A large photograph of the Space Shuttle Endeavour on display in a museum. The shuttle is the central focus, shown from a side-on perspective. It is white with dark blue and black thermal protection tiles. The name "Endeavour" is visible on the white section. The shuttle is mounted on a yellow transporter vehicle. In the background, a crowd of people is seen walking through the museum. A sign in the background reads "Work in Progress".

More than 1 million people visited *Endeavour* during the first four months that the retired space shuttle was on display in the temporary pavilion at the California Science Center.

MOVE

THE MOST RECENT JOURNEY of the retired space shuttle *Endeavour*, which was in October 2012, was far shorter than any of its 25 missions into earth orbit. Dubbed Mission 26, *Endeavour's* 12 mi trek from a hangar at Los Angeles International Airport (LAX) to its new home at the California Science Center was accomplished via four special transporter vehicles and one pickup truck crawling along the streets of Los Angeles and Inglewood, California. The trip was

barely a stroll in comparison with the thousands of miles the shuttle logged during each of the 4,671 times it spun around the earth. Still, from an engineering perspective, the land-based trip presented a series of challenges quite different from what the orbiter faced launching into space.

For example, regardless of the other scientific and technical hurdles involved, the space missions generally rocketed *Endeavour* into orbit through empty skies, with only clouds and the occasional, if unfortunate, bird in the way.

THE JOURNEY TO THE CALIFORNIA SCIENCE CENTER INCLUDING TREES, STREETLIGHT POLES, MEDIAN STRIP BARRIERS, CURBS, AND AT LEAST BE AVOIDED, RAISED, REMOVED, CUT THROUGH,

By contrast, the journey to the California Science Center was cluttered with obstacles, including trees, streetlight poles, telephone and utility lines, building corners, median strip barriers, curbs, and at least one fence and one bridge, and each had to be avoided, raised, removed, cut through, crossed over, or otherwise overcome between LAX and the museum. As part of the journey, some of these obstructions had to be replaced, and the streetlight poles and power and communication lines were restored within hours of their removal.

During the three-day effort, from roughly 11:30 PM on Thursday, October 11—when *Endeavour* left the LAX hanger in which it had been kept for several weeks after being flown piggyback on a special Boeing 747 from Florida—until shortly after 7:30 PM on Sunday, October 14, when it reached its new, albeit temporary, home on the grounds of the California Science Center, the shuttle traveled at an average speed of roughly 2 mph. A permanent facility to house the shuttle is still being designed.

Endeavour arrived at Los Angeles' Exposition Park, the home of the science center,

more than 15 hours behind schedule because of a series of stop-and-go maneuvers on the streets, last-minute adjustments—including additional tree trimming and the relocation of various facets of infrastructure along the route—and other factors. However, the shuttle made the trip without striking a single object along the way, not even brushing up against a tree branch, notes Frank Dominy, P.E., a senior engineer of Sarens, of Alameda, California, part of Belgium's Sarens Group.

Sarens, under the direction of Marty Fabrick at the California Science Center Foundation, was in charge of *Endeavour's* transit from LAX to the science center, during which “the logistics of moving around all of the interferences . . . was definitely the biggest challenge,” Dominy explains.

Although the science center had worked for some time to bring a retired space shuttle to its planned new aerospace wing, the saga of *Endeavour's* road trip began in earnest in April 2011, about one month before the orbiter's final flight into space. That was when the National Aeronautics and Space Administration (NASA) awarded *Endeavour* to the science center, one of just four sites in the United States to receive a retired shuttle. The shuttles *Enterprise*, *Atlantis*, and *Discovery* were awarded to respectively New York City's Intrepid Sea, Air and Space Museum (see *Civil Engineering*, December 2012, pages 16–18, 20); the Kennedy Space Center, on Florida's Merritt Island; and the Steven F. Udvar-Hazy

Center, in Chantilly, Virginia, part of the Smithsonian Institution's National Air and Space Museum.

The science center had worked on its successful application with the international engineering firm Parsons Corporation, of Pasadena, California. Charles Harrington, the firm's chairman and chief executive officer, serves on the California Science Center Foundation's board of trustees. In addition to preparing a detailed logistics plan that determined the best possible route from the airport to the museum, Parsons served as an oversight consultant to the science center throughout the project, notes Gordon Hayase, P.E., who at the time was a senior project manager for the firm. (Hayase has since left Parsons.)

