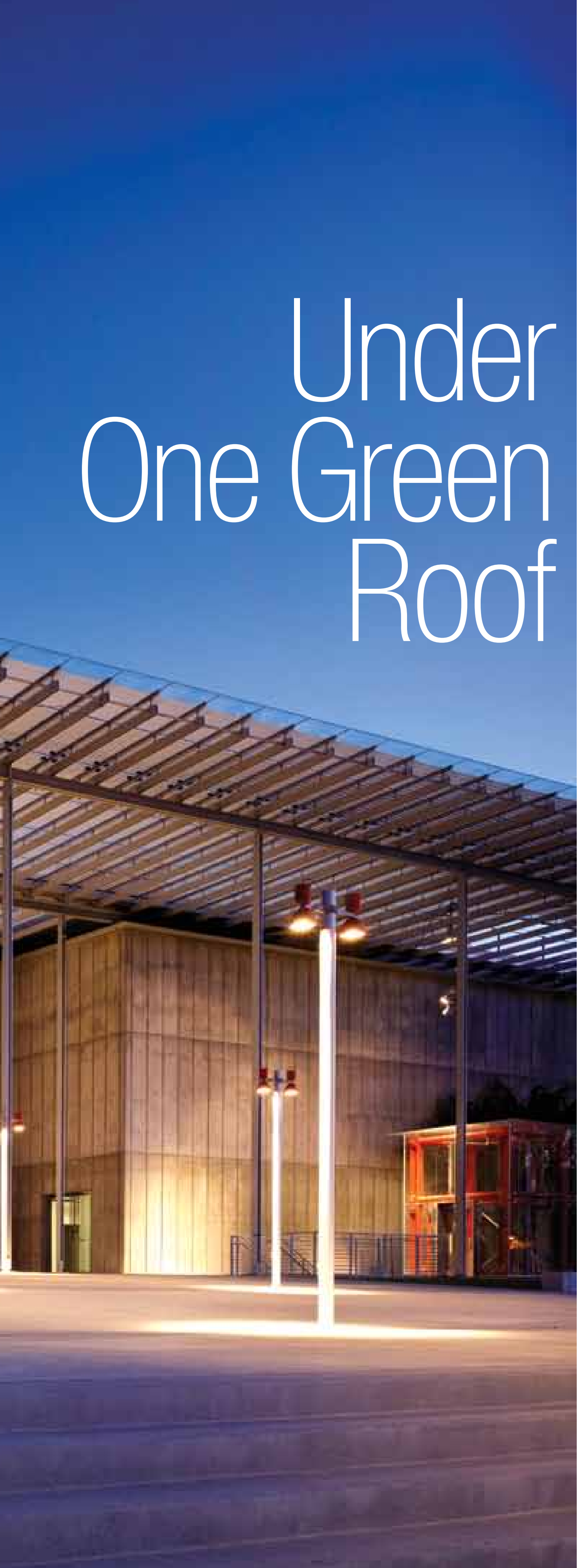
The new California Academy of Sciences building features a contoured, vegetated roof bordered by a cantilevered steel canopy of glazed panels that include more than 55,000 photovoltaic cells. The cells are designed to generate approximately 5 percent of the building's electricity needs.



TIM GRIFFITH

Under One Green Roof

The new California Academy of Sciences building, in San Francisco, has been called the greenest museum in the world because of its undulating, 2.5 acre (1 ha) vegetated roof, its emphasis on environmental sustainability, and its energy-saving technologies. The innovative structure combines a natural history museum, an aquarium, a planetarium, and scientific research operations within one facility.

By Robert L. Reid

THE DESIGN of the California Academy of Sciences' new home, which is being referred to as the greenest museum in the world because of its undulating, 2.5 acre (1 ha) vegetated roof and a variety of other environmentally benign features, began with a few sweeping sketches made in green ink. The artist was Renzo Piano, the Pritzker Architecture Prize–winning founder of Renzo Piano Building Workshop, s.r.l., based in Paris and Genoa, Italy. The year was 1999, and Piano was one of several internationally renowned architects whom the academy's board of trustees had invited to San Francisco to submit proposals for the project.

While the other designers had brought along elaborate three-dimensional models of their proposals, Piano "decided to come out a couple of days early and just sketch some ideas," explains Lawrence Chambers, P.E., an associate in the San Francisco office of the international engineering firm Arup. When the academy ultimately selected Piano's vision, Arup was chosen to turn the design architect's rolling green lines into the iconic "living" roof of the academy's new home, Chambers notes.

Arup was also responsible for the structural engineering of the building beneath the vegetated roof, as well as for the seismic and fire protection systems, the mechanical and electrical systems, the facade systems, the building's acoustics, and the numerous energy-saving features.

Stantec Architecture (formerly Chong Partners Architecture), of San Francisco, served as the local architect for the project.

The academy's $484-million building opened in late September 2008 after nine years of design and construction, and during those years the museum's exhibits were housed elsewhere around the city. In developing the structure and its various innovative features, the design team consulted with such diverse sources as roller-coaster designers and the suppliers of hospital air-handling systems.

