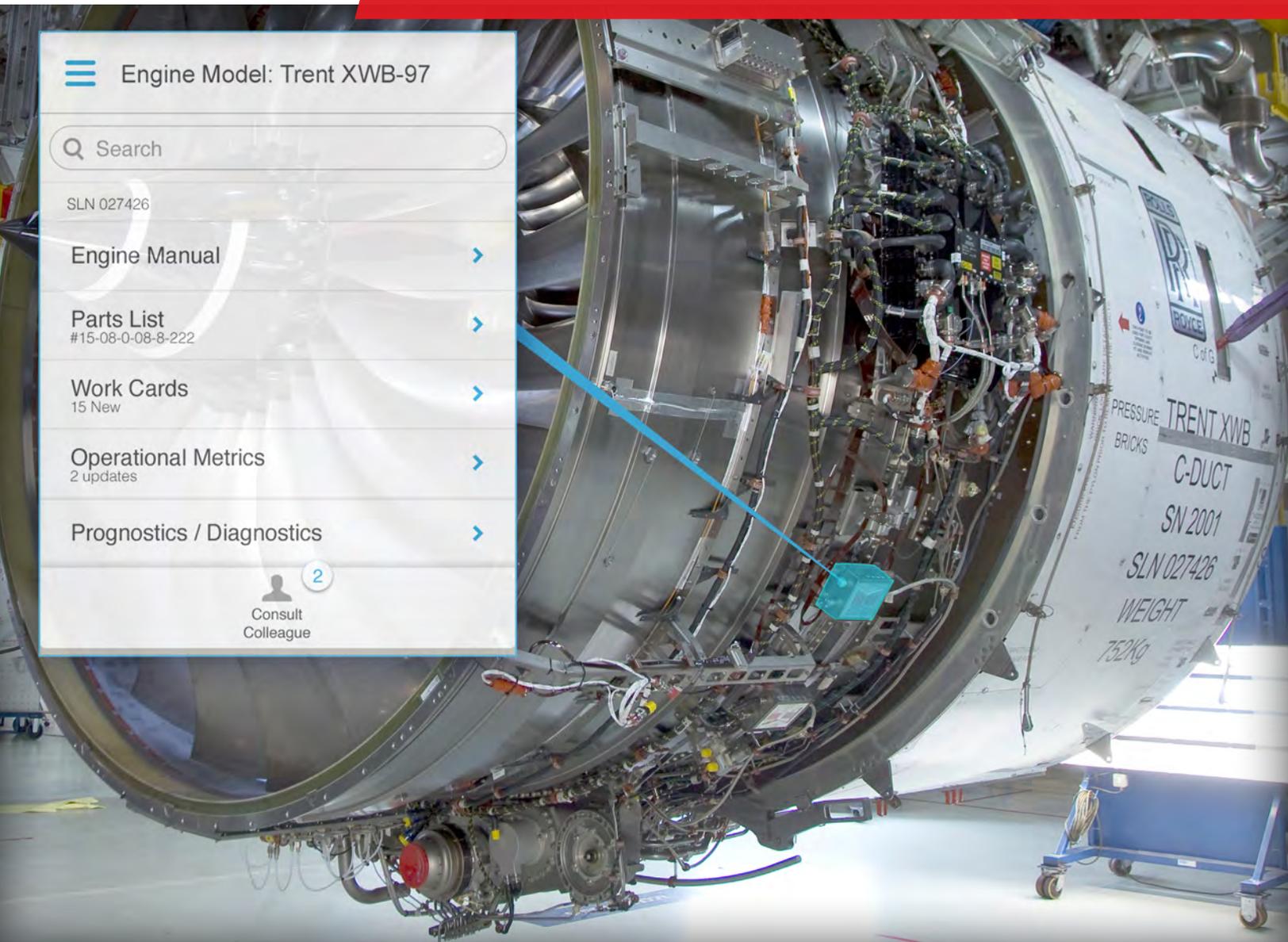


AUGMENTED REALITY IN AVIATION

A Long-Awaited Technology
Comes of Age



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Introduction

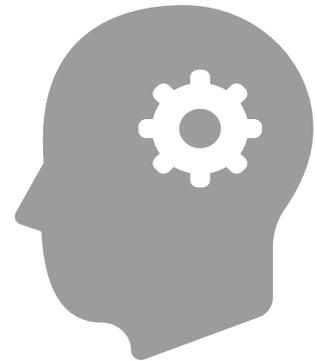
For the better part of 15 years, thought leaders in aviation have signaled the imminent arrival of augmented and virtual reality (AR/VR) in the workplace. As a training tool, a work site task enabler, and overall force-multiplier, augmented and virtual reality have long been heralded as game-changers whose time has come. But until recently, this promise remained unrealized.

Despite the long ramp-up to mainstream, augmented reality has arrived. What's changed to facilitate this long-awaited change? In short, all of the critical enablers have reached maturity -- the underlying technologies, the necessary content and process prerequisites, and the level of workforce receptiveness. These and other key advances have now allowed augmented reality solutions to move forward into production settings at a speed that is dizzying, transforming aviation before our collective eyes.

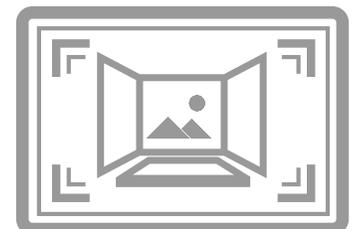
This transformation is affecting all of the players in aviation technical information ecosystem, including Flatirons Solutions. In response to these developments, in 2016 and 2017 we formalized our support of this new medium with a dedicated FJ Innovation Lab, a team that combines internal resources with external industry thought-leaders to infuse startup agility into our established business. Since its inception, the FJ Innovation Lab has built proofs of concept for key AR/VR features, and engaged with customers to identify initial adopters who will help refine use cases and functional requirements for inclusion in our commercially available solutions.

We have reached a tipping point for this technology -- and companies that do not embrace it risk competitive disadvantage and (in the longer-term) irrelevance. In this analysis, we'll look into some of the enablers of augmented reality adoption, best practices for ensuring a successful rollout, and an overview of the benefits adopters are realizing to help build out the business case.

VR



AR



The Long-Awaited Alignment of Enabling Technologies

Powerful, Durable Commodity Hardware

Early evangelists of AR / VR worked at the bleeding edge of what technology could accomplish, leveraging highly specialized hardware like ruggedized laptops, early tablet devices, bulky headsets, and low performance (by today's standards) wireless data networks.

