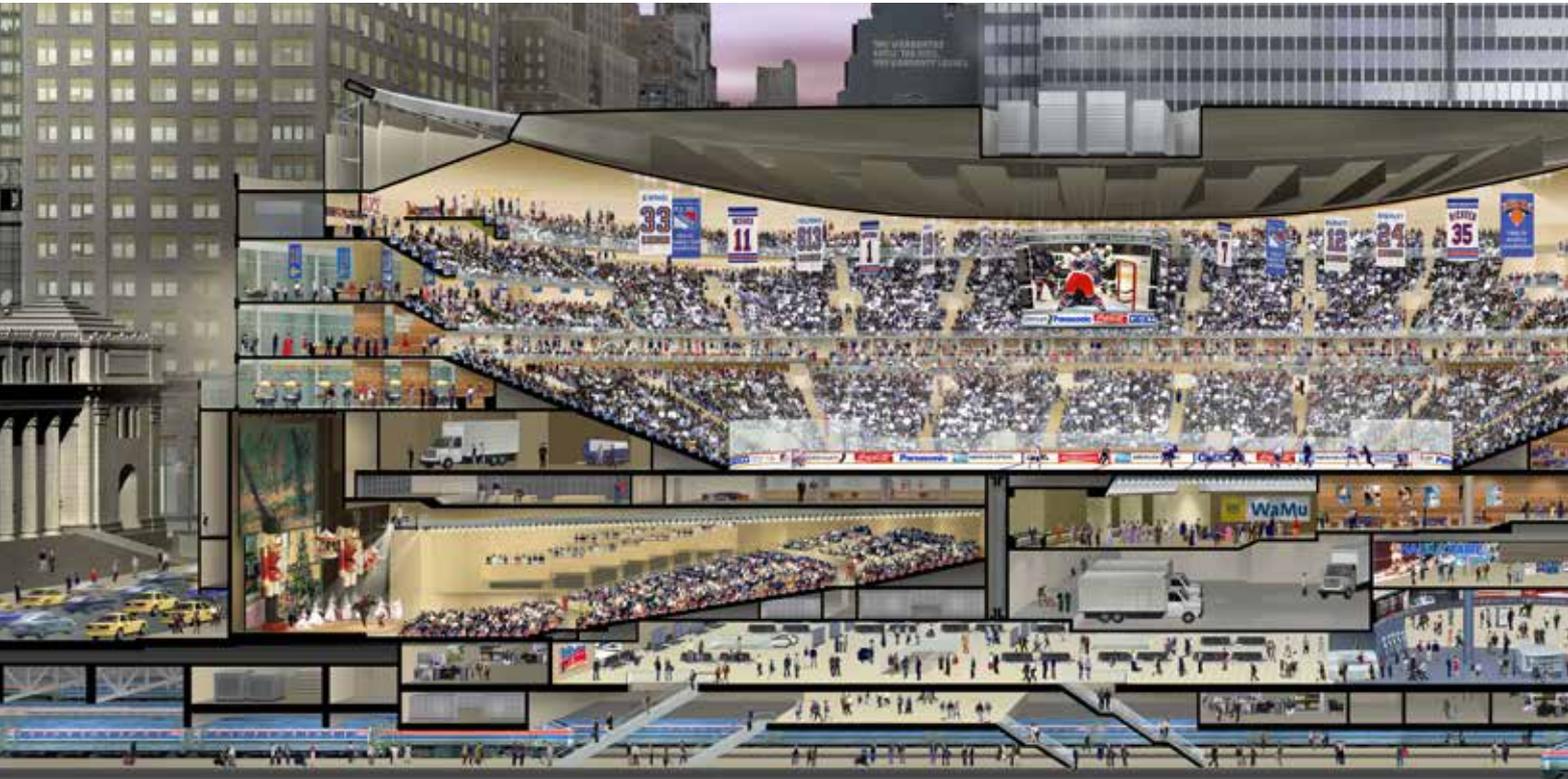


New York City's world-famous entertainment and sports venue gets an extreme interior makeover that gives fans a whole new perspective on the action.



GROWING the Garden

BY CAWSIE JIJINA, P.E., AND
STEPHEN REICHWEIN, P.E.

IN A CITY of big numbers and big dreams, Madison Square Garden fits right in.

