$10M OR GREATER, BUT LESS THAN $25M

NATIONAL WINNER

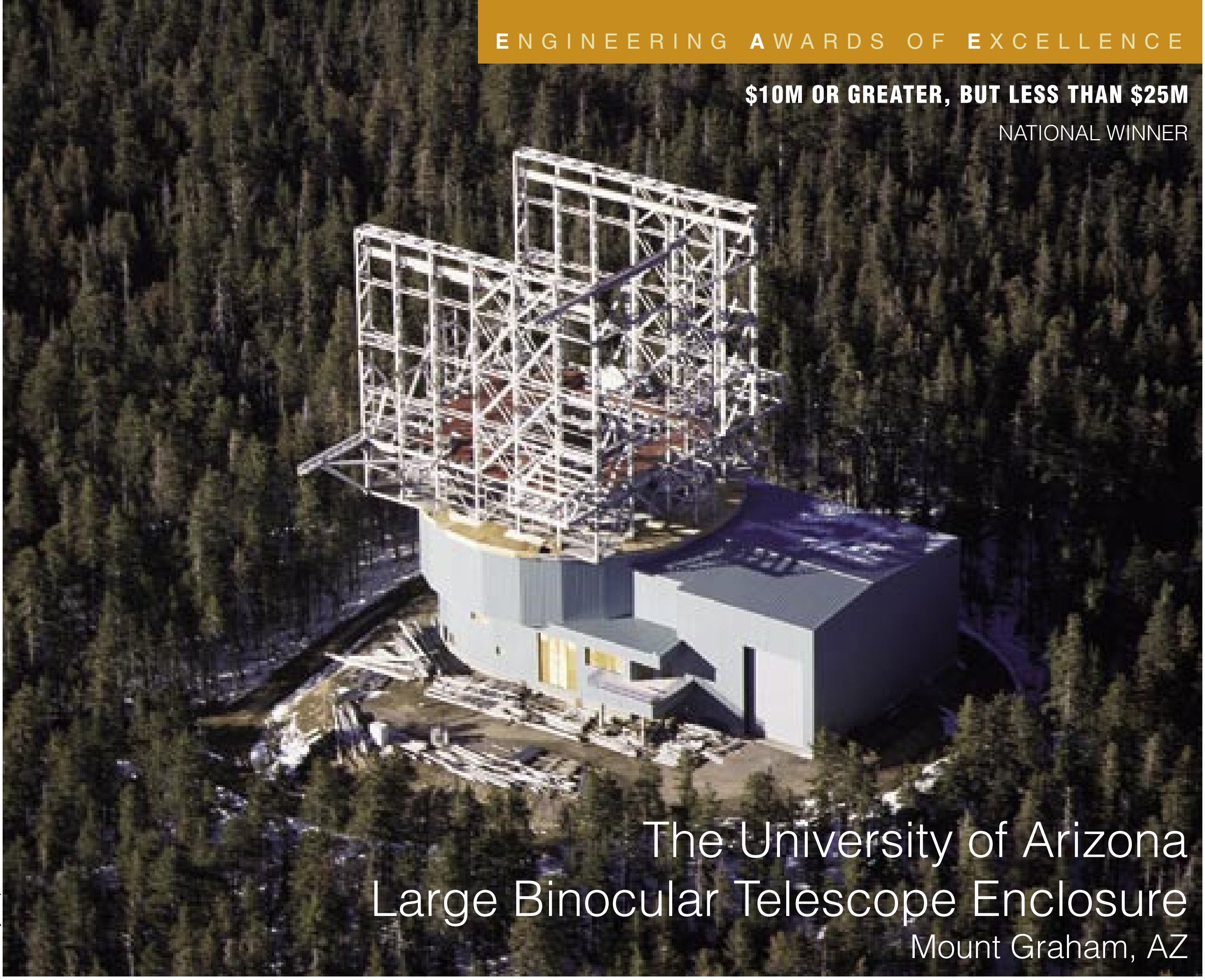

Photo by Stephen Criswell.

The University of Arizona Large Binocular Telescope Enclosure

Mount Graham, AZ

JUROR COMMENT

"A precision structure, with very tight tolerances, designed for unusual loads—movement of the structure due to environmental loads, rotation of the telescope, and thermal loads—not usually significant for structural designs."

The University of Arizona's Large Binocular Telescope (LBT), located on Mount Graham in southeastern Arizona, houses an optical telescope in the equivalent of a 12-story building that rotates on a 38'-high circular concrete wall foundation. Tolerances for design and construction varied from as coarse as 1/16" to as fine as nanometers for the optics.

