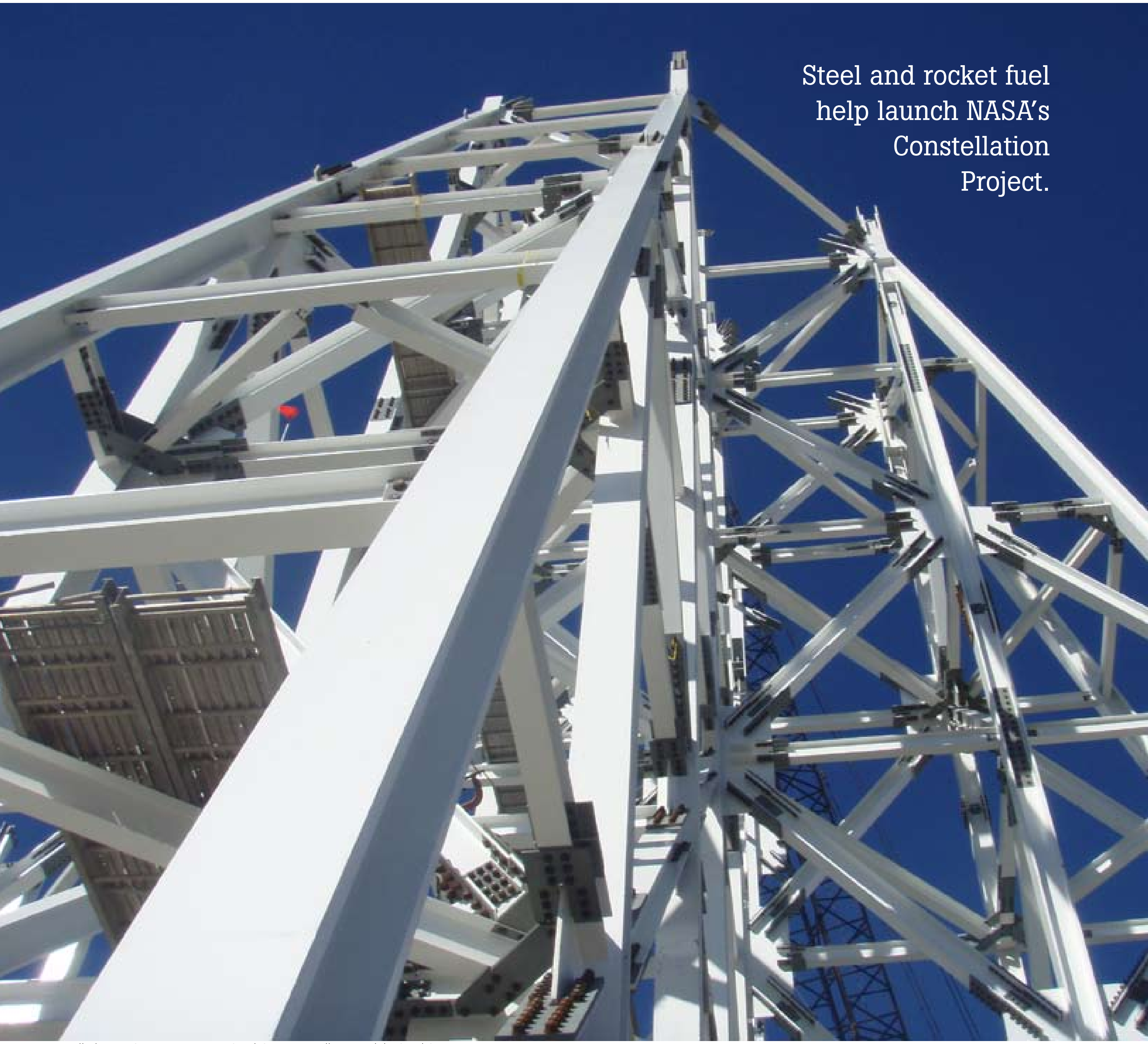
To Infinity



All photos: Courtesy Prospect Steel Company; All 3D models: Steel Systems Engineering

and Beyond!

