ASTANA EXPO CITY 2017

American Institute of Architects
2016 Tap Innovation Award

ASTANA EXPO CITY 2017

Project Team

PositivEnergy Practice
MEP Engineering, Parametric Modeling

V3 Companies
Civil Engineering

Werner Sobek
Structural Engineering

Studio Altieri
Structural and MEP Engineering

GEI Consultants
Geotechnical Engineering

AON
Fire and Life Safety, Security

Rowan Williams Davies & Irwin Inc.
Wind Engineering

Fortune Consultants
Vertical Transportation

Altitude Façade Access Consulting
Façade Access

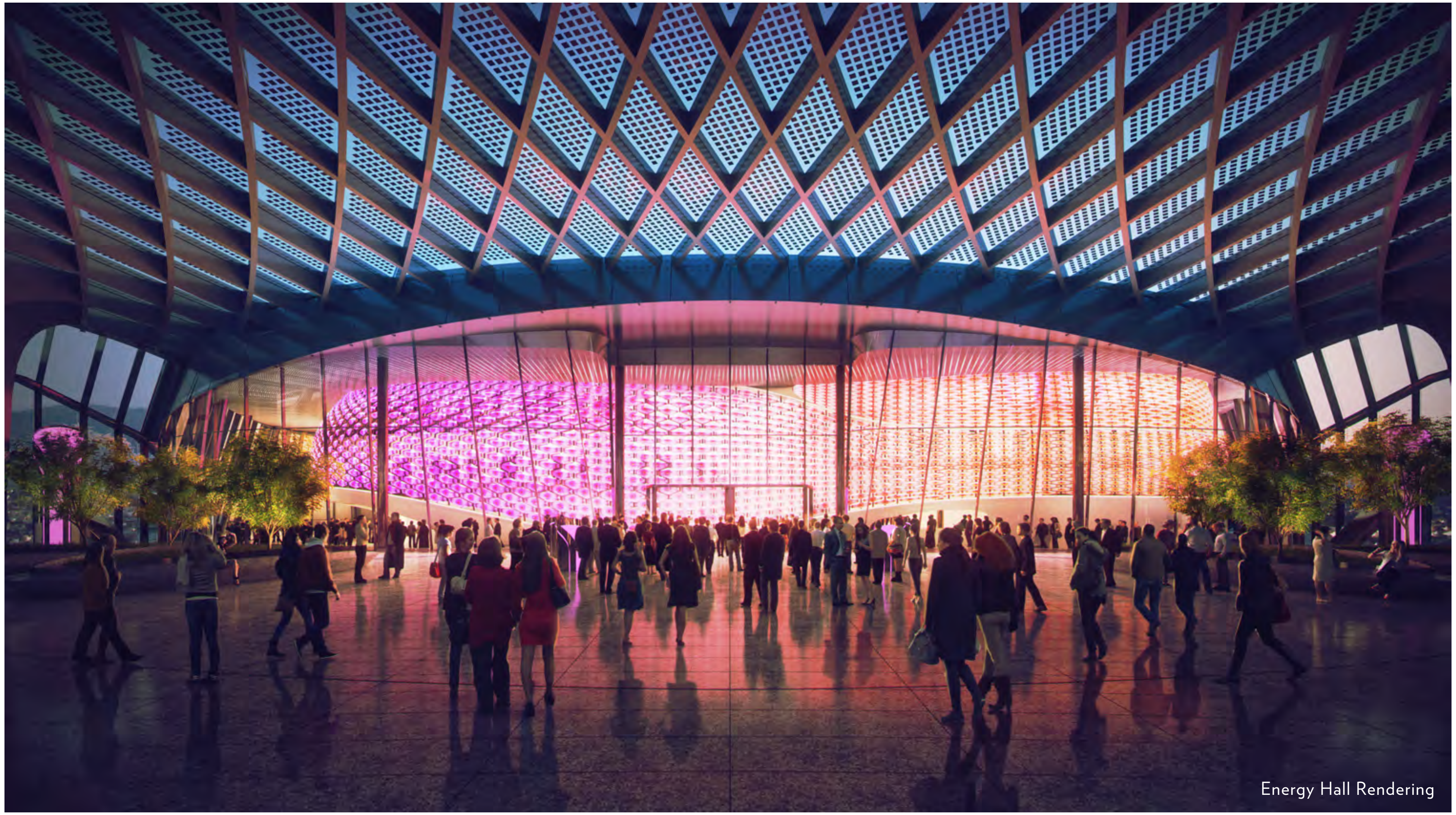
Charcoal Blue
Theater Consulting, Acoustics

CASE
Building Information Specialist

Sembol Construction
Contractor

Planning Partnership
Landscape Architecture

IT Engineering
Design Manager



Energy Hall Rendering

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Project Narrative

The Astana Expo City 2017 master plan embraces the designated concept of "Future Energy." International expositions are held every 2-3 years and choose specialized themes that generates the discourse of the architecture, events, and demonstrations of the event. Future Energy is aimed at finding ways to achieve qualitative changes in the energy sector, primarily for the development of alternative sources of energy and transportation.

Finding sustainable energy supplies is a critical and growing global concern. The solution to these concerns ensures economic growth and improved social standards while reducing the burden on the environment.

Currently under construction, Astana Expo City 2017 will embrace the Expo's focus by becoming the first post Industrial Revolution city, where all energy consumed by the Expo community will be provided from renewable sources; where buildings were designed to be generators of power that will be distributed and stored by a smart-grid system.

Overall Project Rendering

ASTANA EXPO CITY 2017

Project Narrative

Kazakhstan Pavilion Interior Rendering

Covered Mall Interior Rendering

The ultimate goal for the site was to reduce the overall energy demand by using both passive and active strategies. The design team executed a series of studies focused on minimizing the site's energy-use while maximizing the energy-harvesting potential and user-comfort levels. The results dictated the most efficient orientation of the site—and each individual building—in order to optimize the strategies that will reduce the overall energy usage of the Expo community.

All opportunities for power generation were investigated and several were incorporated into the building-design guidelines, including high-performance glazing that will maximize solar heat gain in winter while providing shading in summer; energy piles that will reduce energy demand and provide temperature modulation during winter; energy storage capacity that can meet two days of emergency demand; 100% of rainfall from a 100-year storm event managed on site; and 90% of waste generated on site will be diverted from a landfill.

A significant part of the energy consumed by the Expo community will be provided from renewable sources that were determined by site-specific indicators such as weather conditions, cultural context, and land accessibility. The forms of the buildings were design to reduce their energy needs, allowing the buildings to operate as 'power plants' that will harness energy from the sun and/or wind while additionally saving significant energy through the combined use of passive strategies.

The resulting site-wide infrastructure concept fully integrates the occupants, buildings, and utilities through the use of a smart-energy grid, a smart recycled-water grid, an integrated waste-management system, and an inter-seasonal underground thermal energy storage system. The grid's goal is to manage the Expo community's sustainability goals including peak and total energy-demand reduction, water reduction, and waste-to-landfill reduction.

ASTANA EXPO CITY 2017

Project Narrative

Split into two phases, the 430 acre project will feature exhibition and cultural pavilions, a residential development, service areas including shopping, socio-cultural, educational and civic facilities, parks, and parking.

Phase I includes the design and construction of the exposition buildings including the central Kazakhstan Sphere, Theme, Corporate, and International Pavilions, as well as hotel, residential, retail, and art and performance spaces. Phase I will be completed by June 2017 to serve the world's next international exposition.

Phase II will be the construction of a legacy development for the site. The innovative reuse of the Expo site was conceived during the initial design phase. The Expo buildings will be converted into an office and research park, attracting international companies and entrepreneurs. Expo parking and service zones will be transformed into thriving and integrated neighborhoods.

The reuse of the Expo site was an innovative concept conceived during the initial design phase. A major environmental issue with exposition-type events is that they are used for only an initial run and often remain vacant indefinitely. In researching the fate of previous sites, the design team learned that the approval needed for a legacy development is often difficult and lengthy to obtain from the client perspective due to upfront fundraising.

The design team worked with the client to develop a master plan and architectural design guidelines that would complete most of the post-expo mode components in such a way that a significant amount of public funding would not need to be obtained to fund a functioning post-expo community. The master plan was developed to allow private investment to complete the required tasks such as the residential neighborhood, educational, and office complex.

The team approached the project focusing on the design of a high-performing and integrated post-expo community. While the three month exposition phase was the immediate goal, once concluded the Expo site will transition into a permanent development that serves the needs of a 21st Century community.

Post-Expo Legacy Development

Illustrated Project Site Plan

ASTANA EXPO CITY 2017

Project Narrative

Post-Expo Interior Rendering

The post-expo or legacy development will be one of the most sustainably built communities in the world, when completed in 2018. Key areas taken into account for the efficient transformation from expo to post-expo mode include:

- Streets, sidewalks, and landscaping are designed to be functionally integrated without demolition or reconstruction work
- Buffer zones have been planned around the expo residential neighborhoods to create a more intimate and comfortable residential experience with a separation from main roads around the expo city
- Schools are included in the post-expo master plan to serve the diverse needs of future community
- Exhibition buildings will be transformed and integrated into a first-class office complex
- The site will also be pedestrian and bicycle oriented with dedicated walking and bike lanes
- Connections to public transit will be available to link the expo site to the rest of Astana and an additional bus rapid transit route is currently under development

Post-Expo Rendering

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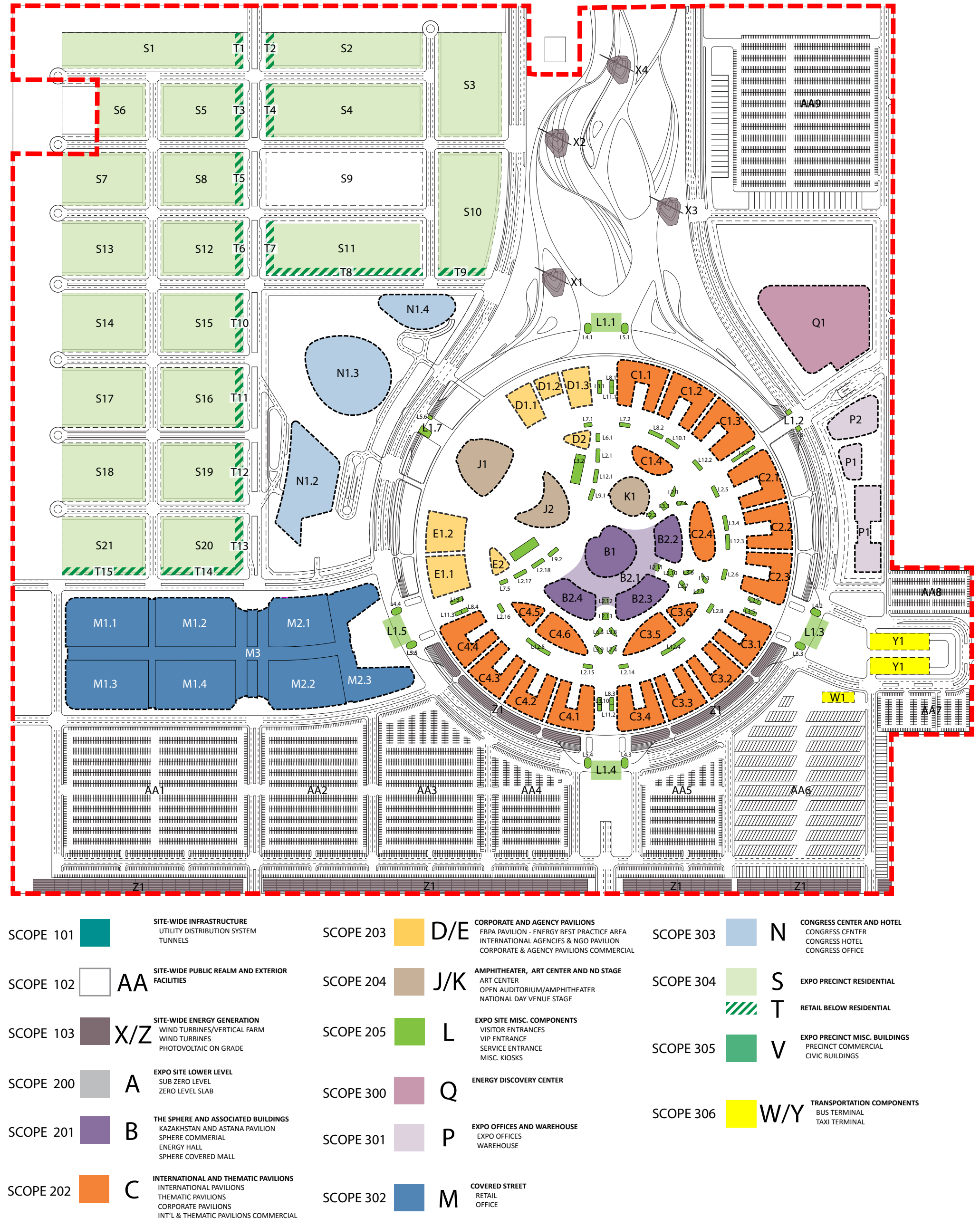
Project - Scale

Overall Construction Site Photograph



Scope Element Diagram - Expo Phase

The Expo site will be designed for two different phases: Phase 1 or the "Expo Mode" will attract 60,000-100,000 visitors each day and will include the design and construction of a series of buildings that will act as a covered city, which will include retail, residential and office spaces; as well as the central Kazakhstan Pavilion; Theme, Corporate and International Pavilions; and art and performance spaces. Phase 2, or the "Legacy Mode", will see the site converted into an office and research park, attracting international companies and entrepreneurs. Expo parking and service zones will be transformed into integrated neighborhoods with an additional 700 residential units, and office, hotel, civic and educational facilities.

