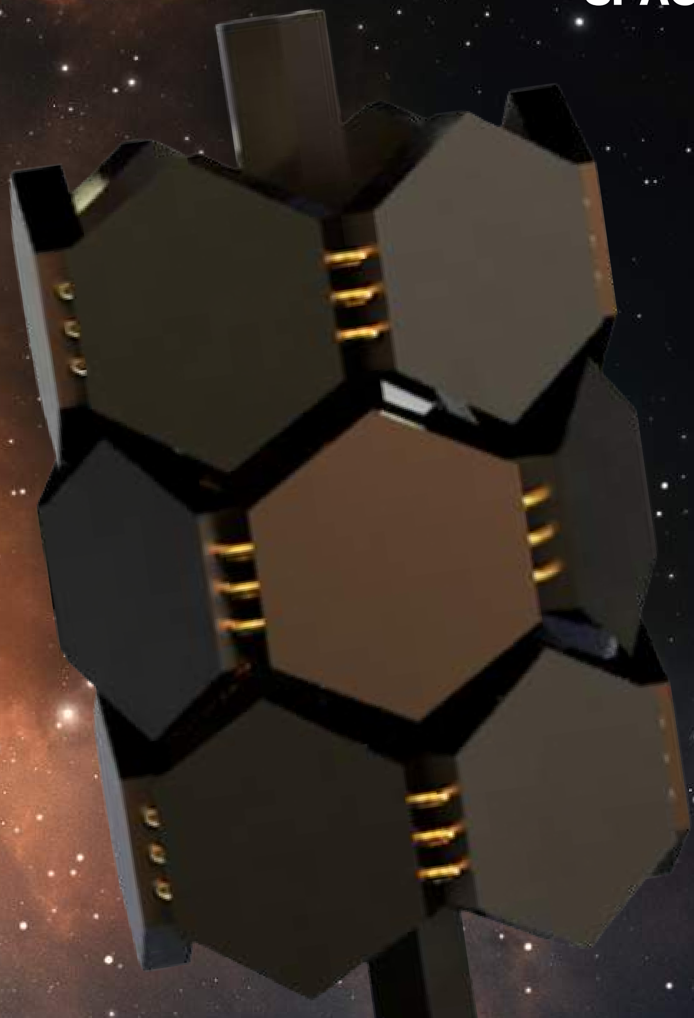
GERARD K. O'NEILL SPACE SETTLEMENT CONTEST

2026 EDITION

HIVE 9

SPACE SETTLEMENT



NATURE INSPIRED. SPACE ENGINEERED.

A scalable, self-sustaining space settlement designed for long-term human habitation amongst the stars.

Table Of Contents

Meet the Team

Vladimir-Andrei Ciobica

Eva David

Daria-Anastasia Dinu

Maia Ivan

Omar-Mohammad Kinj

Amir Mrini

Tudor Anghel-Verioti

*Working collaboratively to build something greater than ourselves, like bees in a **hive**.*

THE MINDS BEHIND HIVE 9

1 Introduction and Vision

WELCOME TO HIVE 9

As humanity faces increasing environmental and societal pressures, the exploration of sustainable living beyond Earth has become increasingly significant. Nature has demonstrated how complex systems can survive in balance, a fundamental principle which will guide humanity's expansion into space.

Core objectives

1. Ensure long-term human survival
2. Achieve ecological sustainability
3. Reduce pressure on Earth
4. Integrate science, engineering and biomimicry
5. Support human wellbeing and social stability
6. Serve as a scalable model for future settlements

The purpose of Hive 9 is to ensure humanity's long-term survival, drawing inspiration from earth, for a new life amongst the stars.

Humanity stands at the edge, the point of no return. After centuries of industrialisation, resource depletion, ecological collapse and climate instability, the very place humanity calls home, has begun to fight back. Wildfires break out, flames burning bright, devouring entire forests and leaving behind miles of barren terrain. Oceans rise and swallow cities. The sky turns the color of ash, and the air burns in our lungs. The terrifying events depicted in films, of the world burning and turning into an uninhabitable wasteland no longer felt like pure fiction, rather, like a predication of the future.