These early efforts yielded some impressive results, but with an end-product that was brittle – in part because of the cost, processing limitations, and overall immaturity of the hardware components that would be placed in the hands of end-users in what are often challenging work environments.

At its core, this approach relied on immature technology that made positive ROI difficult or impossible to achieve. Outfitting a maintenance engineer or trainee with \$10,000 or \$15,000 in delicate, buggy, maintenance-intensive hardware in work places in which temperature, humidity, oil, fuel and other contaminants are the norm is an iffy proposition at best.

But in the years since the release of the first modern tablet devices, we've seen a dramatic acceleration in computing power, portability, connectivity, and cost-effectiveness. Durable, powerful, lightweight tablets and wearables have helped to spawn an ecosystem of AR-enabling technologies like:

- **Low-cost, high resolution AR/VR goggles** that are either stand-alone, or paired to a mobile touchscreen device for some processing and connectivity functions.
- **Ubiquitous mobile video streaming**, even low bandwidth sites, using powerful and intuitive consumer-grade applications like Skype, Facetime, Google Hangouts, and other applications. This feature has already been implemented in some version of CORENA Pinpoint Mobile using Skype for remote consultation.
- **Full integration of cameras** to facilitate telepresence and capture of photo or videos, pattern and facial recognition, etc.
- **Location-based services** to understand where the task performer is relative to their geography, or to tagged assets they may be interacting with.
- **New user interface paradigms**, starting with touch screen and developing now into sophisticated options for voice and gesture control, biometrics, and facial recognition. Our FJ Innovation Lab team is now using these concepts to optimize CORENA Pinpoint for AR/VR-optimized interaction.
- **Devices that are rugged** (as well as water resistant), built atop solid state components with no moving parts, long battery life, and unprecedented reliability.
- **4G (and soon, 5G) networks** that leapfrog the performance and availability of corporate Wi-Fi networks, supplementing and even replacing them in many work settings.