Cordoba Corporation, of Los Angeles, assisted the science center in planning, engineering, and executing the transport of the shuttle.

Because the 122 ft long shuttle, which has a wingspan of 78 ft, cannot move by itself on the ground, *Endeavour* would have to be transported along whatever route was selected. The use of a large flatbed trailer was initially considered, but ultimately a series of four self-propelled modular transporters (SPMTs) was determined to be the best option, says Hayase. The SPMTs, which are multi-axle, computer-controlled vehicles designed for the transportation of massive objects, are capable of being linked together electronically so that they can operate as essentially a single vehicle. Because each pair of wheels on the SPMTs could be turned in any direction, the transporters could move forward, backward, and even sideways like a crab to avoid the thousands of potential obstacles along the route. Using them minimized the number of streetlight poles that had to be removed and the number of trees that had to be cut down, explains Hayase.

Although approximately 1,500 trees were trimmed and 400 were cut down along the route, the science center made a commitment to replace the trees that were removed with more than 1,000 new ones, most of them roughly of the same size as the trees that had been removed, and to provide a minimum of two years of maintenance for the new trees. At press time, all of the trees had been replaced in accordance with the preferences and plans of the cities of Inglewood and Los Angeles, and the science center was working with neighborhood groups to plan the locations of an additional 450 trees that are to be planted. The move team also worked to restore all of the streetlight poles and the poles supporting power lines or other utilities that were temporarily removed within eight hours of the shuttle's passage, notes Dominy.

During the move, *Endeavour* was not attached directly to the SPMTs. Instead, it was secured to a specially fabricated

To view videos of the move, visit our digital edition at www.asce.org/ce magazine, or view the app at www.asce.org/ce app.

CENTER WAS CLUTTERED WITH OBSTACLES, TELEPHONE AND UTILITY LINES, BUILDING CORNERS, ONE FENCE AND ONE BRIDGE, AND EACH HAD TO BE CROSSED OVER, OR OTHERWISE OVERCOME.



frame called the Overland Transporter, which NASA developed decades ago to help transport the shuttles over roads. The frame used the same forward and aft connection points on the shuttle's hull that were used to attach the space vehicle to the modified 747 for transport flights and to attach the external fuel tank prior to a space launch. Ironically, since *Endeavour* was the last of the shuttles to be constructed and by then NASA had stopped using the Overland Transporter, this was the first time that *Endeavour* was carried on the frame, which had essentially been in storage.

The frame itself was bolted to the four SPMTs via a grillage of steel beams, explains Dominy. The remotely controlled SPMTs, directed by an operator walking alongside them, featured hydraulic lifts that could raise and lower the shuttle and the frame over certain obstacles. They also had the capability of operating in either a narrow or a wide configuration, the horizontal clearances varying between 19 and 27 ft. In this way they could straddle such obstacles as a median strip in the road, adds Joe Baddour, a Sarens engineer.

The basic path through the streets of Los Angeles and Inglewood was determined by a process of elimination over a period of roughly six weeks as various teams examined Internet resources and physically drove back and forth along each possible route, documenting the locations of potential overhead or side obstructions, notes Hayase. Two of the most significant

At Los Angeles International Airport, a pair of cranes lowered *Endeavour* onto the Overland Transporter frame, which was already attached to the self-propelled modular transporters that carried the orbiter to its new home.

challenges involved the shuttle's long wingspan and the height of its tail fin. Once the orbiter was lifted off of the 747 via cranes and placed atop the Overland Transporter and the SPMTs, which had already been bolted to the transporter in preparation for the shuttle's arrival at LAX, the fin reached a height of 58 ft above grade, notes Dominy. This height made it impossible to take the shuttle over the Los Angeles freeway system

because the overpasses were too low, Hayase adds.

