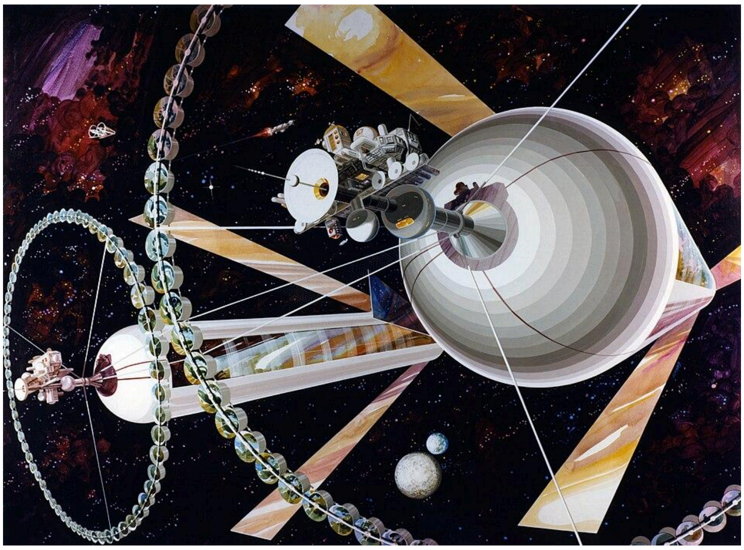
Aurora: A Next-Generation Space Colony in the Kuiper Belt

Authors: Bazarkhan Altair, Sabiruly Mansur, Abenov Aidyn
Quantum STEM School
Astana, 2025

Abstract

We present an orbital station that uses O'Neill cylinder principles, a fully autonomous space colony located in Kuiper Belt, designed to life support 250,000 inhabitants for at least 80 years. The colony provides 0,9g artificial gravity fusion-based energy production, and AI-managed life support systems. The design prioritizes ecological balance, psychological well-being, and independence from Earth. Resource extraction from nearby Kuiper objects supports continuous operation. The paper describes the colony's architecture, energy systems, social model, and environmental management strategy ensuring long-term sustainability.

Table of contents



I. Team members

Bazarkhan Altair
Coordinates the movement of the team
Distributes the roles of the participants

Abenov Aidyn

Writer/Research worker

Sabiruly Mansur

Editor, writer/Research worker

II. Introduction

Human civilization has always looked to the stars, first with curiosity, and now out of necessity.

In the last century, population growth, depletion of natural resources, and growing environmental instability have shown that the Earth alone cannot sustain humanity indefinitely. Going beyond our planet is no longer a science fiction dream, but an important step towards ensuring long-term survival and progress.

The first scientific attempts to imagine a permanent habitat in space began in the middle of the 20th century, when scientists such as Gerard K. O'Neill suggested that orbital settlements could provide stable conditions similar to those on Earth, thanks to controlled rotation and modern life support systems. His research, conducted at Princeton University and NASA's Ames Research Center, has shown that large-scale rotating habitats—whether spherical, toroidal, or cylindrical -can support human life for generations if they are provided with sufficient materials and energy.

In the following decades, engineers explored several geometric models, including the Bernal sphere, the Stanford torus, and the O'Neill cylinder. Each concept faced certain engineering difficulties, but the cylindrical model proved to be the most efficient and scalable. Unlike toroidal or spherical habitats, the cylinder provides a continuous and evenly distributed gravitational field, a large internal surface area for agriculture and housing, as well as mechanical stability due to rotation in the opposite direction, which neutralizes unwanted gyroscopic forces.

Based on these fundamental ideas, the Aurora project proposes a colony with two O'Neill cylinders, designed to operate in the Kuiper Belt, a remote region of the Solar System rich in water ice, methane, ammonia and helium-3, which are necessary to support life and generate energy based on thermonuclear fusion. This arrangement provides a natural opportunity for self-sufficiency: water ice can be processed into oxygen and hydrogen, methane can serve as fuel, and helium-3 is an environmentally friendly energy source for fusion reactors.

When designing Aurora, special attention is paid to autonomy, stability and balance.

Each balloon provides artificial gravity close to 1 g, maintains its own closed ecological cycle, and uses environmental systems with artificial intelligence to regulate air composition, humidity, and waste disposal. Artificial lighting based on thermonuclear fusion replaces sunlight, allowing full control over the change of day and night, even at a distance of 30-35 AU from the Sun. Combined, these technologies allow the colony to function independently for at least 80 Earth years without support from Earth.