BY GEOFF WEISENBERGER

IN MANY WAYS, THE A-3 TEST STAND at Stennis Space Center in western Mississippi is a structural engineer's dream project. It's big, it's functional, it puts all of the structural steel in plain view, and it's relatively isolated and doesn't have to complete visually with other structures.

And, for goodness sake, it involves space rockets! Once it becomes operational in May of 2011, the 235-ft-tall stand will be used to test NASA's newest rocket engine, the J-2X, which will power NASA's Constellation spacecraft, the Ares I, on manned missions to the moon, Mars, and possibly even other planets. The purpose of the test stand is to simulate a zero-gravity environment for up to 550 seconds, as the rocket will need to be able to fire in outer space, 100,000 ft above the earth. No other current test stand can replicate this atmosphere for this duration.

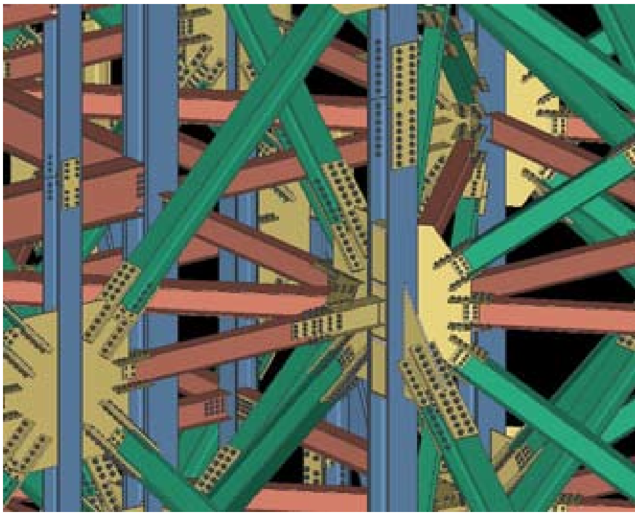
Nothing but Steel

Besides involving rocket science (literally), the tower is also complex from a design—and visual—standpoint. The dense, open-to-view structure features wide-flange beams, painted white, jutting out in all directions and dimensions, without visual hindrances such as walls, windows, and facades. The structure is reminiscent of an old-fashioned wooden roller coaster, except much taller and certainly not as rickety. There's so much steel that it takes the eyes and brain a few seconds to take it all in.

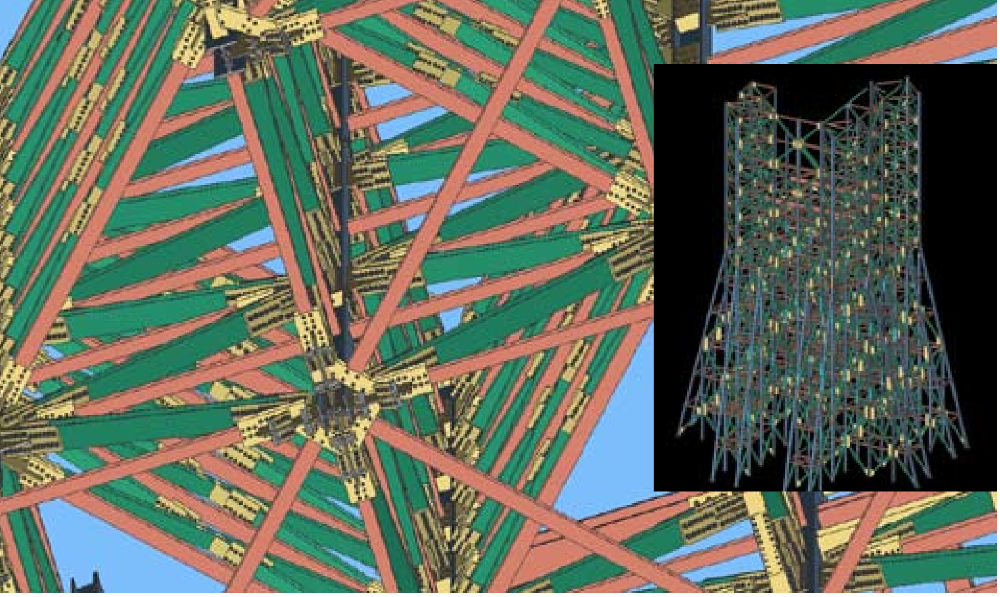
"During erection, we kept calling it the bird test," said Mark McCrindle, project manager with Prospect Steel Company, the project's steel fabricator. "The open structure had so many members projecting out from the central work points—but still, no bird would be able to fly straight through it."