Eventually, a twisting, turning route between the airport and the museum was selected that followed major streets and avoided all but one bridge, a concrete span on Los Angeles's Manchester Boulevard that crosses Interstate 405 near LAX. The maneuverability of the SPMTs meant that the various turns did not pose much of a problem. Even where multiple obstacles, for example, both a tree and a utility pole, were encountered, it was possible to "duck one wing under [one obstacle] at an angle and then get the other wing past the other obstruction," notes Baddour. Prior to the move, Sarens also sent teams on foot and in vehicles along the route, and the team members used laser range finders and surveying equipment to take as many measurements as possible to verify the exact locations of trees, poles, and other possible obstructions, explain Dominy and Baddour.

Parsons also performed a structural analysis of the Manchester Boulevard bridge, determining that the overpass

TO PROTECT THE MOST VULNERABLE UNDERGROUND INFRASTRUCTURE, SPECIAL PLATES WERE INSTALLED AT CRITICAL LOCATIONS BOTH AT LAX AND ALONG THE CITY STREETS.

could bear the weight of the shuttle and its support and transport systems, a total of roughly 400,000 lb.

That weight, however, could have damaged the underground utilities at LAX, as well as the roads in Los Angeles and Inglewood and those cities' underground sewers, storm drains, and buried utilities along the route, many of which dated to the 1920s and 1930s. To prevent such damage, three firms worked to determine the potential risks and to design the necessary protection. Plump Engineering, Inc., of Anaheim, California, and Giles Engineering Associates, Inc., of Waukesha, Wisconsin, and Orange, California, examined the LAX portion of the route, while Plump Engineering and Encon Construction Services, Inc., of Anaheim, California, were responsible for the urban street sections.

In particular, Plump Engineering developed road closure phasing plans and also hired Giles Engineering for geotechnical services to analyze a road at LAX on which the shuttle would be transported adjacent to a runway. Plump Engineering also coordinated and interpreted the geotechnical report and worked with Sarens and LAX to determine which locations along the road would have to be protected.

Giles Engineering also verified earlier work performed by Twining, Inc., of Long Beach, California, explains Terry Giles, P.E., G.E., D.GE, F.ASCE, the president and chief executive officer of Giles Engineering. Using such tools and tests as ground-penetrating radar, hand-operated auger boring equipment, a falling-weight deflectometer, and a dynamic cone penetrometer, Giles Engineering carefully studied the paved and unpaved sections of a service road that led from a taxiway outside of *Endeavour's* hangar to a gate on the airport's perimeter. The taxiway itself was not of particular concern, as a large jet aircraft can weigh much more than the shuttle and its transport vehicles. But the road out of the airport was fairly narrow, notes Giles, which meant that at times the

shuttle's transport vehicles were going to extend beyond the road surface, raising the possibility of damage to the underground utilities or to the pavement. It was also possible that the wheels of the transport vehicles would sink into the soil.

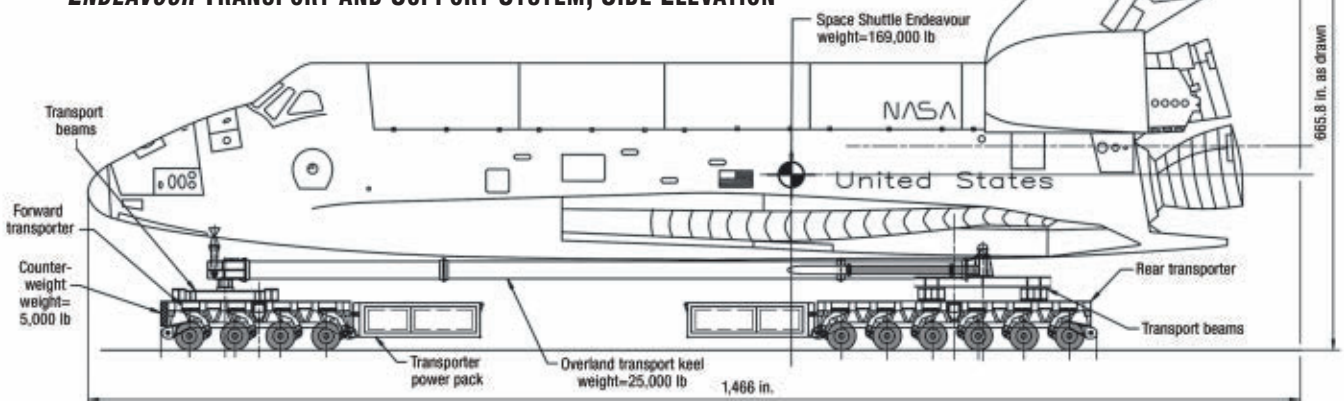
Although some of the streets in the Los Angeles and Inglewood portions of the route were wide enough for the shuttle to move from side to side to dodge the trees and other obstacles, *Endeavour's* long wingspan meant that the shuttle had to remain as close as possible to the centerline of most of the roads. Furthermore, since the pipes and other underground infrastructure ran both perpendicular and parallel to the city streets, it was not possible for the shuttle's transport vehicles to avoid crossing many of these underground systems, explains Richard Plump, P.E., M.ASCE, the president of Plump Engineering. And given the fact that many of the older pipes were made of clay or unreinforced concrete, they were highly vulnerable to cracking, being crushed, or otherwise suffering a complete failure as the shuttle rolled above them.

