SOM

Height: 380M Guiyang World Trade Center, Guiyang, China

Height: 200M Charenton, Paris, France

Height: 320M Zhuhai, China

Daylighting

Solar Irradiation

Passive Conditioning

Controlled Comfort System

High Performance Enclosure

CONTEMPORARY DESIGN PROCESS

Environmental Performance

Energy

Sustainability

Material Science

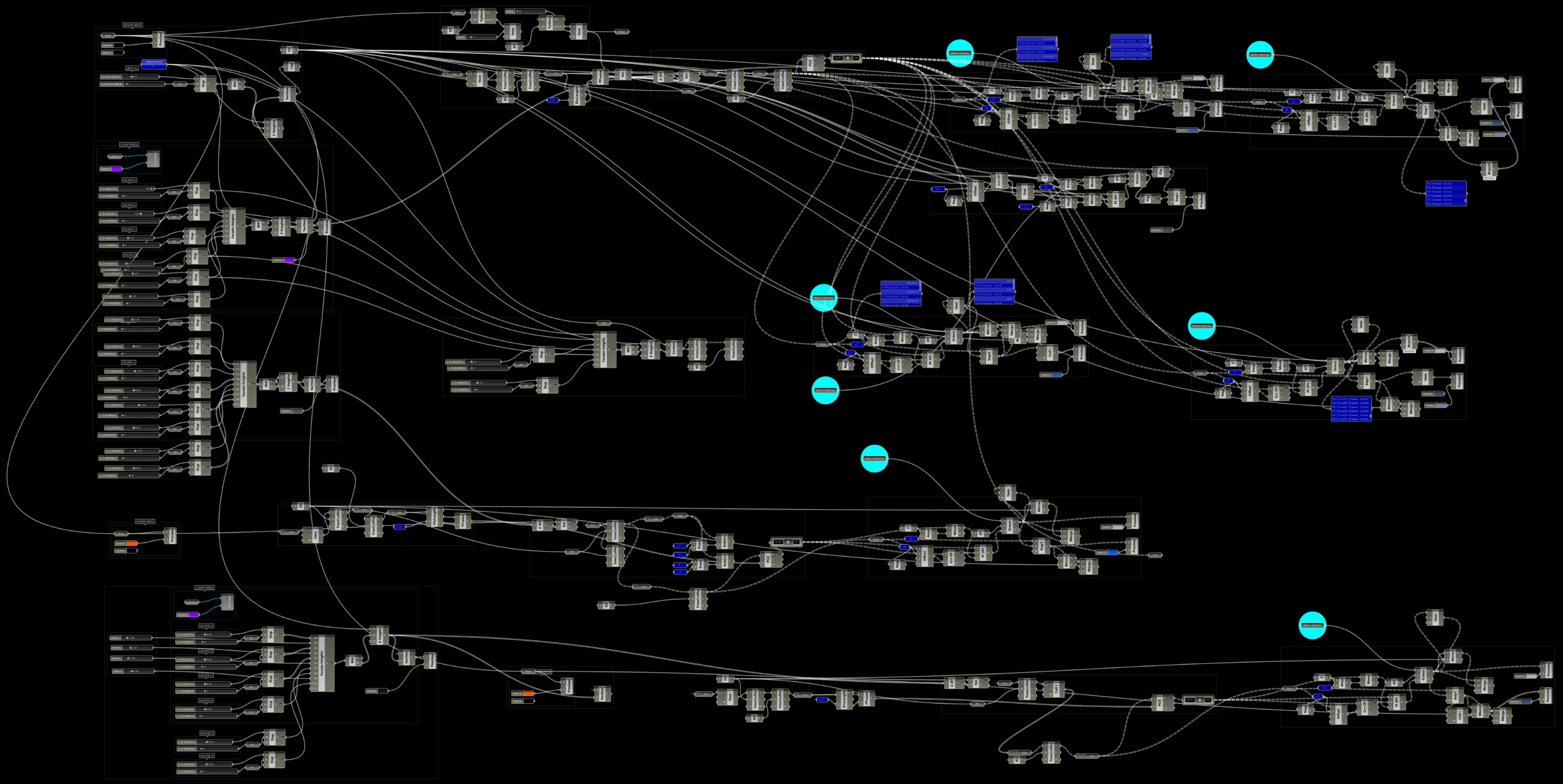
Structural Efficiency

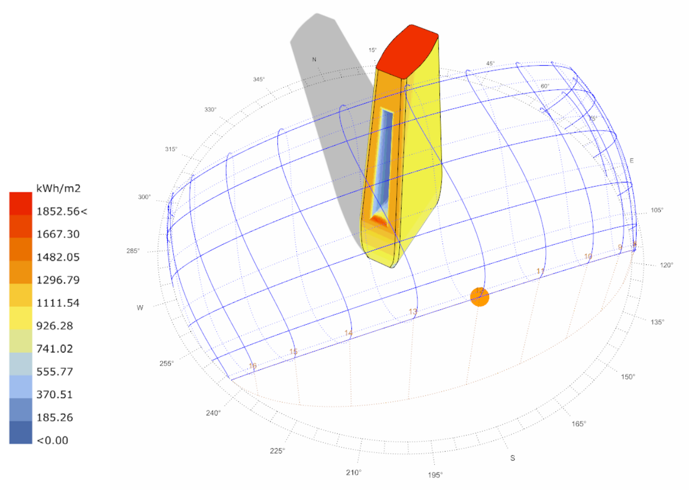
Mechanical Systems

Comfort

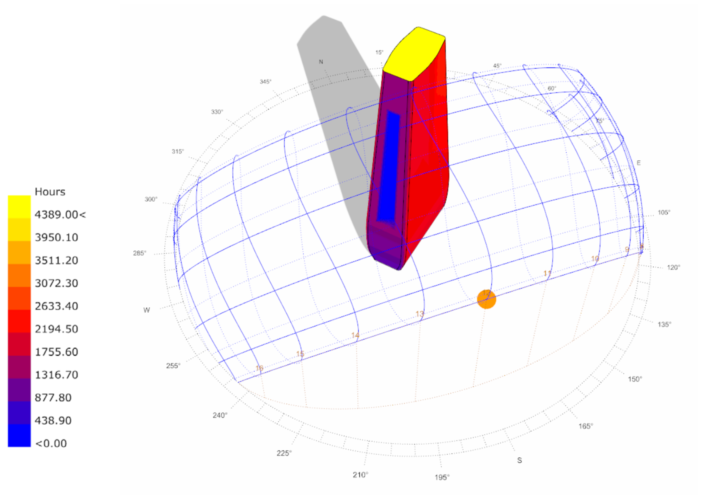
Manufacturing

Constructability





Solar Radiation Analysis Looking North



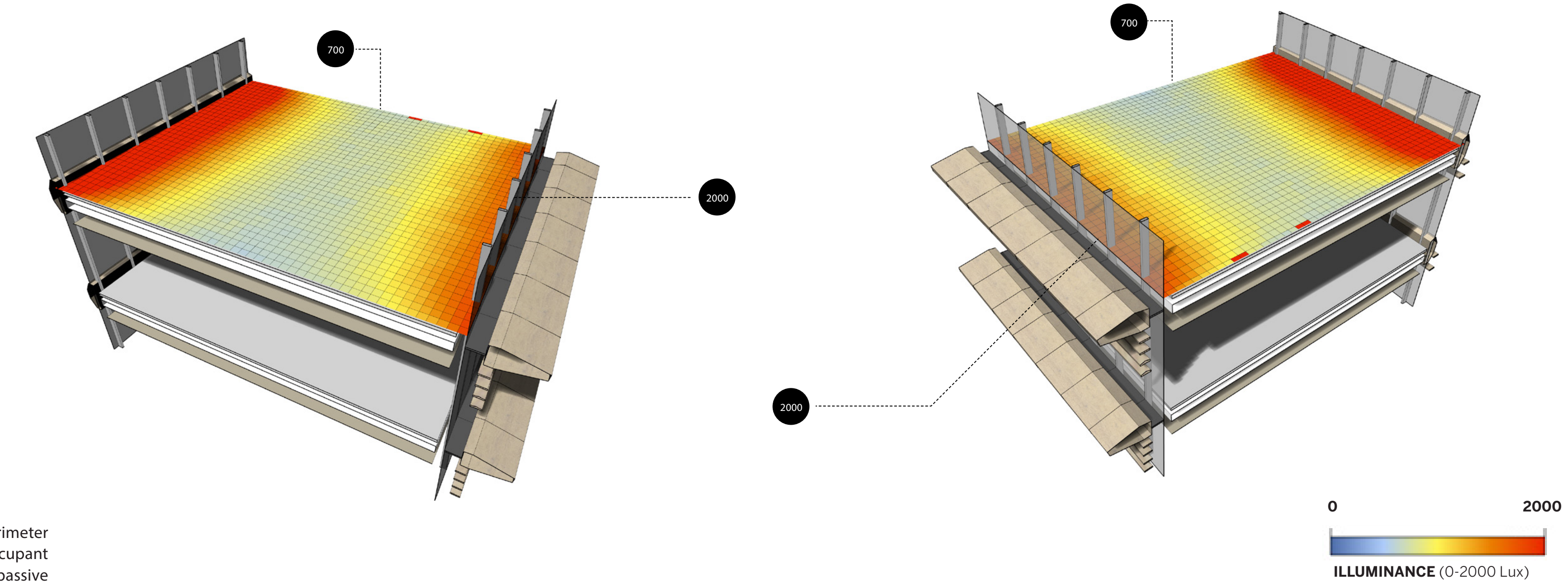
Sunlight Hour Analysis Looking North

Southern Facade Study

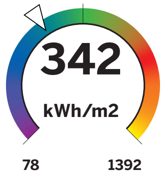
Area Evaluated: **125** sqm

Proposed: Useful Daylight Illuminance (UDI)

High percentages of exterior glazing can also introduce perimeter glare. High levels of glare will have a negative impact on occupant comfort, and can be addressed in conjunction with other passive energy reduction strategies.