"Some evenings, if you stand in the right position and look at it, you can't even see the sky through it," said Mike Rourke, project/safety manager with the project's erector, Lafayette Steel Erector, Inc.

Perhaps the biggest challenge of the A-3 stand from a design standpoint wasn't that it will be used to test rocket engines; it was that rocket test stands aren't exactly typical projects. In fact, a major test stand hadn't been built at Stennis since the 1960s, so it wasn't as though there were plenty of case studies to learn from. And while there are other test stands that have been built with steel, none of them are nearly as large as the A-3 stand.



Multiple steel members project from several "starburst" points throughout the project, as illustrated by the real thing and a 3D model.



The framing of the A-3 Test Stand was so complex that from some angles, the viewer can't see all the way through it.

"All of the technology is long-since gone for this type of project," said Dick Davis, construction project manager with JACOBS, the structural engineer for the project. "We had to start from scratch and create this design from the ground up. The project wasn't so much design-build as it was 'design-as-you-go.'"

"We haven't done anything like this, so we had to make a lot of assumptions, think ahead, and anticipate," agreed the project's lead structural engineer, David Edgar, also with JACOBS.

Stripped Down

As aesthetics weren't driving force behind the design, there was no back and forth with an architect and no worrying about the building fitting in with its surroundings. Besides trees as far as the eye can see, the stand's only real structural competition was three other rocket test stands at the facility, all of them relatively far away. This isolation was a mixed blessing. On one hand, steel had to travel from Prospect Steel's fabrication facility in Little Rock, Ark. to the job site near Gulfport, Miss.—but on the other hand, lay-down area was plentiful. Even so, the work was sequenced very carefully; the material was laid down in phases, as the crane constantatly rotated around the four "quadrants" that make up the structure.

The designers were also presented with a project that wouldn't need to accommodate typical buildings systems. While special piping and equipment for the testing is incorporated into the project, the middle of the tower was left open to accommodate these items. Even so, the design team created a 3D model, using STAAD, and integrated this structural model with a model of the piping/exhaust system, designed by Oak Ridge National Laboratory via PlantWorks (an add-in to SolidWorks 3D design software). The stand will also support fuel tanks on top (103 ft tall), the pad/deck at the top, a lightning mast, and eight different levels of platforms, as well as two stairwells and an elevator. The entire assembly sits atop a massive concrete deck, supported by 300 pilings that go down 100 ft into the sand.

The overall goal was to get the structure as rigid as possible while using as little steel as possible. And given its large size, the project does use what would appear to be a relatively small amount of steel: 3,100 tons. There were 2,161 members in all, not including plates. Again, the stand doesn't need to support the weight of decking, building systems, cladding, or architectural elements. But it does need to be able to withstand up to one million lb of thrust. In addition, the structural integrity of the stand has to meet stringent deflection requirements; only ¼ in. lateral deflection is allowed at 300,000 lb. And since it's smack-dab in the middle of hurricane country, the tower was designed to withstand winds up to 150 mph.

