A ship-in-a bottle approach is used to create the world's largest weighing lysimeter inside an existing greenhouse at Biosphere 2.

Under the DOME

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THE UNIVERSITY OF ARIZONA, in its quest to better understand the varying mechanisms at work in the natural landscape, has built one heck of a science project.

The $6.7 million Landscape Evolution Observatory (LEO) at the Biosphere 2 research facility, just north of Tucson, Ariz., is the world's largest weighing lysimeter; a lysimeter is a measuring device used to quantify the amount of water released through evapotranspiration by changes in weight (there are two types: weighing and non-weighing). LEO will study the interaction of water, temperature, soil and vegetation, amongst other environmental elements, on three full-scale hill slopes that will provide a means to quantify interactions among the different processes associated with incipient hill-slope development.

Steel was selected as the most financially and technically feasible framing option, given the structural constraints created by the existing concrete structure that forms the basement under the LEO space, as well as the need for construction flexibility; the steel framing generally uses W12×40 beams and W12×16 columns.

The three "hills" from the exterior.

The underside of the west tray, including finished steel and instrumentation ports.

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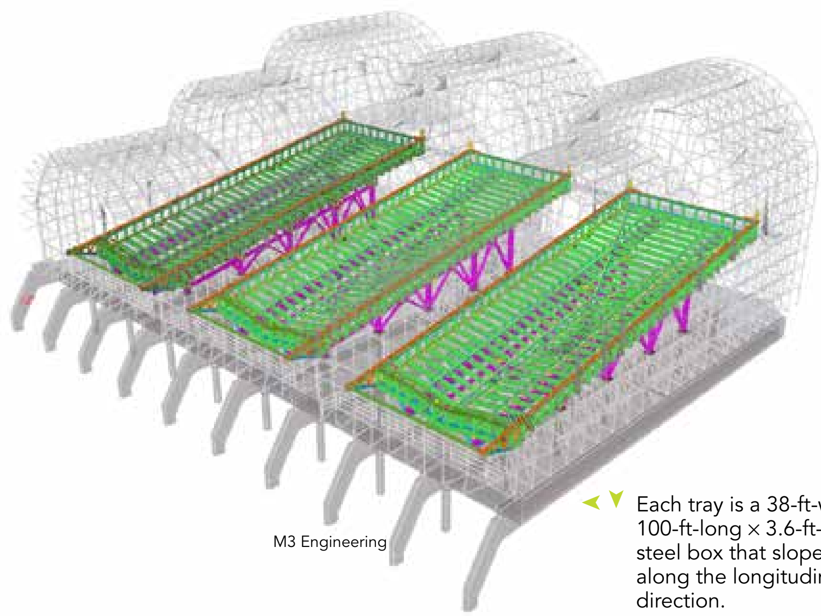

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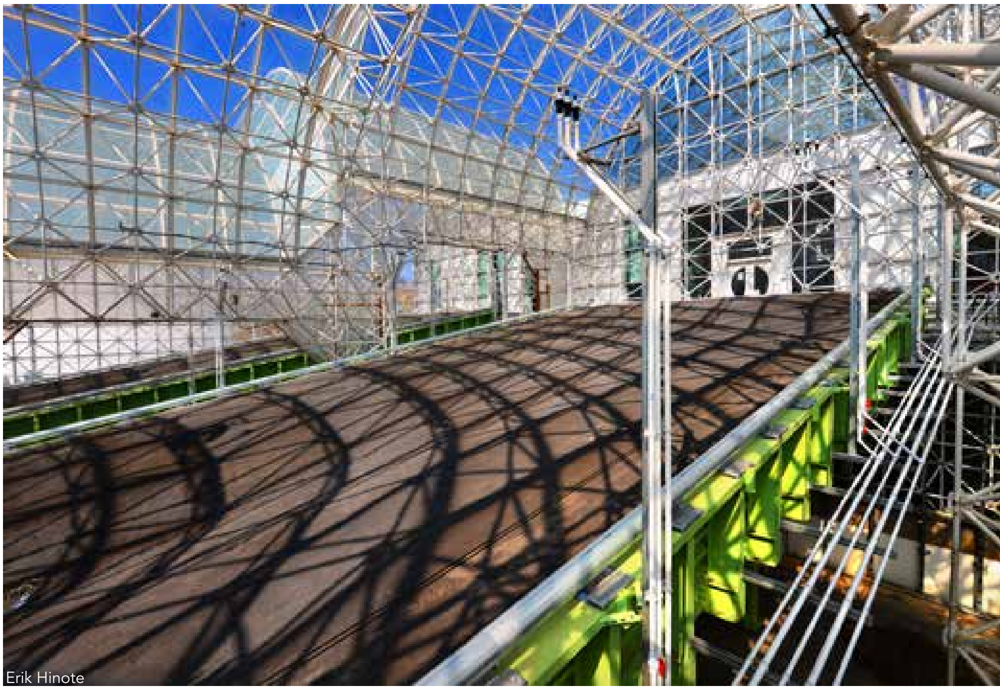
Each tray is a 38-ft-wide × 100-ft-long × 3.6-ft-deep steel box that slopes 10° along the longitudinal direction.