In addition to the basic loading criteria, several operational elements were incorporated into the design of the rotating enclosure including: bi-parting building walls and roof to allow observation, a 55-ton overhead bridge crane, side and rear ventilation doors, a roof snow-melting system, a service elevator, and access platforms for shutters, the elevator, and a weather station.

The enclosure structure is co-rotating—it rotates with the telescope, although by separate drives. To maintain accuracy of observation, the telescope structure must be independent from the building structure. The main rotating structure is a rectangular prism, 105' by 95' by 115' high. The available site, cleared within Coronado National Forest, was limited by permit. The building footprint needed to be minimized, resulting in urban-type construction.

With an overall building height of 168' above grade, the rectangular prism structure has a system of steel beams and columns with braced frames to carry loads down to a three-dimensional steel truss system supported by four bogie drive assemblies. Some fabrication weighed as much as eight tons, while the load transmitted to the support bogies was

Structural Engineer and Architect
M3 Engineering & Technology Corporation, Tucson, AZ

Engineering Software
COSMOS/M

Owner
LBT Corporation, Tucson, AZ

Detailer, Fabricator, and Erector
Schuff Steel Company, Phoenix, AZ, AISC member

Detailing Software
AutoCAD

General Contractor
Hart Construction Management Services (HCMS), Safford, AZ

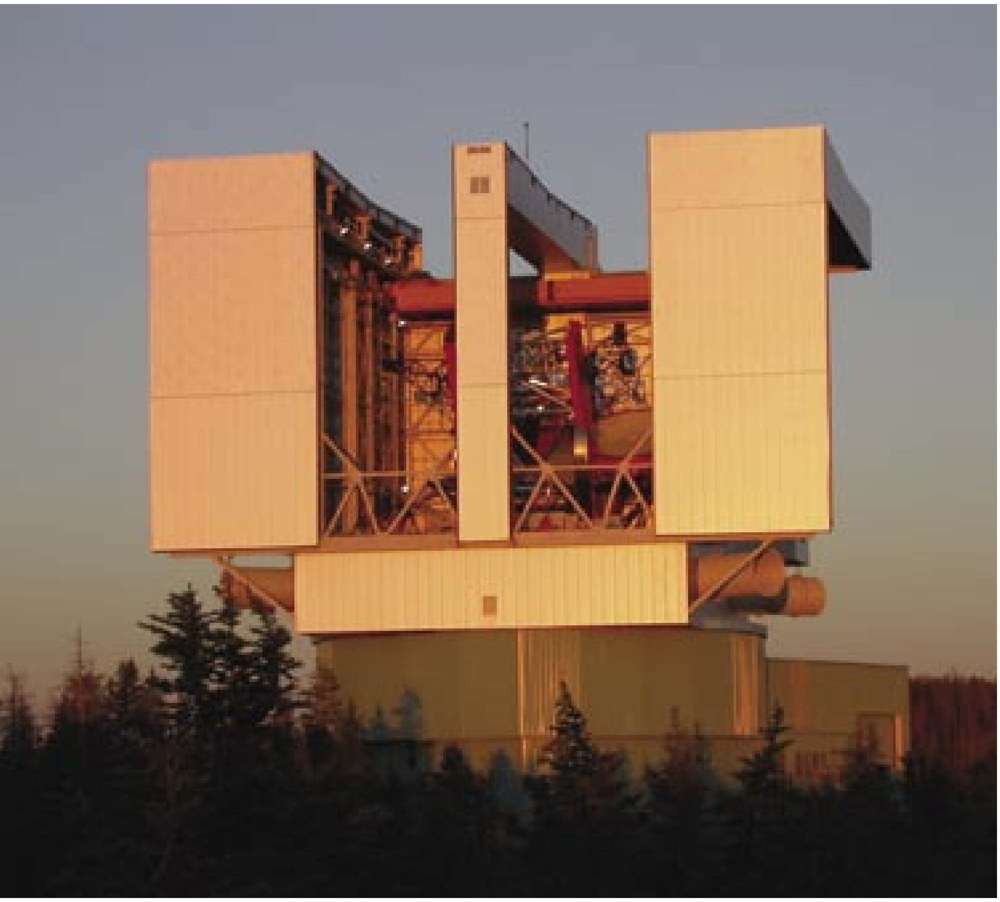

Photo by John Hill.

approximately 2,000 tons. The bogies rotate this mass at up to 2^{o} per second to maintain alignment with the telescope. Bogie assemblies are mounted on a circular steel track 38' above grade.