These and other advancements have not only matured in unprecedented ways, they've seen their cost drop by an order of magnitude below what was possible just a few years ago. Where outfitting a maintenance engineer for AR was a barely possible due to cost and capability limitations just a few years ago, today the ROI is compelling even for harsh environments.

Rich Data Streams for Making AR Content Context-Relevant

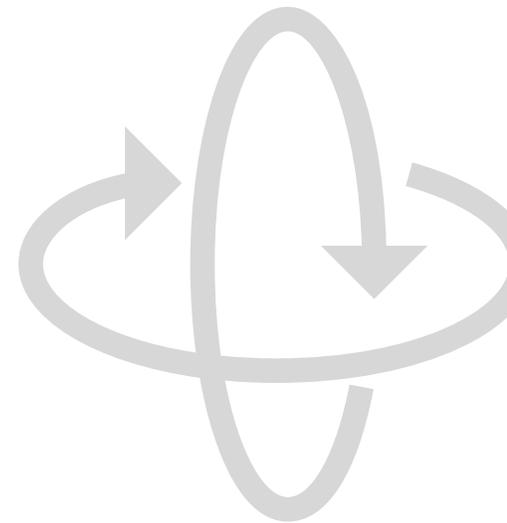
Of course, to make Augmented Reality practical in the complex world of aviation, it takes more than just cheap, powerful hardware. Practical applications of augmented reality in a work environment as complex as an airline or MRO must be informed by the context in which the work is taking place.

Effective augmented and virtual reality must be informed by the technical requirements of the job or training scenario at-hand, the location of the task performer, the condition and location of the item being serviced or operated, the skillset of the task performer, and myriad other pieces of contextual data.

Prior to a few years ago, many of these sources of contextual data either did not exist, or they existed in forms that were highly silo'd, requiring extensive data mining or system integration efforts to harmonize into a form that would inform a task performer or trainee. Thanks to a host of new data sources and integration toolsets that have come to the fore in recent years, augmented reality solutions now have all of the contextual data sources needed to create a seamless experience for task performers or trainees.

Some of the most important of these data streams include:

- **eEnabled (IoT) assets** and components that have an array of connectivity options, including satellite, 4G, Wi-Fi, Bluetooth, etc. for sharing performance data with cloud-based OEM and Operator data exchanges. CORENA Pinpoint and CORENA Pinpoint Mobile have been successfully integrated with AHM/EHM systems to leverage this data for pre-packaging of procedurals relevant to the fault(s).
- **Troubleshooting expert systems** that analyze both performance data and captured fault codes from eEnabled devices to suggest appropriate courses of action to resolve issues using historical lessons learned and data-driven best practices.
- **3D scanners for workspace modeling**, to help inform the super-imposition of the augmented reality interface atop the workspace. Workspace modeling also enhances what's possible in telepresence collaboration, creating an interactive facsimile of the overall environment in which the work is taking place for remote support staff. Our FJ Innovation Lab has utilized this hardware in initial proofs of concept.



- **Drone aircraft** that extend the virtual reach of the task performer, trainee, or remote support staff to areas of the aircraft that are traditionally hard to reach, extending the virtual eye of the maintainer or operator.
- **Location-based services** that are capable of tracking not just the location of the work or training site, but the location of the asset, the task performer, a part, or virtually any other physical part of the process being supported. By understanding which pieces of the puzzle are where, and when, relevant instructions can be queued and superimposed preemptively.