The purpose of this study is to present the scientific and engineering basis of the Aurora settlement: its architectural design, sustainable development systems, verification indicators, and long-term risks. The project demonstrates how, with the help of advanced energy systems and environmental engineering, human life can not only survive, but also thrive in one of the most remote regions of our Solar System.

III. Colony architecture

The Aurora colony has a double O'Neill cylinder that is suitable for long-term habitation in the Kuiper Belt. The two cylinders are 25 kilometers long and have a diameter of 8 kilometers and rotate in opposite directions to compensate for gyroscopic precession. The inner radius is 4,000 meters. The rotation rate is to produce a homogeneous field and a resultant gravity field of 0.9g. The uniform rotation is done with an angular velocity of 0.047 radians per second requiring a rotation period of 134 seconds. The rotation period is optimized to produce a gravity similar to that of Earth without exceeding the boundary beyond which forces of physiology due to Coriolis forces can be realized.

The total inner surface area for one cylinder is nearly 628 square kilometers. Thus, a twin system with a surface area measuring 1,256 square kilometers is required to accommodate a population of 250,000 with a medium density of 200 people per square kilometer. Actually, this will provide a personal space of 30-40 square meters for every human. The city is differentiated into longitudinal sectors for different regions. The Living zones {A} are allocated 35%, agricultural zones {B} are 30%, forest/recreation zones {C} are 15%, industry zones {D} are 10%, while transportation zones are 10% in length. The city is designed in this way in order to ensure a balanced ecological system and to provide for all human requirements as well as redundant systems in case of localized catastrophes.

The framework consists of a combination of titanium alloys, aluminum-lithium panels, and carbon fiber for resistance to cyclic stress created by rotation for over 80 years on Earth. The external radiation shield has a total thickness of 20-30 g/cm² of protective material and is designed to comprise a Whipple shield for resistance to micrometeoroids externally, a central portion that is a combination of polyethylene and frozen water for absorption of radiation, and a final thermal shield. The surface ice that is in plentiful supply in the Kuiper belt is to provide a shield due to its high content of hydrogen and refuel capability. The shield can easily be replaced and serviced via drones from a central location.

The power is generated through helium-3 and deuterium fusion reactors that are mounted in a fixed non-rotating axial module between the cylinders. The generated power is measured at

1.5 gigawatts of electrical power and is routed through fixed superconducting transmission lines that are mounted in a structural framework. The power is supplemented in maintenance cycles through fixed hydrogen-oxygen fuel cells and a fixed network of solar panels that are mounted 40-50 astronomical units away from the Sun for sensor power and emergency lighting. The cooling is facilitated through fixed sodium potassium transfer loops to fixed radiators installed in protected axes.

The role of photons is replaced through artificial sources. The presence of a fragile array of mirrors is eliminated in this design as in earlier orbiting habitat designs. The full-spectral LED array recreates a natural day and has terrestrial amplitude and variation. The variation in level of illumination can range between 300-800 lux in domestic zones and between 200-600 $\mu mol/m^2/sec$ in agricultural zones. The power level to this is directly provided from a fusion power plant. The controlled variation between day and night is provided.