The busiest music venue in the country in terms of ticket sales (third-largest in the world behind Manchester Arena and London's O2 Arena) and the home of the New York Knicks, New York Rangers and New York Liberty it has entertained countless spectators since its opening in 1968 and currently hosts more than 300 events per year.

While the Garden's somewhat distant future remains unknown—it is currently two years into a ten-year permit, at the end of which it will either be relocated or go through the permit process again—its immediate future is looking good following a recent major renovation involving building a new arena within its historic circular shell. The plan called for everything inside the walls to be replaced and included a mandate to stay fully operational nine months out of the year—as well as be ready for the first Rangers and Knicks games of their respective 2012 and 2013 seasons.

The \$1 billion transformation, which encompassed nearly one million sq. ft, included demolition, raising and reconstruction of the entire upper bowl seating structure, raising of the north and south arena roof structures, the addition of two sky bridges (called the Chase Bridges), expansion and restructuring of the 7th Avenue entrance, three levels of structural expansion on the 7th Avenue side for new concessions concourses, a one-tier expansion of the existing west-side hung suites, new lower bowl luxury suites (in-filled beneath the newly raised upper-bowl seating structure), courtside “bunker” suites, external threat mitigation, new MEP and A/V systems, installation of 50 new escalators, dressing rooms and countless concessions outlets. Not only are the arena's building systems massive and complex, but they've also been upgraded numerous times since the Garden was originally constructed, which required countless hours of rummaging through existing drawings and conducting endless field surveys.

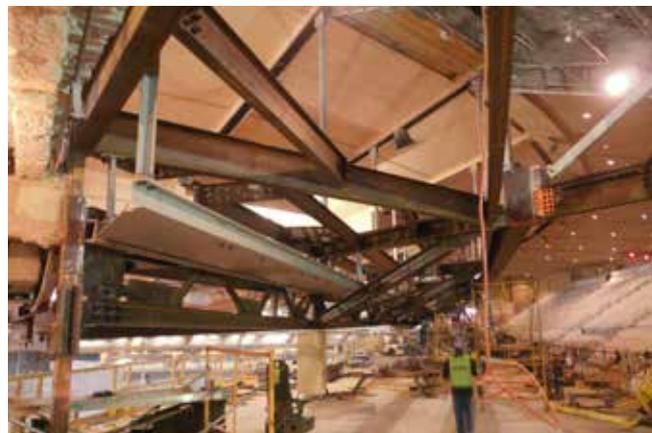
- One of the Garden's two 233-ft-long bridges.
- The renovation included, among other things, reconstruction of the entire upper bowl seating structure, raising of the north and south arena roof structures and the addition of two pedestrian bridges.



Photos courtesy of Madison Square Garden



- ▲ Construction of the arena in the 1960s.
- ▼ Steel support for the upper seating bowl.



Sky Bridges

The signature design feature is the two Chase Bridges—echoing the allure of New York's famous suspension spans and complementing the Garden's curved form—high above the arena seating on each side of the performance floor to provide guests with a bird's-eye view of the action. Each bridge is hung from the suspended cable roof system by slender hangers, and each weighs 330 tons and measures 233 ft long and 22 ft wide, with a combined seating capacity of 430 seats. In addition, the bridges function as promenades, enabling event-goers to stroll about from one end of the arena to the other. The bridges use a total of 154 tons of structural steel framing to support their decks. In addition to its self-weight, each bridge is capable of supporting an additional 300 tons of occupants, evenly distributed. Given the density of the area and the constant stream of people in, around and underneath the Garden—including commuters traveling through the ever-bustling Penn Station—erection was performed from within the walls of the famed venue. Two cranes were navigated up the truck ramp and set up in middle of the arena floor to place the steel and more than 11,000 sq. ft of metal decking. In addition, an elaborate scaffolding system and platform were constructed to give the steel erectors, lathers and carpenters an open and flat working surface.