Using city maps and computer graphics systems, as well as survey teams in the field, Plump Engineering determined the exact locations of the pipes and other vulnerable underground infrastructure. These locations were then marked on the road surfaces or sidewalks with spray paint. The teams also determined the type of pipes that were involved and the depth of the soil. Plump Engineering then mathematically analyzed the potential loads, creating graphic cross-sectional views that made it possible to determine which pipes might be overstressed as the shuttle passed.

To protect the most vulnerable underground infrastructure, special plates were installed at critical locations both at LAX and along the city streets to distribute the weight of the shuttle and its transport system. The systems at LAX included both

SARENS

ENDEAVOUR TRANSPORT AND SUPPORT SYSTEM, SIDE ELEVATION





**ENDEAVOUR
ROUTE MAP** 

steel plates placed directly above vulnerable utilities and flexible plates made from a high-performance thermoplastic material. The latter were used at unpaved locations of the road and where the road turns were particularly sharp, notes Giles. Some 200 steel plates were also used at the end of the taxiway to ensure that no problems occurred there.

Approximately 2,700 steel plates, each measuring roughly 8 by 10 ft in plan and about 1 in. thick, were also installed at 21 separate locations along the streets of Los Angeles and at 4 locations on Inglewood streets, explains Michael Volchok, Encon's president. Normally used to cover trench excavations, these plates were configured to ensure that the covered sections of the roadway would be at least 30 ft wide so that there would be ample room on the outer sides of the SPMTs. The sections requiring plates varied in length from just 24 ft to several hundred feet. So many plates were required, in fact, that the *Endeavour* team had to borrow steel plates from as far away as Nevada and Arizona, Volchok adds. Each plated location represented a "stress point," meaning that a pipe or other facet of infrastructure was buried less than 10 ft below grade, notes Plump. In one part of the route, an 8 in. diameter sewer line and all of its connecting lateral pipes along a roughly 700 ft long stretch were located just 5 ft beneath the road, so the entire length had to be covered with plates.

Yet even with all of the borrowed plates, there were locations along the route that required unique configurations, which in turn meant some "juggling" of plates, notes Volchok. So as the SPMTs supporting the aft end of the shuttle passed over certain plates, those plates were separated from the

rest and rushed forward to an area in front of the shuttle that had not yet been plated, explains Volchok.

But in many cases moving the plates did not mean simply picking them up. When the plates were installed, as much as a week or more before the *Endeavour* move, they were just set down atop the asphalt, says Volchok. But as the regular traffic on those streets rolled over them, the plates began to shift. To prevent this, the plates were welded together. However, this meant that when it was time to take them forward after the slow-moving *Endeavour* had passed, the plates first had to be cut apart by laser, he explains.

Other challenges along the route included a gate in the fence that surrounds LAX. Although the logistics plan devised by Parsons recommended avoiding the gate and cutting through the fence, the science center staff considered various methods of moving *Endeavour* through the gate. Eventually, however, the idea of simply bypassing the gate, cutting a hole by torch in the fence, and demolishing the fence's concrete base was accepted, says Hayase. Both the fence and the concrete base were later restored, he adds.

