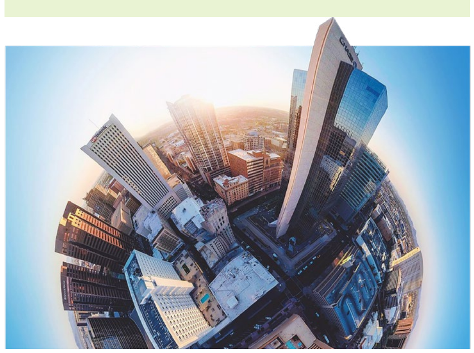
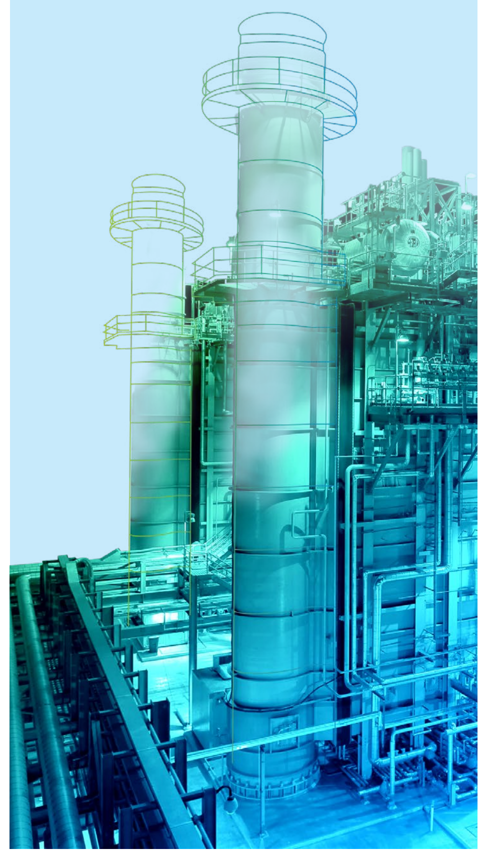
The Industrial Metaverse.





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Problem

As the industrial world moves toward the "autonomous factory" and Industry 4.0, modernization of existing facilities requires the ability to process and contextualize massive amounts of data that continue to grow exponentially. Many companies are already struggling with data overload as more devices are connected, system generated data accelerates, and Industrial (IIOT) sensors are increasingly deployed. And yet, we are still in the early stages with significant digital transformation to come over the next decade and beyond. The promise of Industry 4.0 provides unprecedented levels of automation and control, but this will not happen overnight – rather, it will be a step-by-step journey with immense benefits to be realized along the way.

Throughout this journey, humans will remain the most critical and yet the most unpredictable link in the control systems of these facilities, potentially leading to undesirable results if each step is not carefully planned and executed. With mountains of data as the necessary fuel to make the autonomous factory run, it's essential this data be organized and presented in an intuitive way so that humans can quickly understand, plan, and simulate each step of the journey before it's put into production. Furthermore, the data visualizations that are intuitive for the business analyst, using increasingly sophisticated cloud and analytics technologies, are vastly different from what will allow the operations worker to make practical use of the data to take action on the shop floor, within the refinery, construction site and other operational settings. The IT personas have a different focus and need from the OT (Operations Technology) personas—the so-called IT-OT gap. Without this understanding of the need for humans to interact and engage meaningfully with the data in a manner more suited to their role, guiding them to take data-driven action, the investment in digital transformation will not provide the expected benefits of extracting huge value in operational efficiencies and improving safety.

3D Digital Twins provide a framework to address this challenge.

Immersive 3D Digital Twins.

While there are several definitions, a Digital Twin is essentially a virtual replica of a physical product, system, or process and provides a significant leap forward in the digital transformation of many industries. GE Digital's CTO, Collin Paris, recently described Digital Twin as "a living, learning model that allows you to deliver business value by constantly making sure that the Twin is a replica of the asset so you can get insight into that asset and take action."