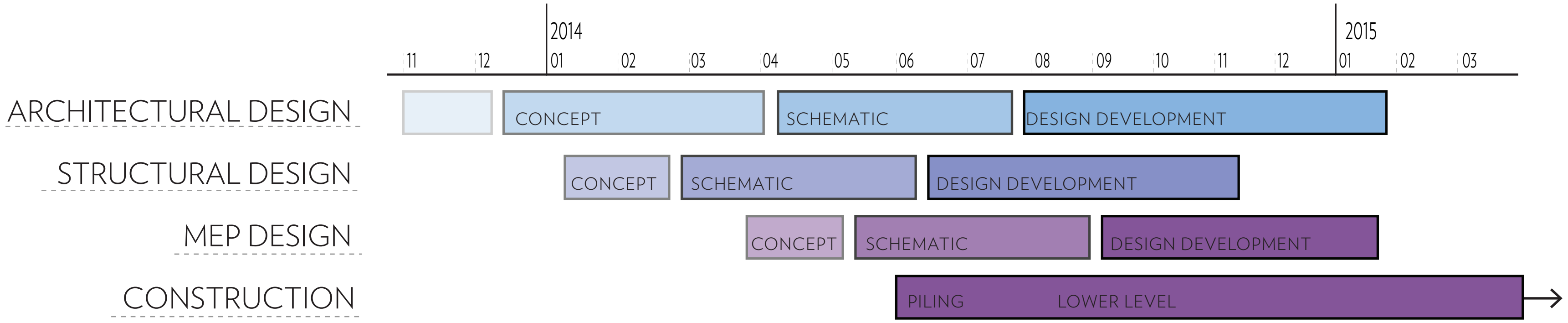
ASTANA EXPO CITY 2017

Project - Schedule

Construction August 2014

Due to a predetermined, fixed date for the opening of the Astana Expo, there was no room for error in the design process. The complex project demanded an aggressive 'Hyper-track' approach with an overlapping design and construction process, starting early in the SD Phase. Building Information Modeling (BIM) made it possible to deliver a working, coordinated set of design documents that met the accelerated schedule and promoted a high level of design communication. In many cases design ran parallel to construction.

One of the challenges of the twelve month design and documentation process was the development of a high-performance building envelope that could function equally well in a series of orientations from northeast clockwise to southwest. The targets dictated that we reduce the grid-energy demand by at least 50% against an ASHRAE 90.1 (2010) baseline and generate a significant amount of electricity using building integrated photovoltaic systems that feed back to the local grid.



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Project - Team

The large design team of over 80 architects managed the work of an international team and served as the primary client contact. The extended project team consisted of consultants from 10 different countries, so tight virtual coordination was the key to its success. Web based video conferences were held on a weekly basis to keep the design on track, and Monthly in-person workshops were held in Astana with the client and various consultants.

The design team understood from the onset of the project that their role as architects and planners would go beyond the delivery of a design. As architects and planners we know that we have a responsibility to advance the profession and to work toward a higher standard for urban development and architectural design, but without full client support these goals are often unachievable.

The design team was able to work closely with the client and the governments in Astana and Kazakhstan to develop urban planning and design guidelines that in many instances challenged the established standards, obsolete codes and regulations that are often faced in parts of the world. The team shared prior experiences with the client, heads of state, and other public agencies, insuring that the most up-to-date sustainability guidelines and principles were followed. Through patience and compromise the team was able to successfully procure and implement a plan for a sustainable community that is capable of catalyzing city development in an innovative way.

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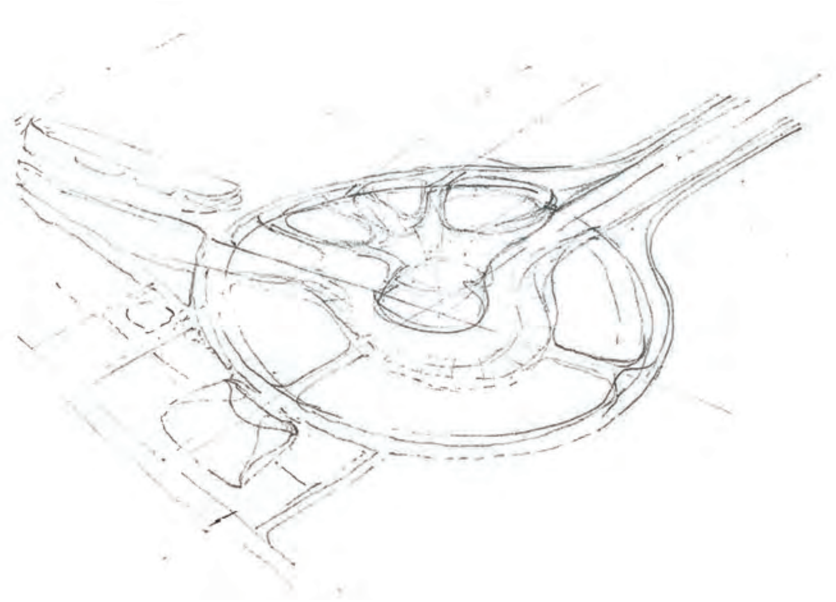
Process - Documentation

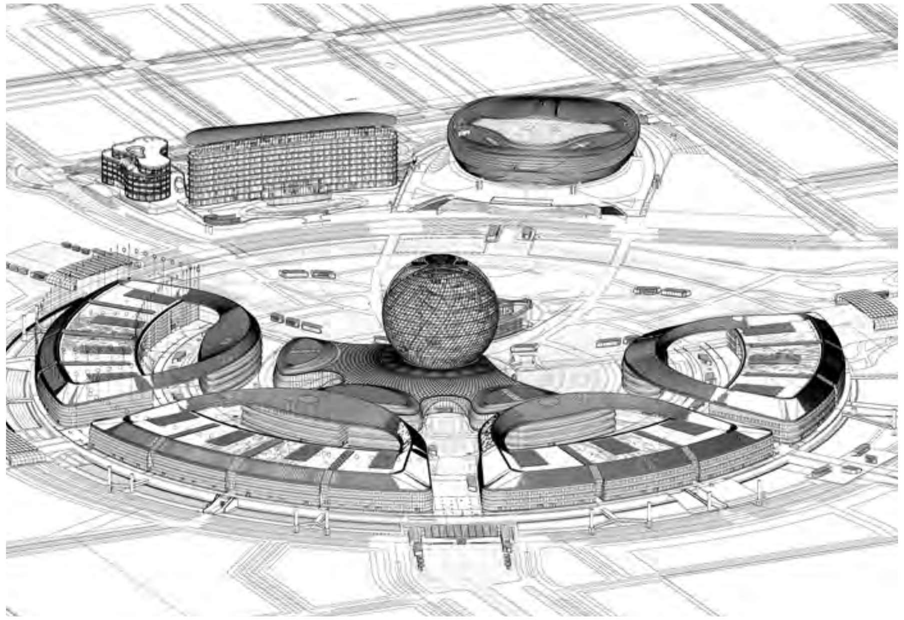
Given the various project constraints, the tight schedule and the scale of the project, the team had to start creating, coordinating and managing documentation quickly. A comprehensive Expo City Revit Model took shape by piecing together the individual building models inside the overall framework model. The inherent connectivity of the Expo City made the scope of work for every single building extend past its property lines, making the data exchange between all models essential in every drawing issued.



Preliminary Sketch 2014

Physical Model 2014

Rendering February 2014



Revit Model January 2015

Construction Site June 2016

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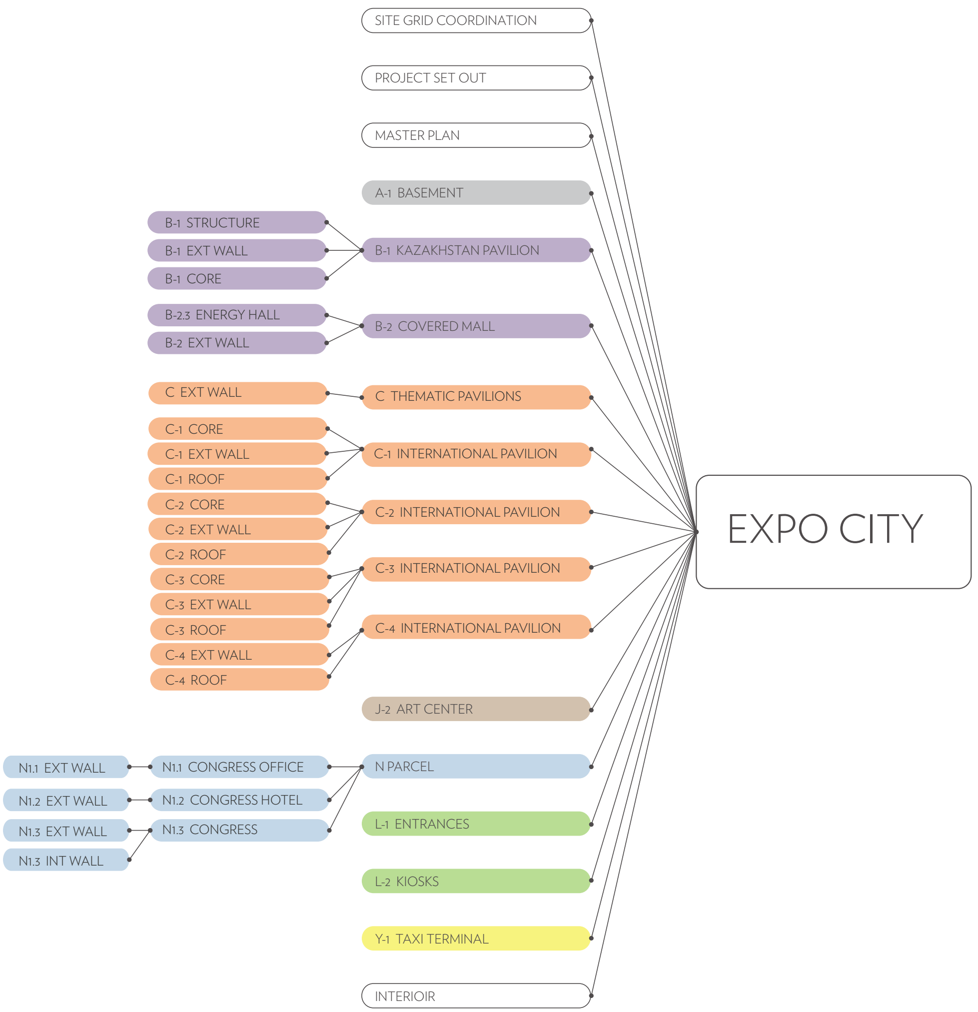
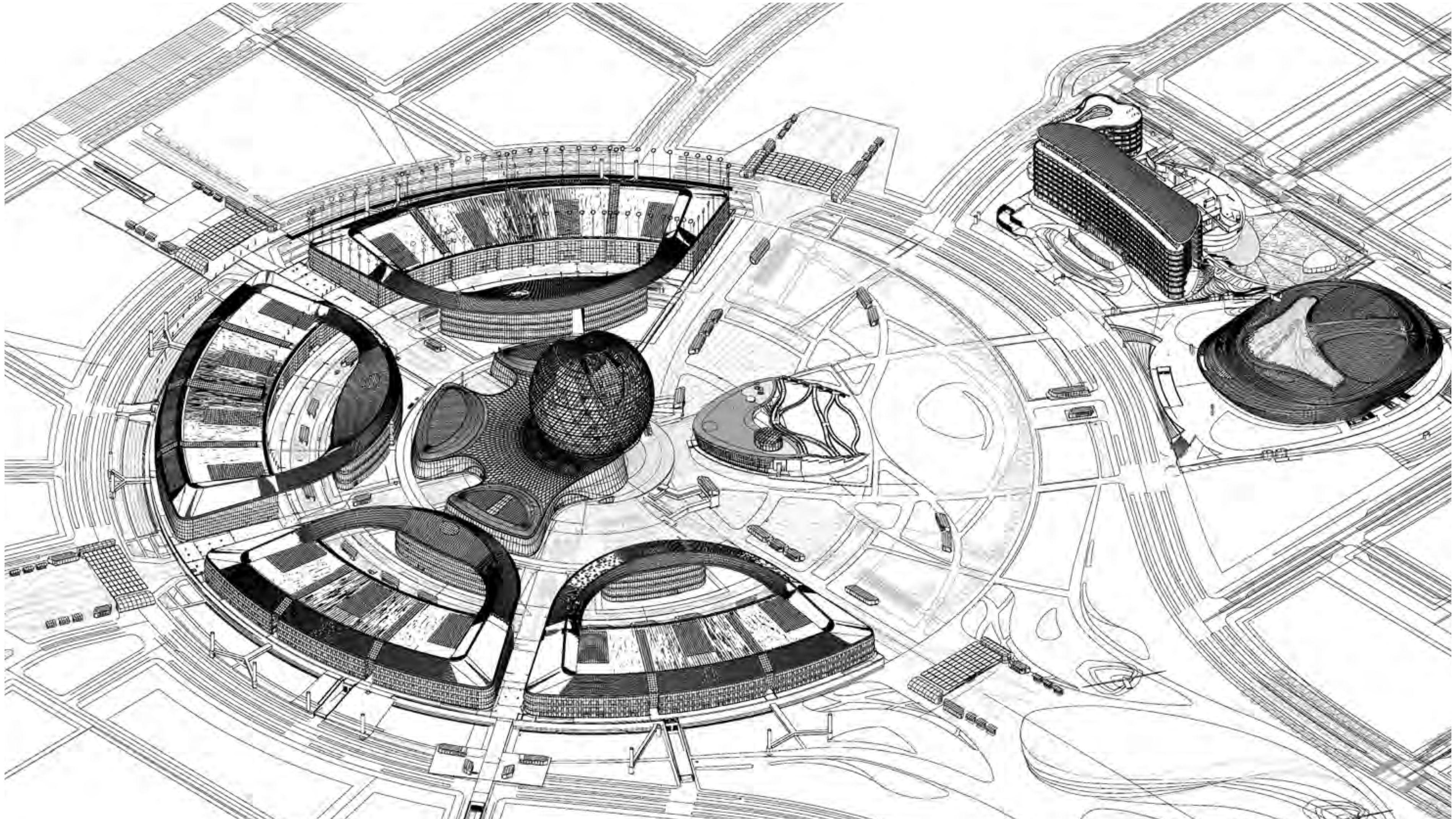
Process - Documentation