Another fence, this one along the route, also had to be temporarily removed, along with the plants around it, so that *Endeavour* could make a particular turn, says Plump. A roughly 80 ft long section of a concrete median barrier, or K rail, had to be cut out and later reconstructed so that *Endeavour* could pass through, says Volchok. To form temporary ramps that would help the shuttle roll over curbs, use was made of stacks of plywood or about 6 in. of compacted clay and gravel material of the type normally used as the base

in new asphalt roads. In one case a median barrier was demolished and a temporary ramp roughly 60 ft long that was topped by steel plates was installed to accommodate an approximately 1 ft change in elevation between the southbound and northbound sides of a road, notes Volchok.

Despite the careful planning that went into the move, the teams walking or driving slowly along with the shuttle as it moved down the streets had to make numerous last-minute adjustments, says Plump. He personally drove ahead of the shuttle in a van, stopping to carefully observe the steel plates as the shuttle and transporters rolled over them “to make sure they were tracking in the right position on the plates and to check to see if the plates were bending.” Fortunately, the stiffness of the plates held up, and the allowable deflection of $\frac{1}{8}$ in. was never exceeded, Plump adds.

Other tweaks along the route included additional trimming of the branches of various trees as the shuttle approached and the temporary removal of streetlight poles and poles supporting power lines. Even then, the SPMTs had to “sort of wobble the shuttle down the road,” Plump says, “rotating the shuttle back and forth to miss the poles that remained.”

As an additional challenge, nearly every aspect of the move, every inch of the way from LAX to the science center, was scrutinized by the media and the roughly 1.5 million people who lined the streets to watch *Endeavour* pass by. Shell Amega, the vice president of communications for the California Science Center Foundation, served as director of media relations for the project. Under Amega’s direction, Omar Merheb, the chief transportation planner for Parsons, assisted as the project’s media liaison throughout the move, ferrying members of the media around the route in golf carts and trucks to help them safely obtain the information or images they needed while “making sure they stayed far enough ahead so the operators of the SPMTs could do their jobs,” notes Hayase.

One of the highlights of the move was the crossing of the Manchester Boulevard bridge, an event that actually became part of a television commercial. Although careful analysis had determined that the bridge itself could accommodate the overall weight of the shuttle and its transporter systems, the spacing of the axles on the four SPMTs as a combined system did not meet the weight distribution standards set by the California Department of Transportation, which has jurisdiction over the bridge, notes Dominy. Thus, a different method had to be found to transport *Endeavour* across that one segment of the trip.

First, the hydraulic jacks of the SPMTs raised the shuttle and its support frame high enough for a special transport system known as a dual-lane dolly to be positioned underneath the orbiter. The shuttle and the frame were then set down on the dolly system, which while not maneuverable enough for the entire *Endeavour* move did have a wheel arrangement that met the Department of Transportation standards, explains Dominy. Once the shuttle was securely positioned atop the dolly system, the SPMTs were lowered and taken across the bridge separately. The dolly system was then connected to a Toyota Tundra pickup truck, which towed *Endeavour* across



the roughly 0.25 mi length of the bridge, Dominy says.

The shuttle had arrived at the western edge of the bridge at about 4:30 PM on Friday, October 12, but had to remain there for nearly eight hours as power lines were shut down and moved out of the way, says Dominy. During that downtime, Toyota completed preparations to film a commercial of the half-ton pickup truck pulling the shuttle, which finally began at around midnight. The Toyota film crew had to be ready when it was time to move the shuttle, Dominy explains, “because there weren’t going to be any second takes. If they didn’t get it in the first take, they were out of luck.”

Operators walked along the route, guiding the highly maneuverable self-propelled modular transporters via remote control.



The bridge crossing, as well as the television commercial, went off without a hitch, and once *Endeavour* was on the other side of the bridge it was reconnected to the SPMTs to complete its journey to the museum. The pickup truck itself has since been donated to the science center as part of an exhibit about the science of leverage.