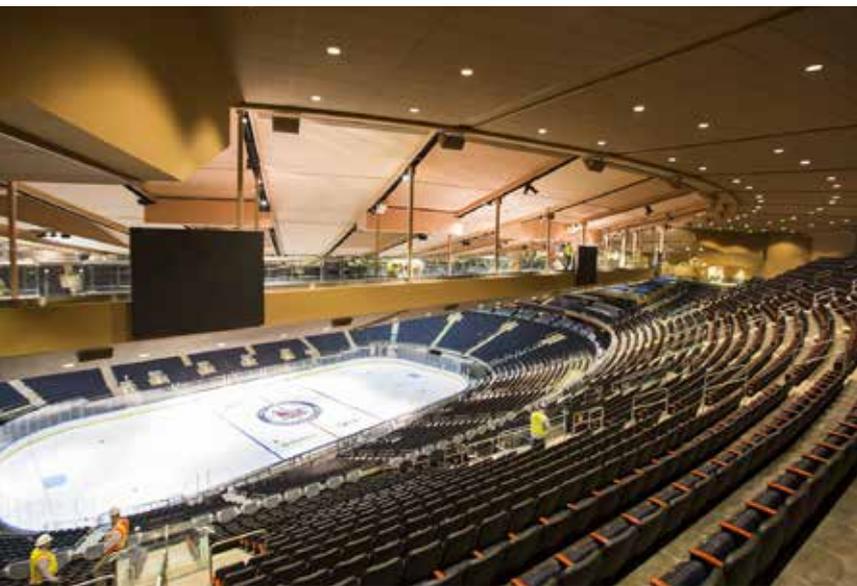
Above the bridges and the Garden's iconic radial ceiling is the "attic," a dark space where the venue's various mechanical and electronic systems convene. The 20 pairs of



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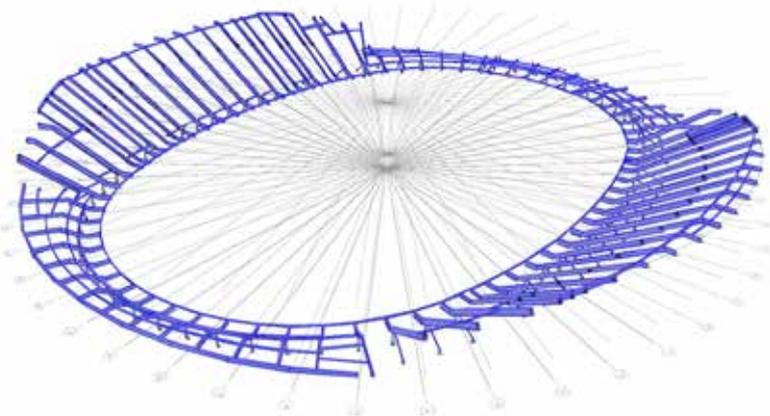
- ▲ The new upper bowl structure needed a sturdy base, as the load on the support structure was increased to the added pitch and height.
- ▼ The renovation encompassed nearly one million sq. ft of space at a cost of \$1.1 billion.



steel trusses that pick up the bridges (10 trusses for each bridge at 6 tons of steel per truss) and deliver the load to the cables were threaded through existing equipment and constructed in this attic space. When you play with cables, dynamic behavior is your nemesis. Because each bridge is hung from the cable roof system, the stiffness of the complete system during rhythmic excitations—such as the reverberations from a thumping bass beat and a rhythmic sway from a dancing crowd during a concert—results in motions strong enough to cause discomfort. Rather than adding stiffness to the roof, trusses and bridge decks (the brute force method), structural engineer Severud Associates opted for a more elegant and cutting-edge design solution in the form of an active tuned mass damping system to dissipate the energy of a group of excited spectators.

Essentially, a tuned mass damper (TMD) is a heavy weight attached to a complex system that moves in the opposing direction to the motion it encounters. Five TMDs, designed by RWDI Motioneering and weighing nearly five tons each, were commissioned in each bridge and were made shallow enough to fit within 13.5 in. of space due to constraints imposed by the sight lines generated from the last row of the upper bowl seating tier. Each TMD is comprised of 4.5 tons of stacked lead plate, a crankshaft and two hydraulic pistons (weighing approximately a half-ton) that translate rotational motion into vertical motion (similar to the engine of a car). The lead plates are put into motion by the movement of the spectators during an event, and the entire TMD system is calibrated to oscillate (move) in the opposite direction as the loading frequency caused by the participants (the spectators). The opposing motion caused by the TMD weakens the loading frequency, dissipating the energy and dampening the perceivable motion throughout the entire structural system.

