Rocket Factory **Takes Off**

By Desi J. Kiss, P.E. and George L. Norville

Manufacturing operations that require overhead material handling systems are not uncommon. However, The Boeing Company, with the help of The Austin Company and Austin's consultants, has created a unique, state-of-the-industry material handling system that operates above most integrated areas in its new 1.5 million-sq.-ft. rocket manufacturing facility in Decatur, AL.

The Boeing Delta Rocket Factory, completed in late December 1999, resides on 175 acres of a 410-acre site in the Mallard Fox Creek Industrial Park and Port located one mile from the Tennessee River. The rocket factory has been designed with all of the equipment and processes matched to produce Delta launch vehicles as efficiently as possible. The river provides a major portion of the route for delivery of the 165' long, 16.7' diameter Delta IV launch vehicle from the factory to launch sites at Cape Canaveral Air Station, FL or Vandenberg Air Force Base, CA.

The Austin Company designed and engineered the facility, while construction was performed by Austin-Alberici, a joint venture between The Austin Company and J.S. Alberici Construction Company Inc.

The main structure of the $450 million complex, the rocket manufacturing facility, required 20,000 tons of structural steel and 100,000 cubic yards of concrete. The factory is one-half mile long and one-quarter mile wide.

The design of the rocket manufacturing facility began with developing a detailed understanding of the Boeing goals. At full production, the factory, designed for maximum efficiency and flexibility like the rocket itself, produces a completed rocket about every seven workdays. The facility incorporates extensive use of digital design tools and numerical machines for manufacturing accuracy, as well as a state-of-the-industry material handling system that includes 33 bridge cranes, some spanning up to 220' and some lifting up to 30 tons.

Structural Considerations

A wide range of design issues was considered in the preliminary design of the factory's material handling system and its various cargo. The rocket industry is an ever-changing field. Therefore, the factory had to be able to expand and change. A combination of steel and concrete maximized the efficiency of the main structure. Large spans up to 220' long and steel trusses with spacing at 35' center-to-center carried the structure's roof system as well as handled the loading from the material handling system. In addition, jack trusses with spans up to 175' allowed continuous overhead material handling flows throughout the building.

A bottom chord level truss-bracing system increased the stability of the roof and the truss system. Controlling deflection and vibration of the bridge crane systems was a primary concern in the design of these trusses.

The crane multi-rail runway systems, the rail networks that enable the cranes to provide the essential floor coverage in each production work center, are underhung from the bottom chord members of the building trusses. Specially designed rail-connection brackets are welded to the truss members at the bottom chord panel points, and then the rails are bolted to the connection brackets.

A one-mile-long catwalk system accesses the truss-cavity-mounted HVAC units installed on steel work platforms. The catwalk system throughout the building also provides access to platforms for servicing the various bridge crane systems.

Over 100 load cases and load combinations determined the controlling member forces. The development of the dead loads, live loads, earthquake and wind loads, snow loads, ponding loads, movable loads and impact loads is a very complex process. Evaluating crane loads was very time consuming when determining the actual force paths through the complex structure. Once the crane loads for this project were determined, the maximum loads were entered into a separate load case for each column line. Then, through a series of load combinations, the effects of the crane loads as well as the other loads were analyzed. The network of bridge cranes also required a stiff truss system to

Above:
Delta IV Rocket Factory, aerial view.
Facing Page:
18.75-ton capacity 3-rail Lowerator crane at floor-mounted monorail spurs in the skin fabrication work center (view looking south).

control deflections and vibrations. ENERCALC and Research Engineer's STAAD-III were used to design the trusses, the crane girders and crane rails.

Installation and System Operation

One of the most challenging aspects of the project included the aggressive design and installation schedule: 11 months from the conceptual crane design to complete installation. The material handling system installation began in November 1998 and was completed in late July 1999.

The crane rails were installed immediately after the erection of the building trusses. Temporary construction platforms, built from steel joists, wood and plywood decking, were underhung from the crane rails. This innovative approach allowed the mechanical and electrical contractors to work from a platform only seven feet below the bottom of the trusses rather than providing scaffolding or man-lifts some 70' in the air.