Recognising the critical nature of this moment, the global community united to design a solution. Putting their differences aside, world powers looked to experts in the scientific community to ensure the future of humanity. All across the planet, their judgemental gaze sweeping through thousands of great scientists. Seven of the most intelligent, resilient and innovative scientists were chosen to help merge innovation, sustainability and engineering excellence into a single vision, becoming the brains behind Hive 9.

Inspired by nature, Hive 9 honours the very planet on which the story of the human race began. On earth, bees create efficient, interconnected ecosystems, working together to build a hive which sustains life both within its honeycomb walls, as well as in the surrounding environment through the pollination of plants by the busy little workers. The Hive 9 team has worked to create a space settlement plan which reflects the same fundamental principles of teamwork, structure and sustainable functionality, designing an off-world home which can ensure the survival of humanity in the case of catastrophic, single-planet failure or the inevitable implosion of the planet under the never ending demands of humanity.

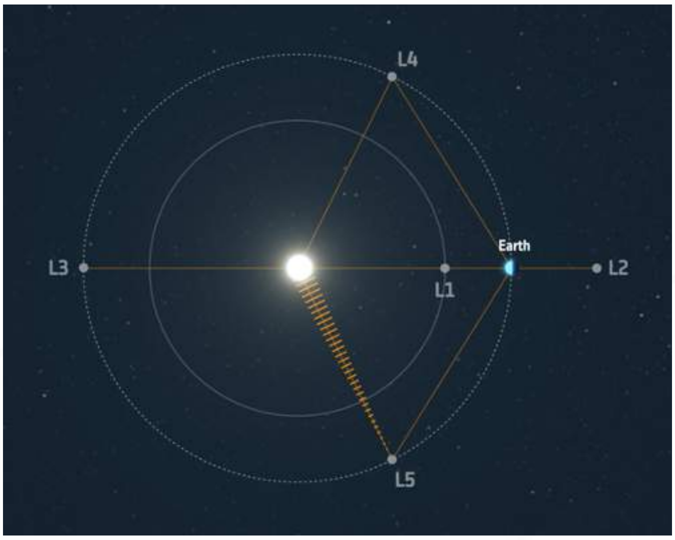
Expanding our reach into space before life on earth proves impossible is essential to human survival, as waiting might mean that humans wait too long and fail in their endeavour to protect the species. By creating a self-sufficient, resilient, off-planet habitat, capable of housing a permanent population, humanity can simultaneously face new frontiers of space colonisation and preserve human knowledge and culture from the past.

2 Orbital Location and Rationale

Hive 9 is located at the Earth-Sun Lagrange Point L5, a region of space that offers exceptional stability, continuous access to solar energy, and long-term resource potential. Lagrange points are positions in space where the gravitational forces of two large bodies, in this case Earth and the Sun, balance the orbital motion of a smaller object. This balance allows objects placed at these points to remain in a stable position relative to Earth, with minimal energy expenditure.

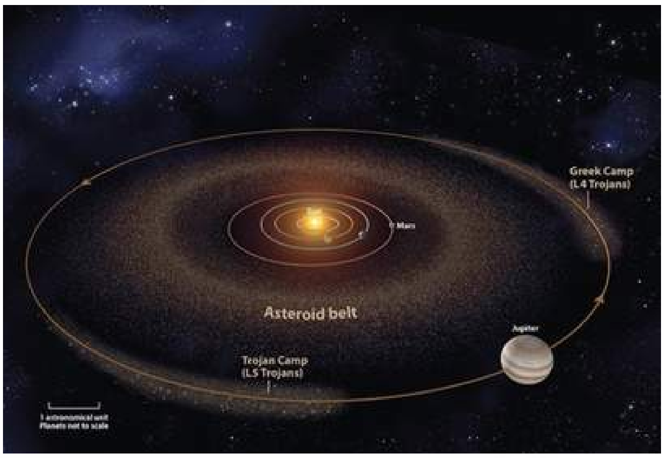
The L5 point is positioned approximately 60 degrees behind Earth in its orbit with the Sun, at roughly the same distance from the Sun as Earth. Unlike Low Earth Orbit, which requires constant station-keeping, L5 is a gravitationally stable equilibrium. This means that if an object, such as the Hive 9 Space Settlement, were to drift away from its original position, gravitational forces would naturally guide it back towards its point of origin. Hive 9 would therefore require significantly less fuel allocated for maintaining the stations position, as a settlement positioned near the L5 Lagrange point can remain stable over long time periods. This was the main deciding factor in the selection of this location, which is considered well-suited for the construction and use of permanent space infrastructure.

