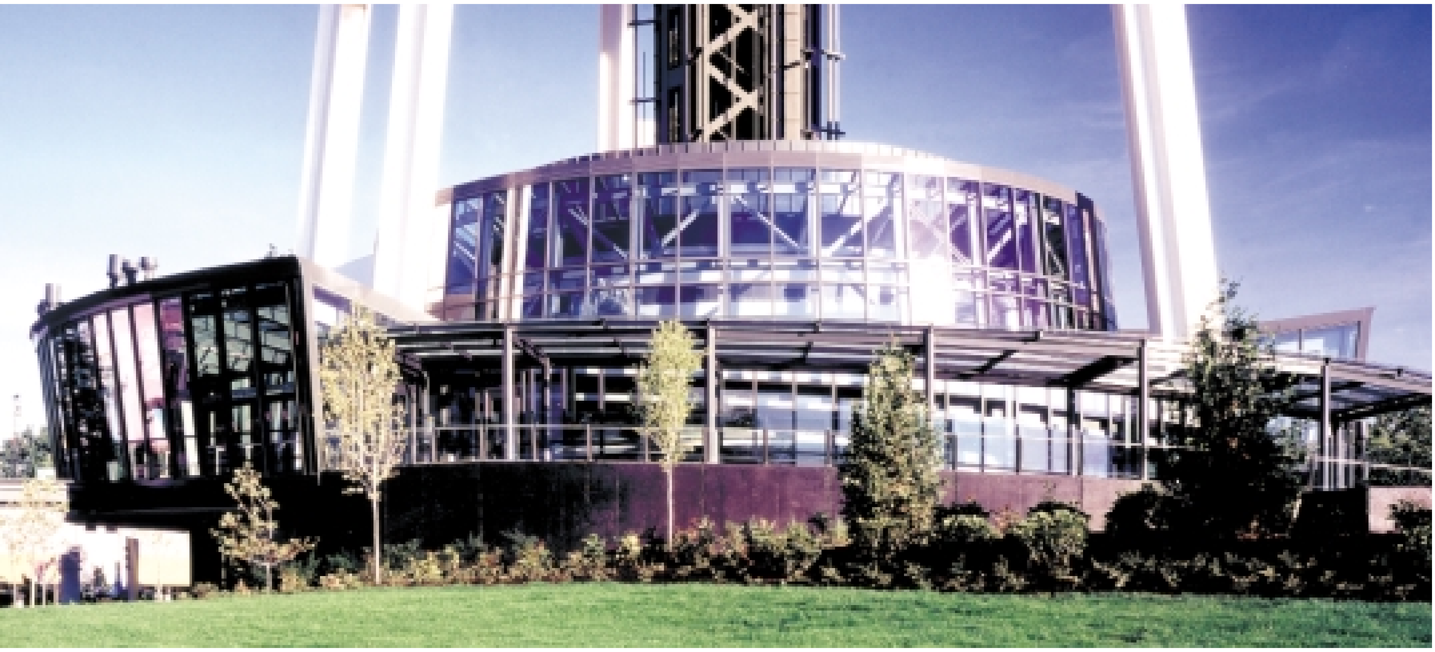
Renovating the Space Needle



Originally constructed for the 1962 World's Fair, the Space Needle annually attracts over one million visitors. To provide a fresh, compelling experience for the Needle's guests and enhance its status as a Northwest icon, the Space Needle Corporation began an extensive $20 million improvement package.

At the center of the improvement package is a 15, 000 sq. ft. pavilion that provides space for ticketing, retail and lobby functions. The enclosed ramp accommodates as many as 400 people and provides shelter from the rain, sun and other natural elements.