A popular and critical success, the new museum has attracted large crowds, earned laudatory reviews, and received the highest certification possible—platinum—in the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System. At 410,000 sq ft (38,000 m²), the structure is the largest public building in the world to achieve platinum certification, and it "stands as an embodiment of the Academy's mission to explore, explain, and protect the natural world," according to a press statement that announced the structure's LEED status.

The new building replaces the original academy facility, a campus of 11 structures clustered in San Francisco's Golden Gate Park that were built between 1916 and 1976. Many of those structures had been severely damaged in the Loma Prieta earthquake, which struck in 1989; some had been closed to the public since the temblor, and it was expected that others would be closed eventually, notes Don Young, the owner of D.R.

Located in San Francisco's Golden Gate Park on the site of the academy's original campus of 11 buildings, the new structure provides more usable square footage while occupying a smaller footprint because of the inclusion of additional basement areas, a more efficient configuration of the interior space, and alterations to the driveway approaches and landscaping. The new design enabled the academy to return approximately 1 acre (0.4 ha) of land to the park.

TIM GRIFFITH

Renzo Piano's Original Sketch for the 'Living' Roof

Young Associates, of San Rafael, California, a consultancy that served as the academy's representative during the design and construction of the new building. Moreover, none of the original facility's structures met the current universal access requirements, there was no consistent basement space connecting the various parts of the museum, and other aspects of the original facility were simply aging, deteriorating, and out of date, Young adds.

Although the old academy buildings were demolished before September 2005, when ground was broken for the new structure, the replacement combines four key elements of the original facility: the Steinhart Aquarium, the Kimball Natural History Museum, the Morrison Planetarium, and the academy's research and education operations. Locating all of those venues within a single structure constituted "almost a literal depiction of what the academy is," notes Young. "The academy is the only institution in the world that houses what it does—an aquarium and a planetarium and a natural history museum and a scientific research institution, with its collection and storage—all under one roof."

At the same time, the new structure also provides the academy with more usable square footage than did the previous facility while occupying a smaller footprint in the park. It does this through the inclusion of additional basement areas, a more efficient configuration of the interior space, and alterations to the driveway approaches and landscaping. The new design was able to return approximately 1 acre (0.4 ha) of land to Golden Gate Park, an achievement in environmental stewardship that complemented the academy's mission, notes Chambers.

The design of the new building can be compared to a tabletop with four legs, albeit a tabletop that is supported on spread footings that can rock back and forth to dissipate the seismic forces in the event of a significant earthquake, explains Chambers. Such a seismic event represents a very real threat to the new structure, which is located within 10 mi (16 km) of the San Andreas Fault.

Measuring approximately 500 ft (152 m) long in the east–west direction and 300 ft (91 m) in the north–south direction, the structure consists of four separate concrete buildings, each three stories high. These so-called table legs are connected to the building's concrete roof and concrete podium and supported by the basement foundation. Oriented to the north, the glazed main entrance is flanked by two of the table leg structures: a re-creation of the old museum's African Hall to the northeast and a gift shop and café to the northwest. The other legs consist of research, collections, and administration (RC&A) space to the southeast and southwest.

Each of the table leg portions features 18 in. (457 mm) thick cast-in-place concrete shear walls that are designed to transfer lateral forces during seismic events. Similar shear walls are located in the basement space, which is two levels deep on the south side of the structure and one level deep on the north side, Chambers says. The building is supported on a shallow spread footing foundation system that ranges from square-shaped reinforced-concrete pads to support the structure's 24 by 24 ft (7 by 7 m) column grid to linear footings beneath the shear walls and mats beneath the aquarium portion's large tanks. Some of the tanks were integrated with the building's ground-level structure and thus will experience seismic-induced forces, Chambers says. The various footings for the foundation range in thickness from 1.5 to 4 ft (0.5 to 1.2 m).

> The new building replaces the original academy facility, a campus of 11 structures clustered in San Francisco's Golden Gate Park that were built between 1916 and 1976.

Although the building code in San Francisco required the use of ground anchors to protect structures of the type making up the academy's new home during seismic events, Arup successfully demonstrated through a nonlinear time history analysis that the rocking tabletop design would perform better during a seismic event than would an arrangement in which the structure was tied down with anchors. The solution resulted in savings of $1.5 million, Chambers notes.

Seven hill-like shapes rise from the contoured concrete slab that forms the museum's roof. Although the roof appears to be continuously curved, the slab is actually supported on curved steel beams in the north–south direction and faceted girders in the east–west direction, all arranged on an 8 ft (2.4 m) grid, notes Chambers. The beams typically span 48 ft (14.6 m) in the flatter portions and up to 96 ft (29 m) over the largest curves. The wide-flanged beams for the roof range from W 18 members of various capacities in the east–west orientation to W 21 members in the north–south orientation, the latter reaching W 21 × 183 for some of the largest spans adjacent to the largest curves, Chambers notes. The faceted sections feature concrete fill on metal deck over the flat portions of the roof and shotcrete up to 5 in. (127 mm) thick over the contoured portions.