Another contributing decisional factor was that accessibility to L5 is energetically efficient when compared to other deep-space destinations. Although L5 is not close in terms of distance, the total energy required to reach it is comparable to a mission to the Moon. Another important advantage of L5 is its exposure to near-continuous light, with no ling nights and very few eclipses, meaning that Hive 9 can rely on uninterrupted solar energy. This supports continuous operation of life-support systems, agricultural lighting and thermal regulation.



Credit: European Space Agency (ESA)

The location of L5 also provides strategic access to valuable resources. L5 lies in an area where Trojan asteroids cluster along Earth's orbit. These astroids are rich in valuable materials such as silicate minerals, metals, carbon-rich compounds, and water ice. Water extracted from asteroids can. be used in a variety of processes onboard such as providing drinking water, breathable oxygen and rocket fuel, while metals and minerals would support in-space manufacturing and construction. This would aid in reducing the settlement's long-term dependence on Earth-based supply chains.



Credit: Astronomy Magazine

3 Development, Launch and Construction Strategy

PREPARING FOR LIFE ON THE SETTLEMENT

Before Hive 9 can become a permanent space settlement, extensive preparations must first take place on Earth. Living in space requires advanced engineering, as well as careful planning for human safety, system reliability and long-term sustainability. Hive 9 will thus follow a phased approach that begins on Earth and gradually transitions to a fully functional settlement at the L5 Lagrange Point.

Earth-based preparations and testing

All major systems are first designed, tested and checked for reliability on Earth. Life-support systems, water recycling units, agricultural modules, radiation shielding materials and robotic assembly systems will be tested to allow engineers to identify weaknesses, improve efficiency and ensure that every element of the settlement can operate continuously and with minimal maintenance.

The crew selected for the first missions into space with need to undergo training in spacecraft operation, emergency response, medical care, robotics and habitat maintenance, in order to prepare for their roles onboard Hive 9.

Residents and crew for the Hive 9 settlement project will be selected based on a series of set criteria, balancing technical expertise, physical and psychologucal suitability and the ability to function effectively as a member of a diverse community. The selection process would prioritise essential skils during the early stages of settlement development, while later stages will transition towards building a fuller society which supports family-based residency and long-term social stability.

Initial launch and transport to L5

The transport of materials from Earth to L5 is conducted in maultiple stages using heavy-lift launch vehicles, sicj as Falcon Heavy, which can place large cargo modules in Low Earth Orbit. The initial launch into Low Earth Orbit is the most energy intensive phase of the journey to L5, thus the Hive 9 team will use reusable rocket technology to reduce costs.

Once in Low Earth Orbit, cargo transferred to a specialised spacecraft for transportation to L5. Transport missions will be primarily uncrewed at first, in order to minimise risk, with supplies, structural components and robotic systems being delivered and positioned before the arrival of a human crew for permanent residence.