Solar Heat Gain Baseline



SED (Solar Energy Density)

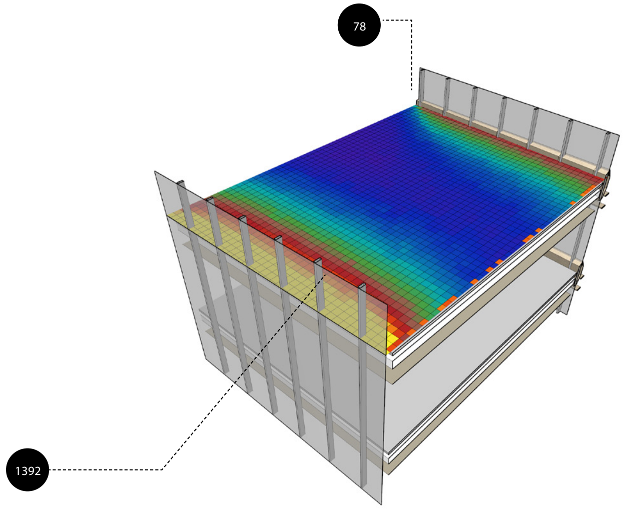
42,800kWh

SE (Total Annual Energy Received) / kWh

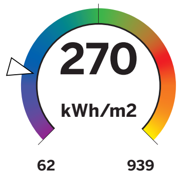
Southern Facade Study

32%

Heat Gain Reduction



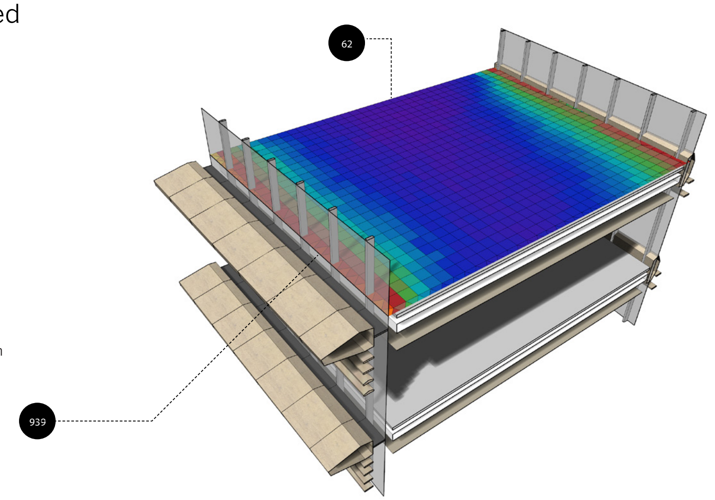
Solar Heat Gain Designed

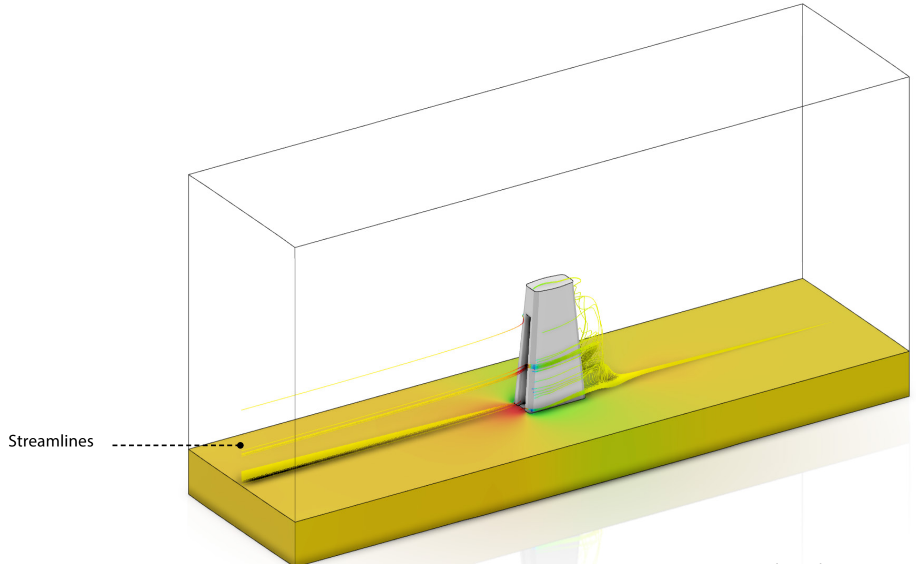


SED (Solar Energy Density)