Mimicking the seven hills on which San Franciscans say their city was constructed, the rooftop hills are blanketed

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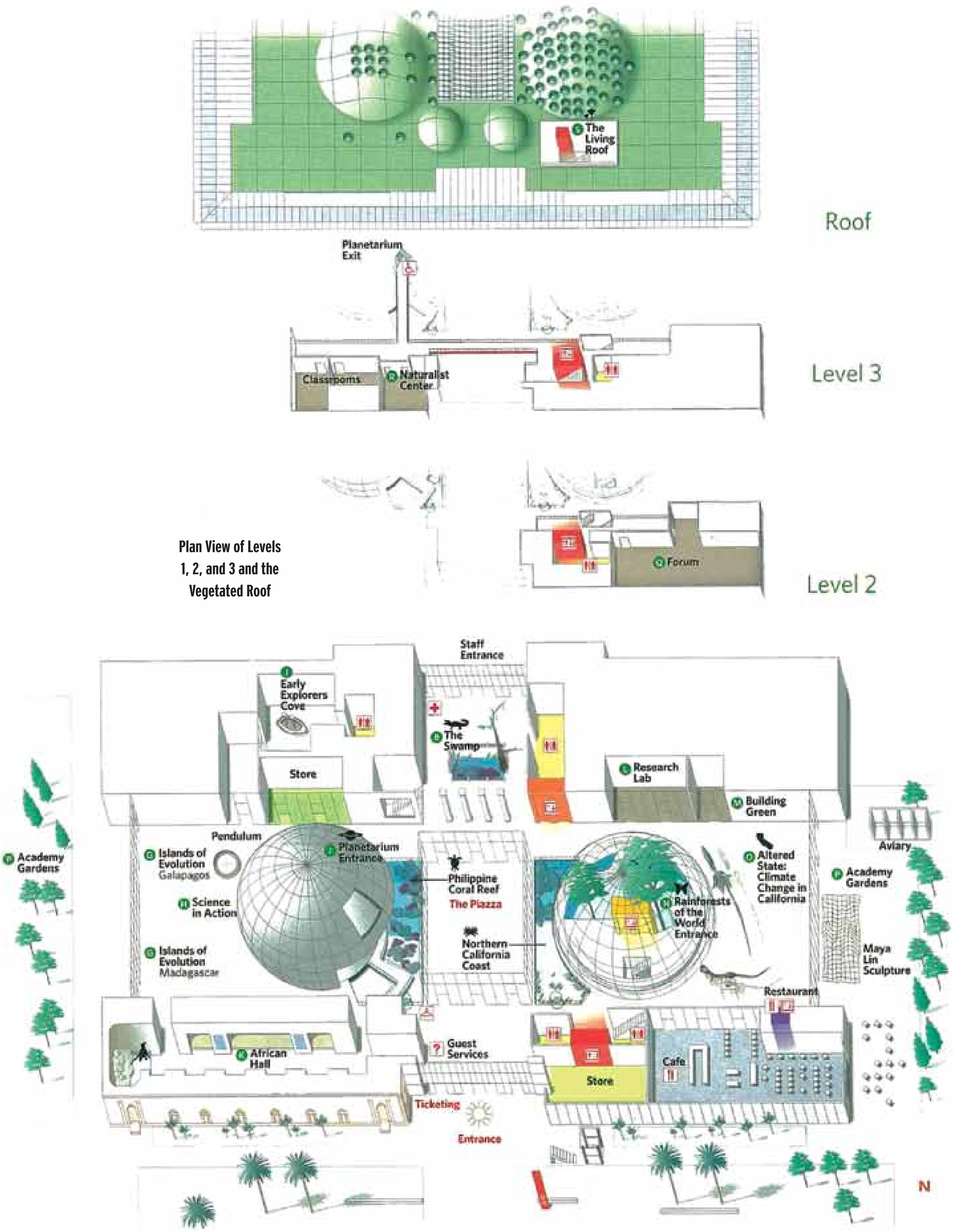

Plan View of Levels 1, 2, and 3 and the Vegetated Roof

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The rain forest exhibit features a 90 ft (27.4 m) diameter dome, or bolla, supported by steel pipe sections that form a series of meridians and parallels. Diagonal stainless steel tension rods provide the lateral bracing. The dome is situated atop an 18 in. (457 mm) wide concrete ring beam that is supported by just six concrete columns in the basement. A spiraling ramp within the dome was designed with the assistance of a firm that manufactures roller coasters.

with 50,000 biodegradable coconut husk trays containing 6 in. (152 mm) of soil to nurture 1.7 million native California plants. Together, the soil and plants, which do not require irrigation, weigh more than 2.6 million lb (1.2 million kg); the living roof system is expected to prevent approximately 2 million gal (7.5 million L) of rainwater from being discharged as storm water.