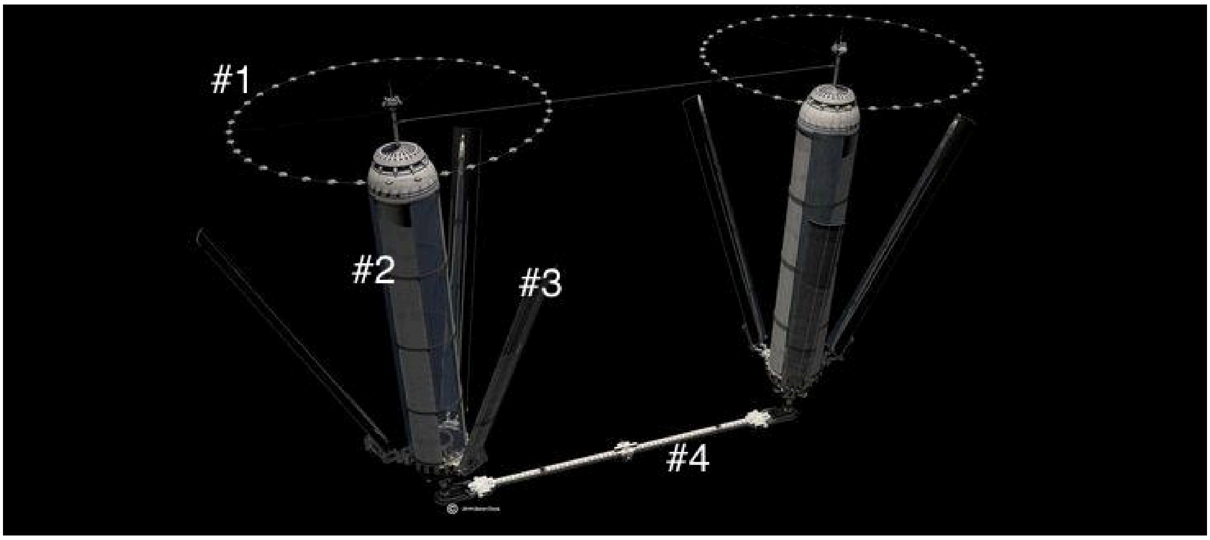
The biospheric design integrates biologic and physicochemical life support cycles. Oxygen is produced from massive plant canopies and high-efficiency bioreactors for Spirulina and Chlorella microalgae. Carbon dioxide is removed through carbonation of water. The atmosphere is maintained through feedback control. The carbon dioxide and oxygen in the atmosphere are controlled through feedback control. The water recycling in this colony is above 95% efficiency. The grey water from sinks and showers is treated in a membrane bioreactor and ultraviolet system for recycling for flushing toilets. The black water is treated in anaerobic digestion tanks for biogas and bioprofile. The bioprofile is made into a nutrient-rich fertilizer. The phosphorus and nitrogen are converted to struvite ($MgNH_4PO_4$) and reused in hydroponic nutrition. The final recycling is through distillation. The cleaned water is reused in domestic and agricultural scenarios.

Food Production: There is integration of hydroponic and aeroponic growth chambers and controlled environmental factors in food production. The crops produced include wheat, soybeans, potatoes, and a variety of lettuce to provide for calorie and mineral requirements of different classes of people. Additional algae tanks are supplemented with carbon dioxide to provide protein-rich substances for making proteins and oxygen. Miniaturization of animal husbandry to promote crop rotation is maintained with 150,000 egg-laying chickens and 2,000 dairy goats bred in pressurized enclosures near agricultural strips. Insect protein farms are involved in decomposing plant materials to produce animal feeds while recycling and conserving resources. The animal humane society is maintained in animal husbandry through provision of required space and temperatures in 0.9g.

Raw materials and water are extracted from close-by objects in the Kuiper belt through self-driven mining craft propelled either by ion and nuclear-electric propulsion. The ice mined is processed and purified to offer a supplementary source of water to add to the reservoir in the colony. Methane and ammonia are processed for industrial materials and energy storage. The availability of in-situ resources makes total independence in interplanetary logistics a reality.

The Aurora cylinders are self-reliant ecological and industrial cycles that are maintained with AI-based environmental grids that are responsive to and in synchronization with variables that include atmosphere, illumination, agricultural growth patterns, and temperature. The respective systems are analyzed through digital twin simulations that are capable of predicting when they are deteriorating and optimized maintenance cycles. The structure is built for a minimum life of 80 years on earth through cyclic replacement of discardable materials that include LEDs and bearings.

By combining this strategic choice of geometry and technological capabilities, a self-supporting habitat is made possible that can sustain a fixed population in the Kuiper Belt. The side-by-side twin-cylinder layout will offer stability and security for inhabitants as well as enough space for human habitation and development in areas of residence and recreation. The habitat will provide a self-contained ecosystem that is self-supporting in all aspects and requirements for human life.



• #1 — Central command and docking node (serves to control the colony, dock ships and place the energy/reactor core in zero gravity)
• #2 - Habitable cylinder (main area of residence and agriculture; creates artificial gravity by rotation)

• #3 — Radiators / panels (remove excess heat and partially provide energy supply of colony systems)
• #4 — Energy transmission farm (connection between cylinders) (transfers energy, cooling fluids and provides transport and technical access between cylinders)

IV. Colony life support systems

This section will tell you about the structure of the colony's biosphere. Cattle breeding, agriculture, and flora. And the circulation of substances.