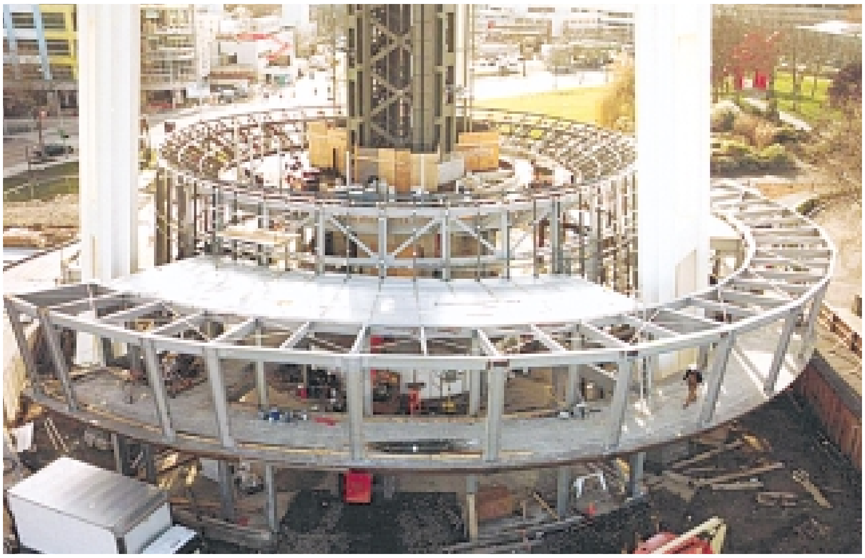
KPFF Consulting Engineers and Callison Architecture undertook the task of improving Seattle's most recognizable landmark. The design team had to comply with the requirements of a 1998 decision by the city of Seattle that officially conferred landmark status to the Space Needle. This designation meant that any improvements to the Needle had to respect the historic and aesthetic nature of the original structure and design, including keeping the legs free of any obstructions. To maintain the Needle open to visitors, construction was not allowed to interfere with normal operations.

THE GLASS PAVILION

The pavilion preserves the integrity of the structure's original design while respecting the strictures imposed by landmark status. The conceptual basis for the design derives from sketches by Victor Steinbrueck, the Needle's original architect. Steinbrueck's sketches depicted a ramp circling the base of the tower.

Like a nautilus, the 15,000 sq. ft. two-story glass pavilion encircles the three-sided base of the Needle and guides visitors up a spiraling ramp to the second-floor elevator level. The whole structure touches the Space Needle as lightly as possible, both physically and visually. Structurally independent of the Needle, the pavilion design specifies as much glass as possible to keep the Needle's legs unobstructed. All surfaces are clad in glass, while glass and metal panels form the roof. The pavilion's structural elements are dark gray to distinguish them from those that are part of the original construction, which are lighter in color.

To keep the Needle fully operational throughout the course of the improvements, the design team developed a construction sequence that allowed the Needle to remain open during construction. The new basement that provides administrative space was constructed first, followed by a temporary ticket booth that enabled work to begin on the new pavilion. A tunnel created with shipping cargo containers served as a visitor walkway through the construction area as the pavilion was constructed. Work was conducted



Opposite: The structural steel framing for the spiral ramp is independent of the structure for the Space Needle. The view of the 518' tall Space Needle is maintained around the entire length of the ramp, which has a glass roof. Photo courtesy Callison Architecture/Chris Eden.

Left: To completely surround the existing Space Needle base while keeping the pavilion structurally independent, the ramp is built like a bridge, with trusses spanning between major structural bents.

after midnight to avoid interruptions to utility services.

Design and construction of the pavilion and other improvement features were completed on budget and on schedule. The new pavilion opened in May 2000, just in time for the busy tourist season.

INNOVATIVE FEATURES

The design team of the Space Needle's new pavilion was faced with a daunting task: improve a 38-year old landmark while retaining the character of a structure recognized worldwide. The pavilion's nautilus design remains true to the original concept sketched by the Needle's original architect, satisfied the requirements of landmark status and enhances the experience of the Needle's visitors.

Made almost entirely out of glass, the pavilion is independent of the Needle and does not obstruct the main structure. The pavilion features a fully exposed, self-supporting steel frame structure that encircles the base of the Needle with glass paneling to preserve the view of the legs. To increase the visual impact of the pavilion, the architect avoided using vertical walls. The pavilion's outer wall angles out at the bottom, while the inner wall forms a truncated cone that leans toward the center of the building and shelters the elevator platform.

Instead of using columns that would have obstructed views of the Needle, the design team devised a cantilevered support system for the glass roof and walls that stands outside of the base of the Needle but inside the pavilion itself.

KPFF utilized Vierendeel truss moment frames for the ramp because this truss is essentially a box with a frame or a slab on each face but no diagonal elements. Using Vierendeel trusses contributed to the preservation of the Needle's views. Braced frames support the ramp inside the perimeter of the Needle's base, providing additional lateral stability. These two braced frames provide the pavilion with exceptional torsional stiffness, an important element to the support of the ramp.

The continually changing dimensions and load characteristics of the ramp mean that no two sections have the same load conditions. Every column, beam and cross brace is unique. In addition, because of the integration of the load-bearing systems, the design team found it necessary to consider gravity and lateral loads together.