Expo Ciry Revit Model Heirarchy



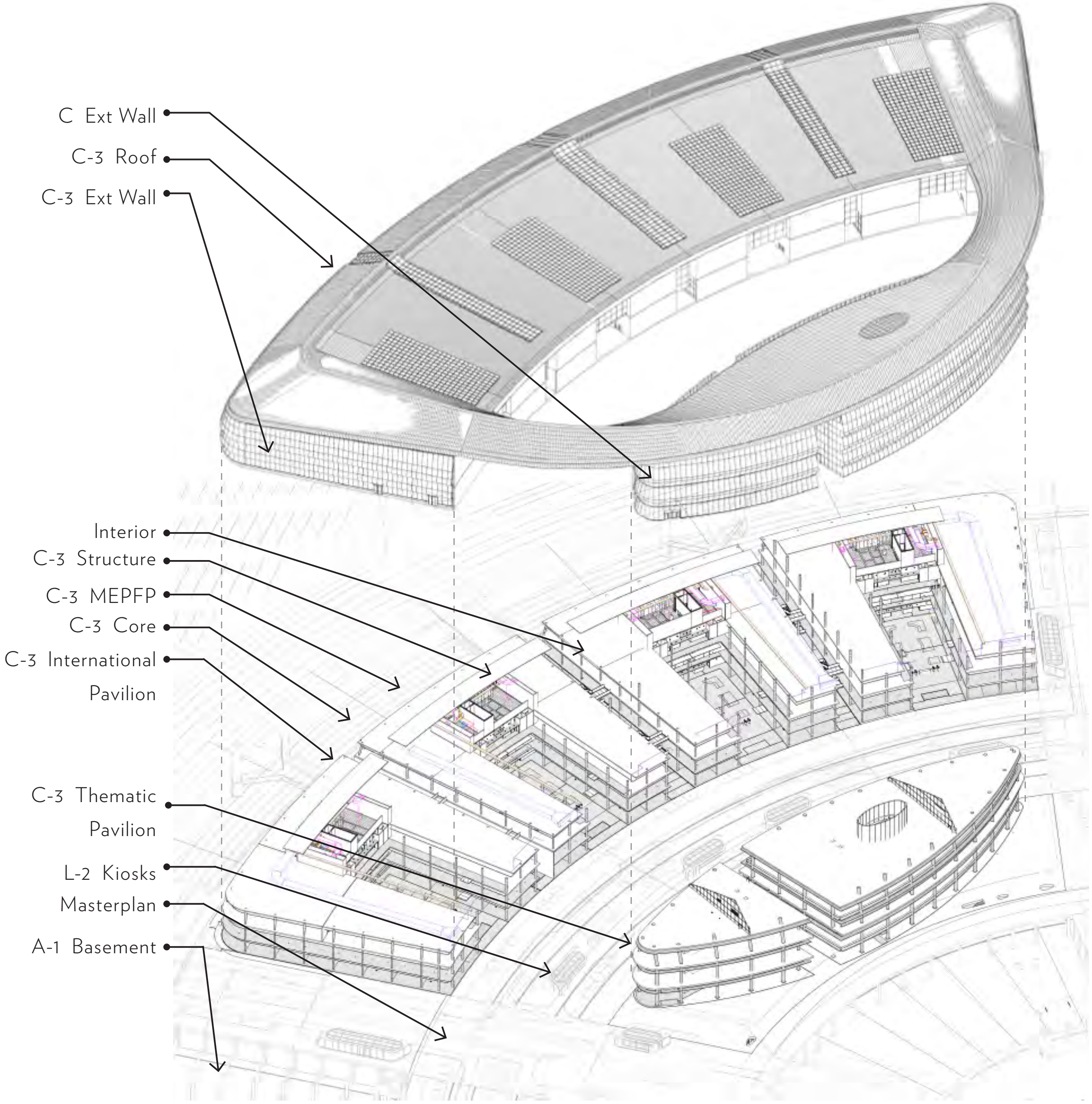
Expo Ciry Revit Model

The Documentation consisted of 1647 sheets generated within 42 Revit Models over the documentation period of 8 months. The Chicago-based design team worked in the same digital space with a constant feedback from changes in the various building models. The use of BIM allowed the design team to work collectively in the virtual environment, getting real-time feedback on changes-a virtue which was essential for meeting the demands of the scale and speed of the project.

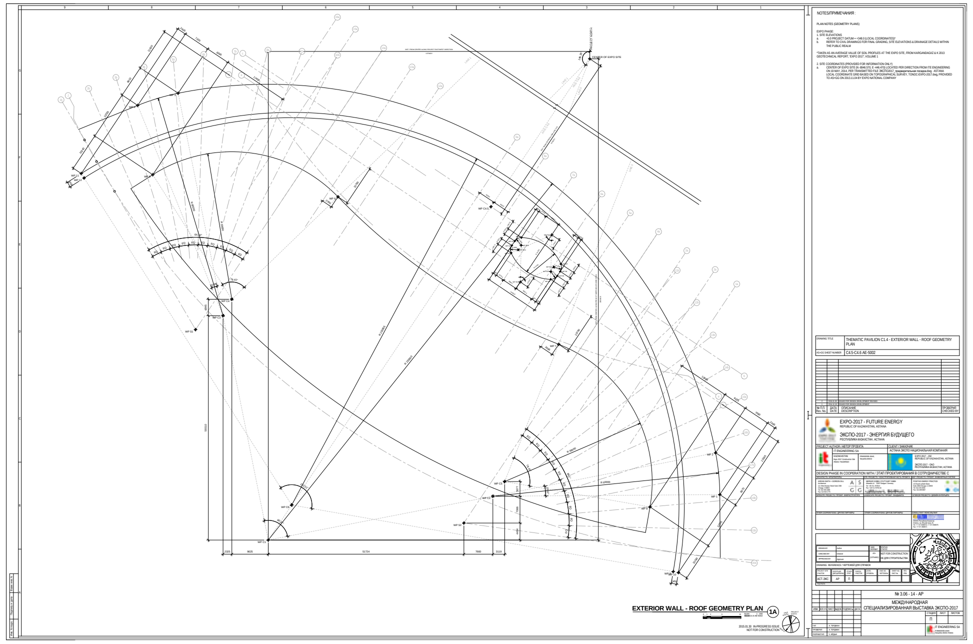
ASTANA EXPO CITY 2017

Process - Documentation

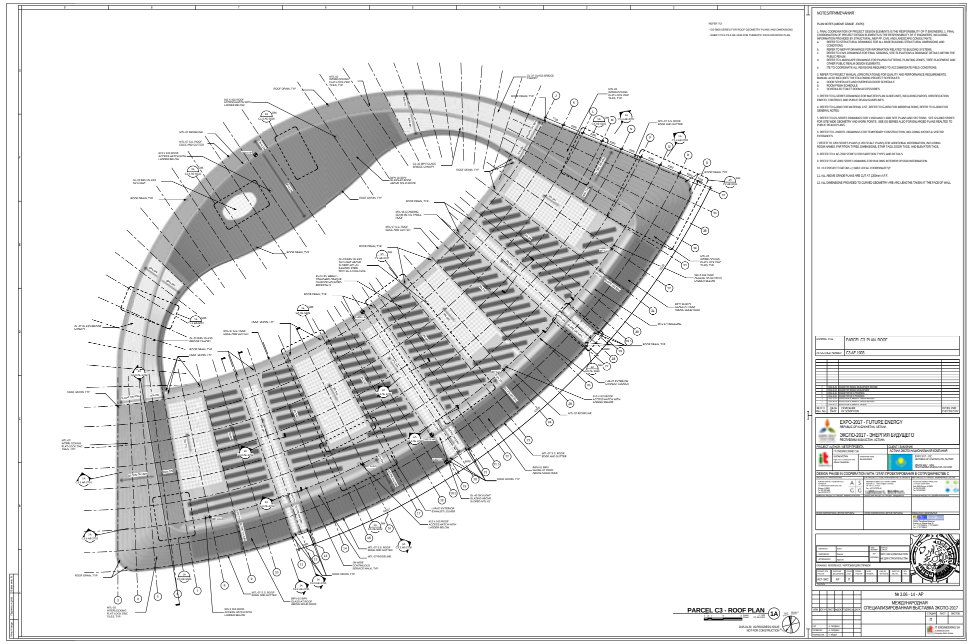
The overall project was broken down into 42 individual Revit models developed by eight teams. Each building was composed of the base building model and the exterior wall model. Each model documents the complex geometric building forms, interior architectural elements, structural framework and MEP systems. This significantly enhanced communication between each design team and the team of international consultants.



C-3 International and Thematic Pavilions Revit model and its components



Thematic Pavilion Roof Geometry Plan Sheet



C-3 International and Thematic Pavilion Roof Plan Sheet

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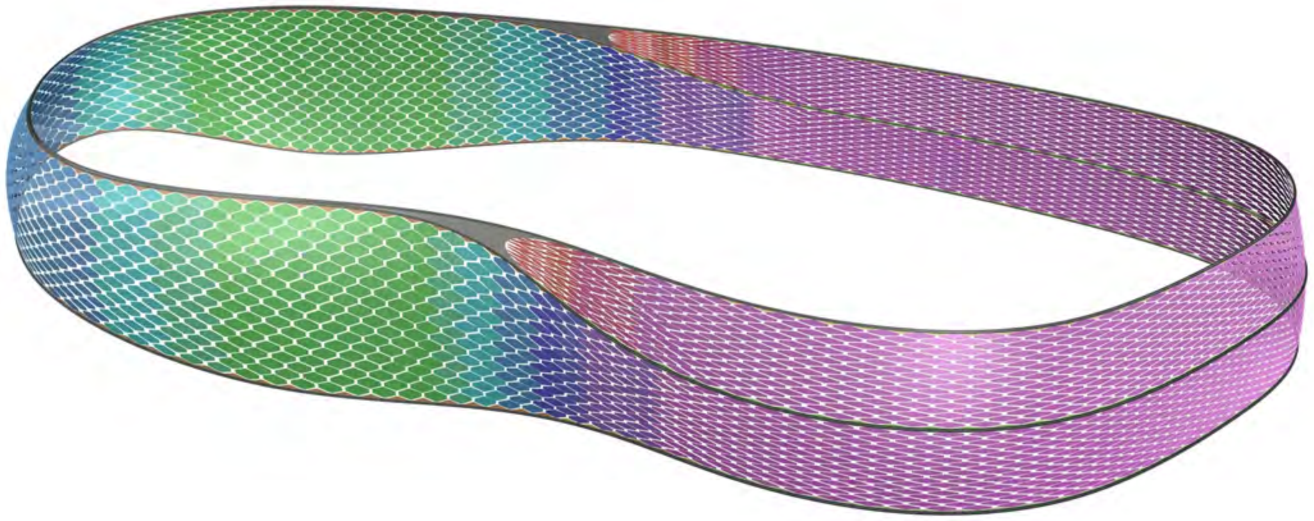
Process - Documentation

Each building has unique challenges in regards to documentation. The design teams created workflows and documentation procedures to illustrate and communicate the design intent through drawings along with 3D models for critical architectural components. Embedded in the documents of these components are the processes and strategies for installation along with the optimization of the component fabrication.



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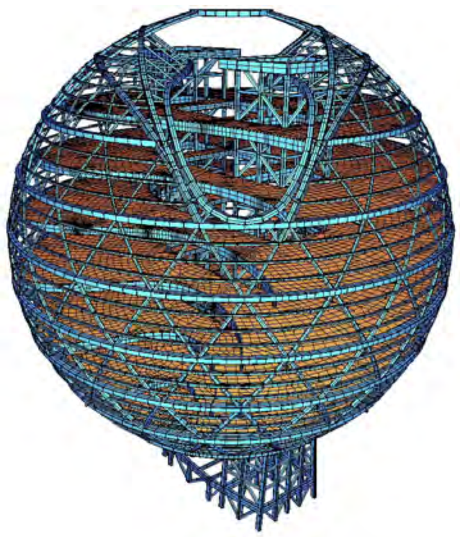
Process - Coordination

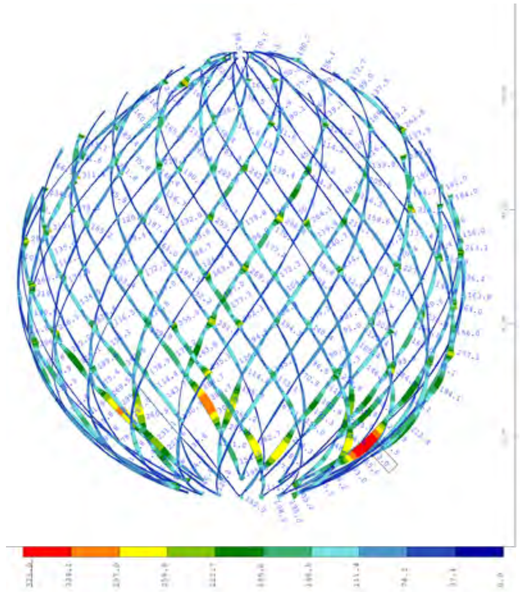
Site Construction Photographs - January 2016

The project team used BIM to explore multiple iterations of a design in virtual space prior to documentation. The iterations were analyzed for design expression, energy impact, and structural integrity, with all team members participating in a coordinated effort. This was particularly important for the sphere, a complex design that required close collaboration with the structural consultant located in Germany.

