STEEL FRAME SUPPORTS GIANT TEXAS TELESCOPE

Structural steel maximized the strength-to-weight ratio while minimizing thermal mass

By Dwight Urrelius, P.E., André C. Nogueria, Ph.D., P.E., and Robert Fry, P.E.

THEY LIKE EVERYTHING BIG IN TEXAS-AND THEIR TELESCOPES ARE NO EXCEPTION. With a primary mirror diameter of 36', the new Hobby-Eberly Telescope (HET) atop Mt. Fowlkes in west Texas' Davis Mountains is the world's largest. The huge telescope has a huge mission: to peer into the fundamental nature and history of the universe.

But as impressive as its size is, its price is even more noteworthy. The HET cost just $13.5 million, a fraction of the cost of similarly sized instruments. For example, the 33'-diameter Keck telescope in Hawaii cost $100 million.

Much of the cost savings can be attributed to the design of the telescope itself. While most of its brethren are optical telescopes, the HET is devoted almost exclusively to spectroscopy. Rather than producing pretty pictures, it will separate the light captured from distant objects into its component wavelengths. By measuring how much light of various wavelengths and intensities an object emits over time, astronomers can gather a wide variety of information, including its chemical composition, temperature and rotation. In an innovative-and cost efficient-design, the 36' mirror is comprised of 91 hexagonal mirrors meshed together.

In addition, designers minimized costs by sacrificing the telescopes ability to track objects across the sky during observation. The mirror will be fixed at an angle of 55 degrees to the horizon and it will only be able to rotate between observations. Though the telescope will only be able to see 70% of the sky, that 70% contains most of the objects of interest to astronomers. Additionally, adding the capability to see the other 30% would have substantially increased the cost of the telescope-which would have exceeded the maximum budget set by the consortium of universities that own the scope.

Design Parameters

Despite the cost savings in the telescopes design, construction tolerances needed to be incredibly tight. The owner's program call for a number of key design elements, including:

Maximum operational wind speed	50 mph
Maximum (survival) wind speed	120 mph
Telescope design weight	60 tons
Bearing support tolerance	1/16"
Telescope Thermal Tolerance	1° C (from ambient)
Floor live load	150 psf

In addition, the design required a rain-tolerant interior.

Structural steel was chosen for the enclosure and support buildings to maximize the strength-to-weight ratio while producing a structure with low thermal mass. The latter was critical, since it was important that the structure give up its heat quickly at dusk to minimize light-wave distortion. Steel framing also had the advantage of shop fabrication with minimum field assembly effort (which was critical due to the extremely remote site), a high frequency of vibration and reduced construction costs.

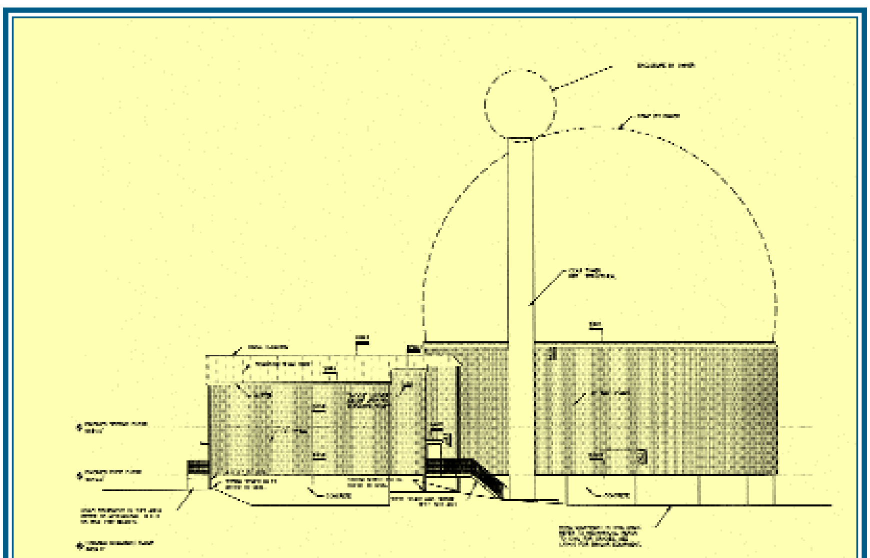
The telescope itself is housed in a steel-framed cylindrical building, topped by a rotating, 85'-diameter, aluminum geodesic dome with a retractable viewing panel. An adjacent double-walled steel pipe tower rises 105' above the foundation and supports the alignment instruments. An adjoining steel-framed support building provides space for maintenance and service equipment and the telescope control room. A round concrete basement beneath the telescope encloses the spectroscopic equipment in a rigidly controlled environment.