A "3D Digital Twin" extends these capabilities to provide an immersive way to interact with these digital replicas and associated data in a highly visual and intuitive way. It helps to translate the data useful to operations personnel in a way other data visualization techniques cannot, delivering data and insight "the last digital mile" to where personnel take action. Meaningful engagement and interaction with the data at the point-of-action will dramatically accelerate insights and understanding. This digital platform augments the operations worker's ability to analyze, understand, collaborate, plan, and simulate actions—it is a critical building block in the Industrial Metaverse.

Lifecycle Stage of the 3D Digital Twin

At the inception of a greenfield industrial operation, Computer Aided Design (CAD), Building Information Management (BIM) systems, or other types of 3D Digital Models are frequently used to assist in the many and complex planning, design, building and coordination tasks involved in such complex, multi-disciplinary engineering and construction feats. 3D Digital Twins created for this stage in the program are focused on the financial, the engineering, and the construction details of creating the operation, integrating the disciplines involved, and ensuring its safe and successful completion before turning over to the ongoing operations team.

From moment the new operation begins using the new facility, a quite different type of 3D Digital Twin becomes essential—now the emphasis shifts to the “living, learning” part of the definition. During the lengthy operational life of the operation, a 3D Digital Twin is only valuable if it stays true to its physical sibling. An efficient sustaining process that adjusts to reflect changes in the physical world is essential to ensure the Digital Twin remains the system of record for visual data. The result? Greatly increased productivity, reduced costs, improved safety and regulatory compliance, throughout the lengthy and productive life of the operation. The emphasis in this paper is on the Operations stage of the lifecycle.

To deliver the most value possible, a 3D Digital Twin should ultimately provide:

- A complete, accurate, and trustworthy representation of the physical world, whether it be asset(s), environment, and/or processes, with a closed loop means of maintaining it
- Integration with enterprise systems of record for real-time and historical data
- An intuitive 3D framework that helps organize and visualize massive amounts of data thereby enabling quicker understanding, better decisions, and more timely action.
- Visualization of output from advanced solutions such as predictive AI analytics and simulation models, in ways that can be cast onto the 3D model canvas
- Real-time monitoring and alerting for situational risk awareness
- The ability to interact with many different users with different perspectives according to the task at hand
- The ability to be consumed by Virtual Reality (VR) and Augmented Reality (AR), which extends the use of a Digital Twin
- A “system of systems” approach that powers the ability to query, analyze, and visualize across multiple facilities and drill into the detailed digital twins of assets and processes within each facility
- Eventually the 4th dimension of time for the ability to track, visualize and understand changes over time

Why it’s so important.

Yes, more data is better.

Like any modern-day setting, industrial operations leaders must balance the deluge of too much data and the need to make data-driven decisions and actions. Every new source of data is a potential source of confusion. Tools like Artificial Intelligence (AI), Robotic Process Automation (RPA), and other digital technologies can help organize and summarize the deluge into consumable insights and prescriptive action. But without delivering the insights and prescriptions to the where and when actions and decisions are made, the impact of those technologies is often dampened or lost. A 3D Digital Twin gives operations personnel that support, a framework within which to unite these technologies, and provide the ability to view the right data at the right time—at the point-of-action. In this new world data will be leveraged to optimize operations, improve top-line revenues, and improve worker safety, productivity, and satisfaction. In this world, the more data the better!