The Sphere structure was modeled as an idealized design expression- the structural team analyzed and engineered the structural forces of the complex grid shell and proposed further optimizations. The refined members were evaluated in the architectural model which was further coordinated and refined. Finally this process was repeated in a feedback loop that pushed the design of the various consultants to be a fully integrated solution that expresses those systems.



Structural Analysis Model



Structural Analysis Model

Design Model

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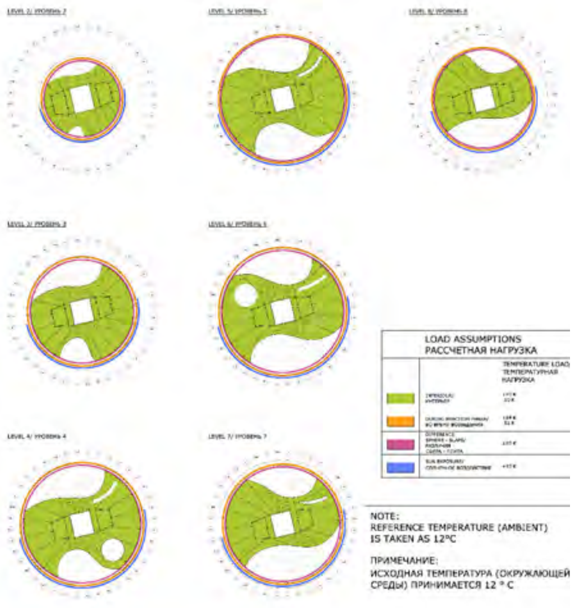
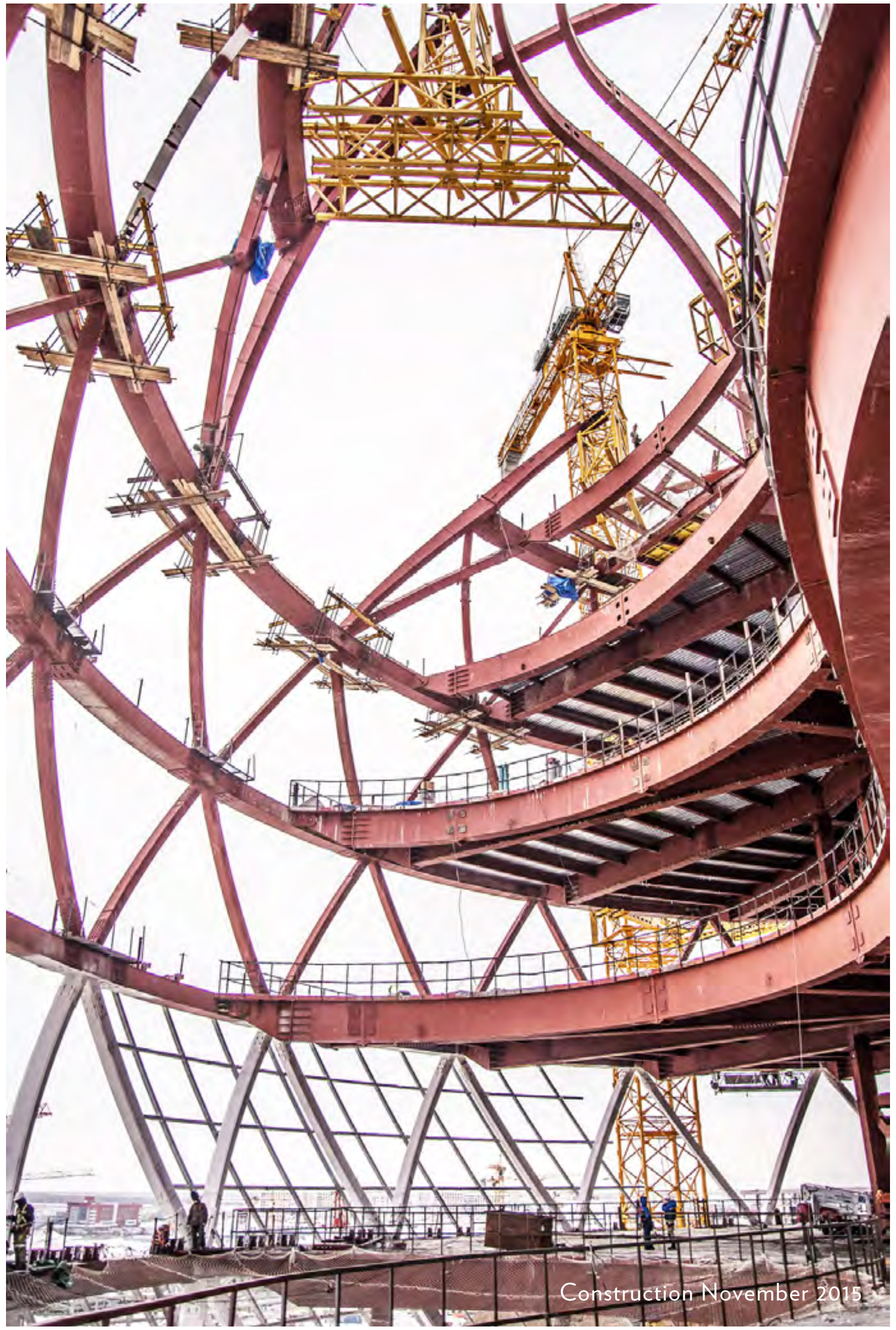
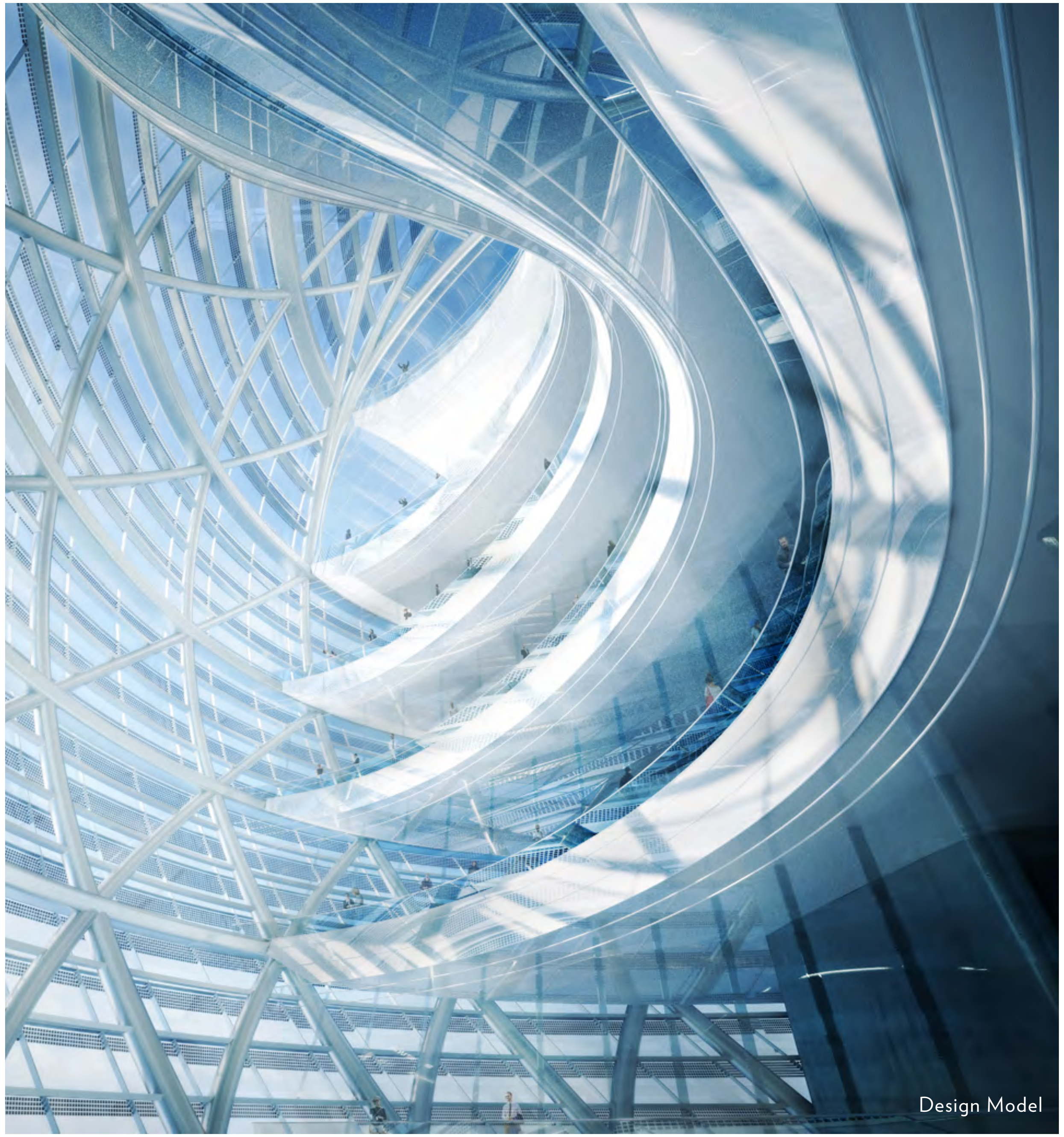
Process - Coordination




Construction November 2015

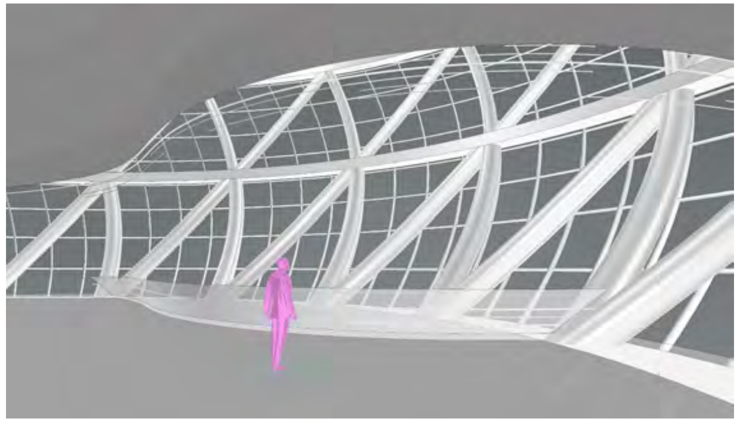

Design Model

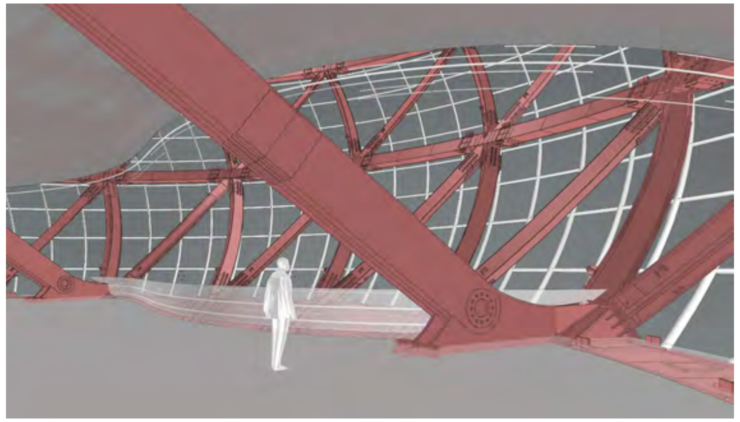
One major design element that required close collaboration with the structural team was the configuration of the slab edges. The program area within the sphere is arranged around two atrium spaces and span column-free from the core to the perimeter sphere structure. The continuity of structural elements as well as the allowable slab cantilever tightened the design of the freeform slab edges.

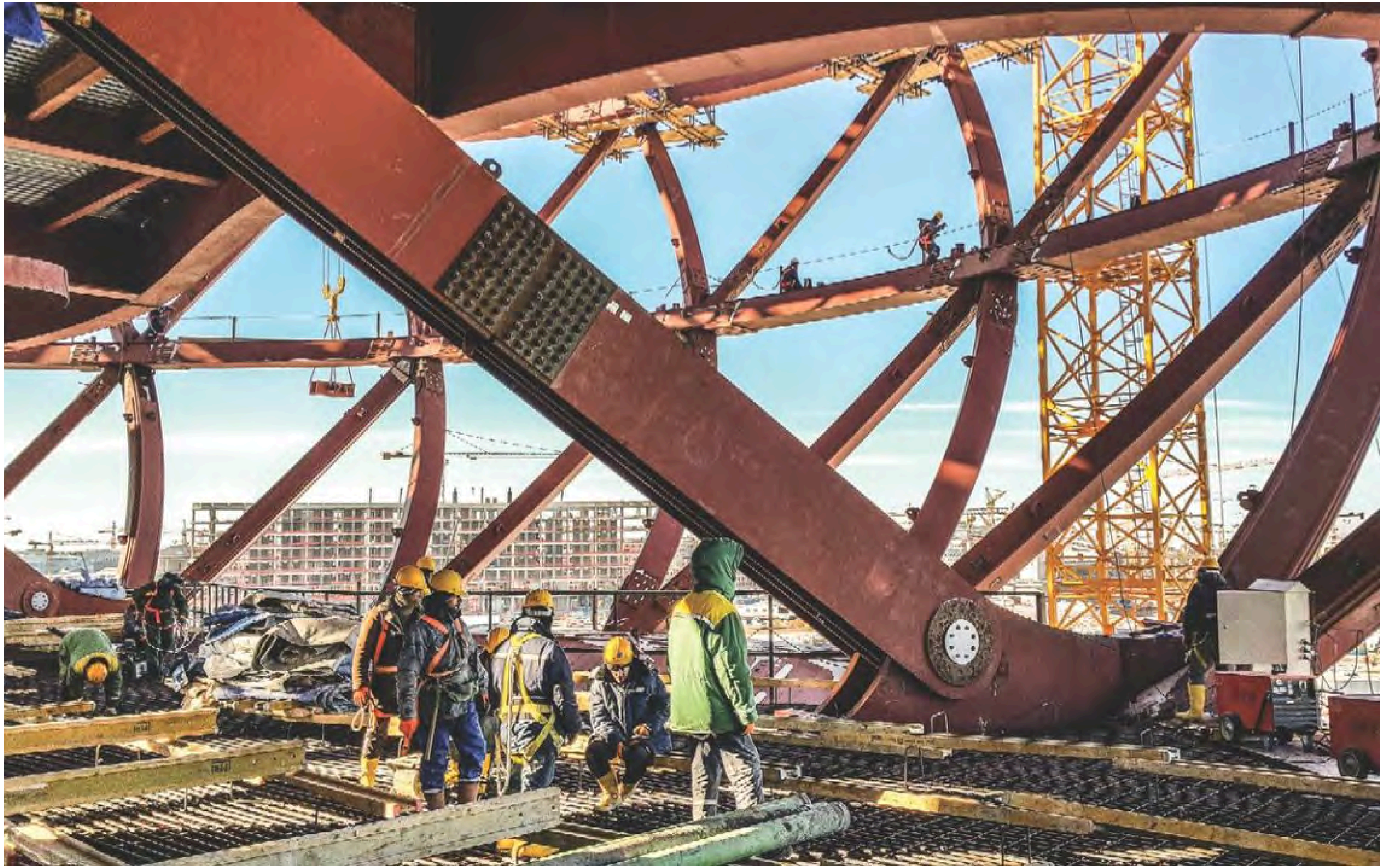
ASTANA EXPO CITY 2017

Process - Coordination

The coordinated BIM models were shared with contractors and fabricators to convey design intent and spatial relationships during construction. Using the design models as a starting point, the fabricators prepared shop drawings with a complete 3D fabrication model which, in-turn, was used by the design team for clash detection and design verification. This constant validation loop required the design model to be responsive to input from the fabricators and structural team.