Sight lines from the last few rows of both the north and south upper bowl seating sections were a huge design concern with regards to the elevation and depth of the bridge decks; if the bottom of the ceiling interrupts a sight line, several rows of valuable seating are at risk of becoming compromised and unsellable. To ensure that the ceilings attached to the bottom of the bridge structure will never interrupt these sight lines, the bridge structure was designed and constructed to have a natural camber. Due to the number of structural elements that ultimately play into gauging the stiffness of the complete system, designing the camber was a daunting task. Severud studied numerous winter and summer loading scenarios—as well as performed several surveys to achieve the correct camber elevations—to ensure that sight lines stayed clear under all conditions.



- ▲ A model of the steel framing for the upper bowl.

Upper Bowl

The existing arena bowl stadia ran continuously from the arena floor to the perimeter of the arena's original shell, and the Garden's owner saw an opportunity to gain prime real estate in luxury box seating by simply "lifting" the entire bowl structure. But the continuous bowl seating also served as the diagonal brace to resolve and balance the lateral loads. By splitting and lifting the upper half of the seating and creating two bowls, the flow of force was interrupted. This force discontinuity was addressed by the structural engineers who used the walls between the luxury suites to direct the flow of force from the upper bowl to the lower bowl and then used the arena floor to balance all forces.

First and foremost, the new bowl structure needed a sturdy base because the load on the support structure was increased due to the added pitch and height; this meant reinforcing the existing Level 07 floor structure by both "sistering" and reinforcing existing steel beams and columns. Secondly, the existing bowl structure was to be removed, which proved difficult as the existing bowl structure provided a pivot point for the perimeter mast columns, which are trying to fall inwards due to the thrust produced by any imbalances in loading on the roof system. This meant designing and constructing a very elaborate temporary bracing system, designed around the impeding upper bowl raker beams. Once the temporary bracing was installed, the existing upper bowl could be removed.

Next came the installation of a new roof structure over top of the existing roof structure followed by fusing the two together at the cable roof "knuckle." Once the two were fused together, the existing roof beams and rakers could be carefully cut away to release almost 50 years of built-in axial loading, and this load was transferred into the newly raised roof structure. Finally, the new upper bowl seating structure could be lifted into place. Once again, two cranes navigated up the truck ramp to set up in middle of the arena floor to place more than 50 40-ft-long to 90-ft-long steel raker beams supporting more than 500 pieces of precast seating.

The latest incarnation of Madison Square Garden was completed in time for the Rangers' and Knicks' home openers, giving the "World's Most Famous Arena" a new lease on life and its patrons a new view of the action. ■

Owner

The Madison Square Garden Company

Construction Manager and Owner's Representative

Jones Lang LaSalle

General Contractor

Turner Construction Company

Architect

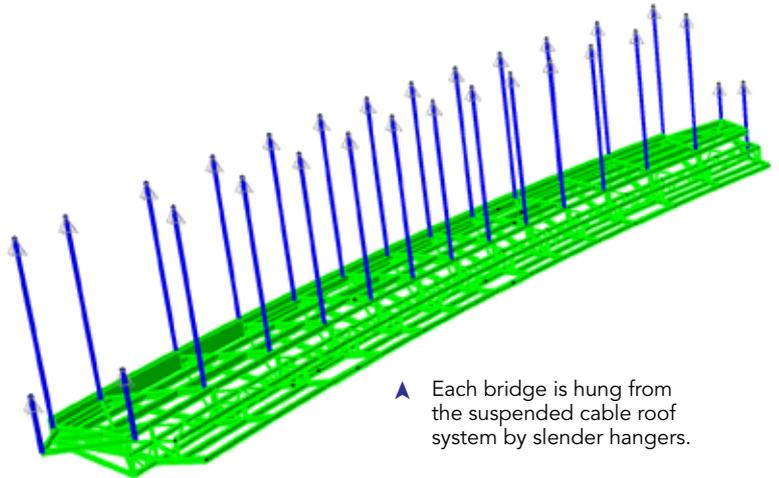
Brisbin Brook Beynon Architects

Structural Engineer

Severud Associates

Steel Fabricator and Erector

W&W | AFCO Steel, Oklahoma City



▲ Each bridge is hung from the suspended cable roof system by slender hangers.



▲ Madison Square Garden currently hosts more than 300 events per year.

▼ More than 500 pieces of precast seating is supported by more than 50 40-ft-long to 90-ft-long steel raker beams.