Displacement control of the structure for operating wind load cases was accomplished by optimal use of diagonal stiffening of the structure. Survival wind load displacements are controlled by latch mechanisms designed to tie the moving parts of the structure together to accomplish lateral stiffening and reduce displacements to acceptable levels.

The rotating enclosure structure consists of eight levels, including a bogie level, a mechanical equipment room, an observation level, a visitors' gallery level, an elevator equipment room, a crane access level, a meteorological level, and a snow-melting roof. The design criteria were as follows:

— Wind speed with telescope operational: 45 mph (shutters open)
— Wind speed with shutters open: 90 mph (telescope not in operation)
— Wind speed survival: 125 mph (shutters closed)
— Base elevation: 10,720' above sea level
— Snow load: 90 psf
— Ice load: 60 psf
— Overhead crane: 55-ton capacity
— Seismic: UBC Zone 2B

Steel framing forms a box with the observing level at the bottom, two fixed walls on the sides that carry the overhead crane runway, and a fixed wall behind the telescope that houses the elevator. The two sidewalls and a back wall incorporate horizontal rolling ventilation doors. Two 33'-wide moveable shutters, one for each of the telescope's 8.4 m primary mirrors, are "L" shaped. The vertical 93'-high leg of each shutter forms the wall in front of the telescope and the 100'-long horizontal leg forms the roof of the box.

Open configuration lattice columns and bracing with thicknesses less than 3/4" were used to minimize the thermal mass of the structure and to increase thermal response to air temperature changes.

The fourth level mechanical room is an interstitial space of the 16'-deep two-way trusses consisting of steel wide-flange chords diagonals and verticals. The interstitial space houses the mechanical and electrical support systems for the telescope.

The LBT enclosure structural design incorporated details to facilitate erection on Mount Graham at 10,720' elevation. The access road up to Mount Graham has several tight curves, limiting the maximum length of a piece to 40'.

All bolted connections were specified as slip critical due to the dynamic nature of loads on the structure. Stress reversals are common during operations. Due to the geometry of the structure, the sidewalls that support the crane rails will move laterally when the shutters are opened and closed. Also, lateral deflections due to wind will affect the operation of the crane as the crane rail supports move in and out.

In order to control the deflections within operational limits for door seals and crane operation, an exterior structural skeleton was provided to both reduce the deflections due to shutter movement and wind loads. The unique configuration of the LBT enclosure combined with the environmentally decreed tight site provided interesting challenges to the structural steel design and erection. Steel provided the flexibility and light weight required for the unique functions of the structure. ★


Photo by Christof Spieler.

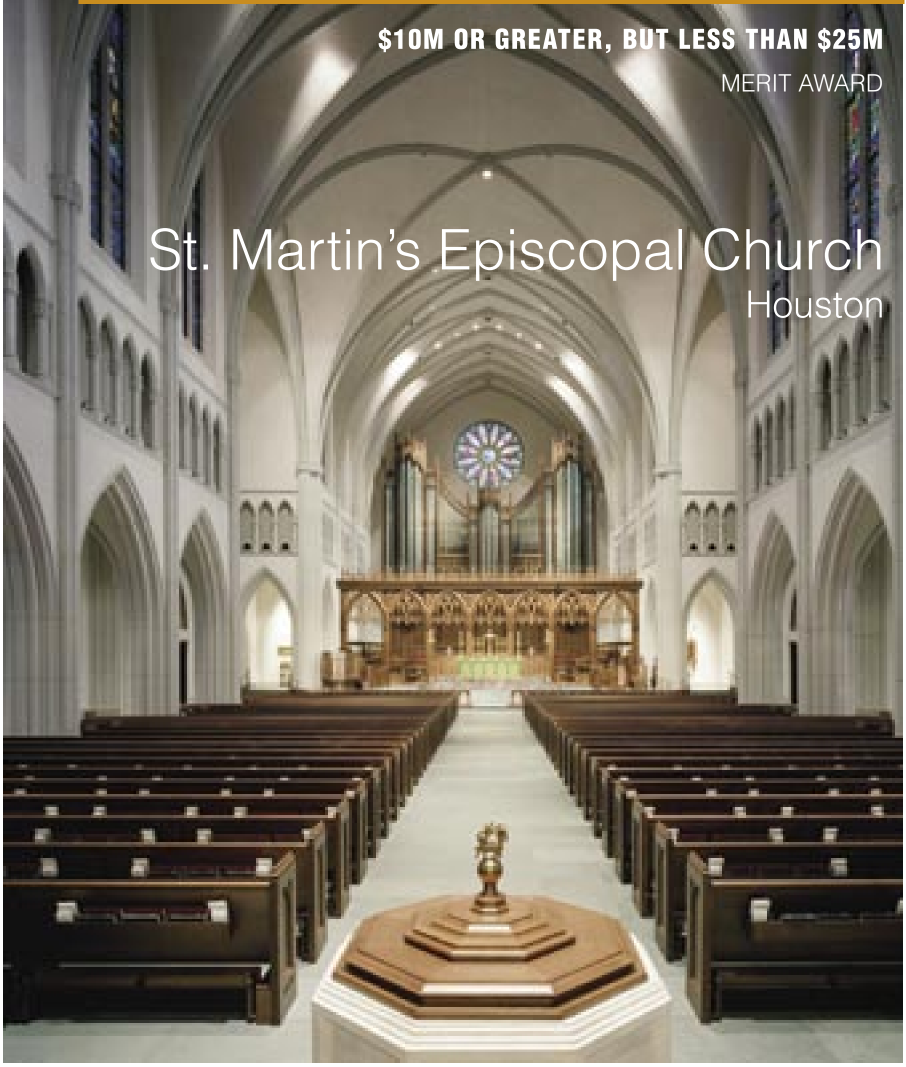
Photo by Mark Scheyer.