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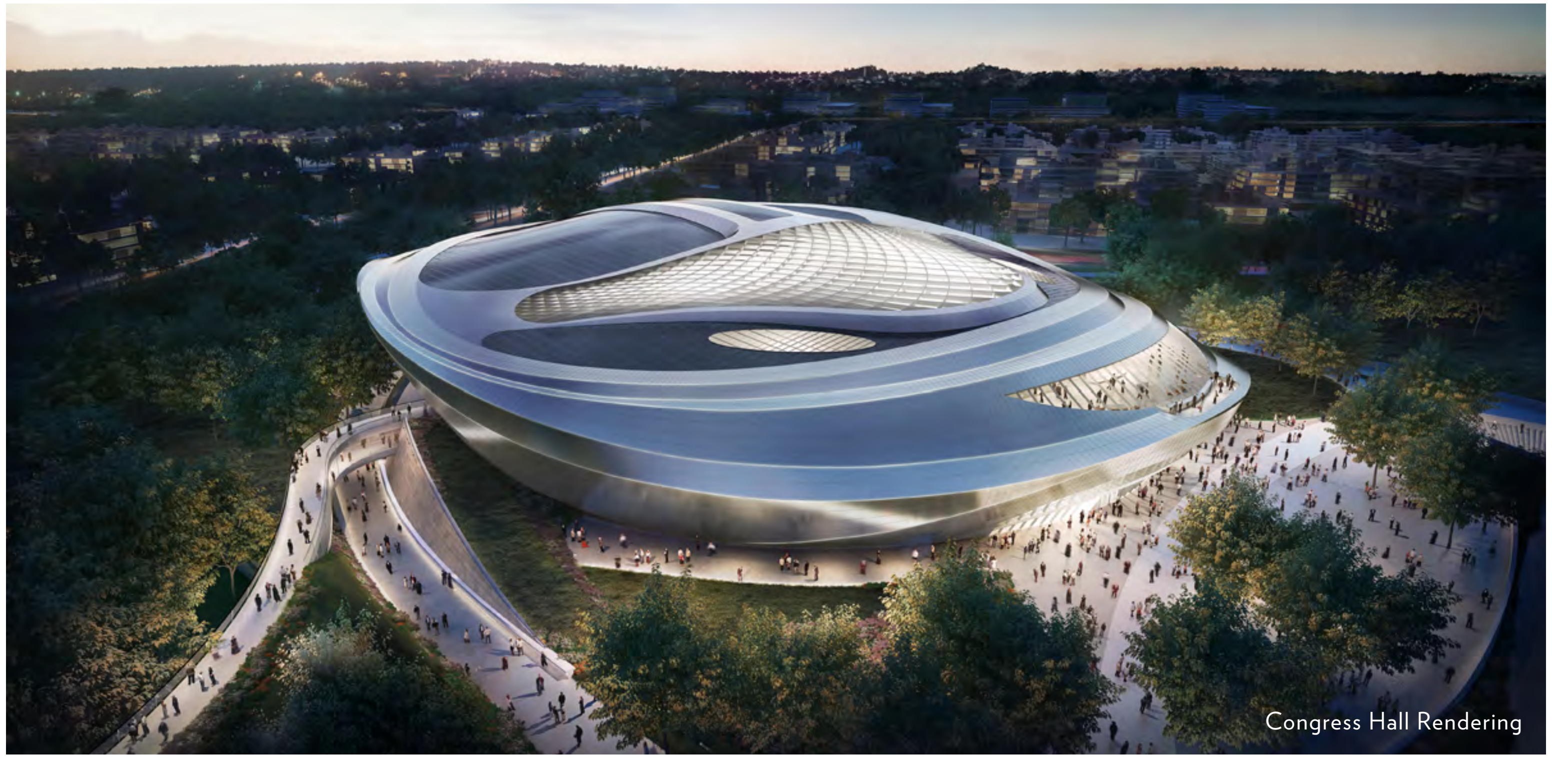
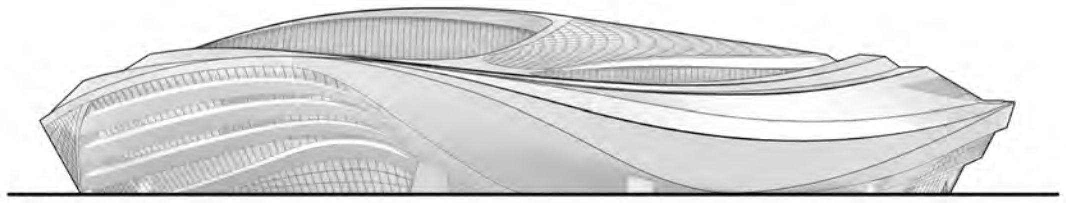
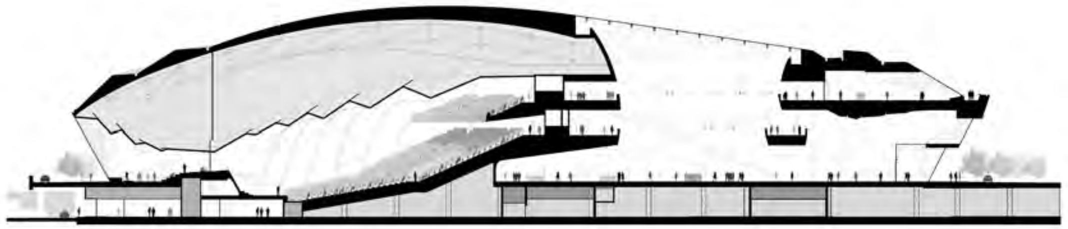
Design - Interoperability

Over the course of the Astana Expo City project, design complexity required the teams to find workflows that allowed integration of software such as Rhinoceros, to maintain the high level of design and fast-pace of the project. Interoperability proved to be an invaluable tool allowing teams to quickly move between design and documentation. Using interoperability the teams were able to maintain the design intent with extreme accuracy while generating fully native Revit geometry. These native Revit models were then able to utilize the full suite of robust tools and documentation benefits within Revit. The benefits of interoperability proved essential as they allowed teams to blend an evolving and iterative design with the documentation.



Congress Hall Rendering





Congress Hall Study Model

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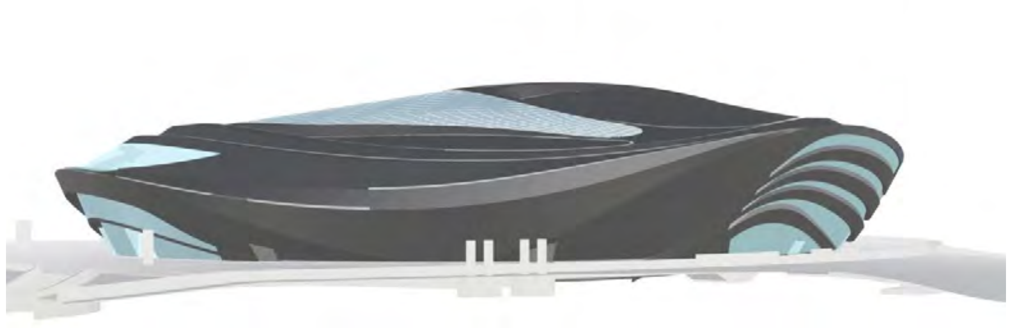
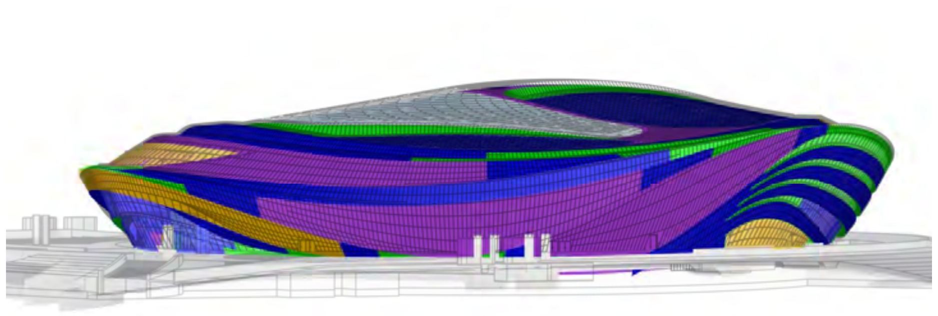
Design - Interoperability

Using a series of scripts in Grasshopper, a plug-in for Rhinoceros, the team generated the design surface geometry of Congress Center. Information gathered in these scripts was used to split surfaces based on area, a process known as "panelization". These panels were then optimized and flattened within an acceptable range of deviation. Once the panelization in Grasshopper was complete, each of the panel vertices could then be organized and sent to Revit using Hummingbird.

In Revit, Adaptive Components were created to retrieve this information and stretch to these points to form a perfectly accurate, fully parametric and native Revit curtain panel. This methodology and continuous feedback loop was applied to every building within the overall Astana Expo 2017 project.

