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Could Arecibo's Collapse be the Last of its Kind?

How Digital Twin Technology will Transform Fault Diagnosis, Predictive Maintenance and Product Development

By: Patrick Bohle, Vice President, Solutions Marketing, FARO® Technologies, Inc.

www.faro.com

As if last year needed any more unhappy news, the global scientific community was dealt a serious blow in its closing weeks: the famed Arecibo radio astronomy observatory in Puerto Rico collapsed.

The observatory was in the middle of a rushed dismantling after two cables failed over the summer and fall. The initial cable failure ripped open a 100 ft. gash in the observatory's 1,000 ft. diameter reflector dish and the site was temporarily closed for repairs. A second cable failure in November sealed Arecibo's fate as engineers concluded the facility could not be saved. A complete evacuation was ordered.

At least one scientist called the dismantling a "scientific gut punch. The end of an era."

While Arecibo's collapse was a tragic loss to the scientific community, it was also a loss to the public at large; no other radio telescope was more famous, featured in movies like the James Bond blockbuster *GoldenEye* and 1997's *Contact*. To those familiar with its iconic structure, Arecibo had a personality – a giant dish scanning the heavens, listening patiently for radio signals from other worlds, or to the background noise of the universe for tantalizing clues as to its origins.

Built in the early 1960s, the 57-year-old technological wonder remained the world's largest single-unit radio telescope until 2016 when the FAST (Five-hundred-meter Aperture Spherical radio Telescope) began operation in China.

Beaten in 2016. Broken in 2020. An ignominious end to a famous telescope.

"Seeing Double Double?"

But what if a tragedy like this never happened again? What if a future failure — of a structure, building, or even assembled part — could be predicted not weeks or months in advance, but years, even before mass production of its component parts? With digital twin technology, the process by which physical objects are converted into digital replicas via 3D laser scanning and monitored and modeled with real-time cloud-based data analytics, that reality is coming to pass.

In just the next few years, in fact, the world's digital twin market is expected to grow at a compounded annual growth rate (CAGR) of nearly 38 percent, reaching $16.4 billion by 2024. About half of that growth, 41 percent, is forecast to occur in North America alone, with the automobile and aerospace industries dominating.

Broadly speaking, digital twin-enabled structural health monitoring and predictive maintenance represent the threshold of where this technology can take the world. For instance, in one recent UK study, two Staffordshire (West Midlands) railway bridges had fiber optic sensors fitted on them during their construction, measuring real-time "strain/stress evolution" and "strain/stress distribution" as a proof-of-concept test. Combined with "finite element" predictive modeling achieved through on-structure sensor data, the information, according to the report, "can be used to help establish a performance baseline, thereby achieving long-term condition monitoring and data-informed asset management as subsequent sensor data are collected throughout the bridge's operating life."

In other words, it could mean that engineering failures like those that befell Arecibo (and others like it) might soon be ancient history.

For instance, had Arecibo been 3D laser scanned and fitted with monitoring sensors, detecting the tensile strength of its primary and auxiliary cables, the structure's long-term integrity could have been tracked. Likewise, model simulations would account for the physical stresses caused by the region's frequent hurricanes, periodic earthquakes, and near-constant humidity and how those stresses impact multi-decadal structural performance. Meteorological and seismic data, both historic and real-time, would add to the accuracy of the digital simulation. While engineers already perform regular inspections on the structures they build, digital twinning allows for unparalleled near-instantaneous insights and much faster reaction times.

That's true not only in failure prediction and structural health monitoring for long-completed structures like Arecibo, but for any structure (like a factory) or part (like an airplane turbine) where monitoring and modeling is desired during construction or retrofit for new or adapted use. Arecibo's auxiliary cables were added in the 1990s without the benefit of predictive maintenance. But consider what will happen when the next generation of ground-based telescopes, say in 20 years, eclipse China's FAST, and are built from the ground up using digital twin technology?

Digital Twin for the Win-Win

The short answer is a better, more robust, safer product, delivered to market in potentially record time. It also means greater flexibility in sharing that data remotely, faster, giving manufacturers the ability to access blueprints anywhere in the world, but with the advantage of complete synchronicity between the physical and digital assets.

Best of all is that nearly any industry stands to benefit, as will consumers. For the automobile industry, the collection of digital twin data from real-time on-road vehicles has the potential to one day provide invaluable performance metrics – metrics that could help advance vehicle design, improve safety and fuel efficiency standards, and perhaps, serve as a catalyst for the accelerated adoption of electric vehicles thanks to enhanced battery performance coupled with improved regenerative braking technology. For manufacturers, products can also begin their lifecycle entirely in the digital realm where a 3D model can simulate real-world performance.