$10M OR GREATER, BUT LESS THAN $25M

MERIT AWARD

St. Martin's Episcopal Church

Houston

Structural Engineer
Matrix Structural Engineers, Houston

Engineering Software
RISA-3D
RAM Steel

Owner
St. Martin's Episcopal Church, Houston

Architect
Jackson & Ryan Architects, Houston

Erector
Steel Masters, Inc., Houston, SEAA member

General Contractor
Tellepsen Corporation, Houston

For the new sanctuary of St. Martin's Episcopal Church, the design team worked hard to capture the form and details of a Gothic cathedral. Beneath the structure, however, the buttresses and pointed arches are anything but traditional.

Gothic architecture was the owners' request. The design team's job was to make it work with a $20 million budget and a tight schedule. Work on design development started in December 2000 and the building had to be completed exactly four years later. The challenge was to replicate, in modern materials, the forms of an architecture based on load-bearing masonry.

Several structural systems were considered for this unconventional building. A hybrid system of steel and concrete was considered. But the final choice was what had been sketched in the first design team meeting: a series of steel frames forming the nave, spaced at 16' on center to match the architectural module, and two X-braced steel structures forming the towers.

Each steel frame, 80' wide at the base and 87' tall at the peak, carries the wind loads for a 16' strip of the façade. The main columns are W27×146. Below 32', the main columns are connected with moment connections and angle braces to the beams and columns of the aisle. Above 47', the columns are joined to the gabled roof truss, which is made up of a wide-flange top chord and double angle diagonals. Under wind loads, the main columns bend in an "S" shape due to the fixity from the aisle frames and the roof truss. No column base fixity was counted on for strength calculations. With allowance made for some fixity, lateral deflection under 110 mph winds is less than 1/300th of the height.

As soon as the steel frames were erected, it was obvious that these were the "bones" of a Gothic church. The diagonal braces of the aisle frames form the arches of the aisle ceiling, and the beams above form a classic triforium, used here for air conditioning ducts. The underside of the roof truss forms the shape of the vaulted ceiling.

Between the frames are tall stained glass windows. To meet deflection requirements, these had to be braced to the W27 columns. A steel frame around the window—fabricated to exact dimensions so the windows would fit in without blocking—is attached to steel tubes welded to the sides of the columns. Several different distributions of wind were evaluated to make sure the columns would not twist excessively under this load.

The towers posed their own problems. The steel structure extends to 108', and above this are 80'-tall pre-engineered steeples. Four W14×176 columns form the corners of the tower. Above 47', the columns are connected with double angle X-braces and ring beams. Below that, the opening for the balcony stairs and a large stained glass window eliminate both east-west X-braces in the tower. A series of girts, sloping beams, and diagonal braces concealed in the tower buttresses transfer the wind loads sideways and down to the ground.

Because the tower brick extends 128'

up and steps back often, shelf angles spaced 8’ to 15’ vertically provide for brick support. A system of tubes wraps around the towers at every shelf angle, following the shape of every buttress, pier, and wall. These are supported on outriggers off the main tower columns or on buttress beams, and are designed to take both the vertical brick load and the horizontal wind loads.

The remainder of the structural system is fairly conventional; roofs are metal deck on steel joists and floors are concrete slab on metal deck on wide-flange beams. The roofs of the aisle and nave are framed with sloping steel bar joists spaced 5’-4” on center. Deep, long-span metal deck was considered early on to eliminate the bar joists, but discussions with the construction team revealed that joists would be useful for supporting the plaster ceiling, lights, and maintenance catwalks. Point loads were specified on the construction documents and the joists were designed to allow these loads to be placed at any point along the joist.