The largest hills rise approximately 15 ft (4.6 m) above the rooftop's open viewing platform to cover two of the museum's signature exhibits: a freestanding planetarium dome 90 ft (27.4 m) in diameter in the eastern half of the building and a similarly sized glazed dome for a rain forest exhibit in the western half. "The curves show the contents of the building and the fact that certain elements do not fit under a flat roof," explains Olaf de Nooyer, a partner in the Renzo Piano Building Workshop and the project architect for the academy's new building, in a written response to questions from *Civil Engineering.*

Other main exhibits include the museum's five large aquarium tanks, some of which begin at the ground level and partially surround the bases of the planetarium and rain forest domes. Protected by concrete walls that typically measure 24 in. (610 mm) thick, these tanks feature doubly curved acrylic panels, the largest of which are 17 in. (432 mm) thick and weigh as much as 40,000 lb (18,000 kg). For example, the tank showcasing a Philippine coral reef and its marine life, the world's largest living coral reef exhibit, is 25 ft (7.6 m) deep and is filled with 212,000 gal (802,000 L) of seawater.

In the center of the roof between the largest domes, a curved, 72 by 98 ft (22 by 30 m) skylight extends over the building's central piazza. The partially glazed skylight is supported on a tensile net of stainless steel rods that suggest a spider web, notes de Nooyer. The center of the skylight is open to the air, although an operable rain screen can cover the open portion in the event of precipitation. A shading system also is available, as is an acoustic screen that is brought into service when concerts are held in the central space, notes Chambers.

The glazed portion of the skylight features triangular panels 6 ft (1.8 m) on a side that employ both patch and point supports. The tensile net system actually consists of two nets made from stainless steel rods—a convex upper net and a concave lower net—that are linked by vertical struts on a 6 by 6 ft (1.8 by 1.8 m) grid. The vertical struts connect the two nets via a series of stainless steel nodal points, and the vertical struts range in height from approximately 18 in. (457 mm) at the corners of the piazza to as much as

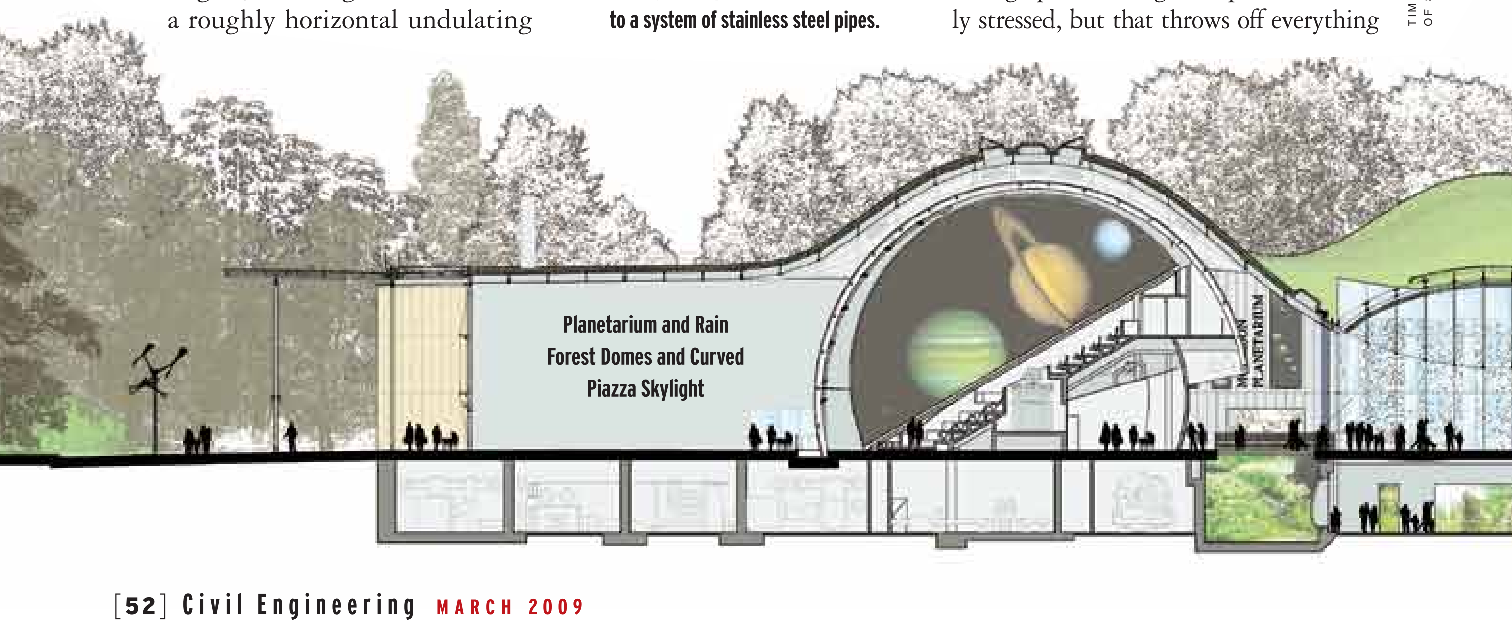
A curved, 72 by 98 ft (22 by 30 m) skylight extends over the building's central piazza. Open to the air, the partially glazed skylight is supported on a tensile net of stainless steel rods—a convex upper net and a concave lower net. Vertical struts connect the two nets via a series of stainless steel nodal points. A roughly horizontal, undulating ring truss is located along the perimeter of the skylight space to transfer the prestress forces back to the main roof. The 3 ft (0.9 m) wide ring truss also serves as an internal gutter to help convey rainwater from the roof to a system of stainless steel pipes.