The complex geometry of the pavilion exceeds that of typical round buildings. As the curving ramp rises at a consistent slope of 1' to 22', the outside radius changes continually, while the inside radius of the ramp is a constant 57'-9". The glass walls have reversing slopes relative to the rest of the building. The geometry of the ramp inside the pavilion largely determined the location of the structure relative to the Needle.

To manage these complexities, the design team opted to use a unified design approach that defined the structure's configuration in cylindrical coordinates rather than the typically used Cartesian coordinate system. The cylindrical coordinate system describes locations in degrees of clockwise rotation, radial distance form a center point and degrees above a horizontal plane.

This approach allowed the pavilion to be viewed as a whole instead of individual segments and was especially important because this allowed gravity-bearing and lateral load-bearing systems to be viewed together. The need to stiffen the ramp against deflection and stabilize the entire pavilion against seismic motion required that both load-bearing systems work together to achieve the necessary stability.

To this end, KPFF used the SAP 2000 (3-D) finite-element program which provided the project team with the ability to complete the design analysis, calculations and create visual models of the pavilion's key architectural features and structural components from any angled desired.

A bridge links the spiraling ramp and the second-floor platform near the elevators where visitors are whisked to the Space Needle's observation areas. Photo courtesy Callison Architecture/Chris Eden.

STRUCTURAL EFFICIENCY

To meet the stringent requirements associated with the Needle's landmark status, the pavilion's design called for a structure made almost entirely of glass. The landmark status allowed the design team to gain a variance to Seattle building code limits on exposed glass, permitting the pavilion walls to be nearly 100% glass, as opposed to the typical requirement of 40% or less. This required careful coordination and forethought to the structure's final design.

The pavilion's supporting elements are made of architecturally exposed structural steel, and many are specially shaped and scaled for aesthetic considerations. Every component inside and outside the pavilion is on view, from ducts to downspouts. Even the mechanical systems are in plain sight.

This aesthetic attention to detailing includes consistently aligned bolt heads in beam connections, smoothly ground exposed welds, smoothly ground full penetration welds at beam splices to eliminate splice plates and gusset plates with 90 degree edges for vertical and horizontal connections. Connection details are also designed to complement the visibility of the pavilion.

The steel framing, which carries gravity and wind loads, also pulls double duty as an aesthetic element. One-inch diameter rods are positioned diagonally for form bracing in the pavilion's roof. The rods are welded to the tops of the ramp beams and create a diaphragm for transferring lateral forces while maintaining the transparent appearance of the pavilion's roof. Because every component inside and outside the pavilion is on view, the design team collaborated with the contractor to coordinate the placement of everything from mechanical and electrical systems to ducts and downspouts.

Since the pavilion is constructed of exposed structural steel, there is no fireproofing in visual areas. KPFF used a water deluge system to achieve the fire rating. The Needle's landmark designation allowed the design team to receive this exemption from typical code requirements that would have required fire retardant material to be applied to the Needle's legs as they pass through the pavilion.

The pavilion's glass is tinted to maximize energy efficiency. The pavilion's structural elements are dark gray to distinguish them from those that are part of the original Needle construction, which are lighter in color.

SIGNIFICANT ACHIEVEMENT

Because of the transparent nature of the pavilion, the steel structure is entirely exposed. This decision imposed a great deal of discipline upon the design team, specifically in the detailing and placement of the structural steel.

Lateral loads were an important consideration in the design of the pavilion. By including Vierendeel truss moment frames in structural design, KPFF has extended the use of these frames to rounded structures with complex geometries or structures requiring lateral support without the use of view-obstructing columns.

KPFF's successful departure from the traditional Cartesian coordinate system in favor of cylindrical coordinates in the design of the pavilion provides engineers with an alternative in designing structurally or geometrically complex structures.

Use of the SAP 2000 (3-D) finite-element program enabled the design team to complete aspects of the pavilion's design in "virtual reality." This program enabled the design team to complete the design analysis, calculations and created visual models of the pavilion's key features and structural components from any angle. Due to the pavilion's complex geometry, this innovation helped resolve structural issues prior to construction.

The pavilion enhances the experience for the million of annual visitors that come to the Space Needle. In addition to providing expanded ticketing, retail and waiting areas, the aesthetic attention to detail of the structurally exposed elements both inside and outside of the pavilion provides the public a brief lesson on engineering.

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