MUSICAL MASTERPIECE

La Seine Musicale, a world-class concert hall on a redeveloping island west of Paris, is a masterpiece of structural, acoustic, and mechanical engineering. Resembling a ship at sea, the concrete structure supports a glassy, egg-shaped auditorium flanked by a shimmering "sail" that moves with the sun, shading the globe and generating solar power.

BY TANCRÈDE DE FOLLEVILLE AND JEAN-BERNARD DATRY

AFTER MANY STOPS AND STARTS, Seguin Island, on the River Seine just west of Paris, is now home to a unique and innovative world-class music hall called La Seine Musicale. Designed by the Pritzker prize-winning Japanese architect Shigeru Ban along with the local firm Jean de Gastines Architectes, the 36,000 m² concert venue features an iconic egg-shaped auditorium and a 30 m high curved "sail" that moves with the position of the sun to shade the interior from heat and light while also generating power via photovoltaic panels.

Located between the municipalities of Sèvres and Boulogne-Billancourt, the island was home to factories owned by the French automaker Renault beginning in 1919. The facades of some structures from this period remain intact today and are classified as historical monuments. After the closure of the last of the auto production facilities in the early 1990s, the redevelopment of the island was subject to several successive attempts that never came to fruition. This turbulent period was symbolized by the abandonment in 2005 of a project planned by the Francois Pinault Foundation and designed by the Japanese architect Tadao Ando

The music hall, which occupies nearly the entire northwestern end of the island, resembles a massive concrete ship gliding along the River Seine.

ANNE-CLAUDE BARBIER FOR SETEC TPI

and the Paris-based engineering firm Setec Travaux Publics et Industriels, known as setec tpi. Then in 2009, French architect Jean Nouvel was entrusted with the responsibility of designing the master plan for the island as a whole, integrating, at each of its pointed ends, two new buildings, one dedicated to music at the downstream (northwestern) end and one dedicated to contemporary arts at the upstream (southeastern) end.

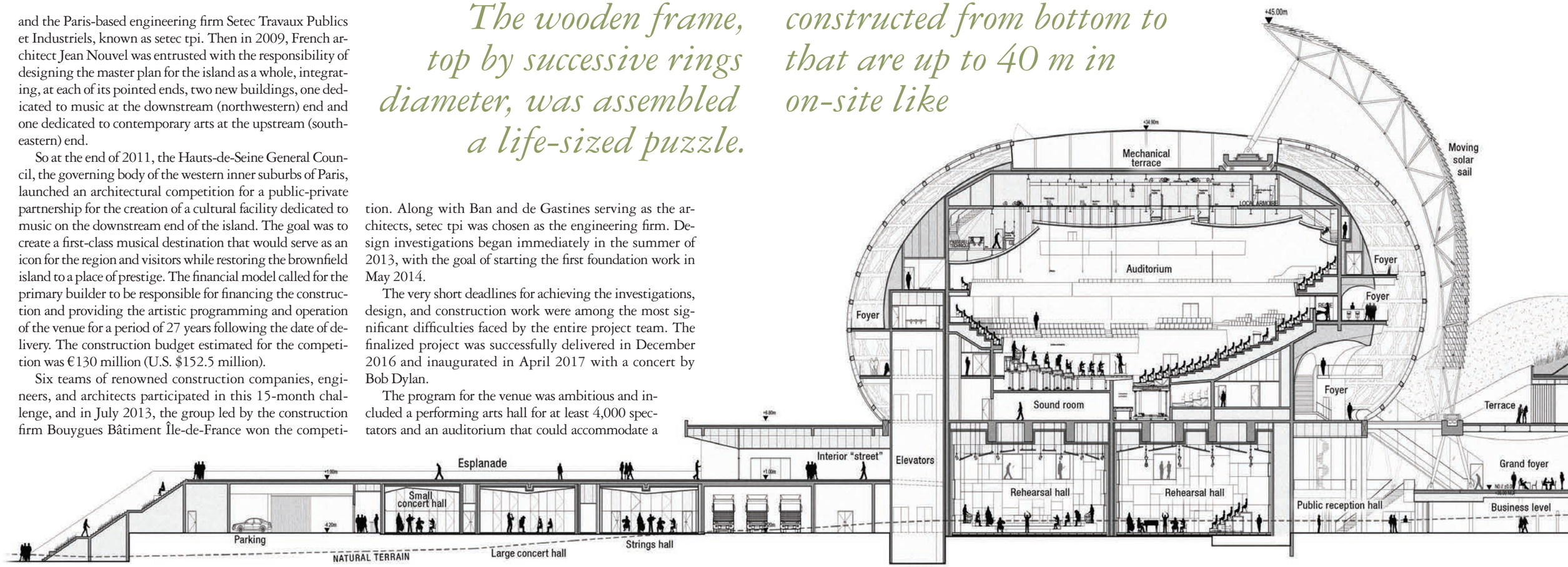
So at the end of 2011, the Hauts-de-Seine General Council, the governing body of the western inner suburbs of Paris, launched an architectural competition for a public-private partnership for the creation of a cultural facility dedicated to music on the downstream end of the island. The goal was to create a first-class musical destination that would serve as an icon for the region and visitors while restoring the brownfield island to a place of prestige. The financial model called for the primary builder to be responsible for financing the construction and providing the artistic programming and operation of the venue for a period of 27 years following the date of delivery. The construction budget estimated for the competition was €130 million (U.S. $152.5 million).