Aurora's biosphere is designed to support 250,000 people living close to terrestrial conditions. It is designed in such a way that it can support itself independently for 80 years. The system includes aquaculture, agriculture, and animal husbandry. Together they maintain the circulation of oxygen, carbon dioxide, water, nitrogen, and organic matter within a completely sealed environment.

Artificial gravity within the habitat remains close to 0.9 g, providing suitable conditions for most terrestrial crops. Atmospheric composition is held at 21% oxygen and about 800 ppm of carbon dioxide slightly elevated compared to Earth levels to stimulate photosynthesis. Each human consumes on average 0.84 kg of oxygen and produces about 1 kg of carbon dioxide per day, numbers derived from NASA metabolic design data. Air renewal is therefore managed not through resupply but through photosynthetic regeneration inside the agricultural domes.

The agricultural sector operates under tightly controlled environmental parameters: temperature between 22 °C and 26 °C, relative humidity of 55–70 %, and a 16-hour photoperiod using LED arrays optimized for photosynthesis. NASA's Biomass Production Chamber and Controlled Ecological Life Support System experiments demonstrated that such closed environments can deliver stable yields for extended durations. Based on these studies, the colony uses seven primary plant species and one auxiliary class for air filtration.

Wheat serves as the principal carbohydrate source. It has been extensively tested by NASA, reaching edible yields of 23–57 g m^{-2} day^{-1} under continuous artificial illumination. In the colony's multi-tier hydroponic farms, approximately two hectares are sufficient to feed ten thousand people. Potatoes, another CELSS-validated crop, provide the highest caloric output per unit of area; NASA's controlled-environment experiments recorded 37.5 g m^{-2} day^{-1} tuber production, equating to roughly 139 kcal m^{-2} day^{-1}. Multi-layered hydroponic stacks occupy around 1.2 ha per 10 000 residents. Soybeans supply essential protein and oil while enriching the nutrient cycle with biologically fixed nitrogen. Experiments conducted at Kennedy Space Center documented average biomass accumulation of 15–16 g m^{-2} day^{-1} under elevated CO_2. One hectare provides enough soy to produce 1.6 t of oil and 5.5 t of soymeal weekly for this population segment.

Wheat serves as the principal carbohydrate source. It has been extensively tested by NASA, reaching edible yields of 23–57 g m^{-2} day^{-1} under continuous artificial illumination. In the colony's multi-tier hydroponic farms, approximately two hectares are sufficient to feed ten thousand people. Potatoes, another CELSS-validated crop, provide the highest caloric output per unit of area; NASA's controlled-environment experiments recorded 37.5 g m^{-2} day^{-1} tuber production, equating to roughly 139 kcal m^{-2} day^{-1}. Multi-layered hydroponic stacks occupy around 1.2 ha per 10 000 residents. Soybeans supply essential protein and oil while enriching the nutrient cycle with biologically fixed nitrogen. Experiments conducted at Kennedy Space Center documented average biomass accumulation of 15–16 g m^{-2} day^{-1} under elevated CO_2. One hectare provides enough soy to produce 1.6 t of oil and 5.5 t of soymeal weekly for this population segment.

For micronutrients and dietary diversity, tomatoes are cultivated hydroponically at yields comparable to modern greenhouses on Earth 28 to 70 kg m^{-2} $year^{-1}$. Though occupying only 0.2 ha per 10 000 inhabitants, these plants also serve a psychological role: their smell, color, and texture help preserve a sense of Earth-like normality. Bamboo contributes both as a fast-growing carbon sink and as raw material for biocomposites and structural panels, producing up to 20–40 t ha^{-1} of dry biomass annually. Microalgae primarily Spirulina platensis and Chlorella vulgaris are maintained in closed photobioreactors (PBRs) that simultaneously generate food protein (60–65 %) and oxygen. Productivity reaches 100–130 g m^{-2} day^{-1}. Approximately 6 000 m^3 of PBR volume with an illuminated area of the same order fully balances the human oxygen demand of 10 000 people. Finally, the colony's ventilation ducts are lined with "dust plants": thin mats of micro-mosses and air plants. These resilient species capture micro-particles and absorb trace CO_2, forming a living biological filter that replaces conventional HEPA cartridges.