12 ft (3.7 m) in the center of that three-story space. Each round, articulated node consists of six elements—a housing, a spherical bearing for each of the four intersecting rods, and a machined ball into which the vertical strut is threaded—that were designed to "follow all the various changing geometries" of the twin nets, says Chambers.

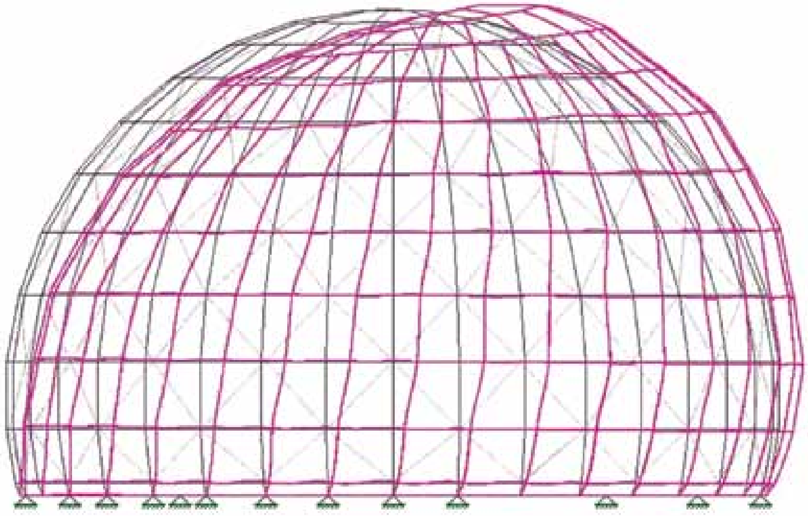
Because the skylight nets are designed on a 6 ft (1.8 m) grid but the rest of the roof is on either an 8 ft (2.4 m) or a 24 ft (7.3 m) grid, the design team installed a roughly horizontal undulating ring truss along the perimeter of the skylight space to transfer the prestress forces back to the main roof. These, says Chambers, amount to approximately 20 kips (89,000 N) for the upper net and 10 kips (44,500 N) for the lower net. The 3 ft (0.9 m) wide ring truss also serves as an internal gutter to help convey rainwater from the roof to a system of stainless steel pipes.

Chambers compares the challenges encountered in prestressing the two nets to tuning a piano: "You get one portion correctly stressed, but that throws off everything

TIM GRIFFITH, TOP; CALIFORNIA ACADEMY OF SCIENCES, BELOW



else!" To facilitate a precise prestressing, therefore, the design team installed special taps and integrated strain gauges at the rod turnbuckles. The taps were then wired into a computer system that carefully monitored each section of the nets as the other sections were being prestressed, Chambers explains. Although it is not expected that the tension in the nets will need to be adjusted over time, the taps are still in place in case staff members of the academy ever need them, he adds.



Rain Forest Bolla's Deformed Shape under a Seismic Load

The perimeter of the contoured roof is bordered by a cantilevered steel canopy of glazed panels that include more than 55,000 photovoltaic cells. These cells are designed to provide a generating capacity of 220 kW; thus they will be able to meet approximately 5 percent of the academy's electricity needs and in doing so will prevent the emission of 400,000 lb (181,000 kg) of greenhouse gases. The canopy extends approximately 32 ft (9.7 m) from the edge of the building, and the outermost 8 ft (2.4 m) is cantilevered, notes Chambers. The canopy is supported on steel beams connected to slender rectangular columns spaced at 24 ft (7.3 m) intervals that are approximately 6 by 8 in. (152 by 203 mm) in cross section and stand 24 ft (7.3 m) tall.