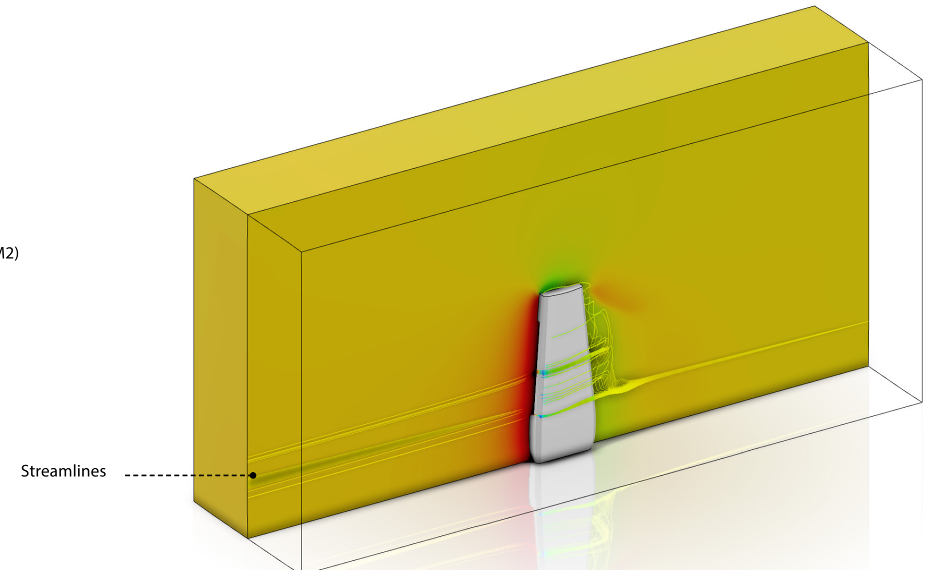
29,200kWh

SE (Total Annual Energy Received) / kWh

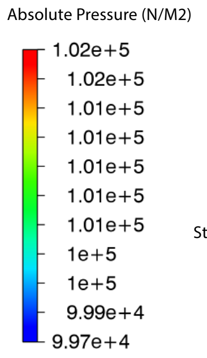


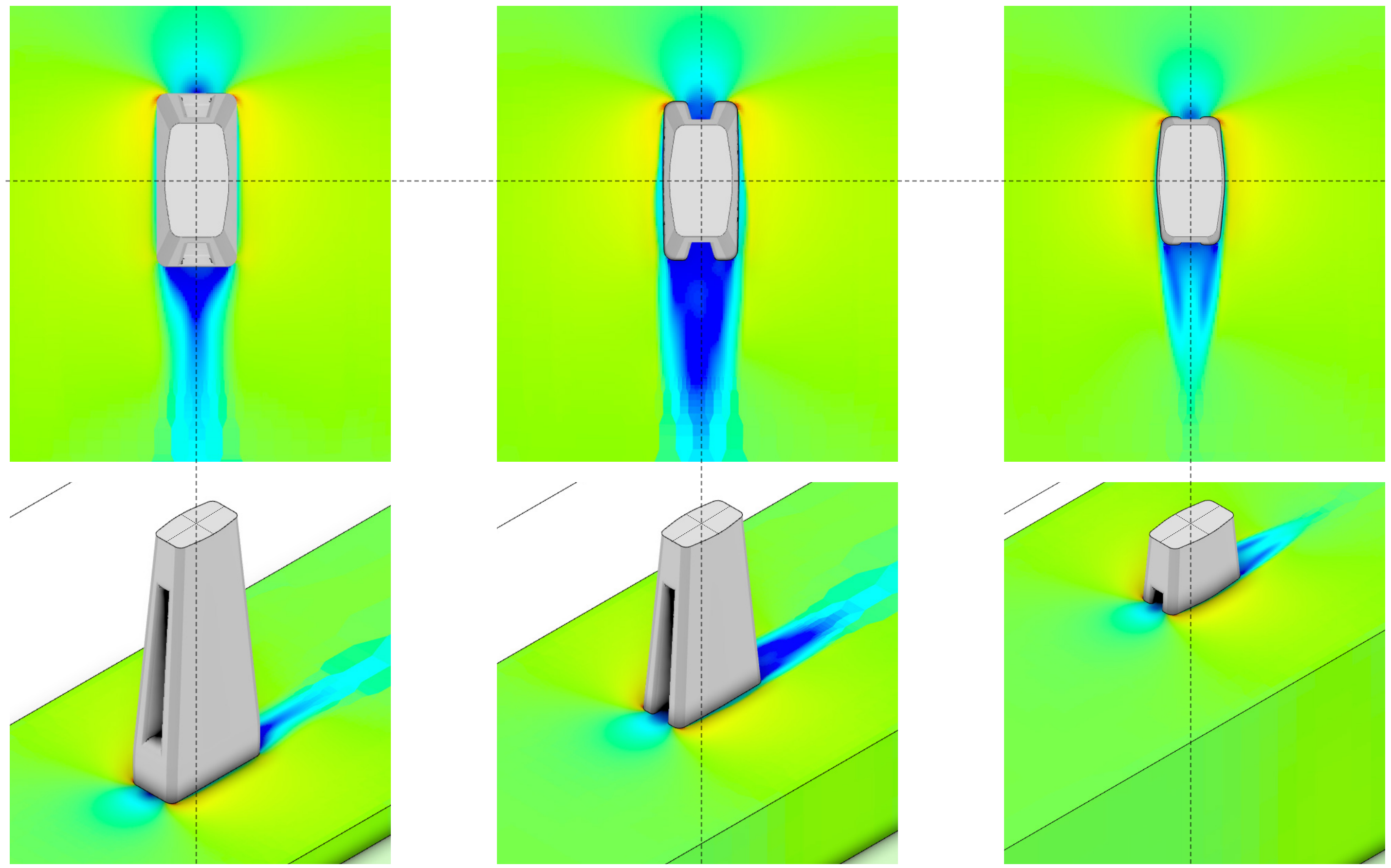


Pressure Analysis Plan Section



Pressure Analysis Vertical Section

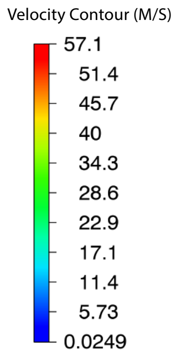




Low Zone Velocity Contour +15M

Mid Zone Velocity Contour +75M

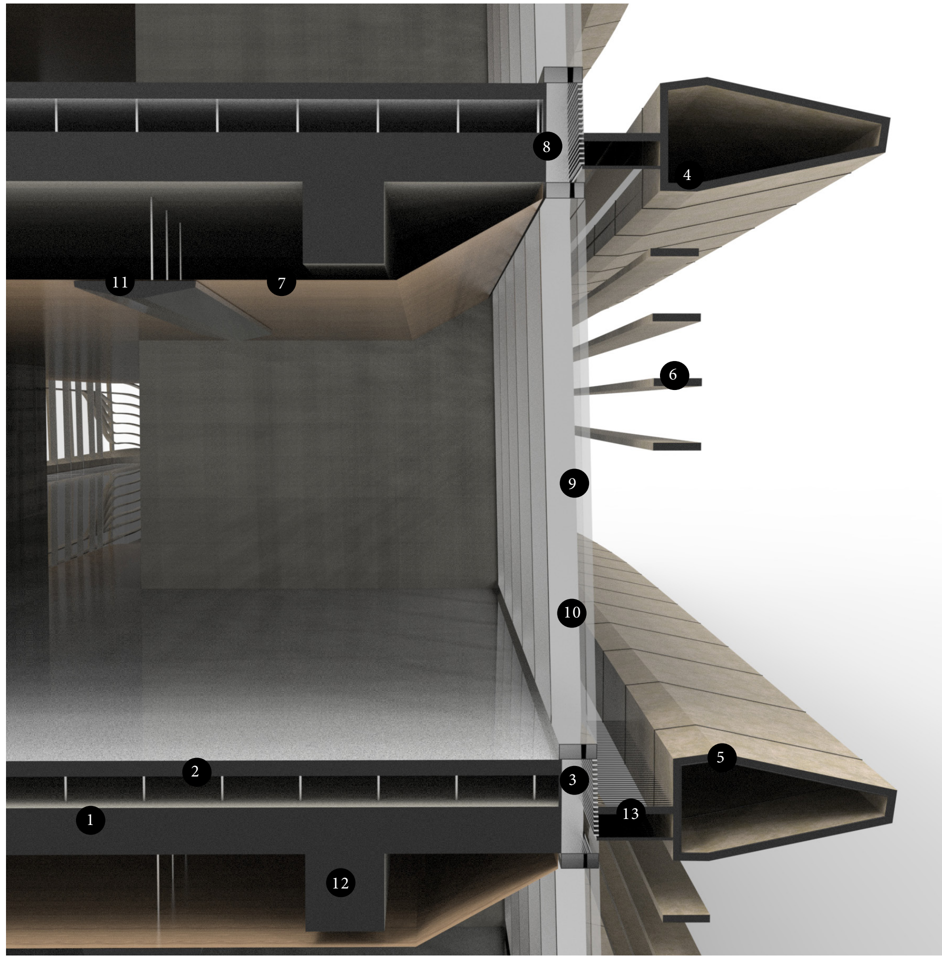
High Zone Velocity Contour CFD +165M



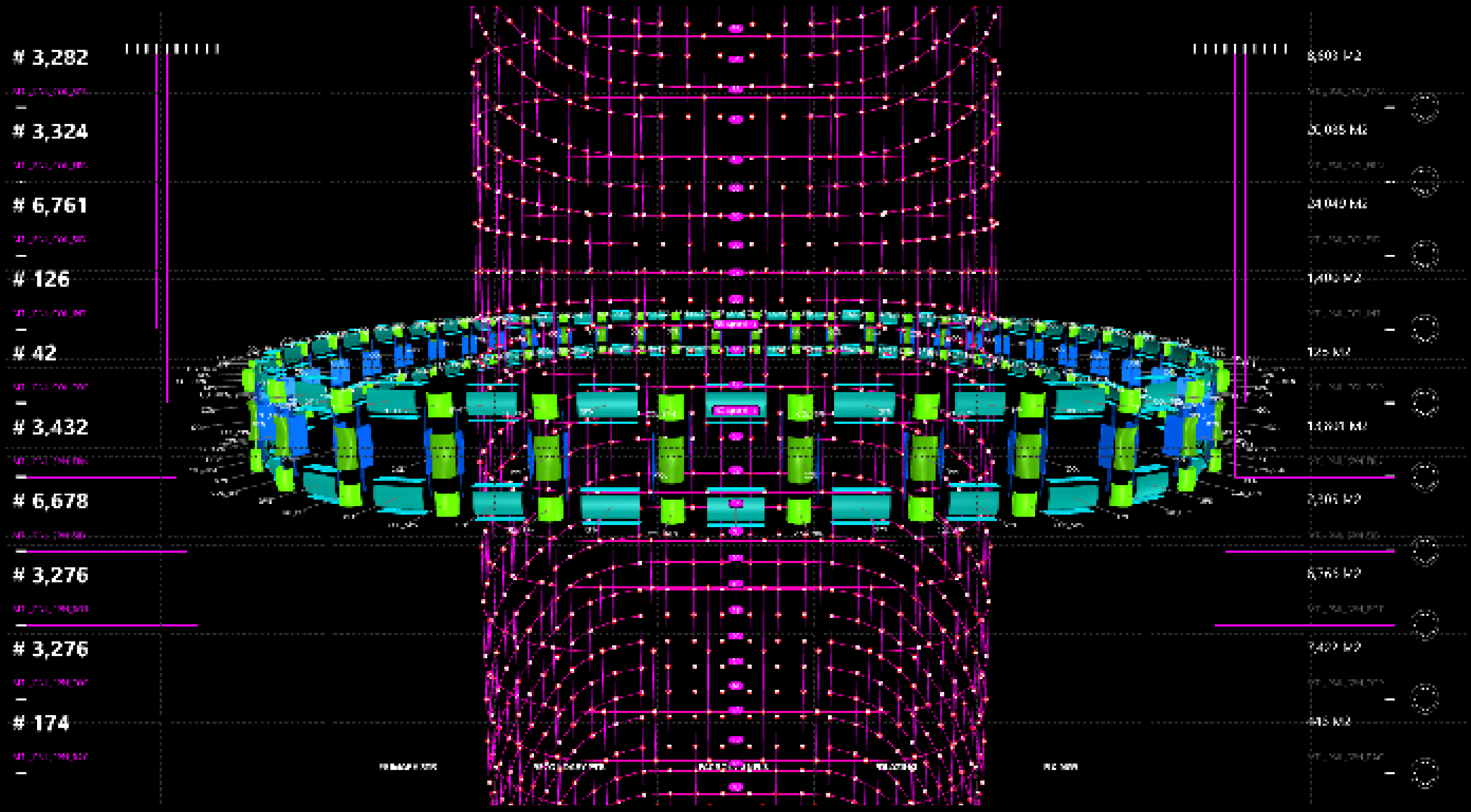
Pressure & Velocity Analysis

To asses performance for wind pressure distributions across the building facades we need to understand both pressure differentials and velocity vectors. We studied wind forces in relation to the facade with minimal area and exposed atrium to understand the dynamic loading and wind flow patterns as they move in and around this zone.

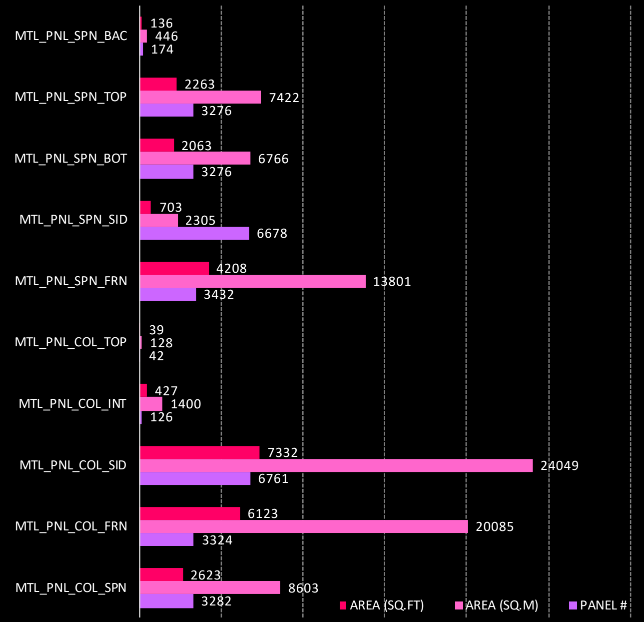
Streamlines are used to identify the directionality and trajectory of velocity vectors. These velocity pathlines are charted along a central axis that begins at the base of the atrium. Due to the interaction of the streamlines with the split massing, we see a change in up and downward direction. The results indicate that wind is primarily directed upward and experiences a reduction in acceleration for the higher regions.



1. CONCRETE SLAB
2. VENTILATED FINISH FLOOR
3. OPERABLE FACADE VENTILATION
4. EXTERIOR LED
5. GFRC SPANDRELS
6. METAL SECONDARY FIN
7. SUSPENDED CEILING
8. METAL SHADOW BOX
9. HIGH PERFORMANCE IGU
10. BUTT GLAZED KISS MULLION
11. CHILLED BEAM
12. CONCRETE STRUCTURAL BEAM
13. MAINTENANCE CATWALK



FAÇADE ANALYSIS			
NAMING CONVENTION	PANEL #	AREA (SQ.M)	AREA (SQ.FT)
MTL_PNL_COL_SPN	3,282	8,603	2,623
MTL_PNL_COL_FRN	3,324	20,085	6,123
MTL_PNL_COL_SID	6,761	24,049	7,332
MTL_PNL_COL_INT	126	1,400	427
MTL_PNL_COL_TOP	42	128	39
MTL_PNL_SPN_FRN	3,432	13,801	4,208
MTL_PNL_SPN_SID	6,678	2,305	703
MTL_PNL_SPN_BOT	3,276	6,766	2,063
MTL_PNL_SPN_TOP	3,276	7,422	2,263
MTL_PNL_SPN_BAC	174	446	136
TOTAL	30,371	85,005	25,916
GLAZING SURFACES	SURFACE #		
GLZ_PNL_FOG	3,195	33,528	10,222
SURFACE CHARACTERIZATION	TYPE #		
FLAT	20,207	41,116	12,535
SINGLY CURVED	3,432	13,801	4,208
DOUBLY CURVED	6,732	30,088	9,173
TOTAL	30,371	85,005	25,916



Architecture as an Art.
Architecture as a Science.

Architecture is characterized by new ways of living, new systems, new methods and new processes.

What defines space architecture?

An architecture which functions as a self sufficient machine, overcoming the limits of architecture that is symbiotic with its environment and which simulates all processes of a sustained ecosystem internally.