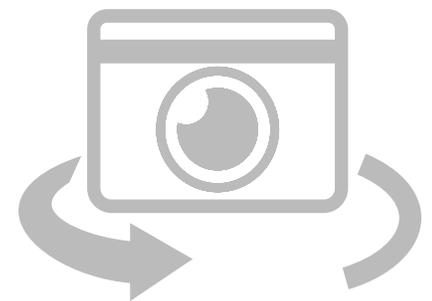
These are just a few of the data sources that combine to help ensure that augmented and virtual reality capabilities enabled through the growth of more sophisticated hardware and networks don't operate in a contextual vacuum.

Improved Access to 3D Models and Real-Time Interactivity

For decades, 3D models were created by and optimized for engineers for use in the prototyping and manufacturing complex products like aircraft, their engines, and key components. Computer Aided Design and Manufacture was an advanced but largely back-office discipline, whose benefits rarely if ever touched the lives of task performers in the field.

The massive investment associated with new generation aircraft like the Airbus A350 and Boeing 787 (fleets now supported for airlines as part of the CORENA Fleet solution) saw that focus change, with digital manuals for those programs for the first time including a large volume of 3D assets derived from engineering models. Some of the ways that 3D modeling is moving beyond this first tentative step out of the back office to support practical augmented reality include:

- **Software that better supports the reuse of engineering CAD** models and their renditions in virtual and augmented reality contexts, such as the work done by Dassault Systèmes in their AR/VR efforts leveraging their source CATIA 3D assets. CORENA Manufacturer is already well-integrated to PLM platforms to facilitate engineering asset reuse at customer sites like Saab.
- **Distributed 3D content creation / image capture**, outside of engineering -- both via dedicated work area scanners (often positioned in room corners) and from simple mobile device and AR goggle cameras and sophisticated image processing software.
- **Real-time pattern recognition tools** that correlate that pattern of stored 3D models with a camera-captured image or video stream for use in real-time augmented reality overlay. Prototypes completed by our FJ Innovation Lab for use cases like engine borescope inspections highlight the promise of this approach.



Just as new aircraft programs like A350 and 787 spurred 3D innovation in our industry for content consumers, so too new modes for the reuse, capture, and recognition of assets in 3D will provide a necessary building block for accelerating the pace of AR/VR adoption in production settings.

Optimizing the Adoption Approach

Incremental Approaches to Adoption

As with any potentially transformative technology or process, radical change can bring risks as well as opportunities. In an industry as intolerant of failure as aviation, risk must be carefully managed to maximize benefit while reducing or eliminating potential downside.

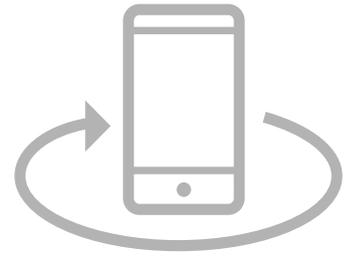
One of the best mitigations against disruptive change is an incremental approach to adopting augmented and virtual reality technology. Aside from minimizing risk, this process also allows ROI to be proven on a step by step basis, and reduces the potential cost impact of a more one-size-fits all approach.

An incremental approach can be applied across multiple dimensions of your business and operation to address the most attractive adoption areas first. Some of the aspects in which a phased approach can be mapped out include:

- **Use case phasing**, which involves identifying a high-value subset of tasks that are ideal candidates for reality augmentation and addressing them first. Augmented reality is not a good fit for all tasks – it is simply another tool that can be applied to suitable tasks that meet a profile that includes:
 - **Operational tasks that are:**
 - Highly complex, requiring the highest paid talent to support their successful execution
 - Physically challenging due to space and access constraints, often requiring specialized equipment (e.g. lifts) as a precursor to meaningful work.
 - Served best by a “brain trust” of collaborators that may span multiple sites, or for which qualified labor resources are at a premium.
 - **Training tasks that:**
 - Involve the most expensive assets that may be in short supply, and for which the cost of failure during the learning curve may be exceptionally high – engines or other costly components are good examples.
 - Require a high number of repetitions to gain proficiency. AR/VR is ideally suited to perform many training iterations in a short period of time with little to no additional cost per session.