Auto factories themselves can be digital twinned as well, monitoring anything from building sustainability and performance, to operations and maintenance, even occupant/employee health and wellness. In the near future factories of all types will benefit from: shorter planning/construction lifecycles, faster car/model turnaround times, increased reliability and efficiency, enhanced automation, and perhaps most exciting, the ability to adopt a "build where you are" approach – copying the design specs of a physical plant and constructing it somewhere else in the world, closer to the demand market. Such decisions will have profound economies of scale impacts.

The same predictive maintenance and factory build potential applies to airplanes too. Fitted with remote sensors and shared via the cloud, metrics like turbine performance, hydraulic controls, and the aircraft's environmental control system (of particular importance in the post-COVID era) can all be instantly monitored and improved before problems occur. Here too, a digital twin can begin virtually with performance maximized – even before the first physical aircraft parts are assembled.

What Digital Twin is, What it Isn't, and What it Can do for You

The key to adopting digital twin technology, however, rests with the understanding that a digital twin is not the same as a digital model.

Digital models are static representations of physical assets. It's a technology that's been in increasing use since the 1980s. A digital twin is a 3D model on steroids, a "living document," synchronized with the physical asset. If something is changed on that asset, the digital model updates accordingly, accomplished through cloud-based software and the growing variety of Internet of Things (IoT) technology that augment the physical asset. In the rush to adopt such technology it is important not to miss this distinction.

Applied to the world's architectural, construction and engineering projects, digital twinning can be expected to:

- Generate efficiency gains across the entire product or asset lifecycle
- Gain insights into real-time customer use patterns which will be fed back into 3D digital simulations resulting in additional improvements
- Predict failures and maintenance based on real-world data fed into the model
- Create a "digital thread" whereby disparate systems and processes can be connected remotely
- Troubleshoot problems without having to travel to the physical asset
- Better understand the interrelationships between the systems within systems that complete a finished product (think buildings, airplanes, automobiles, etc.)
- Monitor and assess historic structures and landmarks for ongoing maintenance or accurate repair

As IoT technology proliferates – with an estimated global market share of $1.3 billion by 2026 and around 75 billion devices connected to the internet – digital twins' reach will only expand. And while startup expense and data migration is a necessary conversion factor, digital twins' return on investment is high, thus justifying its implementation.

"Mirror Worlds," Materialized

In 1963 when the Arecibo Observatory came online it was a different world. One of the first supercomputers, the Atlas, began operations in the UK with a memory capacity of 48,000 words, or about 96 kilobytes. The first scientific papers, let alone the actual hardware for networked computing, the underpinnings of the Digital Age, were still four years distant. Today, digital twin technology is the outgrowth of these pioneering efforts.

As businesses and manufacturers emerge from the global pandemic, outthinking and out maneuvering the competition begins with adopting innovative solutions destined to speed time to decision, distribute better data faster, and share that information with all project stakeholders anywhere in the world, entirely remote.

Digital twin technology is the dynamic real-time modeling approach that stands to achieve just that.

The Six-Point Plan to Developing your Digital Twin Strategy

1. **Asset Assessment** – Take stock of your current facility and inventory. What is the current cost of maintenance and monitoring? How common is downtime? How long does downtime last? What are the labor/overtime costs for addressing emergencies? What is your current time to decision?

2. **Outsource or In-house** – Adopting a digital twin strategy can be outsourced entirely to a third party or the upgrade can occur in-house. Determine which approach is best suited for your needs and if you have the capacity to flex your internal team.

3. **Seek Stakeholder Input** – Identify where/how alignment between all parties involved in asset oversight can be maximized. How will digital twin modeling integrate with your existing workflows? What is the anticipated ROI on such an initiative?

4. **Know Your Competition** – Conduct research on where/what facility and operation managers are doing on similar/related sites. Is everyone in the region you're operating in adopting digital twin strategies? Review trade publications, noting guest bylines or any in-story attributed quotes that speak to this topic. Monitor social media.

5. **Review Vendor Websites** – Spend time on vendor websites to understand their product portfolio and determine which product(s) best meet your needs. Narrow your search to 2–3 options, reach out to vendors and request a demo. Make sure the demo includes an example facility, highlighting workflows from start to finish. Last, seek vendor-initiated on-site scans of your facility/physical asset.

6. **Gain Team Buy-in** – Include IT managers, operations managers and members of the senior leadership team. Once budgets have been approved finalize any decisions with the CFO or staff with purchasing power.