Six teams of renowned construction companies, engineers, and architects participated in this 15-month challenge, and in July 2013, the group led by the construction firm Bouygues Bâtiment Île-de-France won the competition. Along with Ban and de Gastines serving as the architects, setec tpi was chosen as the engineering firm. Design investigations began immediately in the summer of 2013, with the goal of starting the first foundation work in May 2014.

The wooden frame, constructed from bottom to top by successive rings that are up to 40 m in diameter, was assembled on-site like a life-sized puzzle.

The very short deadlines for achieving the investigations, design, and construction work were among the most significant difficulties faced by the entire project team. The finalized project was successfully delivered in December 2016 and inaugurated in April 2017 with a concert by Bob Dylan.

The program for the venue was ambitious and included a performing arts hall for at least 4,000 spectators and an auditorium that could accommodate a symphonic orchestra, all on a 280 m long triangular plot at the northwestern end of the island. With this in mind, the form of La Seine Musicale evokes the image of a large marine vessel, with a long, narrow concrete main structure that is accessed by a grand exterior staircase leading to garden terraces and an aboveground lobby. Atop this are the spherical auditorium and sail. (See the illustrations above.)



A pedestrian walkway was created between the glass-and-timber latticework facade and the concrete that forms the egg's shell, which is covered in iridescent mosaic panels.

FREDERIC STEVENS/GETTY IMAGES NEWS/GETTY IMAGES; *OPPOSITE*; COURTESY OF SETEC TPI

Elevation, Entrance and Auditorium

Positioned at the end of the island, the egg-shaped structure houses an auditorium with 1,100 seats, all placed for optimum acoustic quality. This hall is dedicated to classical music performances. The egg is formed by a concrete shell coated with iridescent mosaic panels; around this shell is a stable and self-supporting wooden lattice that bridges a gap between the concrete and the 4,000 m² of double hexagonal glazing that forms the egg's facade. The wooden frame, constructed from bottom to top by successive rings that are up to 40 m in diameter, was assembled on-site piece by piece, like a life-sized puzzle. Stability during the in-construction phase was ensured by metal tie rods fixed into the concrete walls.

Peripheral passages exist between the wooden mesh and the concrete shell to allow spectators to walk around the egg structure, enjoying impressive views of the River Seine through the glass facade. The roof of the auditorium is supported by lattice beams spanning 30 ft and built using a steel framework. The various components were manufactured in a shop and assembled on-site using prestressed bolts.