SOM

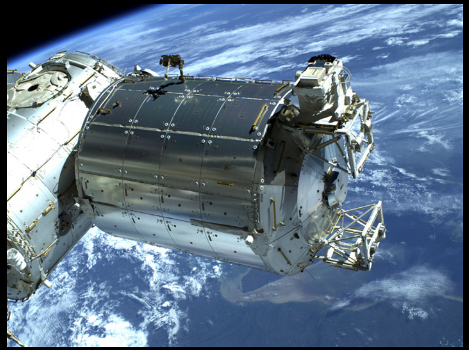
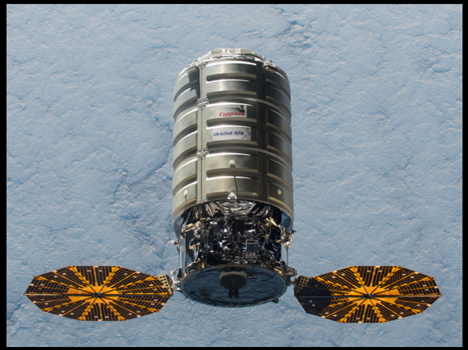
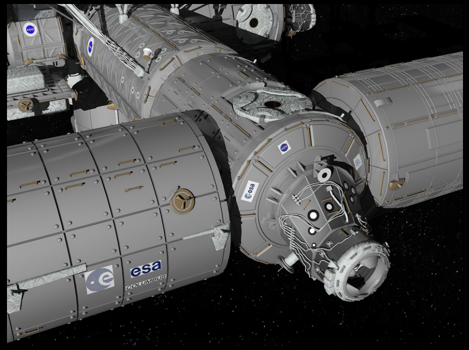
esa

Source: lroc.sese.asu.edu

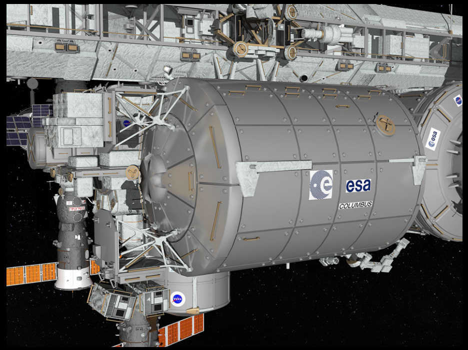

esa
esa
NASA

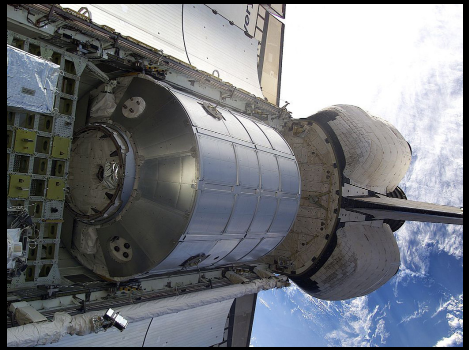
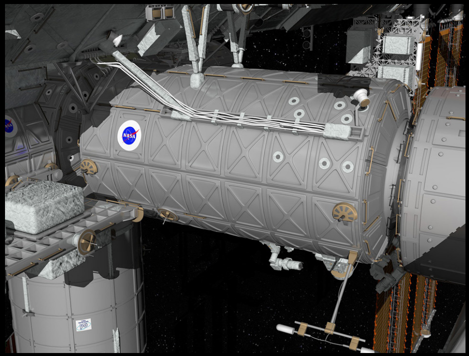
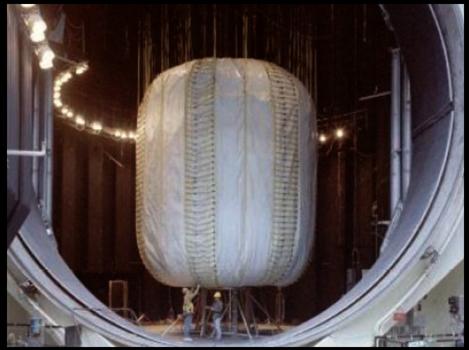
STRUCTURAL SHELL PARADIGMS

CLASS TYPES	STRATEGIC KNOWLEDGE GAP	DESIGN	STRUCTURAL TYPES	ASSEMBLY
CLASS 1 - PRE-INTEGRATED	ENERGY GEN/STORAGE & SHIELD	COMPLEX MODULES	RIGID STRUCTURES	ASSISTED | HUMAN
CLASS 2-MODULAR SYSTEMS	ROBOTIC ASSEMBLY & ISRU	EXPANDABLE & MODULAR	RIGID | CABLE | INFLATABLE	ASSISTED | HUMAN | PNEUMATIC
CLASS 3-IN-SITU ROBOTIC	ISRU AUTOMATION	ADAPTIVE & ROBOTIC	INFLATABLE | REGOLITH | HYBRID	ASSISTED | HUMAN | ROBOTIC




METHODOLOGY

Mission Requirements

Concept of Operations

System Design Drivers

Assumptions

- The Habitat should be capable of accomodating a crew between 4-6.
- Mission Duratiion up to 300 consecutive days per crew.
- Habitat to be deployed on a site with ease of access to resources, illumination and sites of scientific interest.
- Habitat shall provide sufficient radiation protection and meet allowable exposure levels for crew over the mission duration (periods of nominal and solar event radiation levels.)
- Once in operation, the habitat and systems will provide functions for crew activities (life support, crew quarters, hygiene, food preparation, storage, health & well-being) and support science and EVA operations.
- The Habitat and required components will be launched in a undeployed condition.
- Habitat support components need to be compatible with launcher capabilities.
- Habitat and support elements need to be transferred into lunar orbit.
- From lunar orbit, the habitat and support elements are transferred to the lunar surface.
- Habitat needs to be accessible for any crew from the lunar surface in its delivered configuration.
- The habitat and support components will be delivered to the final location and deployed.
- **The habitat will enable a wide range of mission scenarios, from establishing early infrastructure to testing industrial methods.**

MISSION PHASES

Testing

Transporation to Launch Site

Launch

Transfer

Dock - Transport/Service Module

Dock - Gateway

Landing

Deployment from Lander

Transfer to Building Site

Assembly

Operation

Testing
- Testing of the exterior shell structure and interfaces between rigid and vectran mesh structures.
- Packing and securing that the external and internal elements can survive launch vibration and transfer loads. (Digital Analysis)
- Leak testing with entire internal assembly.

Launch
- Mass/Volume and dimensional constraints.

Dock - Transport/Service Module
- Capture habitat in space and provide powering for thermal requirements.

Landing
- High mass lander capability.
- Landing precision of approx. 500 m with a minimum distance to sensitive equipment on the surface considering dust ejection.

Deployment from Lander
- Deployment from lander utilziing a high mass lifting crane and mobility vehicle.
- Automated movement and alignment procedure.

Building Site Transfer
- Regolith stabilization and ground hardening.

Assembly
- Final construction

Operation

External heat dissipation system.
Pressurization & outfitting.
Protection from SPE.
Occupancy, EVA’s and maintenance.

MISSION COMPONENTS

Habitat Service Module

Airlock Module

Launchers

Lander

Tug

Mobile Crane

Power Station

External Radiators

Habitat Service Module

- Supply power to the habitat for thermal control requirements. Minimum non-operational temperature range for sensitive equipment (environmental control and life support systems).
- Habitat manouvre and attitude control during transport for rendezvous and docking with other mission elements.

Airlock Module

- Supply power to the habitat for thermal control requirements. Minimum non-operational temperature range for sensitive equipment (environmental control and life support systems).

Tug

- A purpose-built tug to transfer the habitat, lander and cargo from lunar transfer orbit into lunar orbit.

Launcher

- The mass and volume capability of selected launcher is considered a driver for the mission. A range of launchers were considered for this architecture (Ariane 5, 6, Proton, Soyuz, SLS Block 2, Falcon Heavy and others). SLS Block 2 and Starship performance were considered the most capable.

Lander

- A purpose-built reusable logistics lander will be required to transfer the Habitat and Cargo from lunar orbit to the lunar surface.

Power Station

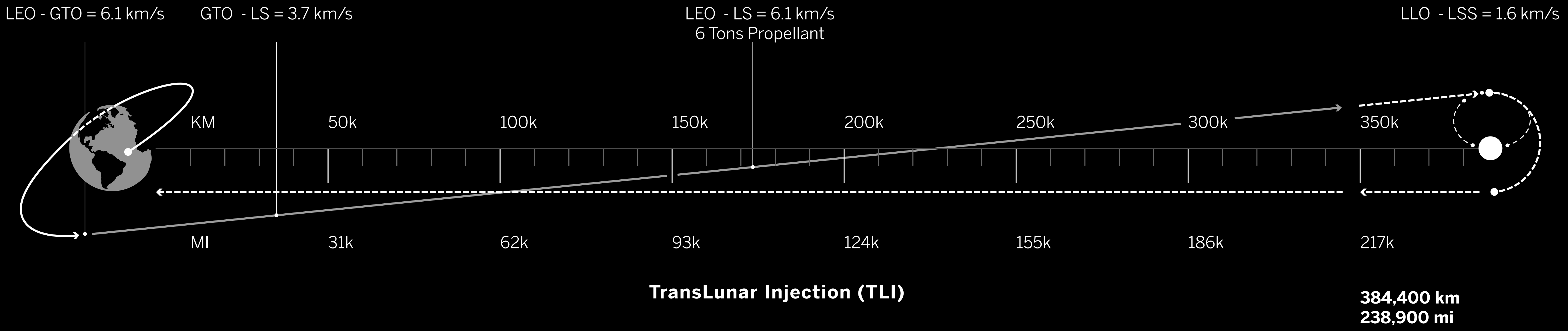
- Nuclear fission generators and solar arrays combined with batteries and regenerative fuel cells for energy storage.

External Radiators

- Heat rejection capacity due to operational equipment and habitat activities will require a significant area of external radiators.

TRANSFER

Staging Orbits (TLI)	Orbit Insertion (Delta V)	Transfer to Low Lunar Orbit (LLO)	Transfer Back to Orbit	Total	Transfer Time
Distant Retrograde Orbit (DRO)	100 m/s	850 m/s	850 m/s	850 m/s	4 Days
Earth-Moon L2 Halo	0 m/s	800 m/s	800 m/s	800 m/s	3 Days
Near Rectilinear Halo Orbit (NRHO)	0 m/s	750 m/s	750 m/s	750 m/s	.5 Day
Low Lunar Orbit (LLO)	1,000 m/s	0 m/s	0 m/s	0 m/s	< .5 Day



CREW ACCOMMODATION

Private Quarters

Dining and Communal Spaces

Workspaces

Exercise Area & Equipment

EVA Suit Donning & DOffing

Medical Care

Hygiene

Translation Corridors

- Recommendations for net habitable volume depend on functions required of the mission, crew size and mission duration. 25 m^3 net habitable volume per person should be considered the absolute minimum for deep space habitats. However, this number is significantly smaller than the minimum net habitable volume of the ISS (85.17 m^3), and older stations like Skylab (120.33 m^3), Mir (45 m^3) and Salyut (33.5 m^3) which all have or had shorter mission durations than 500 days.
- A net habitable area of about 80m^3 per person is recommended for the crew size and long duration of the surface mission.

- The structure and outfitting system of the habitat has to maximise the usability of the habitable volume provided to the crew. The module needs to be highly volume-efficient and designed to optimise habitability.
- Quarters have to provide optimal noise protection and personalised air conditioning and illumination control to provide comfortable living conditions.