- **Incremental adoption by product** or program is critical, since many legacy programs lack the ROI for new investment, even for initiatives as important as AR/VR. Choosing a new program / fleet or one that is near the beginning of its lifecycle may help create a better end-to-end process that facilitates augmented reality adoption. Early stage programs often have more flexibility to adapt content creation and delivery processes to better optimize around end-user AR use cases.
- **Phased adoption by hardware / technology scope** is also advisable for companies making the move from traditional maintenance and operations to an AR-enabled paradigm. AR/VR is not just about putting goggles on all operators / maintainers --- it is a continuum that focuses on providing information resources that are interactive and bidirectional. As an early foray into the field, tablets often provide a good first step in AR adoption since they bring many of the core capabilities needed for AR-enabling -- pattern recognition, image overlay, telepresence / conferencing, voice navigation, and other core features common with a more full-fledged augmented reality environment. By providing an initial, lower-cost environment for fleshing out those work and training types with the greatest ROI, tablet-based augmented and virtual reality is a starting point in the longer AR/VR journey.



These examples are just a few of the ways that manufacturers and operators can adopt an augmented reality strategy that is non-disruptive, and that proves out the ROI fundamentals in a phased fashion. Augmented reality is not a fix-all, and is not suited to all work or training related tasks. But for those tasks that have the right makeup, it can be a powerful asset – and an iterative approach provides the framework to identify and validate those “sweet spot” scenarios for adoption.

System and Process Integration

The manufacturer and operator workplaces that augmented reality solutions inhabit are diverse. Organizations enjoy tremendous choice in terms of the infrastructure they adopt – with a wide range of solutions for Product Lifecycle Management (PLM), OEM prognostics / operational metrics capture, maintenance planning and execution, technical information authoring and management, and so on. For this reason, no two environments are exactly the same and a “one size fits all” approach to Augmented and Virtual Reality rollout does not exist, and likely never will.



“Manufacturers and operators can adopt an augmented reality strategy that is non-disruptive, and that proves out the ROI fundamentals in a phased fashion.”





That doesn't mean that the powerful benefits of AR/VR adoption are out of reach. Lightweight integrations between the technology, data, and process touchpoints can accommodate the unique composition of each organization's IT environment. Powerful web services, Application Programming Interfaces (APIs), middleware / Enterprise Service Bus (ESB) technologies, and process integration tools make the job of correlating and compiling the data needed for both back-office content creators and end-user consumers more cost-effective than ever before.

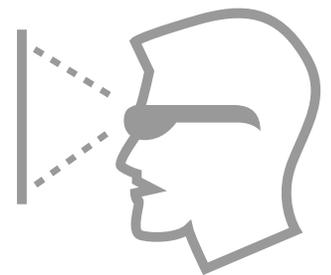
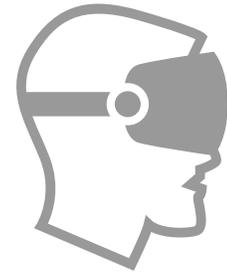
By building a lightweight, flexible integration framework for both content assembly and delivery, AR/VR adopters can achieve the full benefits of AR/VR without undue cost or complexity, or vendor lock-in for any of the critical components that help power their operation.

Identification of Obstacles and “Edge” Cases

Understanding edge cases / barriers is an important part of avoiding the pitfalls that can threaten an augmented or virtual reality initiative. Every project faces obstacles, and AR/VR adoption programs are no exception.