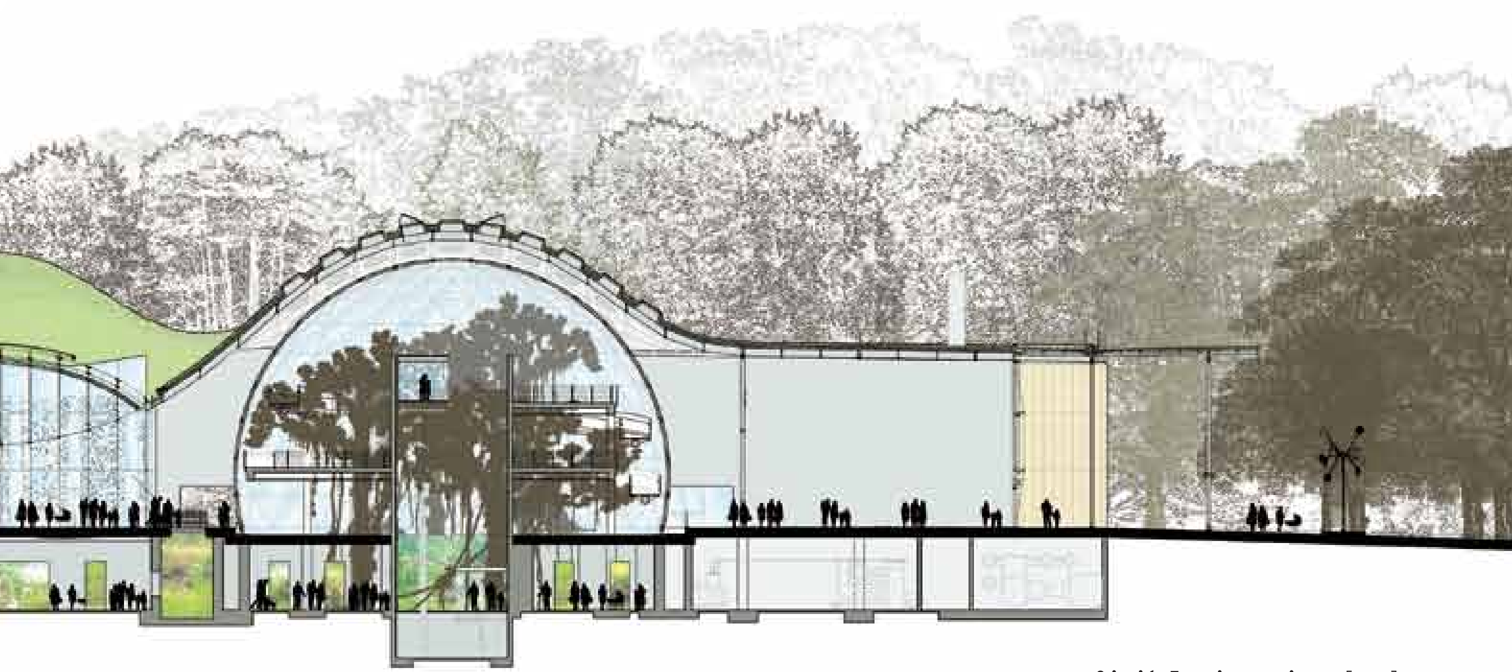
The idea of embedding photovoltaic cells in the canopy developed at roughly the midpoint of the design phase, notes Young. Originally, an open wooden trellis had been considered, but it was decided that that did not complement the rest of the planned structure. Instead, the design team opted for a glazed steel canopy that would feature fritted glass for shading and would make it possible both to install the solar energy system and to use the space beneath the canopy. The fact that the photovoltaic cells are exposed to public view also appealed to the design team, Young adds, because it offered a different approach, the usual practice being to install such cells out of sight on a flat roof.

The massive (150,000 sq ft [14,000 m²]) reinforced-concrete slab forming the building's podium was poured in segments using pour joints to ensure proper curing, drying, and shrinkage in order to avoid cracking. The slab is 14 in. (356 mm) thick to accommodate the high-density shelving units that hold the museum's collections. These units feature a design weight of approximately 250 psf (1,200 kg/m²) and a maximum deflection equal to the length of the span divided by 750, says Chambers.

Exposed steel columns 12 in. (305 mm) in diameter support the roof in the three-story foyers at the northern and southern entrances. Because of the undulations in the roof, these steel pipe elements range in height from 36 ft (11 m) to approximately 40 ft (12 m). With regard to the exposed supports, Chambers stresses that "working with Renzo Piano's group was fantastic because they really appreciate structure. They're really interested in articulating structure as part of the building."

The four columns located at the northern and southern ends of the rain forest and planetarium domes were filled with concrete so that their axial load-carrying capacity

ARUP, TOP



The museum's five large aquarium tanks feature doubly curved acrylic panels, the largest of which are 17 in. (432 mm) thick and weigh as much as 40,000 lb (18,000 kg). The tanks are protected by concrete walls that typically measure 24 in. (610 mm) thick. A mat foundation system was chosen because some of the tanks are integrated into the building's ground-level structure and thus could experience seismic-induced forces.

TIM GRIFFITH

could be increased without increasing their diameters, Chambers notes. The columns at the southern entrance also help to support the steel and concrete bridges that traverse the open space of the entrance foyer to link the three levels of the RC&A sections; the bridges at the northern side of the building are suspended from the ceiling.

The structural column grid continues down through the basement levels with square concrete columns that range from 18 in. (457 mm) to 24 in. (610 mm) on a side, Chambers adds.

Near the southern entrance foyer and just beyond the aquarium tank that has a swamp theme are two lines of columns in the classical style that reproduce a portion of the portico from the original Steinhart Aquarium. Although the design team had hoped to preserve the original Steinhart columns, those proved to be unsalvageable, notes Young. Instead, a freestanding steel moment-resisting frame structure was installed that features replica columns jacketed in concrete reinforced with glass fibers.

Over the years the original academy buildings had been so extensively altered that they were no longer considered to have historical significance and thus did not have to be preserved. This gave the design team for the new museum "a little latitude as we worked through technically what we could and could not save," Young says. Although the team sought to reuse the original academy facilities to the fullest extent possible, the poor condition of many of those older structures meant that only two of the original facades, namely, the northern and eastern sides of African Hall, could be preserved and incorporated into the new design, he notes.