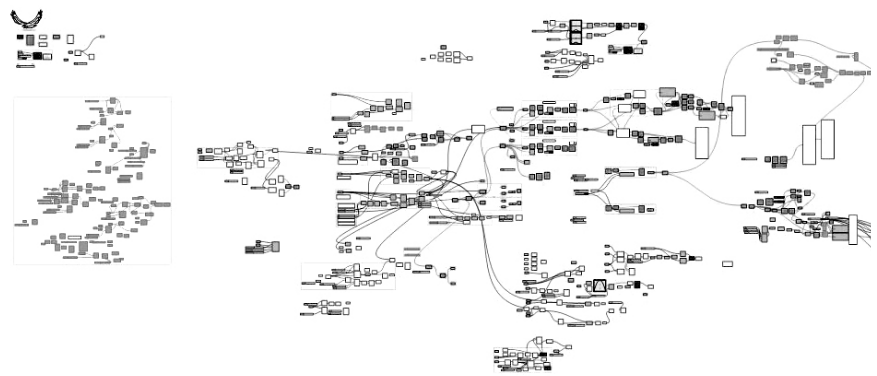


Rhino Model

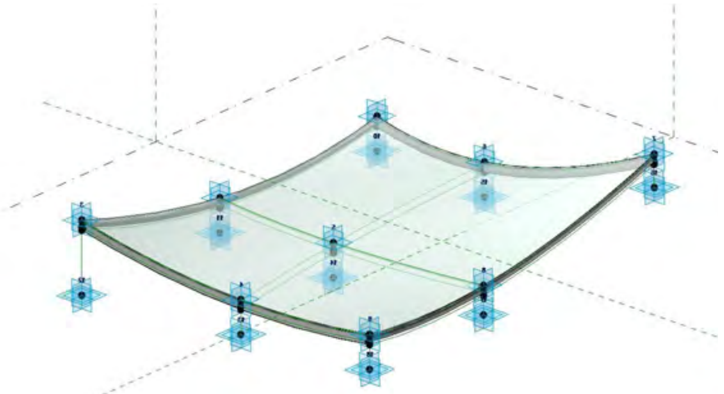


Rhino Model with split and panelized surfaces

Congress Center Construction 2016



Grasshopper Scripts



Adaptive Component

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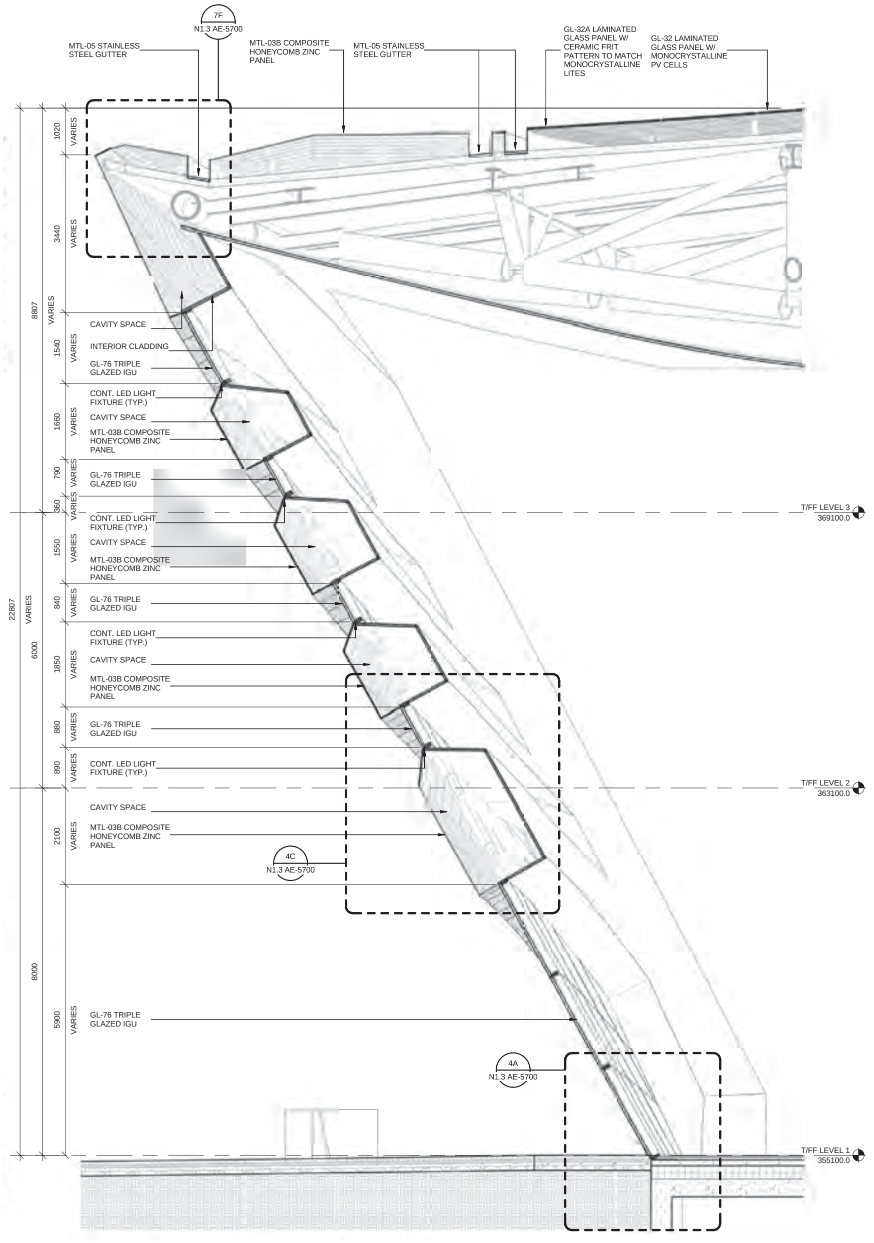
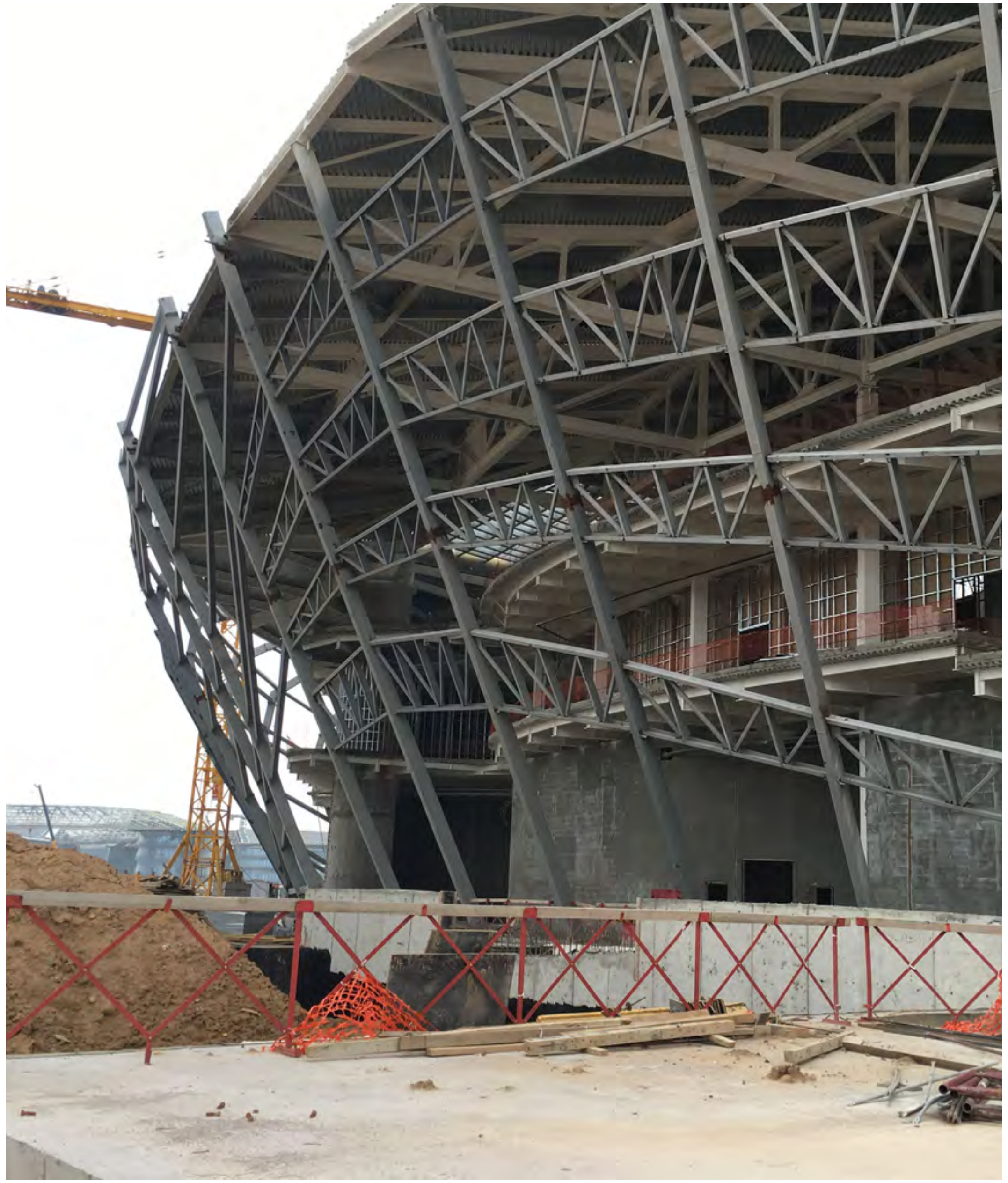
Design - Interoperability

The use of interoperability tools like Grasshopper and Dynamo (a plug-in for Revit) was essential when developing the complex interior spaces and exterior walls of the project models. Over the course of the project three major categories were used to judge the effectiveness of our Interoperability processes: optimization of the workflow, the accuracy of the translated geometry, and file size to help with the usability of the design model by many team members simultaneously.