While the A-3 Test Stand uses a relatively small amount of steel, the number of connections was a different story. Prospect Steel prepared more than 450,000 bolt holes and supplied 150,000 field bolts, the majority of which were 1¼ in. in diameter and 4½ in. long, with direct-tension indicating (DTI) washers. In addition, more than 6,000 ft of 2-in. complete joint penetration (CJP) demand-critical welds were required.

Four into One

The test stand is basically laid out in four quadrants. In theory, if you look at the tower from above, it would appear as four Ls with the corners all pointing toward the center. The tower was erected in 16 sequences in all: four vertical stages for each of the four quadrants. Each vertical stage/tier was approximately 70 ft in elevation, and 47% of the steel is contained in the first vertical stage.

The skeletal nature of the project made for a unique erection challenge. As there is no decking, the ironworkers didn't have platforms from which to work (although some temporary walkways were employed). The "floors" (in this case, the vertical spacing between horizontal members) are 20 ft apart, except toward the top, where the gap narrows to 15 vertical ft. In addition, the column splices were 10 ft above each level, so Lafayette Steel was faced with finding a way to get their workers high enough to make the connections. For the lower levels, a 120-ft man-lift sufficed. But for higher areas, Lafayette employed special "spider" harnesses—essentially, man-baskets with seats—that provided excellent mobility and reach for the workers, as well as a stable, safe position from which to work. These baskets were suspended via cranes.

Busy Junctions

The connection points, in a sense, were the stars of the show—and actually do resemble stars; in some cases, up to 16 members burst in all directions from one point. "Whenever we were done working on one point—where 16 members were framing into—a burst of "Wow!" was uttered while rotating its solid form in the model," said David Schusterman of the project's detailer, Structural Steel Engineering. "It was even more stupendous when the entire 3D model was done. However, we really appreciated it when we saw the pictures of the erection, with the cool contrast of the tower's white paint and against the clear blue sky." (The detailing was performed with SDS/2 3D modeling software.)

"We had to get inventive in terms of locating bolt holes so the erector could actually reach each bolt without interferences," said McCrindle. Given the complex geometry of the project, the chances of steel not fitting up properly in the field were great. So much steel coming from so many directions converging on one point required a very slim margin of error. But in the end, the level of actual error was even slimmer, enabling the project to be completed four months ahead of schedule.

"Less than 1% rework of all connections was performed in the field," noted Al Green, vice president of the Romulus, Mich. office of Prospect Steel. And despite the com-

The test stand used 2,161 steel members in all. This number doesn't include plates, which, as illustrated in these photos, were a crucial and significant portion of the project, given the numerous instances of several members converging on one point. The field bolt count was 150,000.

plexity of the connections, the project was fairly repeatable from an erection standpoint, resulting in only 29 erection drawings being used.

Reaching for the Stars

The steel for the stand topped out in April, and rocket testing is expected to begin in May 2011. In terms of the overall significance of the project, Lonnie Dutriex of NASA summed it up best with an anecdote from early in the project, when he was approached by a former astronaut who happened to be onsite. "When he approached us, our attitude was, 'What are you doing here? This is just a construction site,'" Dutriex recalled. "And he said, 'You guys don't have a clue what you're doing here, do you?' And we told him that we were building a rocket test stand. Then he said, 'No, you're building the first steps of man going to another planet. And one day your grandkids will be able to say that their grandpa worked on that."

When put that way, it's pretty clear that the A-3 Test Stand will be one of the most memorable projects for anyone that worked on it. MSC

Structural Engineer/Designer
JACOBS, Tullahoma, Tenn. and St. Louis

Steel Fabricator
Prospect Steel, Little Rock, Ark.
(AISC Member)

Steel Erector
Lafayette Steel Erector, Inc., Scott, La.
(AISC/SEAA Member)

Steel Detailer
Steel Systems Engineering, Inc.
Sherman Oaks, Ca. (AISC Member)

General Contractor
IKBI Incorporated, Philadelphia, Miss.

Subcontractor
Yates Construction, Biloxi, Miss.