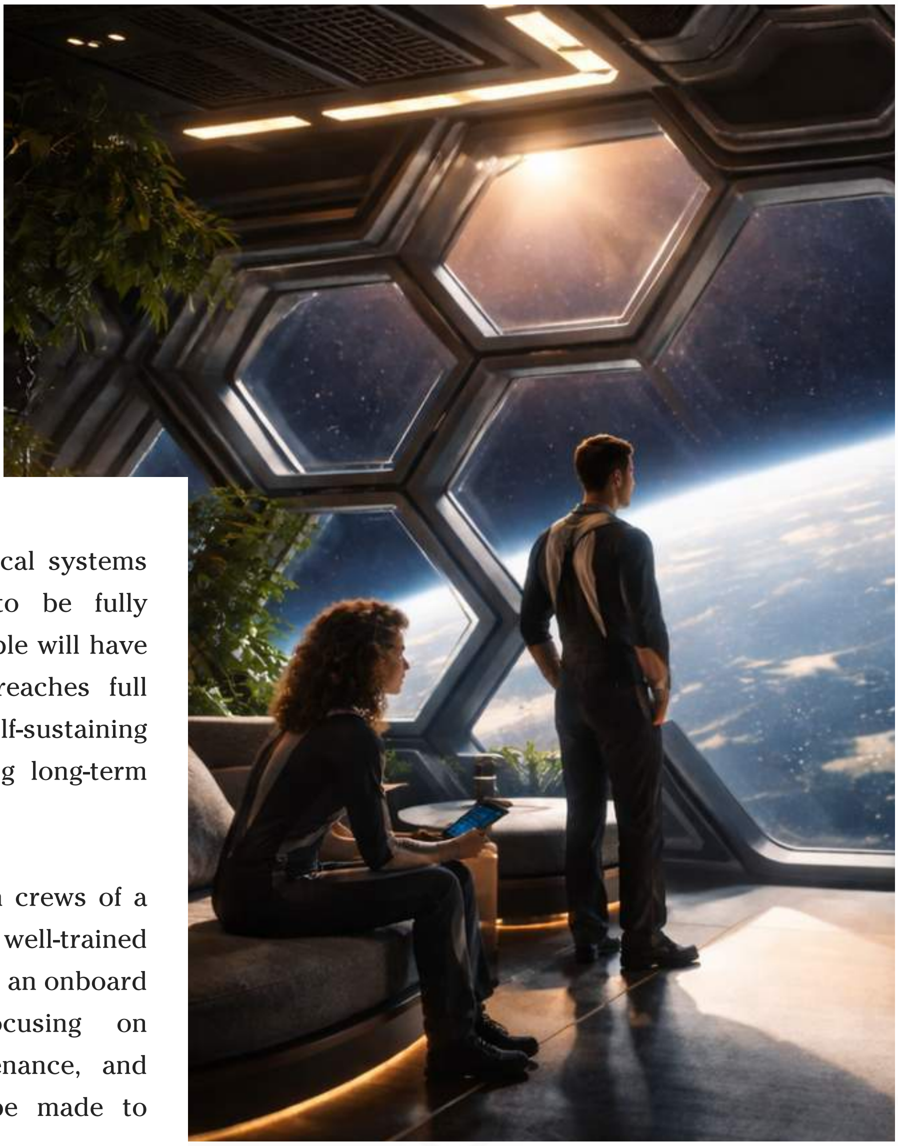
Robotic assembly and construction

The beginning stage of construction at L5 will be carried out almost entirely as an autonomous process with remotely operated robitic systems. Robots will assemble the structural frames, connect habitat modules, deploy solar arrays and install radiation shielding. The use of robotic systems for construction reduces human exposure to radiation and prevents astronauts from having to perform dangerous tasks during what is the most hazardous part of the building proces.

Hive 9 will be constructed in stages so that each aspect of the settlement can be tested and proven to be fully functional before additions to the settlement are made. Early modules will focus on essential systems such as power, air, water and radiation protection. Later phases will add agricultural modules, living spaces, research facilities and recreational areas.

BRINGING THE SETTLEMENT TO LIFE

The staged construction of the space settlement will require crew and residents to arrive in stages until Hive 9 reaches full operational capacity and begins to focus on expansion rather than initial population.



Credit: AI Generated Concept Art by the Hive 9 Team

Arrival of human crew

Human crews arrive at Hive 9 after critical systems have been fully tested and proven to be fully functional and stable. A total of 3378 people will have arrived onboard by the time Hive 9 reaches full operational capacity, functioning as a self-sustaining habitat with the capability of supporting long-term residence on the settlement.

Initial arrival numbers will be small, with crews of a limited number of highly skilled, well-trained individuals being sent in order to establish an onboard workforce of essential workers, focusing on monitoring systems, performing maintenance, and assisting in adjustments which must be made to aspects of the settlement.

During early construction, approximately 40% of residents (approximately 1350 people) will be sent to the settlement, with their selection requiring technical, medical and agricultural expertise, or knowledge of essential life support and safety systems, all of which is required to establish and maintain the settlement. Key roles will include engineers, doctors, agricultural scientists, construction personnel and systems technicians.