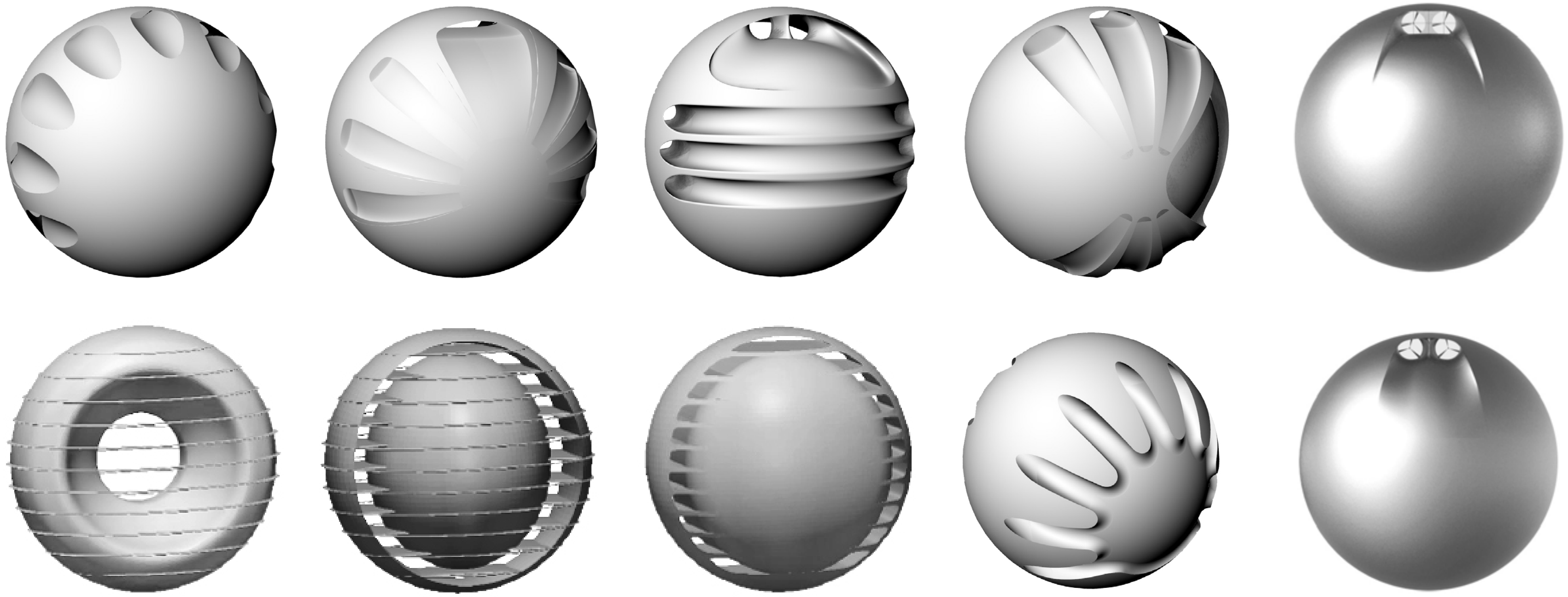
Congress Hall Wall Section Drawings



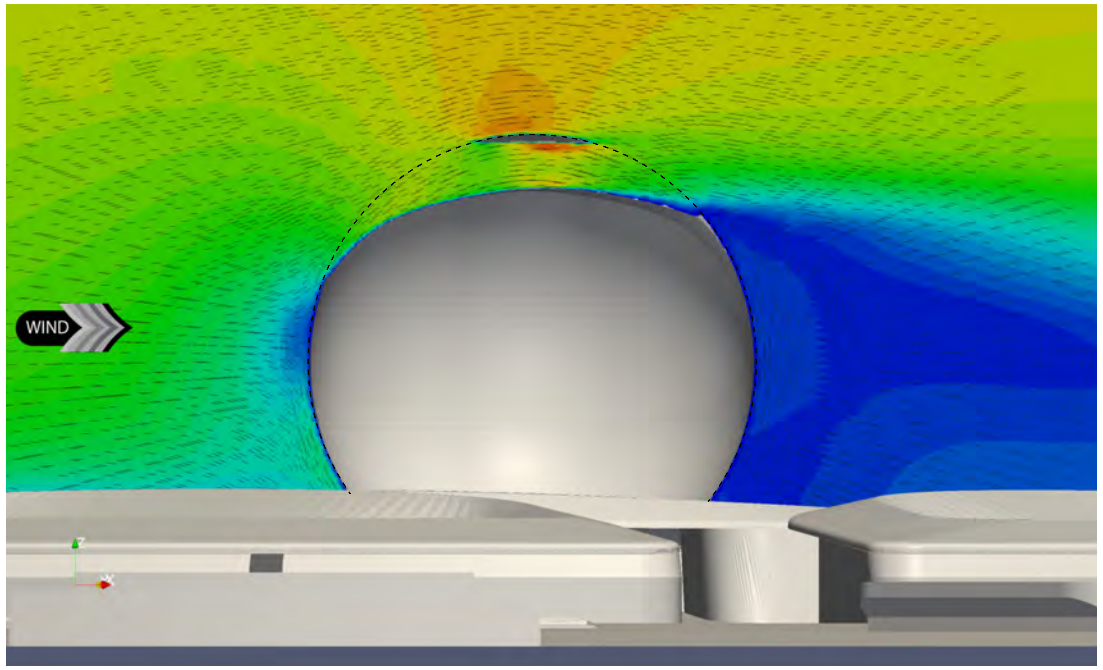
Congress Hall Construction Photograph

ASTANA EXPO CITY 2017

Design - Optimization of Form



Rhino Design Model

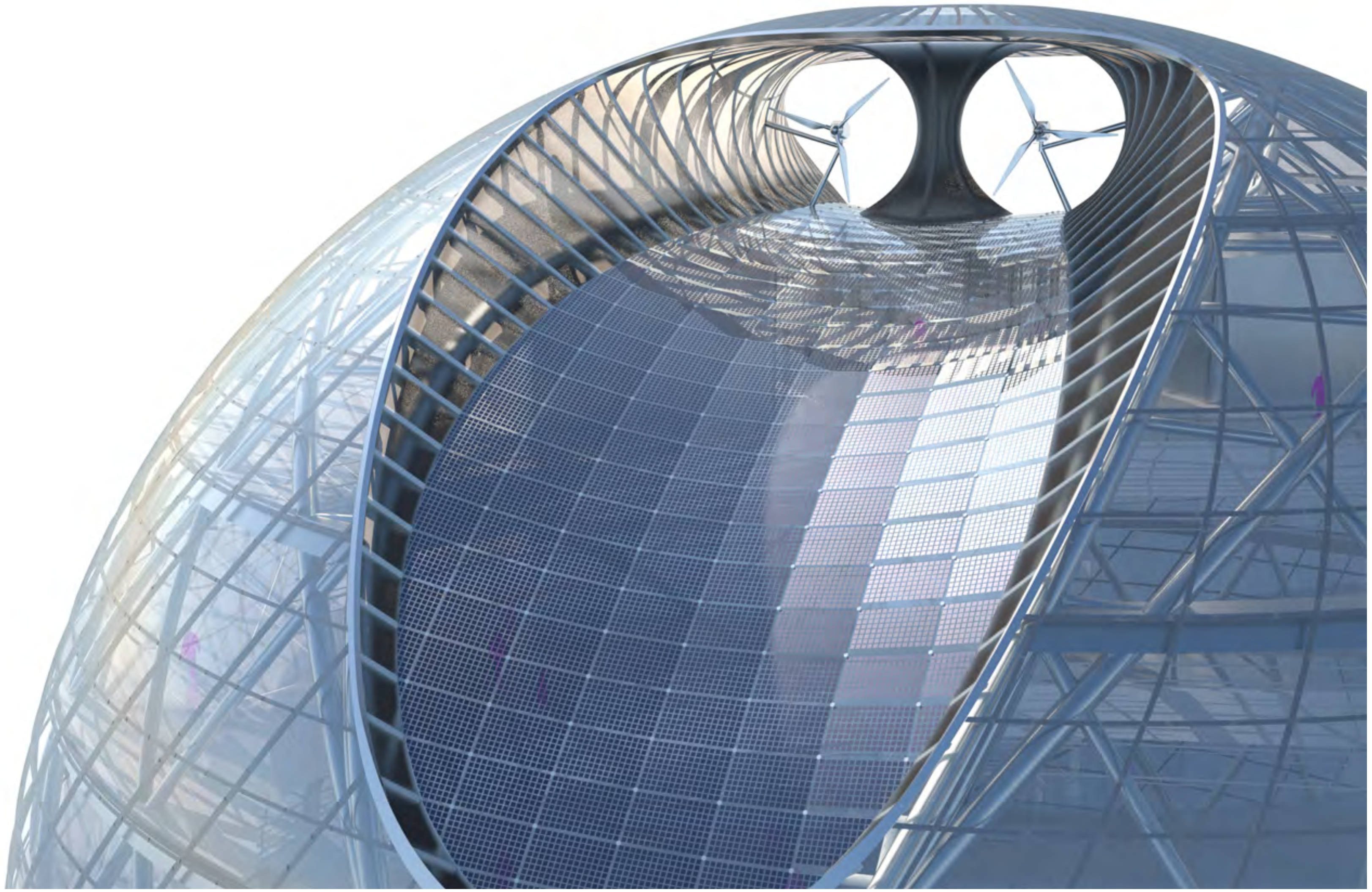


Countless designs were modeled and tested to find an appropriate form that responded to the programmatic requirements but that also optimized the amount of energy generation that could occur. For the design of the sphere these iterations focused on the wind energy that could be harvested from the surface of the sphere. The design team worked closely with wind engineers to design and test multiple overall building forms and eventually the various shape of an inlet on the surface of the building.

ASTANA EXPO CITY 2017

Design - Optimization of Form

Kazakhstan Pavilion Construction Photograph



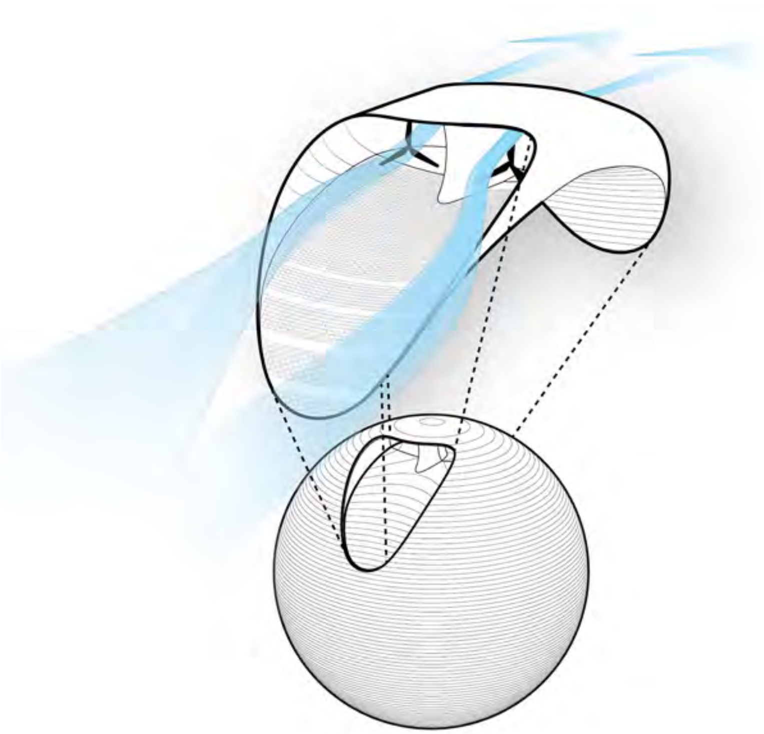
Kazakhstan Pavilion Rendering

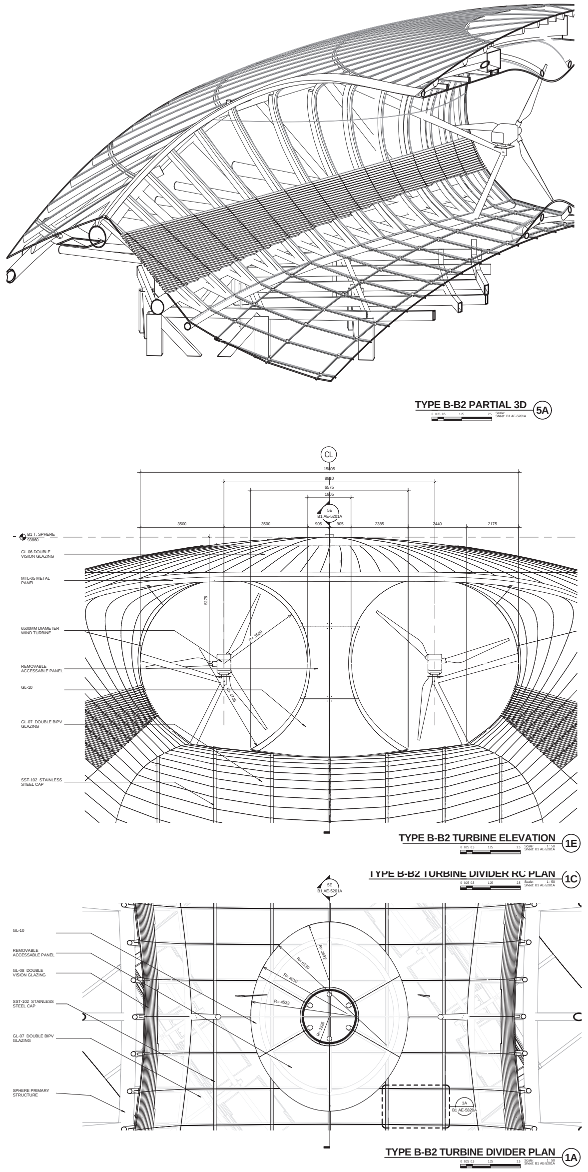
The integration of this particular design element is an example of where design, coordination, interoperability and documentation come together. The balance of the design and engineering systems with the analysis, measuring, and performance tracking, was critical to meeting the overall project goals. Many variables needed to be negotiated and integrated in order to provide holistic design solutions across the Astana Expo City 2017 project.

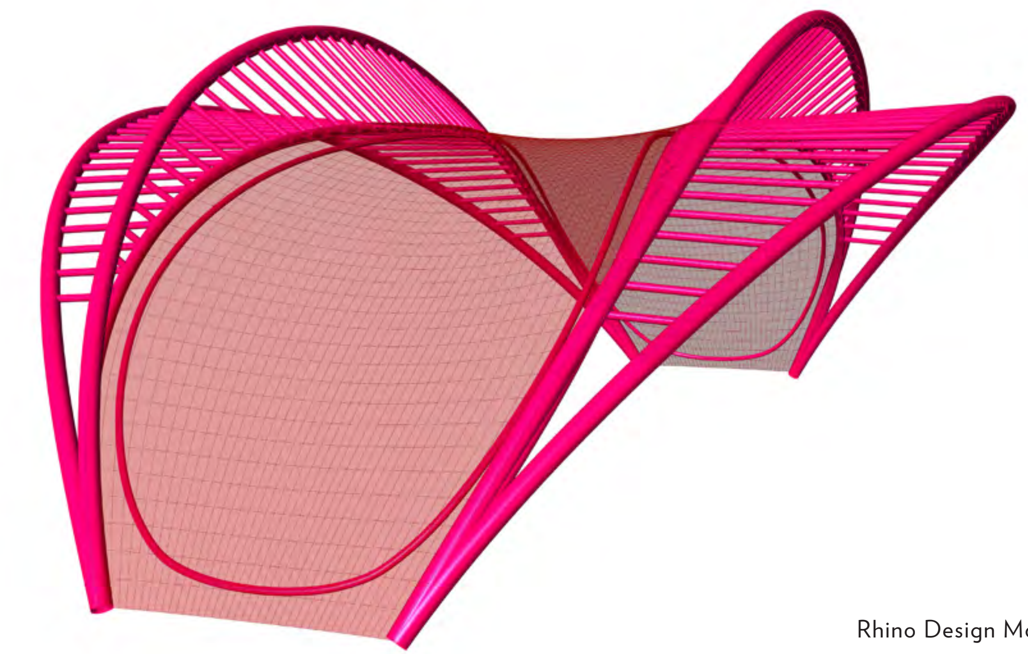
ASTANA EXPO CITY 2017

Design - Optimization of Form

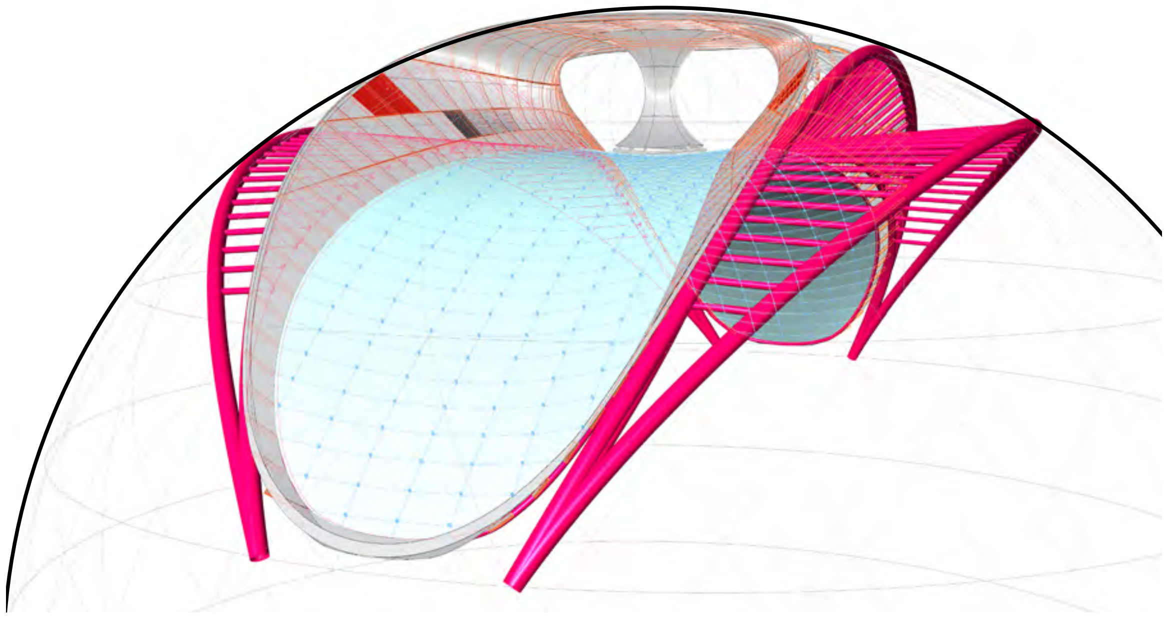
The cable-net surface was modeled through a minimal surface, form finding exercise (using the kangaroo plugin for grasshopper), which was coordinated with the façade and structural consultants for analysis and refinement. This process allowed the design team to alter the end condition of the cable-net and have a reasonable feedback of the resultant geometry in real time so that the size and configurations of the turbines along with the shape of the sphere opening can be tuned / optimized.