Animal and microbial systems close the loop of matter and energy. The colony avoids large cattle due to inefficiency and methane emission, focusing instead on tilapia, rabbits, and black soldier fly larvae. Tilapia are cultured in recirculating aquaculture systems with feed-conversion ratios around 1.6, yielding 7–9 t yr^{-1} per 100 m^3 of water. The fish tolerate largely plant-based diets; effluent water rich in ammonia passes through biofilters hosting Nitrosomonas and Nitrobacter bacteria that convert ammonia into nitrate, which is then used as nutrient solution for hydroponic tomatoes a design proven in aquaponic studies. Roughly 3 000 m^3 of RAS capacity produces ≈240 t of tilapia fillet annually for each 10 000 residents.

Rabbits provide a compact terrestrial protein source with a feed conversion ratio of 2.0–3.0. Fed mainly on soymeal and bamboo leaves, 25 000 animals yield about 60 t of meat per year. Their manure feeds anaerobic digesters producing 0.25–0.35 m^3 CH_4 per kilogram of volatile solids enough to supply 1.5–2.5 MW-equivalent thermal energy while generating nutrient-rich digestate for crop irrigation. Meanwhile, BSF larvae consume all unprocessed food residues, vegetable peels, and grain bran. Reviews of industrial BSF systems report conversion efficiencies of 60–73 % and FCR around 2.1. Dried larvae, containing 35–45 % protein and 20–30 % lipid, become additive feed for both tilapia and rabbits, further reducing the need for imported resources.

This network forms several interlinked cycles. Wheat and potato waste feed the insect bioreactors; the insects feed fish; fish effluent fertilizes tomatoes; and tomato vines after harvest return as compost to the wheat substrate. Soy is pressed into oil for human consumption, while soymeal sustains the rabbits whose manure in turn fuels biogas digesters. Spirulina acts as a universal stabilizer—absorbing carbon dioxide from animal modules, producing oxygen for human sectors, and providing 5–10 % of the colony's dietary protein.

Weekly steady-state output per 10 000 residents equals roughly 23 t of grain (17 t flour + 6 t bran), 35 t of potato, 8 t of soy, 4.5 t of tilapia fillet, 1.2 t of rabbit meat, and 7–8 t of insect meal. Biogas production reaches 180–250 thousand m^3 per week, while the integrated crop systems generate more than 0.84 kg of oxygen per person per day.

Water is fully recycled. Condensation from greenhouse humidity passes through reverse-osmosis filters and returns to storage. RAS water, after biofiltration and nitrate uptake by crops, circulates back to the aquaculture units with less than 0.7 % daily loss. Nitrogen and phosphorus cycles are maintained by biological nitrification and the use of digestate from anaerobic reactors; phosphorus losses are offset by recovery from ash and controlled mineral imports.

Safety systems account for possible metabolic or chemical imbalances. Each sector contains an emergency oxygen buffer equivalent to 72 hours of life support, in liquid form, calculated using the NASA consumption constant. The lessons of Biosphere 2, where oxygen declined because of microbial soil respiration and CO_2 absorption by concrete, are incorporated through sealed, inert-lined floors and strict microbial control. Ethylene accumulation observed in NASA's Biomass Production Chamber when wheat reached 120 ppb is prevented by continuous air scrubbing and photochemical oxidation units.

The biosphere's architecture therefore achieves redundancy at every trophic level: protein sources (soy, fish, rabbit, algae, insect), carbohydrate bases (wheat, potato), and oxygen producers (crops + algae + moss). All flows of gas, water, and nutrients are balanced quantitatively and validated by decades of NASA and university research on closed ecological systems.

Ultimately, this design allows the colony to sustain human life independently from Earth. Every molecule of carbon, nitrogen, and water is perpetually reused. From the tilapia that breathe oxygen exhaled by algae, to the tomatoes nourished by fish effluent, the biosphere functions as a miniature Earth orbiting within the dark expanse of the Kuiper Belt, a living ecosystem engineered with scientific precision.

V. Behavioral Regulation and Social Systems in Long-term Habits

Long-duration, isolated–confined environments (ICEs) demand systems for habit acquisition, circadian stability, and group norms that can survive months to years. Empirically, crews in Mars analogs (HI-SEAS; Mars-500) show that self-organization around shared routines, fixed mealtimes, exercise blocks, cleaning rounds, and science shifts emerges as a resilience mechanism; when autonomy to tune these rules is preserved, adherence and morale improve.

Observational and sensor-based analyses from HI-SEAS and Mars-500 link cohesion and performance to early agreement on schedules, clear communication channels, and rapid conflict resolution protocols.