Budget Requirements (Volume, Power and Mass)

- Galley and Food System
- Waste Collection and Hygiene
- Sleep Accommodation, Health and Clothing
- Operational Supplies and Maintenance

ARCHITECTURAL CONSIDERATIONS

Volume

- Volume Allocation for Mission Task
- Volume for Crew Member Accommodation
- Volume for Mission Accommodation
- Volume for Behavioral Health

Configuration

- Functional Arrangement
- Interference
- Spatial Orientation
- Consistent Orientation
- Interface Orientation
- Location Identifiers
- Location Aids
- Visual Distinctions

Translation

- Internal Translation Paths
- Emergency Translation Paths
- Translation Path Interference
- Simultaneous Use
- Hazard Avoidance
- Path Visibility
- Crew Egress Translation Path
- Crew Ingress/Egress Zones

Hatches and Doorways

- Hatch Cover and Door Operation without Tools
- Hatch Size and Shape
- Visibility Across the Hatch
- Hatch Cover and Door Interference
- Hatch Cover Closure and Latching Status Indication
- Hatch Cover Pressure Indication

Restraints & Mobility Aids

- Crew Restraint Provision
- Crew Restraint Design
- Mobility Aid Standardization
- Mobility Aid for Assisted Ingress and Egress
- Ingress, Egress and Escape Mobility Aids
- EVA Operations Mobility Aids

Windows

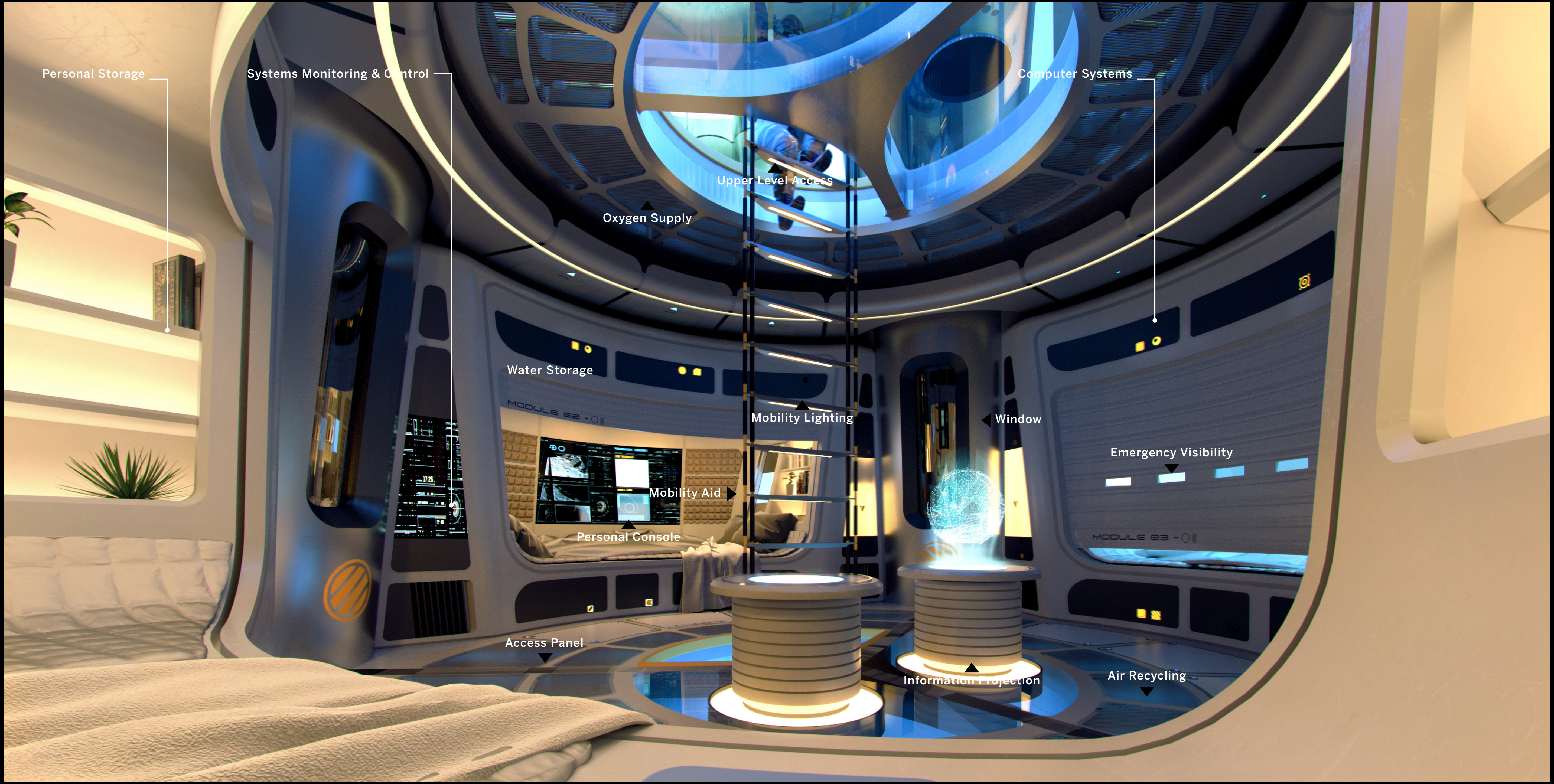
- Window Visibility
- Window Obstruction
- Window Proximity Finishes
- Window Light Blocking
- Window Protection Removal and Replacement/Operation without Tools

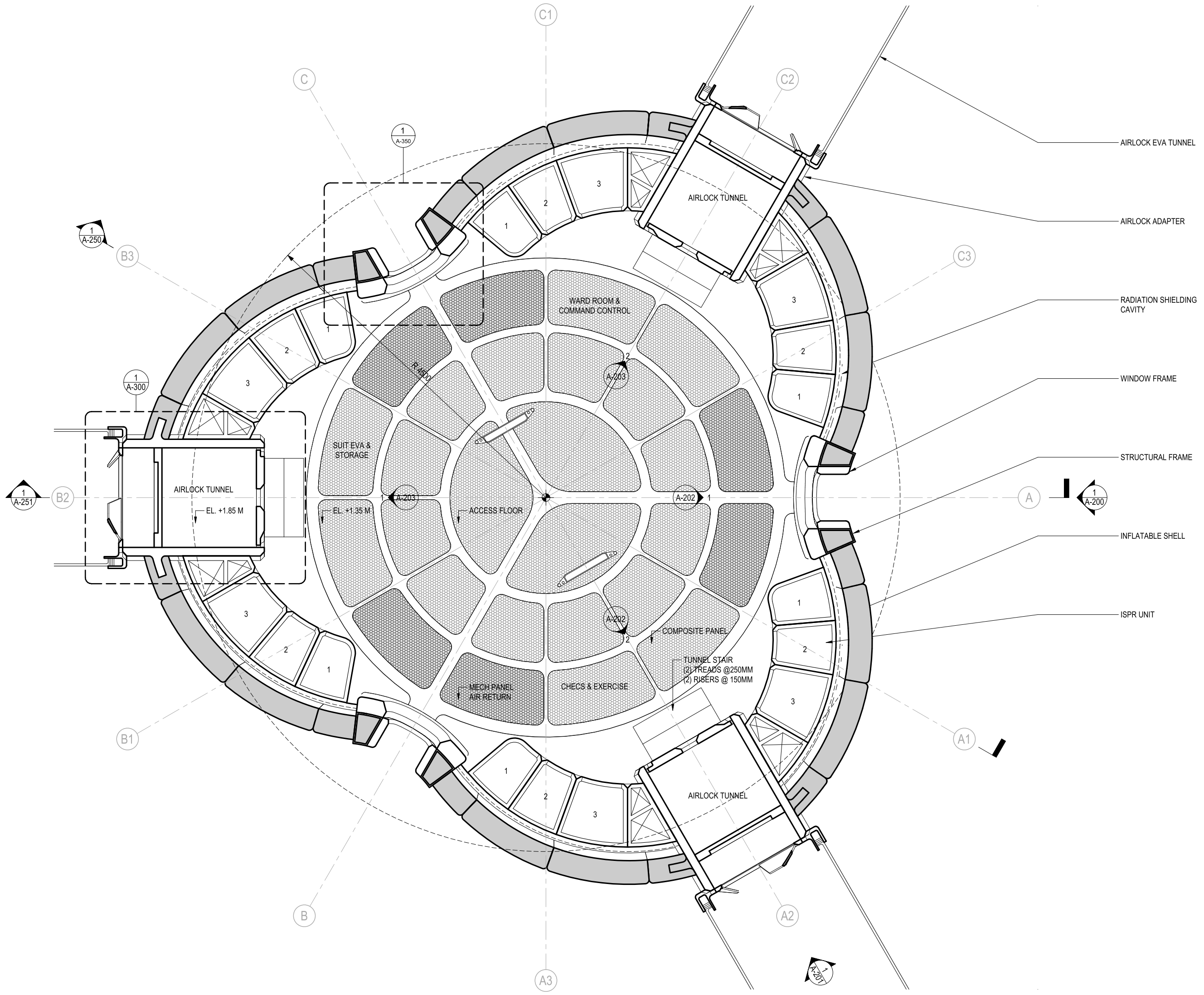
Lighting

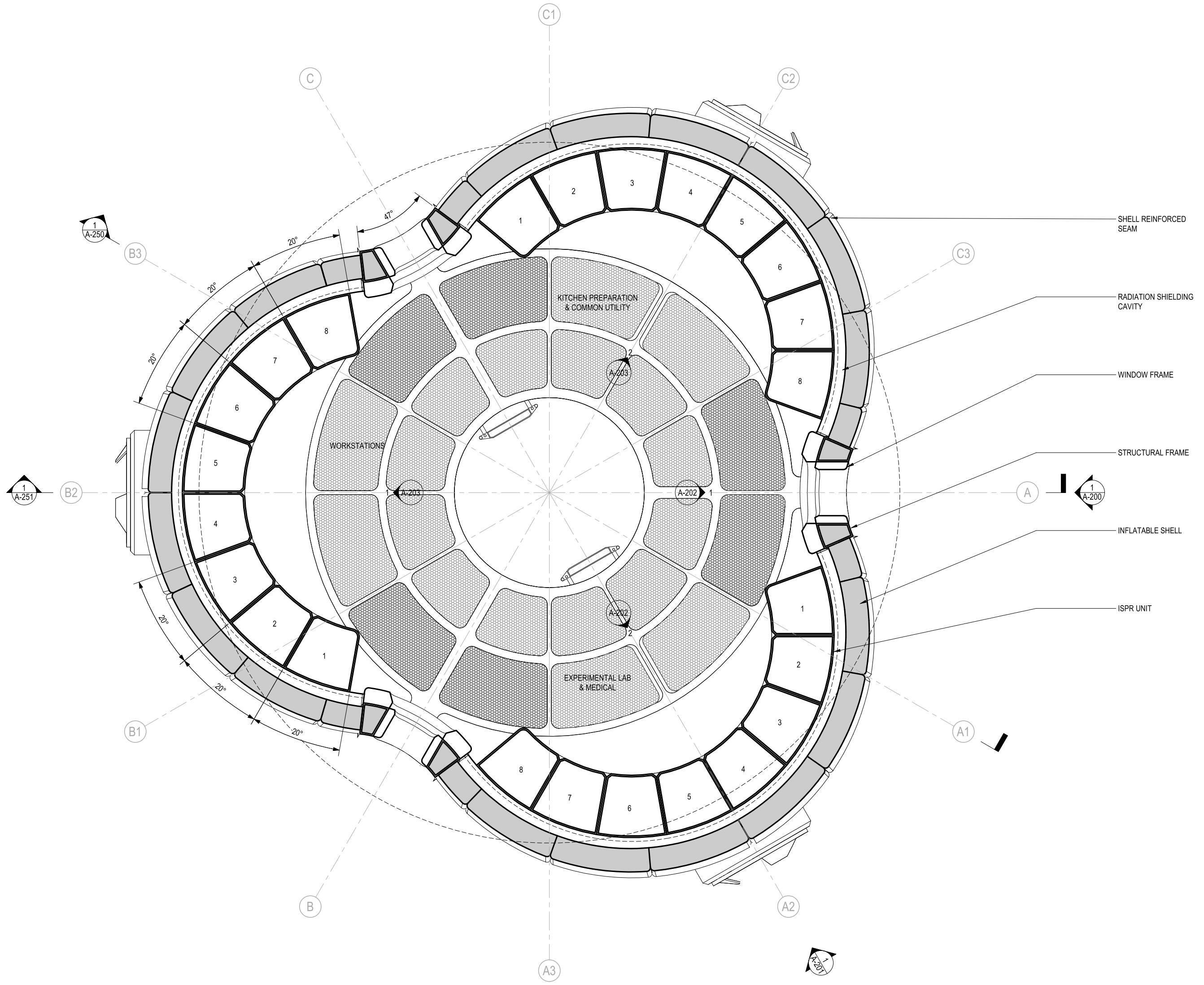
- Illumination Levels
- Exterior Lighting
- Emergency Lighting
- Circadian Entrainment
- Lighting Controls
- Lighting Adjustability
- Glare Prevention