The 82'-diameter outer cylinder structure, which supports the geodesic dome, is comprised

Photo opposite: The Hobby-Eberly Telescope atop Mt. Fowlkes Texas' Davis Mountains

Photo top and above: The 82'-diameter outer cylinder is comprised of 16 wide-flange columns supported by four orthoganal bracing systems. The 32'-high columns are connected at their top elevation by a horizontal circular collar truss.

The primary mirror system is supported on a tube truss frame. To ensure accuracy, the frame was bolted, rather than welded, together.



of 16 wide-flanged steel columns, each 34' tall, laterally supported by four orthogonal bracing systems within the cylinder wall. The W12x72 columns are connected at their top elevation by a horizontal circular collar truss that provides a stiffening ring and support for the rotating dome. The collar truss also provides a catwalk for servicing the dome bearings. Horizontal girts welded to the columns provide a framework for support of the light-gauge steel skin.

The dome is comprised of aluminum members and skin. At the base is a large steel ring on which the dome rotates.

TELESCOPE STRUCTURE

The telescope structure is a 65'-tall bolted tubular space truss wit a 34'-square base and a 33'-hexagonal top. It consists of 8" hss and 8" to 12" wide flange flange members. It supports the primary mirror truss and the top tracker truss. It can rotate 360 degrees in azimuth using air bearings, which act on the top of a 40'-diameter, 40"-tall circular concrete wall. A laser level and steel forms made the top of the wall flat within 1⁄16th tolerance. The lowest natural frequency of this structure is greater than 6 hertz. Accuracy was critical in the design and erection of the truss. For example, each of the 390 steel nodes must be positioned within 1⁄4". To achieve that, the engineers chose a design in which the connecting struts are bolted, rather than welded. Welded joints tend to shrink, which would distort the grid. During a trial assembly, no node was off by more than 1/12th of an inch.

Adjacent to the telescope is a 105'-all Center of Curvature Alignment Sensor (CCAS) Tower, which is comprised of an outer 6'-diameter, 5⁄16"-thich, steel tube and an inner 4'-diameter, 5⁄16" steel tube. The inner tube supports the alignment sensor instrument at the top, which serves as a "target" for fine-tuning the primary mirror segments. The outer tube shields the inner tube from wind forces and supports a spherical shell enclosure at the top. Thus, the instrument is effectively isolated from and unaffected by any wind-induced oscillation.

The telescope enclosure, though, produces a funneling effect on the wind. When the wind direction is tangential with respect to the tower, it reaches an estimated velocity of 170 mph. To safely resist the stresses resulting from this load case, the outer tower tube was braced back to the adjacent cylinder structure.

The x-braced steel cylinder framework permitted simple field connections while providing maximum lateral stiffness and strength to resist the 120-mph winds known to occur at the site. The structural steel collar truss at the top of the cylinder serves multiple functions in an efficient manner: It stiffens the cylinder wall; provides a rigid and precise support for the rotating dome; provides a service catwalk; and braces the adjacent CCAS tower.

The steel-framed cylindrical wall utilizes both an insulated panel and an air space between the steel exterior and interior skins to minimize heat build-up. The thermal properties of the steel structure are aimed at maintaining a primary mirror temperature as close as possible to nighttime ambient temperature 24-hours a day to prevent light wave distortion. Thus, air conditioning and insulation are important during the daytime heat and rapid heat dissipation is important in the evening before viewing starts.

A three-dimensional mathematical model of the cylinder framework was generated during design and used to study deflections and vibrational response, as well as to optimize the structural steel. SAP90 from Computers & Structures, Inc., was used for the design.

The two-story support building uses a simple bolted structural steel frame with x-bracing in all four walls. It supports a metal skin. Again, economy, simplicity and strength drove the design of this building.

The many different specialized components comprising the total project demanded close design coordination throughout. Both the dome and the mirror support structure were contracted separately. Tolerances and other interfacing requirements were of utmost importance, so frequent coordination meetings were necessary.

The resulting structure met all of the operational goals of the owners. And it was completed on time and within budget.

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Project Team

Structural Engineer & Prime Consultant:
Datum Engineering, Inc., Austin, TX

Architect:
Jessen, Inc., Austin, TX

Fabricator:
Ironhorse Ironworks, Lorena, TX

Dome Designer/Contractor:
Temcor, Inc., Torrence, CA

Telescope Frame Designer:
University of Texas at Austin

Owners:
Pennsylvania State Univ.
Stanford University
University of Munich
University of Goettingen