Circadian regulation is foundational: sleep restriction and misalignment degrade vigilance and mood; the ISS solution dynamic, spectrally tunable lighting synchronized to duty cycles was built as a countermeasure and has improved alertness and psychomotor vigilance in operational and analog studies. Colonies should therefore deploy habitat-wide dynamic lighting schedules (blue-enriched morning, blue-reduced evening), lock work–rest windows, and formalize nap opportunities within shift work.

VI. Risk assessment

Hull depressurization. Space contains micrometeorites that move at velocities of up to 70 km/s, but only their diameter reaches a grain of sand. However, this diameter is already enough to depressurize the capsule and lead to an emergency situation. A large space junk piece (e.g., fragment of a retired satellite) would make a hole and an immediate air leak. Additionally, constant stress on the frame will, with time, result in tiny fractures. Temperature fluctuation from heating when under the sun and cooling in the shade is another cause of material wear. Seal too in any joints is weak, hence seal wear or failure to seal the choke properly will result in depressurization. Overheating of the battery or an oxygen tank explosion can also cause an oxygen leak.

Ways to protect and respond

- Multi-layer shell: The outer layer protects against meteorites, the inner layer is sealed, and a shock-absorbing material is placed between them.
- Pressure and sound sensors: Instantly detect leaks and sound an alarm.
- Automatic sealing of the compartment: If the pressure drops at any point, the hatches will close, saving the rest of the cylinder.
- Repair drones: They can arrive and seal the hole from the inside or outside before the crew arrives.
- Capsules for evacuation and shelter: In case of severe depressurization, passengers can move to a safe room with an autonomous air supply.

The O'Neill Cylinder creates artificial gravity through rotation around its axis, typically at a speed of 1-2 revolutions per minute. If the spin is disrupted (begins to slow down, speed up, or destabilize), then:

- gravity will disappear → humans and objects will begin to "float" inside;
  a deadly roll can result – the cylinder will begin to "wobble" or even get disoriented in space;

- Failure of attitude control thrusters or gyroscopes controlling speed of rotation.

- Meteor impact on the side of the cylinder → mass imbalance.
- Unsymmetrical weight distribution – e.g., excessive water, equipment, or population on one side.

Control system failure (power supply or software malfunctions).

Solutions and Risk Mitigation

1. Redundant Rotational Control Systems

Mount multiple independent attitude control thrusters (ion, plasma, or gyroscopic).
When one fails, automatic backup controls.

2. Mass Balancing System

Sensors monitor mass distribution along the cylinder.
Weighing robots and mobile platforms automatically move weights to rebalance.

3. Automatic Stabilization

A computer monitors angular velocity and stabilizes rotation at the first hint of deviation.
Reaction wheels or magnetic motors are used.

4. Structural Protection of Mirrors and Mounts

Mirror mounts must sustain short-duration oscillations and vibrations.
In extreme imbalance, the mirrors can fold temporarily into the cylinder as a last resort.

5. Crew Action Plan

Create an emergency procedure: where to hide, how not to get injured, and how to reorient.
Special handrails and special cables in residential areas to stabilize people during gravity loss.

VII. Conclusion

Aurora demonstrates that a fully autonomous, closed-loop orbital settlement in the Kuiper Belt is technically coherent and socially viable for at least 80 Earth years. A counter-rotating twin O'Neill cylinder (25 km × 8 km, 0.9 g at $\omega \approx 0.047$ rad s^{-1}) provides 1,256 km^2 of habitable area for 250,000 residents, with robust shielding, replaceable ice-polyethylene radiation layers, and a non-rotating axial spine that houses 1.5 GWe class D–^3He fusion, heat rejection, and power distribution. Life support closes the mass balance across gases, water, and nutrients: >95 % water recovery; photosynthetic and algal O_2 regeneration sized to NASA metabolic constants; and a trophic web (wheat/potato/soy + tomatoes/bamboo + Spirulina/Chlorella + tilapia/rabbits/BSF larvae) that recycles organics while diversifying calories and protein. AI-supervised environmental grids and digital-twin prognostics integrate lighting, climate, agriculture, and maintenance, while sector-level O_2 buffers and multilayer hull design provide graceful failure modes.