In the interior of the egg, the seats are positioned in "vineyard" style, in which the seating surrounds the stage on all sides over many closely spaced terraces, creating close proximity between the musicians and the audience, optimizing the acoustical experience. The corrugated ceiling comprises an assembly of small-section wooden tubes, cardboard, and paper, and the walls are lined with wooden slats. Together these signature elements lend the space a unique and intimate atmosphere.

On the exterior, the back side of the globe is surrounded by a basin, which gives the impression that the globe and sail are lying on water. It is also on this rear part that the mobile, triangular sail is located. The sail is made of a three-dimensional tubular steel truss and is covered on its exterior by 1,000 m² of photovoltaic panels—470 in all. The triangular sail is 15 m at its widest point, and much of it was prefabricated off-site to ensure quality control. Mounted on a curved rail supported by a reinforced-concrete beam and sloping tubular posts, the motorized sail can move around the auditorium, following the course of the sun throughout the day.

The shape of the sail evolved considerably during the

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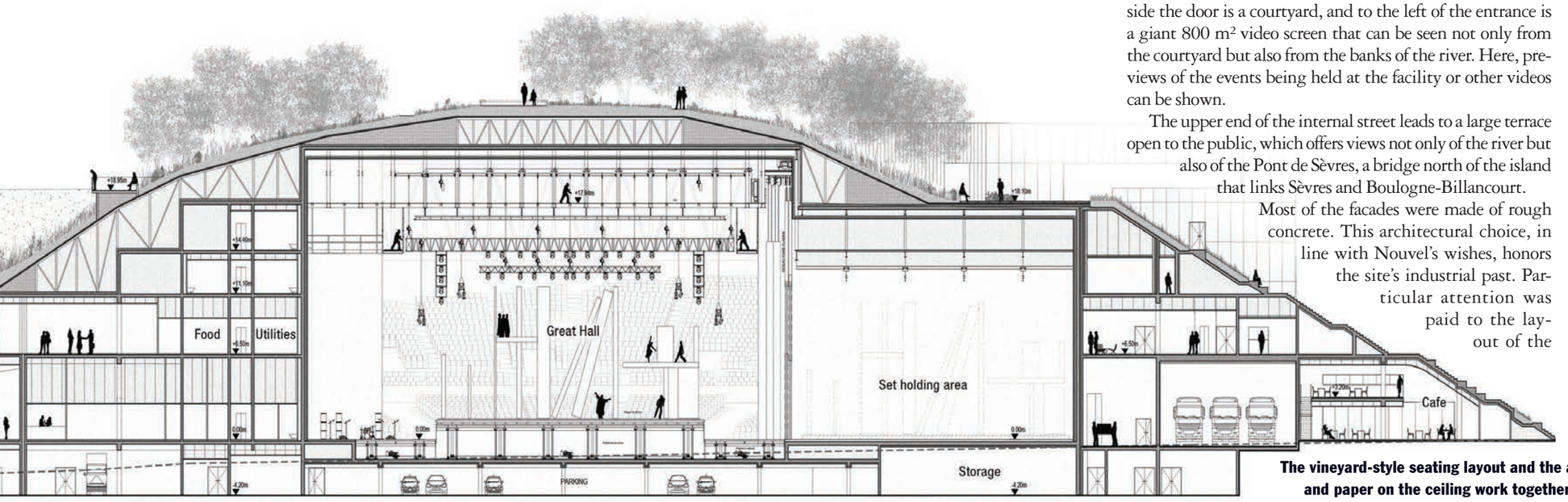

Elevation, Great Hall and Adjoining Spaces

design; at first it was flat and monolithic, resembling a butterfly wing, but it was eventually designed to curve in two planes, resembling the sail of a boat. The geometry of this structure, as well as that of the egg's wooden mesh structure, had to be tested in a wind tunnel during the design phase. The tests were carried out by the Centre Scientifique et Technique du Bâtiment in Nantes, France, using three models: a model of the entire assembly at a scale of 1/500, a model of the auditorium at a scale of 1/250, and a model of the sail at scale of 1/75. On the construction site, the assembly of the sail structure, which was conducted at the same time as the wooden mesh, was a challenge for the construction teams, which had to fit the geometric elements together precisely.

