

Uni-Systems Scores Big in Designing Retractable Stadium Roofs Using Mathcad®



Designing state-of-the-art NFL venues is 'a snap', thanks to 3D engineering calculation software from PTC



In the late 1960's, Uni-Systems, LLC (Minneapolis, Minnesota) was established to develop moveable structures for aerospace giants such as Boeing Aircraft, American Airlines, and Cape Canaveral Air Force Station. Later, the company branched into the military, construction, entertainment, and, in more recent years, sports industries. Uni-Systems has designed, fabricated and installed the mechanization components for five of the last six retractable sports-stadium roofs built in North America, including Reliant Stadium and Minute Maid Park (Houston, Texas), Lucas Oil Stadium (Indianapolis, Indiana), Cowboys Stadium (Arlington, Texas), and University of Phoenix Stadium (Glendale, Arizona).



University of Phoenix Stadium, whose exterior 'skin' represents a barrel cactus, was designed by Uni-Systems to have the country's first fully retractable natural-grass playing field.

As the leading designer and advocate of "kinetic architecture," Uni-Systems creates transformative, mechanized structures that can change to fit the climate, need or purpose of the venue. Prime examples of the company's niche market include designing playing fields that can easily switch from turf to concrete for trade shows, and retractable roofs that can open and close to shield fans from the elements. Combining the disciplines of structural, mechanical and electrical engineering, Uni-Systems handles it all – from concept and schematic design to fabrication, installation and follow-up maintenance.

The Challenge: Design a Cutting-Edge Stadium with Multiple Partners

When Uni-Systems landed a contract to build a multipurpose stadium for the National Football League's Arizona Cardinals at the University of Phoenix in Glendale, Arizona, their task was clear: design and build the first fully retractable, natural-grass playing surface in the United States. Uni-Systems' design team needed to devise a way to move an 18.9 million-pound playing field in and out of the stadium at the touch of a button, so that the venue could be used for sporting events, concerts or conventions. To accomplish this feat, Uni-Systems worked with various teams of structural, mechanical and electrical engineers, which meant sharing engineering data across different disciplines. With the deadline looming, there was no time for a long learning curve or costly rework.

The Solution: Easy-to-Use Mathcad Calculation Software from PTC

Thankfully, Uni-Systems was already using Mathcad, the global standard for engineering calculations from PTC. Unlike proprietary calculating tools and spreadsheets, Mathcad enables engineers to design and document engineering calculations simultaneously, with comprehensive applied math functionality and dynamic, unit-aware calculations. Even better, Uni-Systems encountered very little downtime getting up to speed using Mathcad. And, throughout the design process, the Uni-Systems team kept all calculations in Mathcad, resulting in easy-to-see – and share – calculations.

The Result: New NFL Stadium Debuts to Rave Reviews



The stadium features alternating sections of shimmering metal panels – intended to reflect the shifting desert light – alongside magnificent vertical glass slots, allowing patrons a spectacular view of the horizon from any level of its exterior.

Upon taking the field at the new stadium in their first preseason NFL football game, the hometown Arizona Cardinals team prevailed, 21-13. By all accounts, the stadium itself was also declared a winner. That same year, BusinessWeek magazine voted University of Phoenix Stadium one of the 'Top 10' sports facilities in the world, and in 2007 the Arizona Republic named it one of the seven wonders of Arizona. Today, University of Phoenix Stadium is truly a multipurpose facility with the ability to host professional sporting events, as well as concerts, consumer shows, motor sport races, rodeos and large corporate events.

Collaboration is Key to "Kinetic Architecture"

Uni-Systems has earned a solid reputation for designing moveable structures, a specialty that it refers to as "kinetic architecture."

"Kinetic architecture is the study of mechanizing and moving building elements to modify the form or function of the venue," explains Mike Becker, Lead Mechanical Engineer, Uni-Systems. "In its simplest form, it is bringing movement to architecture."

Among the company's many creations: numerous retractable roofs for sports stadiums and arts venues; mammoth docking stations for aircraft; elaborate storage and retrieval systems; the moveable walls at New York City's Wall Street Ferry Terminal; and even a giant skydiving simulator in Arizona.

But if global manufacturing had a Super Bowl for Engineering, the University of Phoenix stadium – also home to college football's Tostitos® Fiesta Bowl – might very well win the contest.

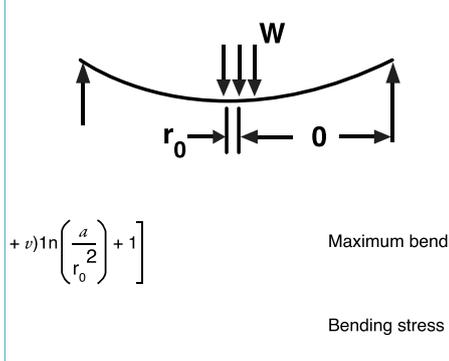
That's because this stadium boasts some amazing engineering 'victories'. For starters, it includes a retractable roof that bi-parts at the 50-yard line and rests over each end zone in the open position. Under the roof, an 18.9 million-pound playing field can be moved in and out of the stadium at the touch of a button, easily changing the venue from a sporting event to a rock concert or business convention.