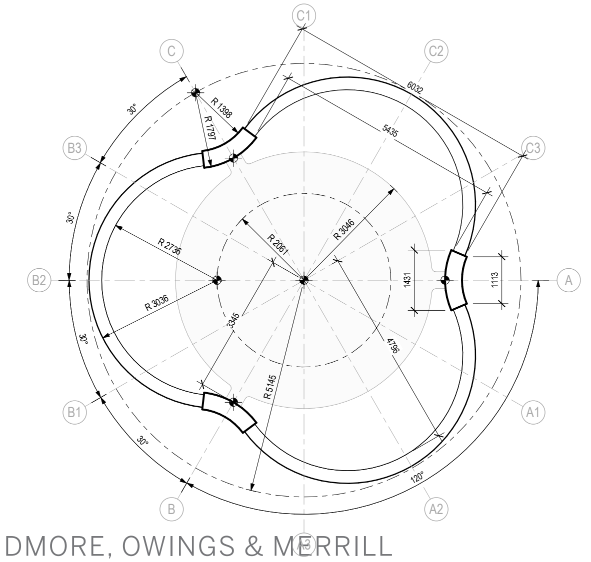
Source: NASA Technical Standards (“NASA Space Flight Human-System Standard, Volume 2: Human Factors, Habitability, and Environments”)

Customized Monitoring Systems
Robotic Equipment
Vertical Translation
Control Interface
Computer Systems
Safety Guard
Oxygen Supply
Upper Level Access
Down Lighting
Mobility Lighting
Structural Window
EVA Monitoring
Mobility Aid
Path Lighting
Lower Level Access
Air Recycling

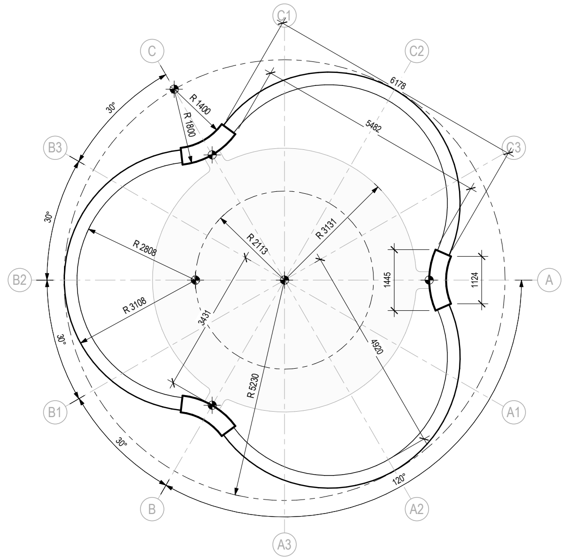

Personal Storage
Systems Monitoring & Control
Computer Systems
Upper Level Access
Oxygen Supply
Water Storage
Mobility Lighting
Window
Emergency Visibility
Mobility Aid
Personal Console
Access Panel
Information Projection
Air Recycling



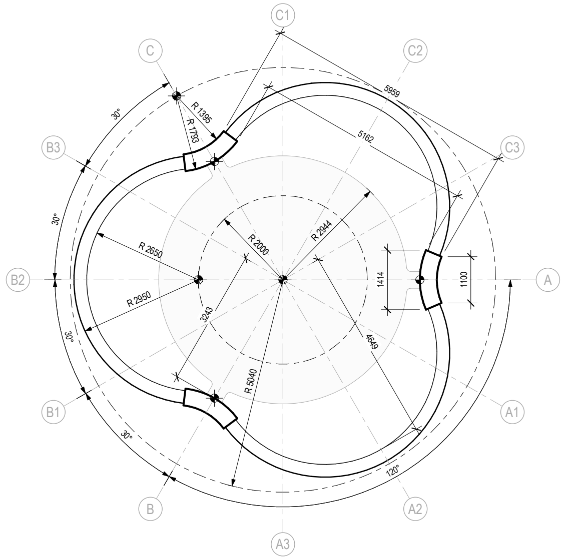




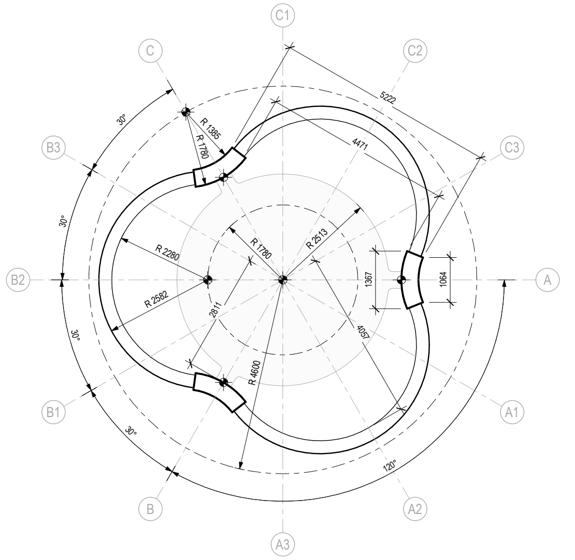
1 | LEVEL 1 SHELL
SCALE: 1 : 50



2 | LEVEL 2 SHELL
SCALE: 1 : 50



3 | LEVEL 3 SHELL
SCALE: 1 : 50



4 | LEVEL 4 SHELL
SCALE: 1 : 50

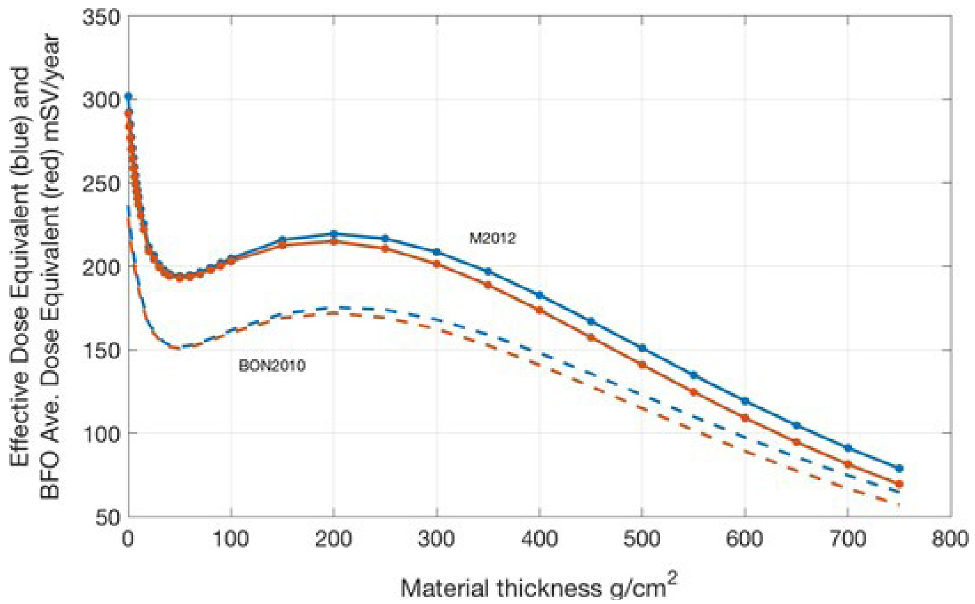
SKIDMORE, OWINGS & MERRILL

RADIATION

Solar Particle Events (SPE)

Galactic Cosmic Rays (GCR)

- Radiation in space is a major barrier to human exploration of the solar system.
- Radiation damage to biological systems includes direct damage, when radiation interacts directly with DNA but the most common process is indirect damage, when radiation interacts with H2O and generates free radicals that in the end will interact with DNA.



Stochastic effects (cancer, leukaemia, hereditary effects)

- No threshold dose, exposure provide an increased risk
- Probability of the effects increases with the dose, not the severity
- No definitively associated with the radiation dose received

Deterministic effects (cataracts, dermatitis, sterility, radiation syndrome, etc.)

- Threshold dose, above which they always appear
- Damage grows usually with the dose intensity
- Typically they manifest soon after exposure.