Beyond the egg-shaped auditorium is a second performing arts hall called the Great Hall, which is dedicated to modern music concerts. Measuring 75 by 45 m in plan, the hall has a seating capacity that can vary between 4,000 and 6,000 seats, depending on the configuration of movable seating; telescopic bleachers are located in the lower part of the hall. The bleachers were built from prefabricated reinforced-concrete elements in the form of an L that extends from the walls, and those on the movable level are positioned on rack-and-pinion beams to move them forward and back. The stage was also designed to be dynamic and can be changed so quickly that up to six shows of varying types can be staged in a 48-hour period. A plenum underneath the seats is used to cool the seating area.

The roof of the Great Hall was also constructed in steel. Large lattice girders, with a span of more than 50 m, were mounted on the perimeter walls using neoprene support devices. These enable the steel beams to span over the bleachers without an intermediate support column, which would have impaired the flexibility and visibility in the hall. Incorporating such column-free sight lines was a requirement of the program.

These steel beams, which are protected by a sprayed-on fireproof coating, also support a 7,400 m² green hill on the roof of the building, comprising a garden open to the public and a panoramic promenade that rises to a point that is 36 m above the Seine. At the far end of this promenade a monumental staircase leads down to the ground level.

To minimize the permanent loads on the roof framework as much as possible, a thin layer of soil—just 40 cm thick—was used for the garden area. In areas of steep slope, the ground is held in place by reinforced-concrete studs that are fixed on the roof slab.

In addition to these two music halls, La Seine Musicale includes a recording studio, rehearsal rooms for artists and orchestras, a grand foyer for exhibitions and receptions, voice schools and meeting rooms for younger artists, and a 2,660 m² corporate space that can accommodate various conferences and seminars. The main building also features an interior "street," extending along the length of the rectangle, connecting the entrance of the structure to the back of the building. Along this street are dining areas and shops. The entire structure is designed to encourage visitors to the island who have not purchased tickets to nonetheless enjoy the many amenities of the concert venue and its outdoor gardens and cafes.

The entrance of the building, at the south end of the structure, is created by a large, dramatic, scissor-style door that folds upward, with the fold pointing outward. Just outside the door is a courtyard, and to the left of the entrance is a giant 800 m² video screen that can be seen not only from the courtyard but also from the banks of the river. Here, previews of the events being held at the facility or other videos can be shown.

The upper end of the internal street leads to a large terrace open to the public, which offers views not only of the river but also of the Pont de Sèvres, a bridge north of the island that links Sèvres and Boulogne-Billancourt.

Most of the facades were made of rough concrete. This architectural choice, in line with Nouvel's wishes, honors the site's industrial past. Particular attention was paid to the layout of the formwork panels of the high walls of the main structure and the formulation of the concrete to ensure a homogeneous color.

During the design stage, special attention was also paid to the acoustic insulation of the music halls. For this reason, some rehearsal rooms are placed on spring boxes so that their sounds do not interfere with the auditorium. The top support of the sail, located on the technical terrace of the egg, is also supported by spring boxes, which reduce the vibrations generated by the displacement of the motorized sail. The cages of the freight elevators used to bring large musical instruments, such as pianos, into the auditorium are also acoustically isolated.

The entire structure is founded on a set of 800 reinforced-concrete piles, 1 m in diameter, which descend to a depth of 30 m to reach a sound, chalky base. There was a concern that unexploded ordnance might be present at the site because during World War II, the Renault factories were accused of collaborating economically with the occupying forces and were therefore bombed several times by the Royal Air Force of the United Kingdom. So the drilling of the piles into the first 4 m was carried out in a careful and controlled manner in the presence of munitions specialists to protect against possible risks; fortunately, no problems were discovered.