A few of the common AR/VR adoption issues to be aware of include:

- **End-user adoption barriers**, like:
 - Content creators who are invested in book paradigms, and unable or unwilling to adopt a new approach to technical information creation and delivery.
 - Users who are culturally averse to AR/VR due to their comfort level with legacy tools and processes, and who resist change generally.
 - Users who require corrective lenses or have other physical accommodations that may not be well-served by a commercial off-the-shelf hardware approach.
- **Content related obstacles** that include:
 - Content associated with legacy programs or products that is not well optimized for repurposing in an AR / VR environment.
 - Content that does not exist, and needs to be created outside of engineering to facilitate improved interactivity and data usability.



- **Platform or supplier obstacles**, including:
 - Missing or immature technology components – either for content creation or delivery. Thankfully as outlined in this paper a rich marketplace of enabling software and hardware solutions for both creating and consuming AR/VR content have begun to appear.
 - Suppliers who are unfamiliar with AR/VR, and lack the expertise needed to support the transition. Fortunately, the marketplace for AR/VR savvy suppliers is growing, and partners to supplement existing supplier relationships can be found.

In each of these categories, an incremental approach that identifies but initially bypasses problematic areas during initial adoption phases (as outlined in a prior section of this paper) is advised. This approach allows the adopter to gain confidence and familiarity with more straightforward use cases, products, and platforms. By understanding and avoiding areas of undue complexity, organizations adopting AR/VR can hone their skills on areas in which the cost/benefit fundamentals are strongest, building their competency to address more complex issues in follow-on phases.

Additionally, regular and open communication with affected stakeholders is a key enabler to success. Internal Public Relations (PR) efforts can help to engage and disarm potential obstacle areas by acknowledging them, and communicating how they will be addressed in the long-term.

The Compelling Benefits of Successful AR / VR Adoption

Strong Maintainer Productivity Growth

Adopters of augmented reality in aviation maintenance are reporting strong gains in productivity for those tasks that meet the criteria outlined in the prior sections of this paper. Thanks to shorter task performance times, less re-work due to a higher quality, reduced time away from the worksite to access manuals / systems, improved access to subject matter experts, and a host of other reasons Augmented Reality is already delivering big competitive gains for the after-market teams of companies like Boeing, GE Aviation, Dassault Systèmes, and others.



In separate studies, these companies and others have consistently reported improvements in task performance times from 15-35%, depending on the complexity of the task (more complex tasks yielded higher rates of productivity improvements). For an OEM after-market team these savings levels are massive, typically amounting to millions per year for a medium to large manufacturer. For an airline operator fielding a large fleet, the potential for saving is far greater – and creates a powerful differentiator for manufacturers that provide this capability as part of their offer.

Improved Safety

Safety is an assumed part of our business. The stakes involved in aviation are so high, and the level of regulatory oversight so stringent, that safety is mandatory component of everything that a manufacturer or operator does in support of their business.

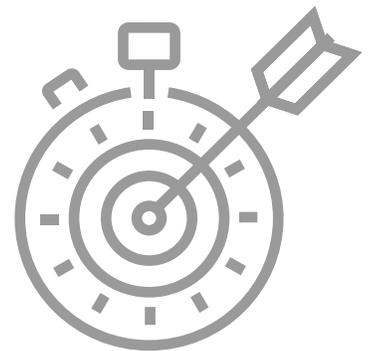
However, despite this singular focus on safety, the truth is that in any human system there is the potential for error. Tools that substantially reduce the rate of error in complex task learning or performance have a tremendous positive impact on safety. Organizations already adopting augmented and virtual reality report error reduction rates for complex tasks approaching 50%, with a corresponding improvement in safety.

Through more effective knowledge transfer, better problem diagnostic / debugging support, improved sharing of subject matter expertise, or providing a safe venue for training where learners can perfect their skills with a low cost of failure, augmented and virtual reality promote safer, more efficient operations.

Reduced Training Cost and Time to Competency

Like many industries, aviation is experiencing a generational shift that has the potential to disrupt access to critical skills and expertise. Generations of maintainers and operators who learned their subject matter via books and hands-on training in both commercial and defense settings are retiring, and a new generation of workers is entering the market for whom these traditional options are either unavailable or ineffective.