Endeavour reached the outskirts of Exposition Park at about 1 PM on Sunday, October 14; the major part of its journey was thus completed. However, considerable work remained. It would take another six hours to move the shuttle around and through the park, which is home not just to

the science center but also to other museums, gardens, and the Los Angeles Memorial Coliseum sports stadium. The shuttle would have to be rolled across a series of high-density polyethylene mats that were put down to protect the lawn and be moved into a large steel-frame building on the western side of the science center's facilities. That building, the Samuel Oschin Space Shuttle Endeavour Display Pavilion, was constructed on a site that will someday be part of an outdoor rain forest exhibit. For the next several years, however, it will temporarily shelter *Endeavour* while its permanent home, the Samuel Oschin Air and Space Center, is being

designed and constructed, explains Tony Budrovich, the science center's senior vice president for operations. Both facilities were funded in part by gifts from the Mr. and Mrs. Samuel Oschin Family Foundation, of Placentia, California.

The core of the roughly 17,500 sq ft temporary display pavilion is a pre-fabricated steel structure produced by Butler Manufacturing, of Kansas City, Missouri. Measuring roughly 150 ft long, 116 ft wide, and 75 ft tall at the peak of the roof, the basic building is reinforced in key locations to accommodate the project's unique requirements. In particular, its western wall could be removed entirely so that the shuttle could be brought into the building, notes Budrovich, and *Endeavour* will eventually be removed from the facility in the same way. Although the trip from LAX to the science center has frequently been described as *Endeavour*'s last journey, the orbiter will be moved again, most likely just on the roads within the park, so that it can be installed in the Samuel Oschin Air and Space Center, which is scheduled to open in 2018 on the eastern side of the science center, notes Budrovich.

The pavilion is supported by moment-resisting steel frames formed from tapered, built-up steel columns and beams located transversely, especially right at the opening in the western facade. "The lateral stability of the west wall is not dependent on the wall element itself, but just on the columns and the beams forming the moment frame," explains Atila Zekioglu, P.E., S.E., M.ASCE, a principal of the international engineering firm Arup and the buildings practice leader in the firm's Los Angeles office. Arup was responsible for the structural and seismic design, as well as for fire safety; lighting; the mechanical, electrical, and plumbing systems; and other aspects of the temporary display pavilion.

The lateral stability of the eastern wall, which cannot be removed, is provided by a series of X-shaped braces formed from steel rods that range in diameter from $\frac{3}{8}$ to $1\frac{1}{2}$ in., says Huseyin Darama, Ph.D., P.E., M.ASCE, an Arup senior engineer. The roof elements are also supported by steel purlins that are Z shaped in section.

The foundation system features drilled concrete piers 24 in. in diameter that vary in length from 12 to 20 ft, the longer piers positioned beneath the building's columns, says

Transported by self-propelled modular transporters, *Endeavour* avoided many obstacles on its 12 mi trek, in this case by straddling a concrete median strip.

Zekioglu. The piers are arranged beneath pile caps that were placed flush with the pavilion's concrete floor slab. At the eastern end of the pavilion is a 3 ft thick concrete grade beam that supports both the wall and the columns in that location.

The pavilion's floor slab provides an "ultra-flat" design with a "nice finish...some of the smoothest concrete you'll ever see," notes Budrovich. The slab is typically 6 in. thick but also features 8 in. thick sections along the travel paths of the SPMTs, which were arranged in the wide configuration at the front and the narrow configuration at the back as *Endeavour* was moved into the pavilion by Sarens personnel, says Zekioglu. To meet the specifications for the overall flatness and levelness of the pavilion slab, Morley Construction Company, of Santa Monica, California, the project's general contractor, used a system that employed lasers for the purpose of screeding, or smoothing, the concrete.



NASA/BILL INGALLS

ENDEAVOUR CAN GLIDE GENTLY BACK AND FORTH BY AS MUCH AS 24 IN. IN ANY DIRECTION DURING AN EARTHQUAKE.

When reentering the earth's atmosphere, *Endeavour* was protected by hundreds of ceramic tiles on its underside. The shuttle is elevated sufficiently above the pavilion floor for visitors to walk beneath it, but they will be discouraged from reaching up to touch the fragile tiles, notes Zekioglu. *Endeavour* is still attached to the Overland Transporter, and it will remain so until relocated to its permanent display. At present it is positioned atop a series of four seismic isolators that are fixed to the pavilion floor via 64 in. tall steel pipe support columns, says Darama. Manufactured by Earthquake Protection Systems, Inc., Vallejo, California, the multistage isolators are of the Friction Pendulum type and are 60 in. in diameter. They have been designed to enable *Endeavour* to glide gently back and forth by as much as 24 in. in any direction during an earthquake, explains Zekioglu.