Pile caps measuring 1.4 by 1.4 m in plan and 0.8 m in depth are situated atop the piles. The concrete for the pile caps was cast in place.

The vineyard-style seating layout and the artistic arrangement of corrugated wooden tubes, cardboard, and paper on the ceiling work together to improve the acoustic performance of the circular hall.

COURTESY OF SETEC TPI, *ABOVE*; FREDERIC STEVENS/GETTY IMAGES NEWS/GETTY IMAGES, *OPPOSITE*

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The entrance to the facility sits just to the right of the 800 m² video screen that entertains not just visitors but those on the shores as well.

Because Seguin Island is located in a flood zone, the building was elevated in compliance with France's flood risk prevention plan, *Plan de Prévention du Risque Inondation*. Doing so placed it above the floodwater elevation benchmark. Some superficial embankments, which had been polluted by the industrial activities of the Renault factory, were removed.

At the north and south, the building is flanked by two exterior passageways built on stilts. The southern passageway allows vehicles to access the parking spaces underneath the Great Hall, while the northern passageway provides an open-air walkway.

The site was located on a particularly restricted building area with no real space for storage, which was another significant constraint for the construction crews. Supplies were provided just in time to match the construction progress, and the large structural steel elements were stored in barges moored along the Seine. At the peak of the construction activity, there were up to eight tower cranes operating simultaneously on the very tight site.

La Seine Musicale has been well received by critics and has already received several awards, including the Best Futura Project at the convention known as the Marché International des Professionnels de L'immobilier (International Market of Real Estate Professionals) in 2015 and the 2017 Entertainment and Culture award from Grand Paris, a government initiative that aims to transform Paris and its surrounding areas into a sustainable, equitable, 21st-century city. The design and construction of La Seine Musicale was a fascinating adventure that will long be remembered by all who worked on the project. **CE**

de Folleville

Datry

Tancrède de Folleville is the chief engineer of setec tpi in Paris, and Jean-Bernard Datry is a director of the firm and also serves as a vice president of the French civil engineering society, L'Association Française de Génie Civil.

PROJECT CREDITS **Owner:** Hauts-de-Seine General Council **Public-private partnership:** Bouygues Bâtiment Île de France of Chilly-Mazarin, France; TF1, of Boulogne-Billancourt, France; and Sodexo Group, of Issy-les-Moulineaux, France **Architects:** Shigeru Ban, Tokyo, and Jean de Gastines Architectes, Paris **Structural studies and structural engineering:** setec tpi, Paris **General contractor, structural work, and civil engineering:** Bouygues Bâtiment Île de France **Mechanical, electrical, plumbing, and public health consultant:** Artélia, Lyon, France **Acoustical consultant:** Nagata Acoustics, Tokyo **Glass facades and motorized sail:** RFR, Paris, and T/E/S/S atelier d'ingénierie-Paris **Geotechnical studies:** Terrasol, a division of setec tpi **Foundations:** Soletanche Bachy, global **Steel framework:** Horta Coslada, Spain **Timber frames:** HESS Timber GmbH & Company KG, Kleinheubach, Germany **Motorized sail:** Baudin-Chateauneuf, Châteauneuf-sur-Loire, France

PHOTO BY NASSER BERZANE/SIPA USA (SIPA VIA AP IMAGES). *ABOVE;* ANNE-CLAUDE BARBIER FOR SETEC TPI, *OPPOSITE*

The sail is made of a three-dimensional tubular steel truss and is covered on its exterior by 1,000 m² of photovoltaic panels.

The 30 m high sail rotates around the globular auditorium on a curved rail supported by a reinforced-concrete beam. Its top is supported by posts mounted on spring boxes.