Structure

Thermal

Radiation

Safety

Performance

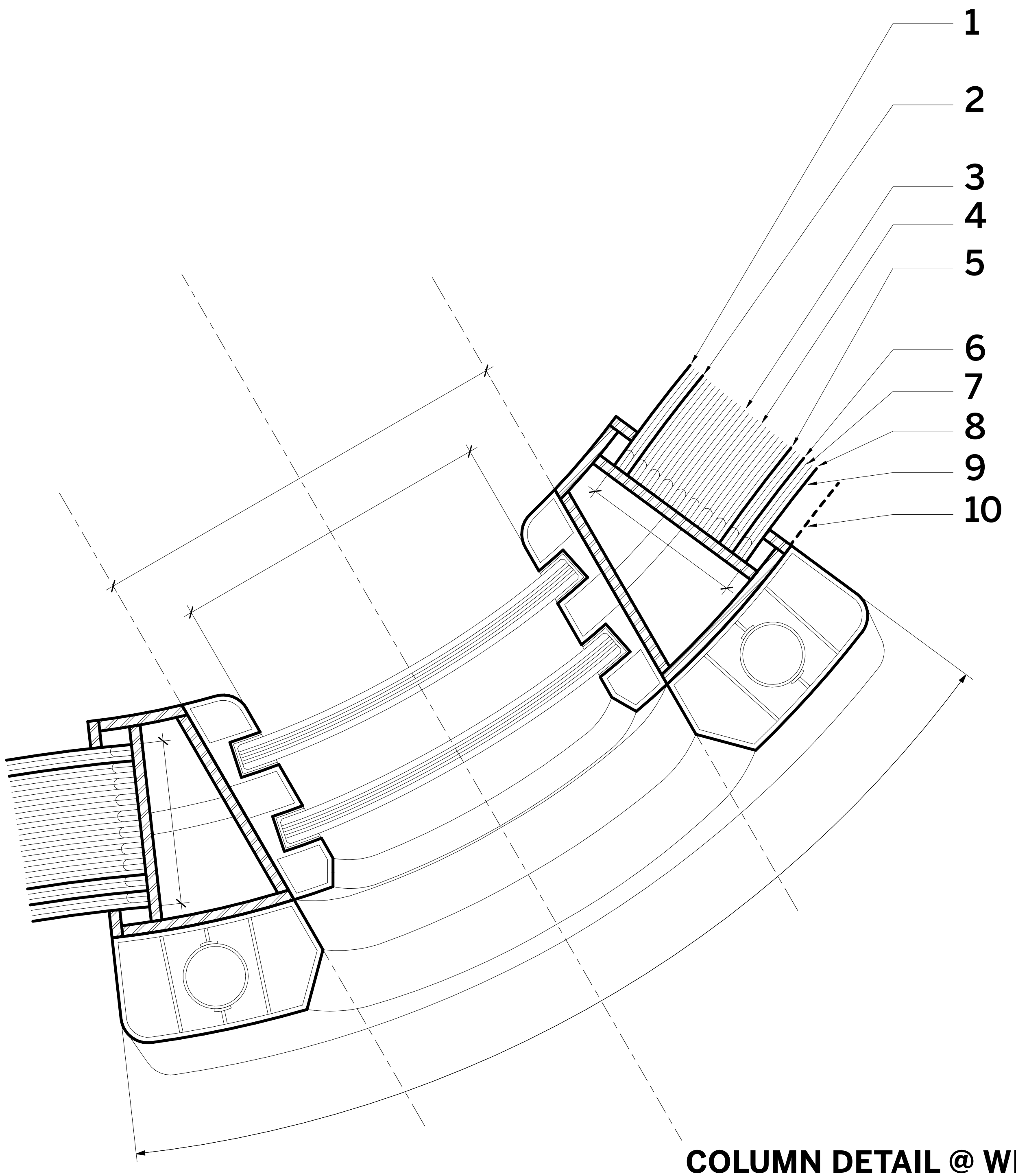
Comfort

Exterior

- Layer 1 - External deployable system in the form of straps.
- Layer 2 - External protective layer for dust and mechanical resilience. Nextel AF-62
- Layer 3 - Multi-Layer Insulation (MLI) for thermal control. Typical multilayer (20 layer) combination of double aluminized mylar/kapton.
- Layer 4 - MMOD fabric layer
- Layer 5 - MMOD foam support between MMOD layers made of light weight polyurethane open foam cell structure.
- Layer 6 - Kevlar or Vectran restraint layer used for structural support.

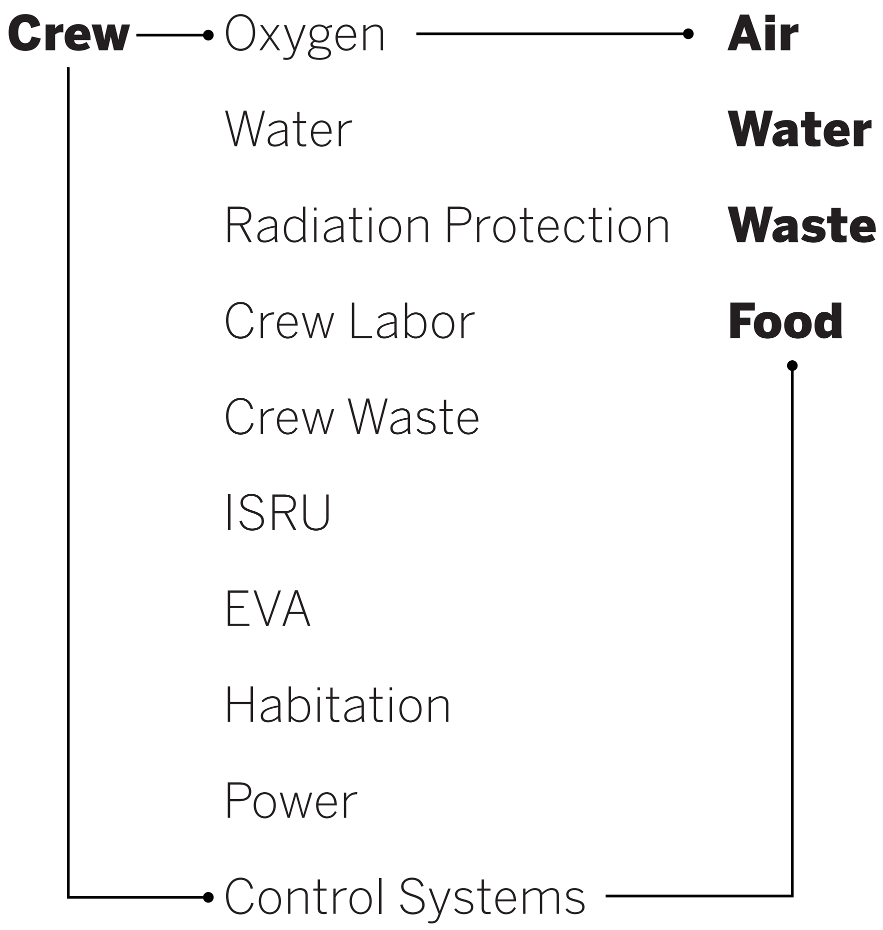
Interior

- Layer 7 - Bladder layer used for air containment within the habitable zone. This can consist of a complex combination of combitherm/silicone/polyurethane from transhab or more recent technology by Bigelow.
- Layer 8 - Bladder seperation layer composed of Aramid Kevlar.
- Layer 9 - Final inner bladder protection layer made of nomex aramid fabric.
- Layer 10 - Internal water layer for increased radiation protection.



COLUMN DETAIL @ WINDOW

LIFE SUPPORT



- Regenerative closed loop systems for air and water are recommended, with as high as possible recovery efficiencies, to reduce supply from Earth;
- A first step towards on-site food production is highly desirable, i.e. production limited to up to 5% of the daily diet, to prepare for future bigger crew sizes, when supply–from-Earth strategy will become economically unsustainable;
- On-site storage of wastes, preferably outside the habitat, is proposed at this stage; recycling of wastes would become attractive when food production would become fully operational and therefore resulting in the generation of significant mass of inedible biomass.
- Full redundancy (i.e. based on different technologies) seems mandatory in the current context, to address all kind of emergency situations with the appropriate safety level.

POWER

Habitat Intrinsic Power

Mounter Solar Panels

Battery

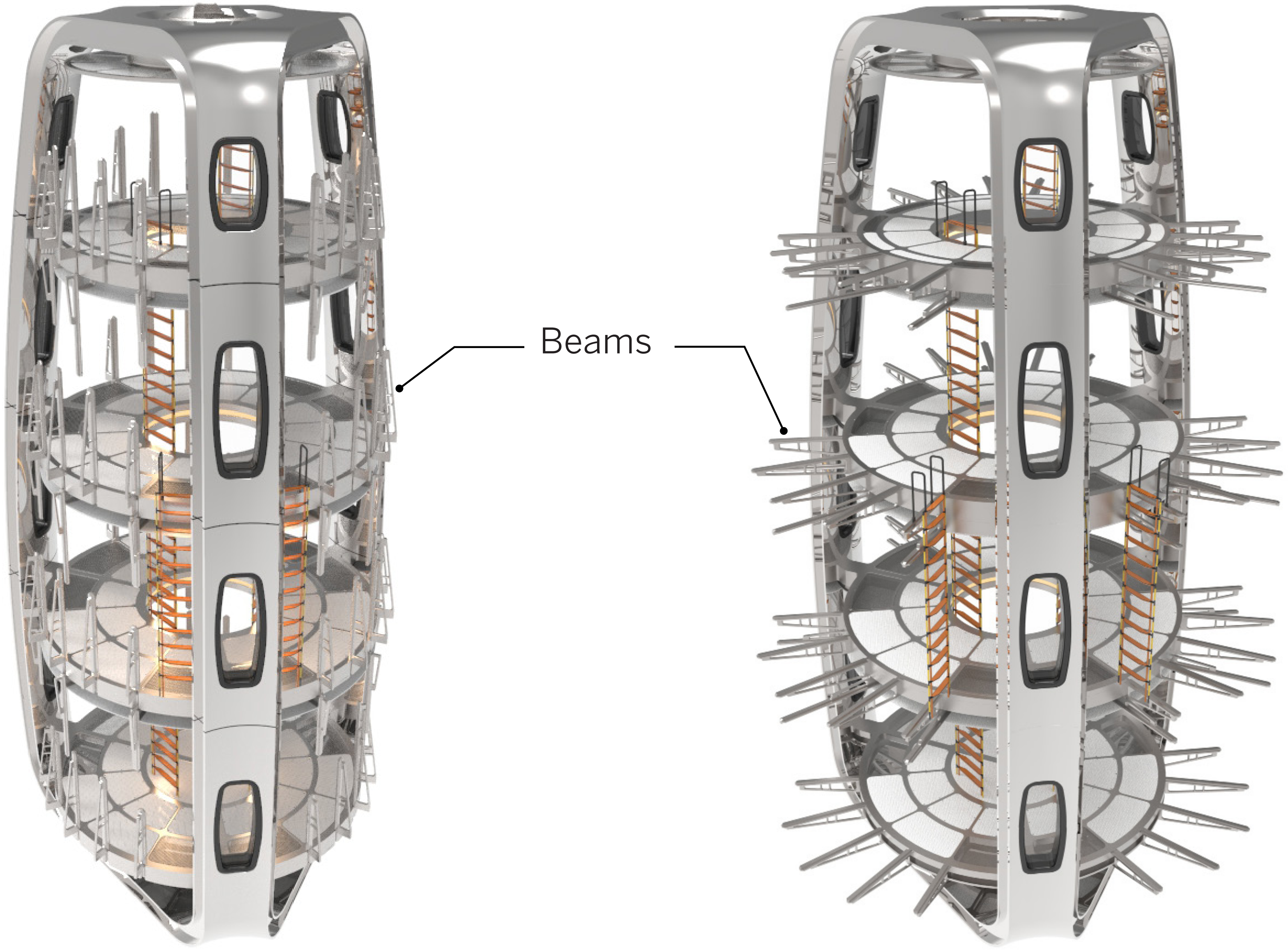
Power Distribution and

Conditioning Unit (PDCU)

