Construction At Warp Speed

Boeing's new rocket booster manufacturing facility had to meet a 26-month schedule from groundbreaking to full occupancy

By Desi J. Kiss and Todd A. Hill, P.E.

It is difficult to imagine the size of the new Boeing rocket booster manufacturing facility until you stand in its enormous shell and look into the web of 220' long trusses, 85' to 100' in the air.

The Boeing Delta IV launch vehicle factory now under construction is a 1.5 million-square-foot facility. The factory is designed to manufacture the largest structural component of the Boeing Delta IV family of rockets, the common booster core. The cores are 125' in length and 16' in diameter - roughly the size of a Boeing 737 airplane fuselage. The main structure consists of approximately 20,000 tons of structural steel and 94,000 cubic yards of concrete. It is one-half mile long and one-quarter mile wide.

Design and construction of such a behemoth holds many significant challenges, perhaps the largest on this project being the schedule: 26 months from groundbreaking to full occupan-

cy. The design/fabrication/erection schedule for the structural steel was only 18 months. This demanding schedule, which began in November 1997, was driven by The Boeing Company's strategy for being the first to market in the burgeoning rocket industry with their next generation booster. In order to support the company's endeavor, the factory had to be complete on time, creating a great challenge for the design-build team.

THE PROJECT

The Delta IV complex consists of four structures located on 410 acres in the Mallard Fox Creek Industrial Park in Decatur, Alabama. The main structure is divided into 10 subordinate areas, each separated by expansion joints and utilizing different lateral systems, including braced and portal frames. Bay spacings are 35' long. Pratt truss lengths of up to 220' are used for the main roof framing system. Clear heights vary from 50' to 110' high. Jack trusses, 110' to 175' long, allow continuous column-free flow throughout the building.

In typical rectangular building construction and after the first few bays are finished, the erector gets a "feel" for the sequence and flow of erection, and the speed at which subsequent bays can be finished is increased. However, the Delta IV factory is designed around the manufacturing process of a specific product, and each area is customized to support production, leading to significant variations in bay heights and lengths. Design did not permit the factory to have 110' uniform clear height everywhere, which compromised efficiency. Therefore, the building had erection variations that posed a challenge to the erection schedule.

The factory, even though enormous, has smaller structures within it. These include:

- High-Bay Weld Mezzanine — A four-level, rigid-frame structure which is used to support

the vertical rocket for a full-height vertical weld.

- Chemical Process Tank Line — This 25' tall, 40' wide, 220' long rigid-frame structure supports chemical tanks used in the various chemical processes required to treat the metals for the rocket.
- X-ray Booths — Two 100' long by 40' tall by 40' wide structures used to inspect the welds for quality.
- Office Mezzanine Core — This three-level structure, 44' wide by 450' long, provides office areas along with a mechanical mezzanine level to support various equipment and multiple 36" diameter chilled-water pipes used to cool the entire building. This structure also provides the main lateral force resisting system for a major portion of the structure.
- Miscellaneous Paint, Insulation and Assembly Booths — Each one rivals the size of a small aircraft hangar.

The Schedule

Preliminary design started out for a building that would be constructed on a yet-to-be-determined site. The complex could be located anywhere from the hurricane coast of Florida to the expansive clay soils of Alabama to the seismic instability of Southern California. Obviously, a wide range of design issues had to be considered. With the site variable came the variation in building codes. The site was selected in time to complete the preliminary design, which was then used for an early mill order of structural steel in order to meet the aggressive schedule. Although some steel sizing was conservative due to the lack of accurate loading information, this helped to simplify connection design by minimizing stiffeners and provided structural capacity to accommodate later design revisions.

The Boeing design criteria required the factory to have the ability to expand and change. Column-free spaces were desired to alleviate problems with moving equipment and processes. A complex material handling system provides a continuous automated flow of rocket parts. A total of 33 bridge cranes, with up to 30-ton capacities and lengths of 215', were hung from the bottom of the trusses. The bottom chord of the trusses had to be designed as a continuous beam to accommodate a variety of crane rail locations. Load points were positioned to give conservative results because crane information wasn't finalized until well into the steel fabrication process. Some trusses were loaded with four different bridge cranes at one time. Computer analysis for an individual truss could require hundreds of load combinations. ENERCALC and Research Engineer's STAAD-III were the computer design programs used for this project. Portions of the project, namely the 125' tall high-bay area required three-dimensional analysis to fully determine load-path directions. Computer design, along with intuitive planning of preliminary framing systems, allowed Austin-Alberici to meet the design schedule.

The network of bridge cranes

also required stiff trusses to control deflections and vibrations. This allowed for extra capacity on the truss framing prior to the installation of the crane system. Construction platforms, built from steel joists, wood timbers, and plywood decking were hung from the crane rails. These platforms allowed the mechanical and electrical contractors to work from a surface only 7' below the bottom of the truss, rather than utilizing scaffolding or man-lifts some 65' in the air. The construction platforms also created more staging areas and open construction areas below. The crane rails were placed immediately after the erection of the trusses to facilitate early placement of the construction platforms. Crucial coordination of work on the platforms and below helped to drastically reduce the schedule and decrease cost.

Crane rail connections also created a challenge for the design team. Excessive weights due to some cranes and the construction platforms didn't allow normal "off the shelf" clamping by crane contractors. A universal connection was desired for ease of fabrication; however, roof trusses were in different stages of fabrication and erection. Other variables to be considered were crane rail connection locations, crane rail depth, and bolt patterns. The design team decided to make the vertical plates a uniform thickness and configuration, but the horizontal plate of the crane rail connection would have to vary because of the crane rail bolt configurations. Connections were welded or bolted to the roof trusses depending on where the truss was in the fabrication/erection process.

Erection practices also helped to reduce the schedule. Purlin framing was placed in 36' by 35' modules, rather than by individual pieces, to speed up erection. Modules made up of two roof joists on either side of a W-section were welded together on the ground then hoisted into place. A