While new use cases are continuously being identified, some of the initial benefits are:

Reduced operational costs with data-driven efficiencies

- Streamline inspection and maintenance activities by organizing, prioritizing, and verifying tasks, to get more done in less time and with less re-work
- Identify faulty components and take corrective action before they fail
- Automate maintenance “workflows” – check inventory, order parts, schedule maintenance, etc.
- Assure warranty and insurance coverage documentation
- Reduce overtime expenditures and travel to remote sites

Top line revenue gains

- Capture lost revenue opportunities by reducing unplanned and planned

downtime and outages
- Increase asset reliability through "timely" maintenance with AI predictive analytics
- Greater output and billings

Improved Safety and Reduced Risk
- Minimize the amount of time humans spend in hazardous environments
- Drive situational risk awareness
- Train virtually with VR before stepping foot into the environment
- Simplify and streamline maintenance tasks in the real world with information delivered via AR
- Simulate and visualize outcomes before making changes in the real world

Regulatory requirements met more easily
- Quickly identify missing/needed compliance updates
- Improve compliance reporting, by providing a verifiable record of changes made

Improving Energy Efficiency, Resource Management and Sustainability
- Pinpoint visually energy loss points, taking input from measurement systems
- Supporting the operations of emissions management and low carbon control programs through more effective spatial visualization
- Reducing energy and fuel expended in transportation to operational sites, through enhanced remote monitoring capabilities

Building and Maintaining the Digital Twin

While they both use the underlying framework of an accurate 3D model, there is a big difference between engineering CAD models and “as-built” operational models that reflect their different purposes. A CAD model is used as the blueprint for construction and there are typically deviations from the original engineering plans during the initial build and as time goes by additional changes are made to the environment. In some cases, the differences are small, but they can rapidly accumulate to become significant and CAD models are rarely updated unless the plant undertakes significant new construction. In contrast, for an operational 3D Digital Twin model to be used effectively, it MUST be trusted as an accurate and up to date replica of the real-world physical environment. Otherwise, it loses its value as workers lose faith and ultimately stop using it.

The Foundation

The starting point for 3D Digital Twin models can be created in two main ways:

- Import and use 3D CAD engineering models, and then update the 3D Digital Twin model to reflect real-world variances and changes.
- When 3D CAD models are not available, various methods using laser scanners, LIDAR and drones can capture the visual data necessary to create the model foundation.

One or a combination of both methods, augmented with AI for stitching the inputs together, create an integrated, complete, and coherent visual foundation for the Digital Twin. Current technologies as of the time this paper was written allow model accuracy and resolution to be established to within a few millimeters of variance from the physical environment—this foundation provides a very high-resolution image of the industrial scene. For the sake of taking accurate and trusted measurements in the model, this level of accuracy is critical. In other cases, it may not be required.

“Intelligizing” the Twin

Once the foundation is established, AI-powered processes “intelligize” the model: using the information from asset master systems, highly precise attach points called tags are created, and accurate asset, process, and other attribute labeling is added. These tags become the conduit through which relevant data can flow, providing a highly intelligent, spatially aware model. They are also the integration points for data tools, including data and AI platforms.

Connecting the Twin

Next, the 3D model is exposed and attached to data sources in two principal ways:

1. Connecting directly to enterprise systems of record and operational systems through API's and connectors; these near-real time connections can be bi-directional, with the ability to "write-back" to systems of record.
2. Integrating to data and analytics platforms, including data warehouses, data lakes, AI and machine learning platforms. These connections allow the 3D twin to display highly intelligent AI-generated insights, predictions, and recommended actions.

3D Digital Twins can visualize data from sources such as:

- Manufacturing Execution Systems (MES)
- Supervisory Control and Data Acquisition (SCADA)
- Enterprise Resource Planning (ERP)
- Geographical Information Systems (GIS)
- Engineering Document Management Systems (EDMS), for P&IDs and isometric drawings
- Data historians
- Computerized Maintenance Management Systems (CMMS)
- IIoT sensors
- Live video or image feeds
- Interactive manuals and training videos

Maintaining the Twin

As noted, maintaining the 3D model to be a replica of the actual physical plant is critical for an operational Digital Twin. Model Maintenance of Change (MMOC) is the process of updating the model as changes are made in the physical world without taking the 3D model offline, thereby allowing operators and other end-users continuous access to the tool on a 24/7/365 basis. This is accomplished by a combination of software functionality, business processes, and visual data capture required to update the 3D Digital Twin.