Solar Power Plant

Nuclear Fission Power Plant

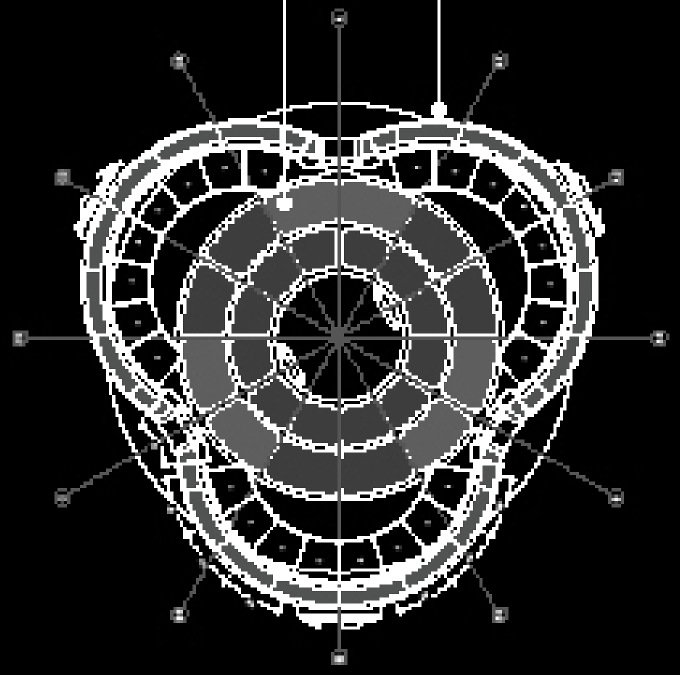
- The internal temperature of the habitat is 10°C for transfer case and to 22°C for surface phases. To keep the inside of the habitat at **10°C** (temperature required for ECLS transport), **11kW** of heating power is needed.
- The ISS has a continuous power delivery capability of 84 kW, with maximum power output of 108 kW. However 25 to 35 kW of this total is available for payload operations.
- During the transfer to the Moon, the power required is driven mainly by heaters, in order to keep the internal environment of the Habitat at the desired temperature. In nominal operations, both during the lunar night and day, the power budget is driven by the ECLSS.
- A power of 5 kW has been allocated to science operations.
- In total, including a 20% system margin, the average power requirement is **57 kW** during the day and **60 kW** during the night.
- Detailed studies have assessed the illumination conditions in the lunar south pole with some locations receiving sunlight for up to **92%** of the time at **2m above ground.**
- The most optimal areas of the south pole for this study were assessed to have atleast **80%** of long-term illumination at **2m** height above the surface.
- The habitat would be supplied with electrical power by an external surface "**Power Station"** with a continuous power capacity of **59 kW** of the Habitat.
- A fission reactor system weighing **5.6 metric tons.**

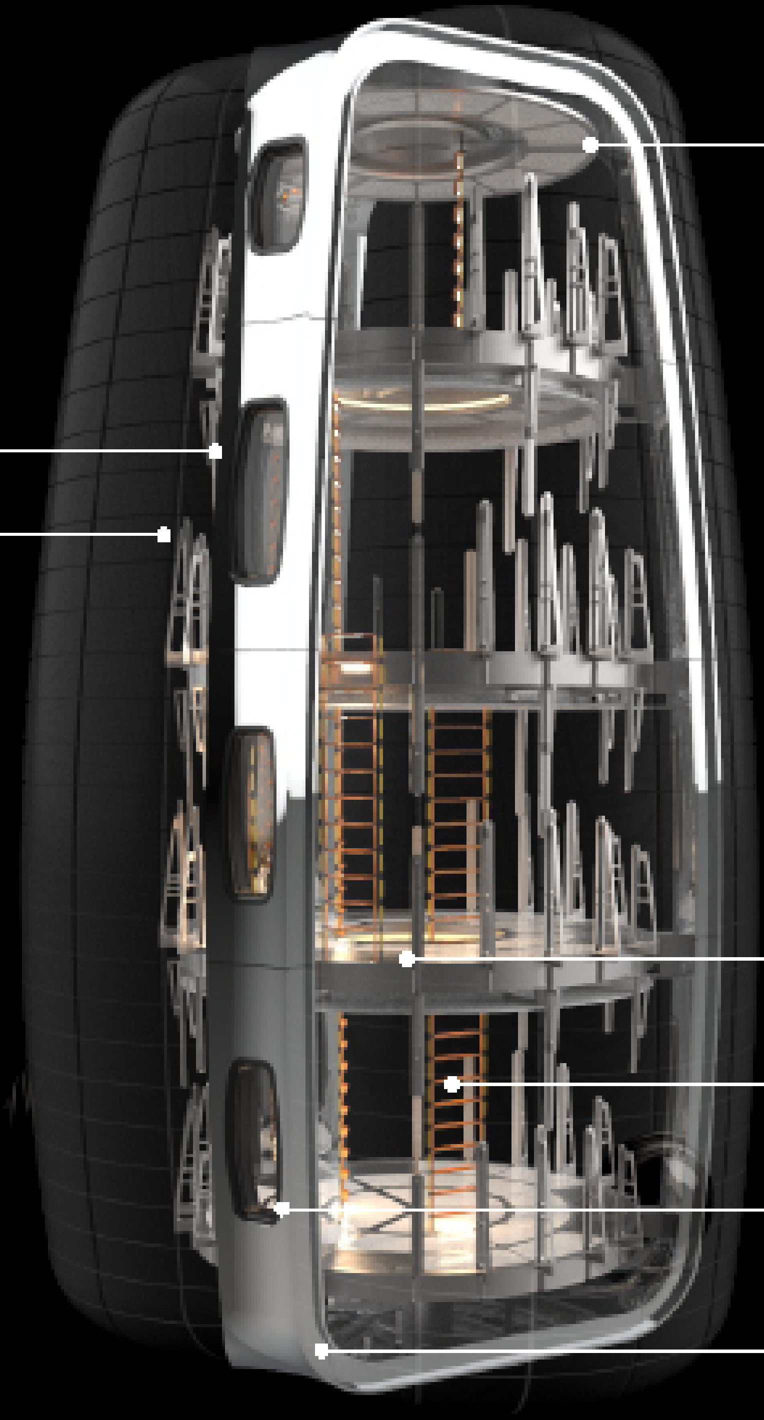


Stowed Condition | **Deployed**

ONE MOON

A single unit offers a net habitable volume of up to 390 m³ (13,772 ft³) and a habitable area of up to 104 m² (1,120 ft²). To maximize function and minimize structural obstructions, the mechanical systems are located within the composite floor assembly, and payload rack units are stored at the perimeter against the shell walls. The module is protected by a multi-layer assembly, with structural mesh woven directly into the columns to increase resistance under tension. The inner wall layer is designed to aid the life support system—it is composed of water and other hydrogen-rich materials, which provide passive radiation shielding. This solution allows for better control of interior ambient lighting conditions, efficient air movement and recycling, easy communication and visibility, and seamless physical mobility.





DESIGN ELEMENTS

VOLUME BY ZONE

59.10 M³

61.98 M³
RECREATION

172.20 M³
WORKSPACE

40.12 M³
EXERCISE

30.43 M³
HYGIENE

24.70 M³
MULTI-PURPOSE STORAGE

180.35 M²

104.22 M²

SYSTEM VOLUMES

133.56 M³
STRUCTURE

73.58 M³
CIRCULATION

58.42 M³
WALLS

44.20 M³
STORAGE COMPARTMENTS

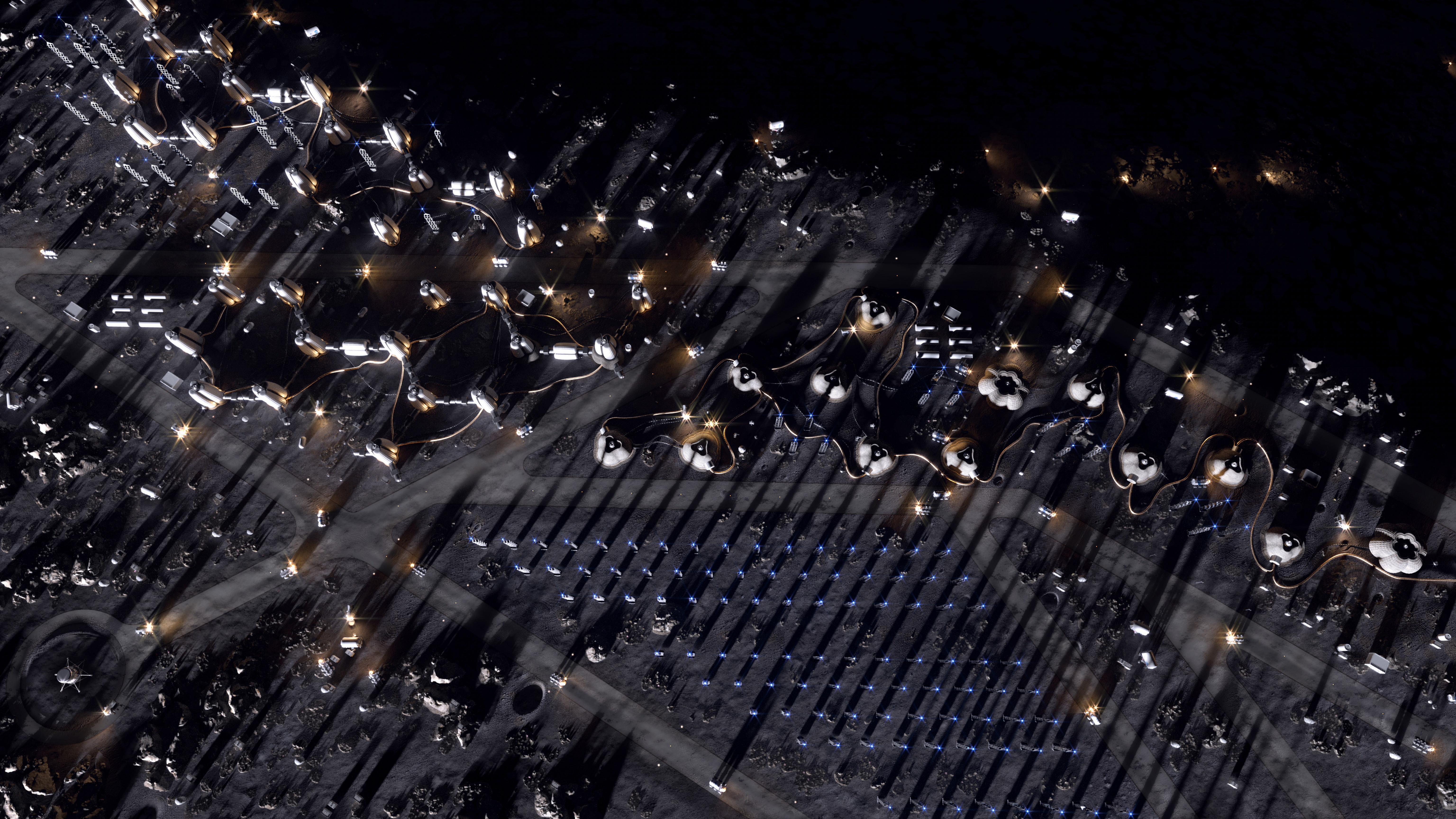
COMPOSITE STRUCTURAL SHELL

3
OF CELLS

30
OF HORIZONTAL SECTIONS

8
OF VERTICAL SECTIONS

240
OF PANELS



SKIDMORE, OWINGS & MERRILL

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