Rhino Design Model

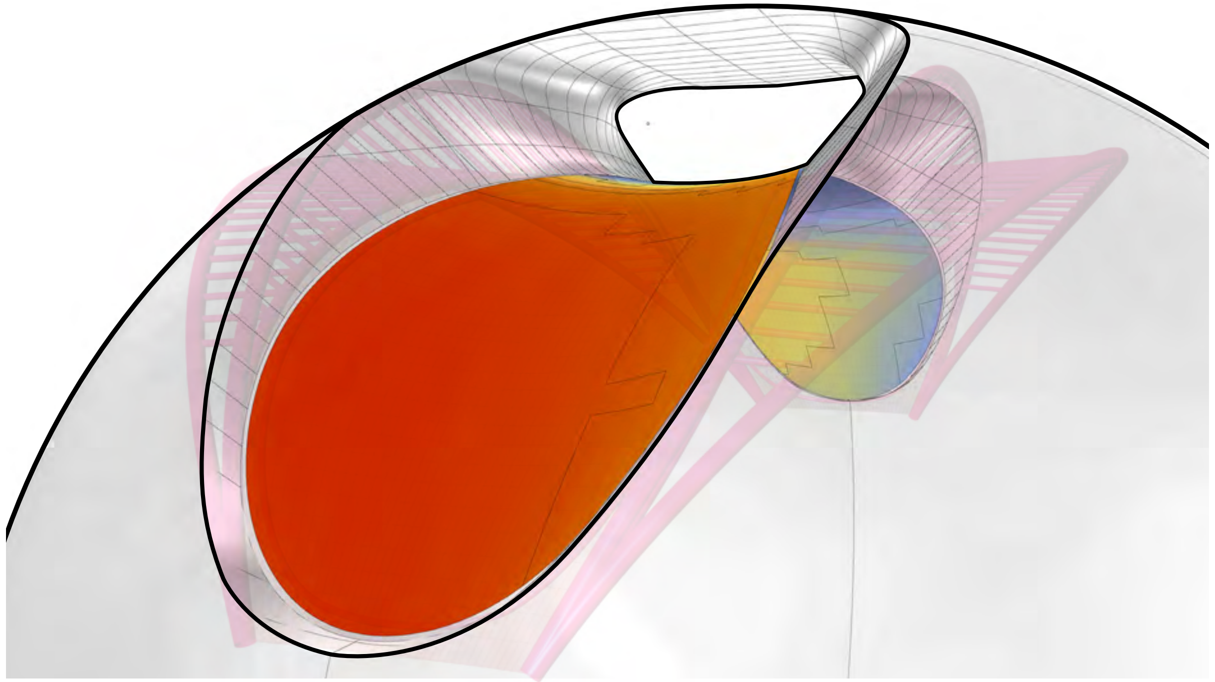


Rhino Design Model

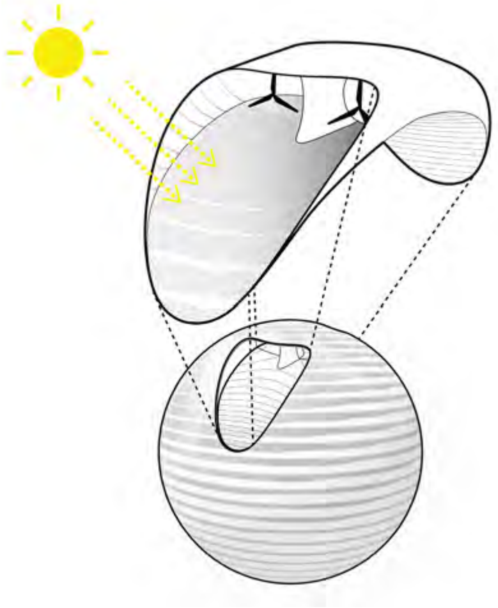
ASTANA EXPO CITY 2017

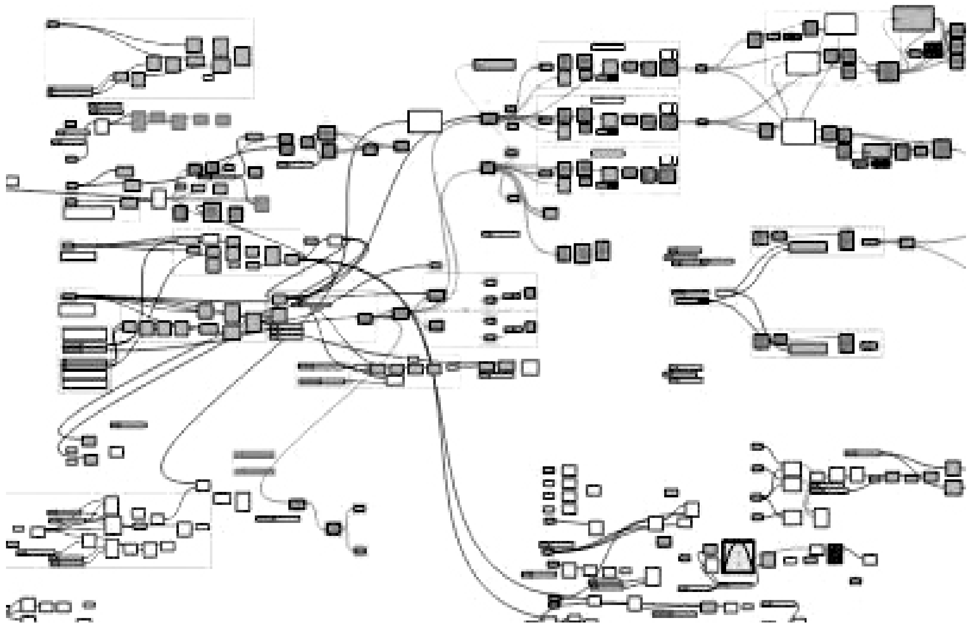
Design - Optimization of Form

After the initial form was chosen, more detailed analysis was conducted using Rhino / Grasshopper to further refine the form and to maximize sun exposure for the solar panels. Many investigations were completed and tested to integrate the BIPV panels while balancing the requirements of other critical building components such as MEP surface area requirements, collision with other architectural elements, maximizing wind swept area for the turbines, and the rationalization the double-curved minimal surface geometry. Using current and customized interoperability tools in Grasshopper and Revit along with custom Revit families, the form was translated between the various software packages without needing to use any heavy and incompatible imported geometry.

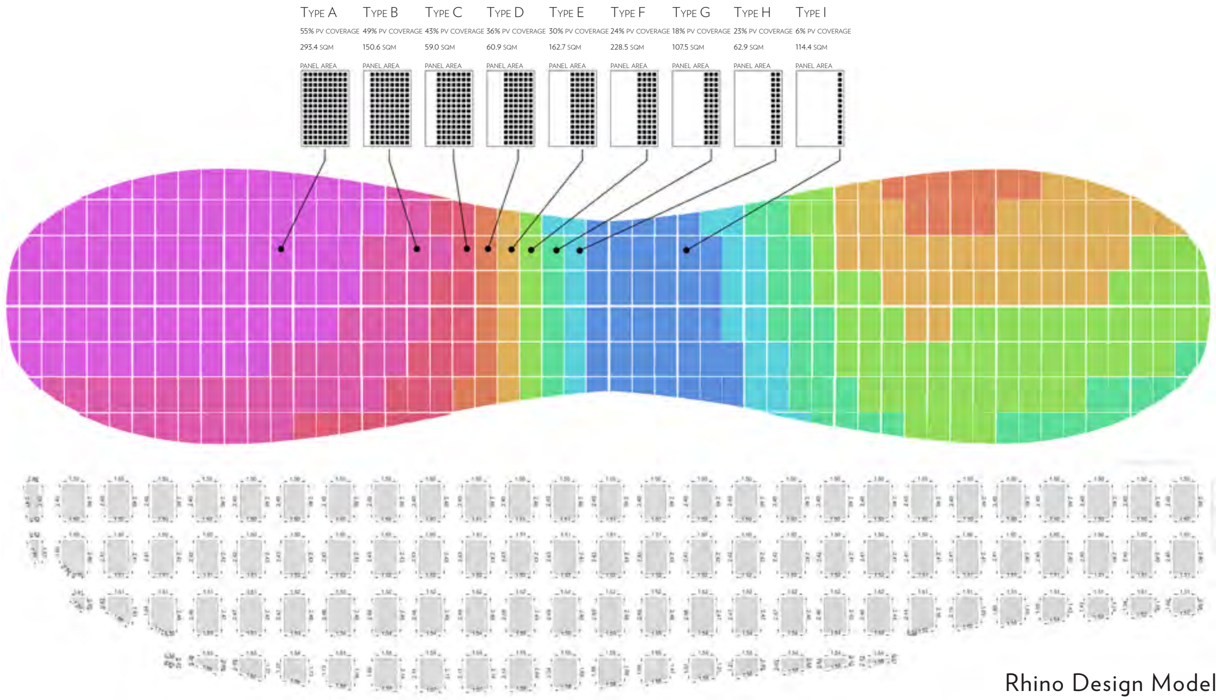


Rhino Design Model





Rhino Design Model



Rhino Design Model

ASTANA EXPO CITY 2017

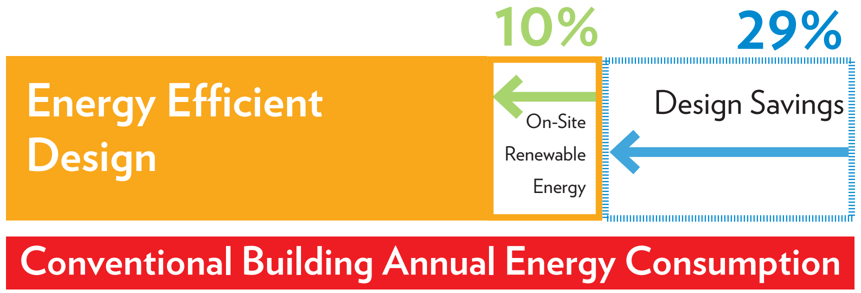
Performance

The master plan was designed to meet the five pillars of a Post-Industrial Revolution, which include shifting to renewable energy, designing and constructing buildings as power plants, decentralized energy storage, implementing smart grids, and usage of non-fossil fuel based transport.

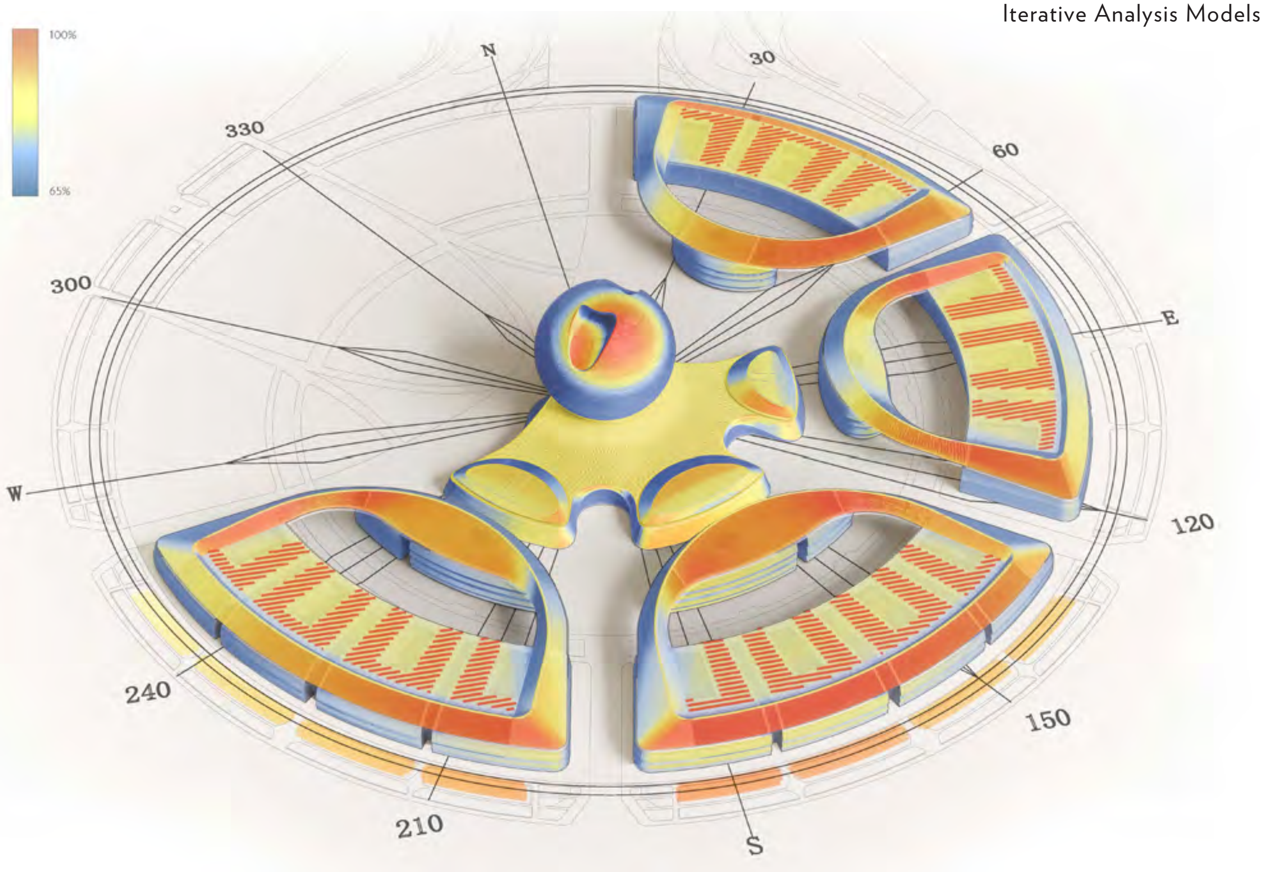
The team also developed a series of Key Performance Indicators that addressed a number of sustainability themes including energy, carbon, water, waste, and biodiversity. They tracked these internally throughout the entire design process, providing progress reports to the client. As a consequence, a significant percentage of the energy consumed by the expo community will be provided from renewable sources, with buildings having been designed as generators of power which will be distributed by a site-wide smart grid.

This project utilized advanced simulation software to inform decisions during the design process. This took place at a number of scales—from testing different orientations and building envelope configurations using advanced CFD Simulation, to studying the elimination of thermal bridges while at the same time bringing external structural elements into the spaces, the design team worked closely with the supply chain to identify and specify appropriate solutions and materials. The mechanical systems were tailored specifically around the building envelope performance, allowing us to offset additional investment in the façade system through minimizing the cost of the mechanical system and consequently the life-cycle costs of the building.

As a result of this approach, the post expo development will be one of the most sustainably built in the world. 100% of the post-expo non-potable water demand will be provided by the on-site water reclamation facility. 28% of the post expo electrical demand will be met from on-site BIPV energy systems. The total post-expo grid energy demand is 47% less than an ASHRAE 90.1 2010 Baseline, while the office buildings during post-expo will use 21%-39% less energy than ASHRAE 90.1:2010 Baseline (overall reduction is 38%). We also specified that all insulation (a significant component of the energy performance strategy) was accompanied by third party verified EPDs allowing us to reduce the Global Warming Potential and other environmental impacts of the materials used on the project.



Iterative Analysis Models



Expo Site Radiation Analysis