The general contractor and key subcontractors, including the steel fabricator and erector, were brought in early in the design process. Matrix structural engineers worked directly with the steel detailer to answer questions rather than go through a formal RFI process, and shop drawings were submitted in multiple packages to allow fabrication to begin as detailing continued. The result: The building was completed on schedule and in time to install the pipe organ before the first service, Easter 2004. ★

Photo by Christof Spieler.

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MERIT AWARD

Photo courtesy KL&A, Inc.

Robert Hoag Rawlings Public Library

Pueblo, CO

Graphic courtesy Antoine Predock Architect.

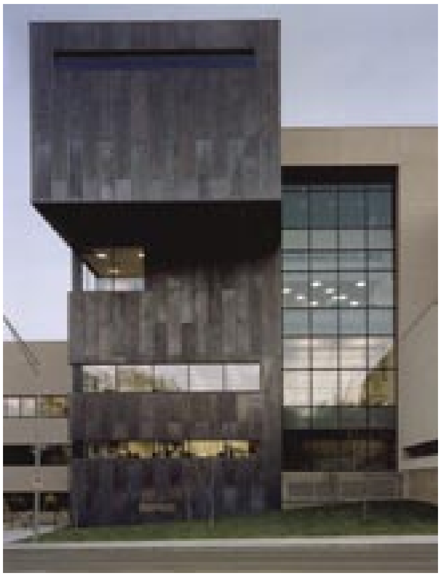

Photo by Timothy Hursley.

Pueblo's new Robert Hoag Rawlings Public Library serves as a meeting place, a gallery for art and permanent displays, and a location for special events. The 109,000 sq. ft structure uses bold architectural forms and the juxtaposition of architectural finishes—with conventional composite steel framing in most areas—to create interest and drama on a budget.

The first structural challenge was an overhead structure spanning approximately 98' and connecting two sides of the library on opposite sides of a street. This "skyway" included two levels of library stacks and administration spaces, as well as mechanical equipment behind tall, sloping parapets on the roof. The plan geometry of the skyway was trapezoidal in shape, with a glass-clad triangular hole through the middle, allowing light in and a view of traffic passing below. Four one-story tall trusses are located at the third floor level, with the second floor level suspended below. Directed spherical bearings were used to allow free movement due to rotations at the ends of the trusses and thermal movement.

The library's most prominent structural steel feature is a wedge-shaped trellis. It forms a point starting at the north side of the building that descends at 4˚ for 368', ending in a 45'-long cantilever that is only 2'-9" deep at its spring point. The trellis is made of built-up, wedge-shaped tube sections connected by channel sections and diagonal flat plate braces. At the north side of the building, the deep end of the wedge contains a gallery that cantilevers 16' beyond the face of the building. This was accomplished with a steel moment frame that allowed side windows in the gallery.

The main stair in the atrium lobby cantilevers 20' from the slab edge support. However, the landing at the end of the cantilever—typically a stiff element that resolves the forces between the structural stair runs—is 22' long. An HSS 16×16 member was used to connect the stair runs. A splice was required in this HSS member to make the stair compo-

Structural Engineer and Detailer
KL&A, Inc., Golden, CO,
NISD member

Engineering Software
AutoCAD
RISA-3D
RAM Structural System

Detailing Software
SDS/2

Owner
Pueblo City-County Library District,
Pueblo, CO

Architects
Antoine Predock Architect PC,
Albuquerque, NM (design)
Anderson Mason Dale Architects,
Denver, CO (executive)

Fabricator
Zimkor LLC, Littleton, CO,
AISC member

General Contractor
H.W. Houston Construction Co.,
Pueblo, CO

nents portable and constructible, but the architectural finishes did not allow for any plates or other protruding elements. A completely field bolted splice was devised that fit entirely within the shape of the HSS to meet these challenges.

The 54'-tall atrium glass wall was achieved with minimal structural support by providing horizontal tube-steel girts at the floor levels, with slender sag rods supporting the girts from above.

Perhaps as important as the building's structural elements was the project delivery approach, driven by the needs of the owner and contractor to meet a tight schedule. Structural engineering firm KL&A employed its own in-house steel detailing staff, using the 3D steel-detailing/modeling package SDS/2. Detailers were able to start work on the 3D model during the construction documents phase, which in turn resulted in the issue of complete shop drawings shortly after the final issue of structural construction documents, and before the final architectural package was released. ★