each volume will also break down a demonstrative batch of enterprise AR deployments and strategic takeaways. We've already begun selecting and assembling the most impactful case studies for the next batch, and we'll continue to refine the list. Stay tuned for much more in Volume II…

Image Source: Microsoft

ARtillery Intelligence

Key Takeaways

- **AR's benefits are being demonstrated in various enterprises, especially in industrial settings.**
- AR line-of-sight visualization breeds operational efficiency in areas like assembly and maintenance.
- Primary formats are remote AR assistance and automated pre-authored sequences.
- Recorded AR sessions are evolving to better capture and distribute institutional knowledge.

- **Enterprise AR advantages and ROI gains result from several micro and macro factors.**
- *Micro-benefits* include unit economics in production output (e.g., speed, accuracy and safety).
- Example: tasks can be completed faster by reducing reference to, and translation of, 2D instructions.
- *Macro-benefits* include profitability gains, job-strain reduction and institutional knowledge retention.
- Example: Lessening strain delays retirement, while recorded sequences distribute knowledge optimally.

- **Amplifying the value of successful AR deployments, bottom-line impact can scale up quickly.**
- When applied across large-scale operations, efficiencies can add up to millions of dollars in impact.
- The cost for AR implementation is often recouped quickly when it's applied effectively and at scale.
- The business case for these ROI gains will eventually overpower inertia and adoption impediments.

- **Meanwhile, several organizational hurdles and points of friction stand in the way of AR's benefits.**
- "Pilot purgatory" has emerged as enterprise AR's biggest pain point, diminishing real deployments.
- Causes are mostly organizational and cultural, such as inertia and natural resistance to change.
- Failure to reach deployment squanders the opportunity and sunk-cost investments in AR.

- **Pitfalls originate within three main areas we've identified as the "3Ps": *people*, *product* & *process*.**
- With *people*, industrial AR's value proposition should be customized to individual stakeholders.
- With *product*, the principles of product/market fit should be followed… just like consumer products.
- For *process*, AR product planning, deployment and communications require tactical precision.

- **Drilling down on one of the 3P's, *people* communications are critical to successful AR deployment.**
- After all of the investment in AR research and deployment, it will fail if end-users don't adopt it.
- Internal communications should therefore stress personal benefits like reduction in job strain.
- Medtronic achieved this by demonstrating to medical pros that AR can lessen time with paperwork.

- **Similarly, product fit includes deploying AR where it can have the most impact (not a silver bullet).**
- AR has proven effective with complex non-repetitive tasks such as heavy-equipment assembly.
- It conversely doesn't add value to simple repetitive tasks such as changing the oil in a car.
- AR can also add considerable value wherever there are current systems of guidance by paper instruction.
- Impact can be felt greatest where there are "high stakes" such as GE's use of AR in jet engine inspection.

- **The importance of following all these tactics is to set AR investments up to succeed.**
- AR investments can be protected rather than lost, if deployed with the right best practices.
- Points of failure are often within enterprises themselves (as opposed to AR vendors/providers).
- AR success therefore results from tactical execution around a set of common success factors.

- **In the near term, enterprise AR will continue to linger in early adopter phases.**
- Enterprise AR will reach a tipping point in the next 3-5 years, followed by rapid industrial adoption.
- ARtillery projects enterprise AR spending to grow from $2.77 billion in 2019 to $15.8 billion in 2024.
- Meanwhile, the opportunity remains with early adopters that can get a head start on reaping AR's rewards.
- Case studies throughout this report unpack and demonstrate many of the above principles.

About ARtillery Intelligence

ARtillery Intelligence chronicles the evolution of spatial computing. Through writings and multimedia, it provides deep and analytical views into the industry's biggest players, opportunities and strategies.

Run by analysts and former journalists, coverage is grounded in a disciplined and journalistic approach. It also maintains a business angle: Though there are lots of fun and games in spatial computing, cultural, technological and financial implications are the primary focus.

Products include the **AR Insider** publication and the **ARtillery PRO** research subscription, which together engender a circular flow of knowledge. Research includes monthly narrative reports, market-sizing forecasts consumer survey data and multi-media, all housed in a robust intelligence vault.

Learn more **here**.

About Intelligence Briefings

ARtillery Intelligence Briefings are monthly installments of spatial computing analysis. They synthesize original data to reveal opportunities and dynamics of spatial computing sectors. A layer of insights is applied to translate market events and raw figures into prescriptive advice.

More information, past reports and editorial calendar can be seen **here.**

About the Author

Mike Boland was one of Silicon Valley's first tech reporters of the Internet age, as a staff reporter for *Forbes* (print) starting in 2000. He has been an industry analyst covering mobile and social media since 2005, and is now Chief Analyst of ARtillery Intelligence and Editor-in-Chief of *AR Insider.*

Mike is a frequent speaker at industry conferences such as AWE, VRLA and XRDC. He has authored more than 120 reports and market-sizing forecasts on the tech & media landscape. He contributes regularly to news sources such as *TechCrunch*, *Business Insider* and the *Huffington Post*.

A trusted source for tech journalists, his comments have appeared in A-list publications, including *The New Yorker*, *The Wall Street Journal* and *The New York Times*.

Further background, history and credentials can be read **here.**

Methodology

This report highlights ARtillery Intelligence viewpoints, gathered from its daily in-depth coverage of spatial computing. To support narratives, data are cited throughout the report. These include ARtillery Intelligence original data, as well as that of third parties. Data sources are attributed in each case.

For market sizing and forecasting, ARtillery Intelligence follows disciplined best practices, developed and reinforced through its principles' 15 years in tech-sector research and intelligence. This includes the past 5 years covering AR & VR exclusively, as seen in research reports and daily reporting.

Furthermore, devising these figures involves the "bottom-up" market-sizing methodology, which involves granular revenue dynamics such as unit penetration, pricing and growth patterns. More on ARtillery Intelligence market-sizing research and methodologies can be read **here.**

Disclosure and Ethics Policy

ARtillery Intelligence has no financial stake in the companies mentioned in this report, nor was it commissioned to produce it. With respect to market sizing, ARtillery Intelligence remains independent of players and practitioners in the sectors it covers, thus mitigating bias in industry revenue calculations and projections.

ARtillery Intelligence's disclosure and ethics policy can be seen in full **here.**

Contact

Questions and requests for deeper analysis can be submitted **here.**

Reference

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[i] ARtillery Intelligence Report, **Headworn AR Revenue Forecast, 2019-2024** (sign-in required)
[ii] ARtillery Intelligence Report, **Mobile AR Revenue Forecast, 2019-2024** (sign-in required)
[iii] ARtillery Intelligence Article, **Can AR Curb Institutional Knowledge Loss?** (sign-in required)
[iv] See Article, **How AR Affects the Brain** (sign-in required)