Because of the proximity of the science center to several faults, the seismic system protecting *Endeavour* is designed to accommodate earthquakes ranging in magnitude from 6.5 to 8, Zekioglu notes.

The pavilion also features fabric ductwork, rather than sheet metal, for its air-handling systems so that nothing would be located "directly above the orbiter that could create a potential falling hazard," notes Zekioglu. For the same reason, the lights inside the pavilion are arranged so that the fixtures do not hang directly above the footprint of the orbiter, he adds.

The Los Angeles office of ZGF Architects LLP provided architectural services regarding the science center site and the temporary display building, and its work also included optimizing angles for viewing *Endeavour* inside the pavilion, Budrovich says.

ZGF, in collaboration with San Francisco-based EHDD, is also designing the Samuel Oschin Air and Space Center, and Arup will be responsible for the structural design. Although the plans for the final display of *Endeavour* are still being developed, the concept involves removing the orbiter from the Overland Transporter and displaying it in its upright, launch position. To complete the appearance of being poised for lift-off, *Endeavour* will also be attached to a pair of flown solid rocket boosters and a full-scale replica of its 154 ft tall main fuel tank, explains Budrovich.

Just as it took extensive cooperation by multiple companies and agencies to send *Endeavour* into space 25 times, Dominy notes that the effort to bring the shuttle to the California Science Center could not have been accomplished without "a tremendous team effort" by all of the various firms involved, as well as by the local utilities, state transportation personnel, police and fire authorities, LAX officials, city engineers, other public officials, community members, and the philanthropic community. The historical and scientific importance of the shuttle also led a number of the firms to do-

nate all or part of their services to the science center, among them Parsons, Cordoba, Sarens, Arup, ZGF, and Earthquake Protection Systems.

The temporary exhibit opened on October 30 and has proved to be popular, attracting more than 1 million visitors during *Endeavour's* first four months on display. The shuttle is not the heaviest object ever to be moved through the streets of the Los Angeles metropolitan area; a boulder that formed part of an art installation at the Los Angeles County Museum of Art weighed 340 tons (see "Project to Support Massive Artwork Boulder Will Have 'One Chance to Get It Right,'" *Civil Engineering*, March 2012, pages 28, 30-31, and *Civil Engineering*, September 2012, page 21). But if not the heaviest, for one of the Sarens engineers it was certainly the most memorable. Calling it a "once-in-a-lifetime experience," Baddour takes special pride in his involvement because of a family connection to the space program: his grandfather worked as an electrical engineer for NASA for 30 years, including the earliest days of the shuttles. "So being able to help retire one of the shuttles was a big deal for me," Baddour explains. **CE**



Robert L. Reid is the senior editor of *Civil Engineering*.

PROJECT CREDITS Client: California Science Center Foundation, Los Angeles **Shuttle transport consultant:** Cordoba Corporation, Los Angeles **Logistics and oversight consultant:** Parsons Corporation, Pasadena, California **Shuttle transport, Los Angeles International Airport to California Science Center:** Sarens, Alameda, California **Geotechnical oversight, Los Angeles International Airport:** Plump Engineering, Inc., Anaheim, California, and Giles Engineering Associates, Inc., Waukesha, Wisconsin, and Orange, California **Roadway and urban infrastructure consultants:** Plump Engineering, Inc., Anaheim, California, and Encon Construction Services, Inc., Anaheim, California **Tree removal, replanting, and maintenance:** ValleyCrest Landscape Companies, Calabasas, California **California Science Center site and temporary display building architect:** ZGF Architects LLP, Los Angeles **Temporary display building structure and shuttle display seismic design:** Arup, Los Angeles **Seismic isolators:** Earthquake Protection Systems, Inc., Vallejo, California **General contractor:** Morley Construction Company, Santa Monica, California **Temporary display building heating, ventilation, and air-conditioning systems:** DMG Corporation, Orange, California **Fire protection:** Fike Corporation, Blue Springs, Missouri, and Honeywell Fire Systems Group Services, Duluth, Georgia