For Uni-Systems, the University of Phoenix stadium presented a mix of challenges that called for a blend of mechanical, electronic and controls solutions. For example, Uni-Systems engineers devised a patented cable-driven system for safely transporting the roof panels along a sloped path.

"It's our job to make sure that the loads that are produced by the mechanization and transferred by the mechanization are understood by the other structural engineers on the project," Becker explains. "Additionally, our approach to working on a construction project is unique, in that we work on every stage of the project, from beginning concept to ongoing maintenance – and everything in between."

With Mathcad's unique visual format and scratchpad interface, Uni-Systems engineers were able to integrate standard mathematical notation, text and graphs in a single worksheet. Better still, engineers had no problem capturing the knowledge they needed for this complex project.

base for the middle weldment is what is being looked at in
plate with outer radius equal to the furthest edge of our s
k's Formulas for Stress and Strain 7th ed. Table 11.2-16.



"My favorite part of Mathcad is that it's easy to use. Engineers new to the system can accomplish tasks in a matter of hours and become experts in two weeks. There are no special programming skills required."

Mike Becker,
Lead Mechanical Engineer,
Uni-Systems

Capturing Critical Calculations

Uni-Systems owns a unique position in its field because its engineering team combines the disciplines of structural, mechanical and electrical engineering. Clients choose Uni-Systems because it can work well with the various other architecture and engineering firms needed for a job of this scale.

For the Uni-Systems design team, the first obstacle is controlling the roof on a slope. That's because the roof always wants to move to a state of low potential energy.

"We designed a 480-horsepower system to move the two roof panels and maintain control of the roof," explains Becker. "The system also includes eight cable drums or winches that move each roof panel. That adds up to a total of 16 cable drums on the project. Each cable drum is powered by four 7.5-horsepower motors that wind up a one-and-a-half-inch diameter cable. Synchronizing these drums was the real challenge."

In addition, the stadium includes an opening on one side that enables operators to move the playing field outside, thereby keeping the natural-turf playing surface exposed to sunlight – essential for growing natural grass.

With its complex, one-of-a-kind design, accurate calculations were vital.

"Throughout the project, I kept the calculations in Mathcad," explains Becker. "This displays the equations and results plainly, and has easy annotating capabilities."

And because calculations in Mathcad are so easy to read and understand, the Uni-Systems team had no problem sharing calculations with engineers and designers working on the other architecture, construction and engineering teams on the project.

"We created a critical sample calculation book in Mathcad for the team," explains Becker. "We bound it and plan to use it for future projects, too."

"My favorite part of Mathcad is that it's easy to use," says Becker. "Engineers new to the system can accomplish tasks in a matter of hours and become experts in two weeks. There are no special programming skills required."

Easy Integration Keeps Project on Schedule

Mathcad's easy integration with other 3D CAD systems was a great benefit for Uni-Systems engineers when working with partners on the project.

"For about six months, I traveled to Phoenix every other week to meet with Hunt (general contractor), Walter P. Moore (structural engineer), HOK (architect) and Schuff Steel (steel erector)," explains Becker. "These design meetings were vital for making sure that all parties understood the intricacies of the design."

The Uni-Systems team appreciated how seamlessly Mathcad worked with the other CAD systems, including AutoCAD®, SolidWorks® and COSMOSWorks®. There were no problems documenting, validating, verifying or sharing relevant calculations.

In addition, Uni-Systems' engineers used specialty routines designed in Mathcad to test different design and safety scenarios.

"We performed a proof of concept physical test by fabricating a pair of cable drum drives and lifting a 90,000-pound concrete weight to simulate the load the cable drums would see on the roof," explains Becker. "Mathcad made it simple to design the test setup and analyze the results of the test."

As a result, Uni-Systems delivered the much-anticipated stadium on time, in large part thanks to Mathcad's ability to increase the productivity of the team's engineers.

Just Completed: Lucas Oil Stadium

Uni-Systems recently completed another impressive project at the Lucas Oil Stadium, the new home of the Indianapolis Colts – a project that called for exactly twice the quantity and horsepower of what was used in the roof at the University of Phoenix stadium.

"And, on top of that, we were dealing with not just two rails per roof panel but five, all of which had to be kept, if anything, in closer coordination than at the University of Phoenix stadium," explains Becker. "The drum drives are distributed on each of the rails. The control system must synchronize the efforts of each group of drum drives closely to prevent applying damaging loads into the roof structure."

The engineering calculations made with Mathcad during the University of Phoenix design process saved valuable calculation rework time during the design and manufacturing of the cutting-edge Lucas Oil Stadium project.

Today, Uni-Systems continues to rely on Mathcad's engineering calculation capabilities in its latest projects, which include designing the retractable roofs at the Dallas Cowboys' new stadium – now in the construction phase – which will host up to 100,000 fans, and the Florida Marlins new Major League Baseball stadium, which is now in the early design phase.



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