3D Digital Twin in Action

The use of 3D Digital Twins for operations is linked tightly to the use of the source systems of record listed in Figure 1, providing a seamless alternate view of the state of the operation, historical records, presented visually in situ. As the visual source of record for an operation, plant, or facility, operations teams will constantly refer to the 3D Digital Twin during operations meetings, replacing the use of paper plans or blueprints. The 3D Digital Twin will be an essential part of delivering, investigating and addressing critical alerts, as well as the communication of the resolution to management. Planned actions can be packaged into highly specific and effective visual work packages. In each of these activities, a visually rich representation of the situation and context is highly effective in increasing understanding and clarity of situation. Using the 3D Digital Twin in these activities has been shown to produce benefits as listed above. The use of Digital Twins in general is small yet growing as of 2022, the increasing extension with spatial data as described in this paper, into 3D Digital Twins will accelerate their usefulness and prevalence in operational settings. The opportunity to provide value throughout the long service life of operations is immense.

The future of Digital Twins.

Augmented and Virtual Reality

As AR and VR technologies continue to mature, they will become a natural way to consume and interact with Digital Twins. VR is promising as an efficient and effective way for workers to safely train and practice tasks remotely before traveling or stepping foot into hazardous environments. AR on the other hand will become a powerful tool to help workers in the field more efficiently execute critical tasks such as:

- Locating and identifying assets
- Providing step-by-step instructions for inspection and maintenance activities
- Accessing real-time and historical data, including sensor data, during site walk-abouts
- Referencing important documents like isometric diagrams, operation manuals, training videos, and many others

While there may be some cultural and regulatory hurdles to clear for widespread adoption of AR glasses in hazardous situations, the future is very promising.

Putting AI and Simulations to Use

Ensuring the Digital Twin has access to all relevant systems of record and analytic data systems will enable output from AI-generated predictions, including behavior, events, and outcomes, as discussed above. Simulation engines already can generate realistic visual renderings of future behavior, powered by AI-predictions. As an organization increases its analytic maturity and begins adding competing AI models, and simulation models, the attached Digital Twin will become an increasingly powerful visualization of the past, current, and simulated or predicted future as these AI and simulation models become more pervasive and widely deployed.

4D Digital Twins

As implied above, animating the past, current, and future with simulations necessitates adding time as the 4th dimension to digital twin models. The ability to visualize changes to products, systems, and/or processes over time will make teams more efficient and productive in planning and executing these changes. Having the ability to look back and understand past changes that led to the current day “as-built” will act as a digital thread that sheds insights into how and why things came to be as they are today. Being able to simulate and visualize the result of potential future actions and changes to the environment before making them will provide huge value in both worker safety and bottom-line financial benefits.

Digital Twin as a “System of Systems”

As digital twins become more widespread and pervasive throughout an organization, it will be important to create data networked linkage of these twins to act as a “system of systems.” This will provide the ability to visualize, query, and analyze across the network of twins and gain insights at both a macro and micro level. Similarly, it will provide the ability to zoom in or out to the desired level of detail across a global portfolio of sites and assets.

Summary.

The industrial world is at the precipice of realizing incredible gains in productivity, operational efficiencies, and safety through digital transformation that harnesses the power and insight available from exploding data volume and depth. The Immersive 3D Digital Twin, connected to an ever-maturing integrated data ecosystem is key to conquering the deluge of data, by delivering the insight and prescribed action to the Point-of-Action. It is key to unlocking the opportunity that data provides.

Organizations that embrace emerging technologies like 3D Digital Twins, AI, VR, AR, and Robotic Process Automation (RPA), will be well positioned to leverage the power of their data and establish competitive advantage over those that are slow to adopt. When they can deliver it into the hands of those personnel taking the action, the value is created. This digital transformation is the new frontier of opportunity for those prepared to embrace it and may be the downfall of those who do not.