Today's new workforce is comprised of digital natives – workers who were raised on mobile, interactive, always-available information. Augmented and virtual reality promise not only to make those who are currently performing complex work more efficient, it removes a significant barrier to entry for the new workforce.



And regardless of the demographic, metrics on learning effectiveness relative to cost for augmented reality versus traditional learning scenarios in aviation are compelling. By removing the pre-requisite of a physical asset (with a value that may range from hundreds of thousands to hundreds of millions of dollars) from the equation for many training scenarios, augmented reality enhanced training can reduce the cost of hands-on exercises by an order or magnitude. More importantly, AR/VR enabled training vastly improves training outcomes through increased repetition, providing a failure-tolerant environment in which the learning curve can be overcome without detrimental impacts to safety or operational costs.

Improved Customer Satisfaction

Perhaps the hardest to quantify, improved customer satisfaction is an important aspect of AR/VR adoption. For end-customers, AR/VR enhanced publications translate to products that are easier to operate and maintain efficiently. Less tangibly, they create a brand impression of the supplier and product that is positive thanks to better usability, flexibility, and support.

For internal customers, including after-market staff who support customers, the benefits are equally strong. Work done quickly, efficiently, and correctly the first time (every time) builds job satisfaction, and improves the levels of retention within the service team.

The economic fundamentals of AR/VR are fully justified based on measurable ROI in productivity, asset utilization, and other metrics. However the indirect positive impacts to brand perception, customer satisfaction / loyalty, and talent retention are likewise significant, and should not be overlooked.





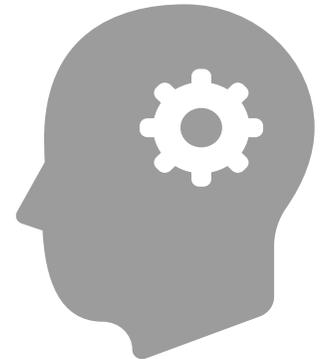
Summary

Augmented and virtual reality have now reached a mainstream tipping point, thanks to a wide-ranging set of advancements including the enabling technologies, data gathering/analytics capabilities, and operational best practices outlined in this paper. The long-awaited maturation of AR/VR brings many organizations to an important crossroads where doing “business as usual” is no longer a viable option for those wishing to remain competitive.

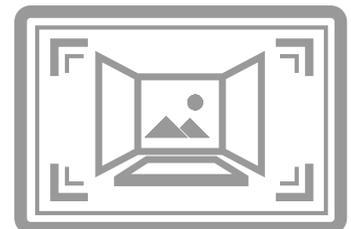
Flatirons Solutions is committed to fully leveraging the power of this new technology to improve the experience of asset operators in the field, and for manufacturers seeking to improve the customer experience for their products. With more than 25 years of demonstrated success in shifting the paradigm of technical publications – first from print to digital, then from digital to mobile – we are well-positioned to help our customer reap the benefits of the AR/VR revolution that's underway.

As we've seen, the fundamentals behind making a business case for AR/VR have never been stronger. As a partner to some of the industry's most important manufacturers, operators, and suppliers, Flatirons is committed to using the full potential of this important tool to help transform the experience of maintainers, operators, and trainees for the better.

VR



AR



ABOUT FLATIRONS SOLUTIONS

Flatirons Solutions® provides solutions for content lifecycle management for large asset industries like aviation, defense, rail, and marine. For more than 20 years, it has helped manufacturers, operators, and military forces maintain and operate complex assets more effectively. Its software and service solutions help organizations to deliver the right information, at the right time, to the right people.

www.flatironssolutions.com

info@flatironssolutions.com

FLATIRONS SOLUTIONS REGIONAL HEADQUARTERS

AMERICAS | Flatirons Solutions, Inc. | Boulder, CO | +1 303 544 0514

EUROPE | Flatirons A/S | Birkerød, Denmark | +45 4594 9400

ASIA | Flatirons Solutions India Private Limited | Chennai, India | +91 44 6693 6949