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Three Hills

Each of LEO's three identical hill slopes are comprised of steel planting tray structures, built inside an existing steel space-framed greenhouse that was previously used for intensive agriculture, and are anchored over an existing elevated concrete floor structure. Three components form the hill-slope steel structures:

1. The tray is a 38-ft-wide × 100-ft-long × 3.6-ft-deep steel box that's open on the top and slopes 10° along the longitudinal direction. Varying transverse slopes along the tray's length form the ridges and a valley channel that simulates a hillside landscape. To form this compound slope, the tray is built with transverse U-shaped

Steel deck attachment.

Column erection at the east tray.

frames made of wide-flange beams, spaced at 1 m (3.28 ft) on center to match the sensor grid spacing, thus resembling the ribs of a boat's hull structure. All the transverse wide-flange beams are attached to two 33-in.-deep longitudinal wide-flange girders that connect to the substructure. Each tray is clad on the bottom and all four interior vertical faces with 3-in.-deep steel type-N deck, fiber-reinforced cement board and a special waterproofing membrane, all to contain a 1-m-thick layer of finely crushed basalt, irrigation water and a complex array of more than 2,800 different sensors per hill slope.

2. The substructure is a group of 12-in.-deep wide-flange beams and double-angle steel braces that connect to 10 14-in. square hollow structural section (HSS) columns aligned directly over existing concrete columns of the basement structure. It supports the tray through ten load cells centered on the top of each HSS column.

3. The personnel transporter is a mobile steel structure, similar to a gantry crane and certified for human transportation, that traverses over each tray widthwise, traveling up and down its full length and allowing scientists to monitor the surfaces without disturbing the soil. It is composed of an HSS frame that holds a steel basket and is sustained on four rolling supports that run along two round HSS rails, one along each long side of the tray.

The load cells—which have the capacity to measure up to 165 tons with the accuracy to detect a change in water weight equivalent to a layer of 0.20 in. thick (about 2 lb/sq. ft) over the tray—are rigidly attached on their lower end to the column cap plates. They have a special self-centering pinned connection at the top, which minimizes both the overall moment transferred to the load cell as well as the size of the related connection at its base.

The original scheme of erection was to use temporary spacers in lieu of load cells until the steel structure was placed in position. However, Parsons Steel, the steel fabricator and erector, recommended continuing to these spacers until all welding was done, to avoid affecting the load cells circuitry during the construction. Furthermore, before construction started, Parsons proposed the addition of a jacking system at the top of each column to facilitate the exchange of the load cells for temporary spacers once the soil was loaded. This system was endorsed by all involved parties since, in addition to simplifying the construction, it also provided a safer way to exchange a load cell in case recalibration or maintenance is required.

Scanned In

Months before construction started, laser scanning technology was used to recreate a model of the existing building in order to accurately determine the interior dimensions of the existing building's available space. This helped enormously in finding possible clashes as well as designing such items as the personnel transporter. It also allowed the designers to maximize the use of space and reduce or eliminate costly modifications during construction. In addition, steel shop drawings were developed using Tekla Structures as part of the design documents; this saved money and time during the construction phase as detailing complexity and any clashes were solved during the design phase. The model used to generate the shop drawings was also used to quantify materials and helped Parsons understand the complex structures in a more efficient way before starting fabrication.

The space dedicated to LEO has only one direct entrance from the outside, measuring 10 ft wide by 12 ft high. As this entrance could not be widened for construction equipment without incurring major modifications to the existing dome shell, Parsons created a special transporter to insert the 280 tons of steel pieces into the LEO space. This transporter was discussed early in the process, before construction began, and allowed steel supplies to be brought into the space in a timely fashion. Field connections were predominantly bolted connections for ease of construction as well as to set a limit on the size and weight of pieces that were transported to the construction site. Furthermore, a compact crawling crane was used to lift and erect steel components of the personnel transporter in spaces as tight as 6 ft wide.

Building LEO required not only coordinating steel erection for each hill slope alone, but also inclusion of space for painters, electricians, irrigation plumbers, scientists and the contractors that brought in the special soil for each tray. Creating not just one but three "ships" inside of this large "bottle" required weekly interaction from all parties of the project team. Different construction scenarios were studied before beginning erection, and these were reevaluated as the project progressed. The hill slopes were built from east to west, with each successive one being closer to the construction entrance, increasing the level of complexity as the available space was reduced. The construction crane and other mobile equipment were successfully removed from the LEO space on time, completing a tight 16-month schedule, and the construction team managed to move in and out of a really tight space with great skill. And scientists are now working within this space to gain better insight on the outside landscape and its evolution. ■

Owner
University of Arizona, Tucson, Ariz.

Construction Manager
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Steel Fabricator and Erector
Parsons Steel Erectors, Inc.,Tucson, Ariz. (AISC Member/ AISC Certified Fabricator and Erector)

A mini-crawler crane in tight quarters, erecting the personnel transporter.


.Ruben Ruiz. Paul Ingram

A special transporter introduces steel into LEO through the only opening (10 ft wide by 12 ft tall).


.Ruben Ruiz. Paul Ingram


.Ruben Ruiz. Paul Ingram

LEO's first girder.

An installed load cell.

Girder erection.


.Ruben Ruiz. Paul Ingram


.Ruben Ruiz. Paul Ingram


.Ruben Ruiz. Paul Ingram


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A view of the east tray, showing the soil, irrigation system and personnel transporter structure in the background.