While green in the environmental sense is a term often applied to the new academy building, the material palette for the building was "frugal," notes de Nooyer. Much of the interior takes the form of light gray concrete walls and white acoustic panels that are suspended from the ceiling in a pattern that resembles the scales of a fish. "The use of color has been sporadic," de Nooyer explains. Color is used "only to indicate circulation of visitors, to leave the spaces neutral from a color perspective to allow the exhibits to fill the space."

The 90 ft (27.4 m) diameter dome for the new Morrison Planetarium features a truncated sphere that cantilevers approximately 12 ft (3.7 m) above a ground-level portion of the aquarium tank with the Philippine coral reef. Within the planetarium dome, the cantilevered beams also form part of the raked seating bowl that overlooks a screen with a diameter of 75 ft (23 m). The exterior of the dome is supported laterally by a steel chevron diagonal bracing system beneath white gypsum cladding that is reinforced with glass fibers. Longitudinally, a series of wide-flange W 8 steel sections is arranged on a 20 degree grid in plan so that these supports always land on a floor column at the dome's base, notes Chambers. The horizontal supports are 8 in. (203 mm) steel pipe sections following a 10 degree fan arrangement.

A curved beam spans 96 ft (29 m) in the column-free space over the dome. The lateral thrust from the resulting arch action, which varies from 2 to 4 kips (8,900 to 17,800 N), is transferred to the shear walls of the adjoining African Hall and to the eastern RC&A space, which act as abutments, Chambers notes.

On the western side of the museum, the 90 ft (27.4 m) diameter rain forest exhibit dome—also called the bolla—is supported by a grillage of steel pipe sections, each roughly 3 in. (76 mm) in diameter, that form a series of meridians and parallels. Here diagonal stainless steel tension rods provide the lateral bracing. The longitudinal supports are arranged on a 10 degree grid to follow the same spacing as the structure's doubly curved glazed panels, which are 0.75 in. (19 mm) thick and approximately 8 ft (2.4 m) square and are supported by cast spider brackets, notes Chambers. The dome is situated atop an 18 in. (457 mm) wide concrete ring beam that is supported by just six concrete columns in the basement.

With a depth of 4 ft (1.2 m), the ring beam is larger than would be necessary to simply support the bolla, notes Chambers. The additional depth was required by the mechanical system planners to accommodate an air-diffusing system designed to reduce the condensation generated by the humid conditions within the rain forest exhibit. Because Arup was handling the designs for both the structural and the mechanical systems, "we could all talk together and coordinate things like that more readily," Chambers says.

A spiraling ramp rises through the bolla supported on a spine of 20 in. (508 mm) diameter steel pipe sections, and attached fins brace the concrete-stiffened walking surface. To control vibrations on the 5 ft (1.5 m) wide walkway, the 30 ft (9.1 m) long pipe sections were filled with concrete. Still, the sinuous geometry of the ramp presented a unique challenge to the design team: finding a structural steel subcontractor capable of fabricating the pipe curvatures. Ultimately, the project turned to Fabriweld Corporation, of Clearfield, Utah, a firm that designs roller-coaster systems. Although the ramp design seemed unique by traditional structural engineering standards, Fabriweld actually considered the bolla problem "relatively simple, because they were used to very complex geometries," adds Chambers.

Although it is not expected that visitors to the rain forest will race through it at roller-coaster speeds, a timed egress analysis by Arup fire engineers did demonstrate that the bolla could be evacuated quickly enough in the event of smoke or fire to avoid the need to install an intrusive exhaust fan system.

The design team also found innovative

The re-created African Hall features a penguin exhibit that is designed with the same type of air filters as those used in hospitals. The new African Hall also features the only two facades from the original academy buildings that could be preserved and incorporated into the new design.

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An undulating, 2.5 acre (1 ha) vegetated roof blanketed with 50,000 biodegradable coconut husk trays containing 6 in. (152 mm) of soil to nurture 1.7 million native California plants helped the academy's new home attain platinum certification in the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System. The 410,000 sq ft (38,000 m^2) structure is the largest public building in the world ever to achieve platinum certification.

JON MCNEAL © RPBW

solutions to other environmental and mechanical system challenges on the project, notes Paul Switenki, P.E., a mechanical engineer who is an associate in Arup's San Francisco office. For instance, because penguins are highly susceptible to airborne diseases, air filters of the type used in hospitals were installed in the new penguin exhibit that has become a central attraction of the re-created African Hall, Switenki says.

The building also features natural ventilation systems and heat recovery technology that will help reduce energy use, Switenki adds. For example, a radiant heating system consisting of coils of plastic pipes on insulation embedded in the floors of certain exhibit spaces is expected to reduce the building's energy needs by 10 percent annually. Overall, the building is expected to use 30 percent less energy than would a more traditional structure.

The building is plumbed to use recycled water provided by the City of San Francisco, and this will help reduce the structure's water consumption by 20 percent compared with a more traditional structure. For the most part, the recycled water will be used in the restrooms and in the aquarium life-support systems. As in the original academy facilities, the new building fills its aquarium tanks with seawater pumped directly from the Pacific Ocean through a line that runs for more than 3 mi (4.8 km) under Golden Gate Park.