The crane rail connections created a challenge for the design team. As a consequence of the use of the work platforms described above and also the excessive weight of some cranes, the crane contractors precluded normal clamping. Also, the roof trusses were in different stages of fabrication and erection. A universal connection was desired for ease of fabrication and because of time concerns, as well as to address the variables of the crane rail connections, crane girder and rail depths and bolt patterns. The structural design team decided to make the vertical plates a uniform thickness and configuration but allowed the horizontal plate of the crane rail connection to vary due to the crane bolt connections. The connections were welded or bolted to the bottom chord member of the roof trusses, depending on where the truss was in the fabrication/erection process.

The complex material handling systems enables production personnel to generate continuous automated and semi-automated production flows. In order to meet the production goal of 40 rockets per year, the necessary rocket parts that make up each complete rocket must flow on preset schedules . The cranes assist in the sequencing of sufficient quantities of the parts through the various production, inspection, testing and assembly processes to meet the plant's design objective. Several cranes have two hoist-carriers and hoists, which can provide a synchronous dual-hoist lifting capability. These multi-hoist cranes incorporate load summation devices to prevent overloading of the bridges as well as the building's structure.

Each major work center in the facility has its own appropriately


Crane multirail runway system installation.

sized cranes and runway systems. The major crane systems are the skin and ring material delivery system (SRMDS), the chemical processing tank line (CPTL) system and the skin/ring/dome (SRD) delivery system. The SRMDS delivers raw materials to the skin fabrication milling work center and the ring fabrication milling work center. After machining is completed on the parts, the SRD System transports milled "skins" to the skin press brake work center and machined rings are delivered to the chemical process tank line work center. After chemical processing, the parts, underhung on load bars, are processed through several inspection and treatment work centers with travel, dispatching and transferring provided by the SRD System. The approved parts are then transported to the weld centers for the fabrication of the rocket's cylindrical propellant tank sections and the placement and welding of the domes to those cylinders.

The final assembly takes place in the integrated assembly and check out (IACO) work center, where all the major Delta IV components, including the rocket engine, are connected in line with the fuel tanks. The final assembly crane system provides for movement of the main rocket sections to support the final assembly, checkout and testing of the assembled rocket. Each of the two 30-ton-capacity bridge cranes contains two carriers that can be controlled from one radio-control transmitter to make lifts of parts or subassemblies with one or two hoists. Both cranes and carriers can also be operated simultaneously from a single transmitter, with all motions synchronized as to speed. The synchronized crane controls ensure that the crane travel and hoist drives operate together.

After final assembly and check out, the cranes placed the completed rocket onto the KAMAG transport vehicle. This specially designed, 175' long multi-axle carrier transports the rocket from the focused factory to the loading dock on the Tennessee River. The KAMAG with rocket onboard is driven onto the specially designed seagoing ship for movement to the rocket launch site.

Project Team

The Austin Company supplied design services and led the detailed design effort for the entire structure, as well as the design coordination of the material handling system and the review of the cranes and monorails steel shop drawings.

The structure's truss system, the catwalk access system and the universal crane girder connections were fabricated by the tri-venture team including Havens Steel of Kansas City and Hillsdale Fabricators of St. Louis. The erection team included Hillsdale Fabricators.

Four contractors were involved in the construction of the material handling system. CNA Consulting and Engineering of Bellevue, WA helped integrate the manufacturing process with the material handling system and building design. T/C American Monorail Inc. of Hamel, MN, General Conveyor Inc. of Corona, CA and CTI Systems S.A. of Luxembourg (Europe) provided the system and oversaw its installation.

The 20th century has seen extraordinary strides in building materials, design concepts and methods, and construction practices. The challenge of the new century will be the in-depth coordination and enhanced communication among the many members of a project team for cutting-edge time management. Communications on this project were greatly enhanced by the use of an extranet and e-mail. The design-build team managed to finish the installation of the material handling system on schedule, within the project budget and with an excellent quality and safety record.

The Austin Company's Desi J. Kiss, P.E., served as a Supervisory/Lead Structural Engineer on the Delta IV Project. Austin's George L. Norville served as the project's Material Handling System Coordinator.

Owner: The Boeing Company

Structural Engineer: The Austin Company

Steel Fabrication: Havens Steel and Hillsdale Fabricators

Steel Erection: Hillsdale Fabricators

Construction: CAN Consulting and Engineering, T/C American Monorail Inc., General Conveyor Inc., and CTI Systems