Aurora's distinctiveness lies not in any single component but in the system-level synthesis tailored to the outer Solar System:

(1) a mirror-less, spectrally tunable LED "sun" that decouples ecology from distant insolation; (2) a Kuiper-Belt resource economy (water ice, NH_3/CH_4, and He-3) that makes true logistical independence credible; (3) a compact, multi-trophic agro-aquaponic architecture that couples CELSS-validated crops with industrial BSF bioconversion and RAS tilapia to close loops with high areal productivity; (4) a behavioral operating system—circadian-aware lighting, schedule governance, conflict-resolution protocols—derived from ICE/analog evidence to sustain cohesion at population scale; and (5) active rotation-safety engineering (redundant attitude control, auto-balancing masses, reaction-wheel stabilization) that treats spin-integrity as a first-class reliability problem.

In sum, Aurora converts classic O'Neill geometry into a 21st-century outer-system habitat: fusion-powered, AI-managed, socially resilient, and materially self-reliant. It shows a credible path for humans not merely to survive, but to build a flourishing, Earth-like civic life far beyond the frost line—turning the Kuiper Belt from a remote frontier into a sustainable home.

VIII. Reference(APA style in 7th edition)

Architecture and Engineering of Orbital Habitats:

1. O'Neill, G. K. (1974). *The colonization of space*. *Physics Today, 27*(9), 32–40. https://doi.org/10.1063/1.3128863
2. O'Neill, G. K. (1977). *The High Frontier: Human colonies in space*. William Morrow & Company.
3. Häuplik-Meusburger, S. (2011). *Architecture for astronauts: An activity-based approach*. Springer.
4. Zubrin, R. (2019). *The case for space: How the revolution in spaceflight opens up a future of limitless possibility*. Prometheus Books.
5. Johnson, R. D., & Holbrow, C. (Eds.). (1977). *Space settlements: A design study (NASA SP-413).* NASA Ames Research Center.
6. Heppenheimer, T. A. (1977). *Colonies in space.* NASA / Harper & Row.

—---

Biosphere, Life Support, and Ecological Systems

1. Barta, D. J., & Henninger, D. L. (1994). *Regenerative life support systems: Engineering analysis and operation*. SAE Technical Paper 941276. https://doi.org/10.4271/941276

2. Drysdale, A. E., Sager, J. C., Wheeler, R. M., & Knott, W. M. (1994). *NASA's advanced life support program: Closing the loop*. *Advances in Space Research, 14*(11), 5–10. https://doi.org/10.1016/0273-1177(94)90433-2

3. Nelson, M., & Dempster, W. F. (1996). *Living in space: Results from Biosphere 2's initial closure, an early testbed for closed ecological systems on Mars*. *Life Support & Biosphere Science, 2*(1), 31–45.
4. NASA. (1997). *Controlled Ecological Life Support System (CELSS) program overview*. NASA Ames Research Center.
5. Sager, J. C., Wheeler, R. M., Mackowiak, C. L., & Knott, W. M. (1992). Nutrient solutions for space-based plant growth. SAE Technical Paper 921320. https://doi.org/10.4271/921320
6. Wheeler, R. M. (2010). *Plants for human life support in space: From Myers to Mars*. *Gravitational and Space Research, 23*(2), 25–35.

—---

Behavioral Regulation, Psychology, and Social Systems

1. Palinkas, L. A. (2003). *The psychology of isolated and confined environments: Understanding human behavior in Antarctica*. *American Psychologist, 58*(5), 353–363. https://doi.org/10.1037/0003-066X.58.5.353
2. Pagel, J. I., & Choukèr, A. (2016). *Effects of isolation and confinement on humans—Implications for manned space explorations*. *Journal of Applied Physiology, 120*(12), 1449–1457. https://doi.org/10.1152/japplphysiol.00928.2015
3. Wu, A. C., & Kring, J. P. (2021). *Lighting for circadian regulation and psychological health in space habitats*. *Frontiers in Astronomy and Space Sciences, 8*, 673941. https://doi.org/10.3389/fspas.2021.673941
4. Fong, T., & Nourbakhsh, I. (2005). *Interaction challenges in human–robot space exploration*. *Interactions, 12*(2), 42–45. https://doi.org/10.1145/1052438.1052463

—---

Tools: ChatGPT, Gemini, Grammarly.
Link to the 3d model:
https://sketchfab.com/3d-models/space-colony-oneill-cylinder-d9b2646016a64aa69d7ecdf43d5849c5, we took an Open source 3d model from the sketchfab website, from the author Hagia