Building materials with a high percentage of recycled components were used throughout the academy's new home. For example, cotton batting made from recycled blue jeans that is used as wall insulation is expected to retain heat better than do the more typical fiberglass or foam-based materials. Moreover, approximately 80 percent of the materials from the demolished original structures were recycled for use in other construction projects in the Bay Area.

The academy's new home earned LEED points in six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. On October 7, 2008, the U.S. Green Building Council awarded the building a total of 54 points, 2 more than needed for platinum certification.

In announcing the certification, Gregory Farrington, Ph.D., the academy's executive director, noted that "our goal was to create a new facility that would not only hold powerful exhibits but serve as one itself, inspiring visitors to conserve natural resources and help sustain the diversity of life on earth."

Jean Rogers, Ph.D., P.E., who led the effort to achieve platinum certification and is a principal in Arup's San Francisco office, adds that "pushing the envelope on sustainability required testing to give the owner confidence that the systems would perform as intended." Thus, prototypes of most of the critical systems were tested during the design phase using full-scale mock-ups. The mock-ups encompassed not just test beds of the various plant mixtures and substrates that were established facing north, south, east, and west but also of the structural steel, the concrete, the planting system, and the portholes of the undulating roof, along with the photovoltaic cells and other systems, Rogers notes.

As a scientific research facility as well as a museum, the California Academy of Sciences stores 18 million specimens in jars and special containers and in doing so utilizes an estimated 100,000 gal (378,500 L) of flammable liquids. Special warehouse spaces protected by fire walls and a mist deluge system were created within the main building to safeguard the facility, its visitors, and its employees.

Floor-to-ceiling glazed walls 35 ft (11 m) tall located between the shear walls, along with numerous porthole skylights in the contoured roof, provide extensive natural lighting. The glass walls have a low iron content for enhanced transparency. Speaking of the building's setting in Golden Gate Park, de Nooyer puts it this way: "The design is a statement and an example of the fact that a natural history

museum does not need to be an introverted, opaque, and dark building. The building allows light to enter wherever possible for the simple desire to be in a daylit space, but also to have a constant visual connection with the surrounding nature."

The porthole skylights, conical openings that expand from a diameter of approximately 3.5 ft (1.1 m) to 4.5 ft (1.4 m), can be opened and closed by actuators to facilitate natural ventilation of the interior spaces, adds Switenki. The skylights and operable vents above the entrances and near the top of the glazed walls take advantage of a "stack effect" caused by the buoyancy of hot air to draw hot air out of the building on still days, a process that is augmented by a cross-flow effect on windier days, notes Switenki. The portholes, vents, and other systems throughout the building are controlled automatically by temperature sensors and other monitoring devices, including two small weather stations located on the living roof.

Building materials with a high percentage of recycled components were used throughout the academy's new home.

The vegetated roof should also keep the building's interior spaces cooler by approximately 10°F (5.6°C) than would a traditional roof.

At the same time, that roof presented an unusual challenge for the mechanical systems engineers, adds Switenki. "Usually, in any kind of building, you have the rooftop to work with" when dealing with mechanical systems, he explains. But that wasn't possible with the new academy building. So Arup's engineers worked closely with the architects to find locations for the various systems within the interior of the building, resulting in the creation of mechanical spaces that are multiple stories in height.

In other cases, the need for natural lighting for the Philippine coral reef and rain forest exhibits had to be coordinated with the space available on the roof for the skylight portholes, adds Young. Likewise, the large energy requirements of the rain forest bolla, which maintains a constant temperature of 82°F to 85°F (28°C to 29°C) and a relative humidity of at least 75 percent, had to be reconciled with the low-energy design of the naturally ventilated public spaces surrounding the exhibit.

Still, such challenges combined to make the project truly fascinating for the designers, especially because the academy was willing to take the long view with respect to a return on its investment. When the owners of commercial buildings adopt innovative mechanical or structural solutions, they usually want to see a payback on those investments within five years, notes Switenki. But the academy realized that the energy-saving measures and other innovations in its new home would be achieved only after a considerably longer period of operation. "This was a fun building to work on because we had that luxury," Switenki explains. "We could say, 'Here's an innovative system that will cost you a few more bucks up front, but it will pay for itself in fifteen years.' A lot of owners won't do it that way, but [the] academy did." **CE**

PROJECT CREDITS Owner: California Academy of Sciences, San Francisco **Design architect:** Renzo Piano Building Workshop s.r.l., Paris and Genoa, Italy **Local architect:** Stantec Architecture, San Francisco **Structural engineering, mechanical and electrical systems, fire engineering, sustainability consulting, acoustics consulting, lighting design, facades, and pedestrian simulation:** Arup, San Francisco **Owner representative and project manager:** D.R. Young Associates, San Rafael, California **General contractor:** Webcor Builders, San Francisco **Geotechnical engineering:** Rutherford & Chekene Consulting Engineers, San Francisco **Vegetated roof:** Rana Creek, Carmel Valley, California **Rain forest exhibit ramp design:** Fabriweld Corporation, Clearfield, Utah **Landscape architecture:** SWA Group, Sausalito, California