This process is a pathway, transitioning humanity from a single-planet species to a civilisation amongst the stars, far beyond the boundaries of Earth's atmosphere.

After stabilising the settlement, a further 35% of the total population (approximately 1180 people) will be populated from further supporting fields such as education, research, governance, logistics, creative industries and service roles. These individuals will be selected in order to provide additional support to social, cultural and economic development.

The final 25% of residents (approximately 850 people) will consist of family members and non-technical residents, all of whom will be selected as a conscious effort to create a stable and multi-generational community.

Each stage of the population process will emphasis physical and psychological suitabbility for long-duration space habitation and the ability to live cohesively with others in a closed environment.

4 Structural Design and Materials

CREATIVING A HIVE

The design for Hive 9 is insppired by one of nature's most efficient and resilient structures: the beehive. More specifically, the intenral honeycomb geometry found within a hive which serves as the foundation for both the settlement's structural design and internal elements and layout. This biomimetic approach allows Hive 9 to combine strength, efficiency and scalability in a form which supports long-term habitation in space.

Structural design

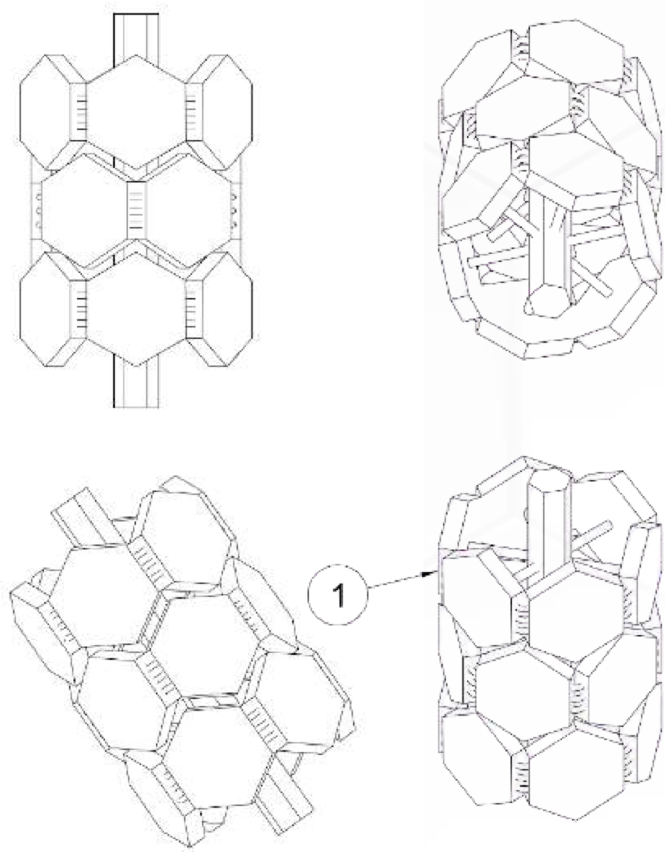
Hive 9 is a vertically expandable, rotating settlement. It consists of a central core in the form of a hexagonal prism, surrounded by multiple concentric rings made up of interconnected hexagonal modules.

The hexagonal structural core houses critical systems such as power distribution, environmental control processor units, docking coordination systems and gravity systems. This is the backbone of the settlement, around which all other aspects of life on Hive 9 are built.

Each ring consists of six large hexagonal modules which are connected by reinforced structural corridors. The "corridors" will serve as transportation tunnels and will connect the various sections of the settlement for an easier flow of power, water, data and workers. Each module functions as an individual cell within the larger settlement and can be used for living spaces, agriculture, research or technical systems.

Hive 9 generates gravity by rotating on its central axis, with the outer face of each module functioning as the "floor", as the centrifugal force presses residents outward against the habitable surface. Elevators connect the rings to the central core, using a linear magnetic elevator system, while corridors incorporate a train-like transportation for ease of movement.

STRUCTURAL DESIGNS



Credit: Original Design Created in AUTO CAD 360 FUSION by the Hive 9 Team

Zoning within the settlement:

Residential Modules

- Apartment structures; medical and childcare centres; educational facilities; recreational spaces

Agricultural Modules

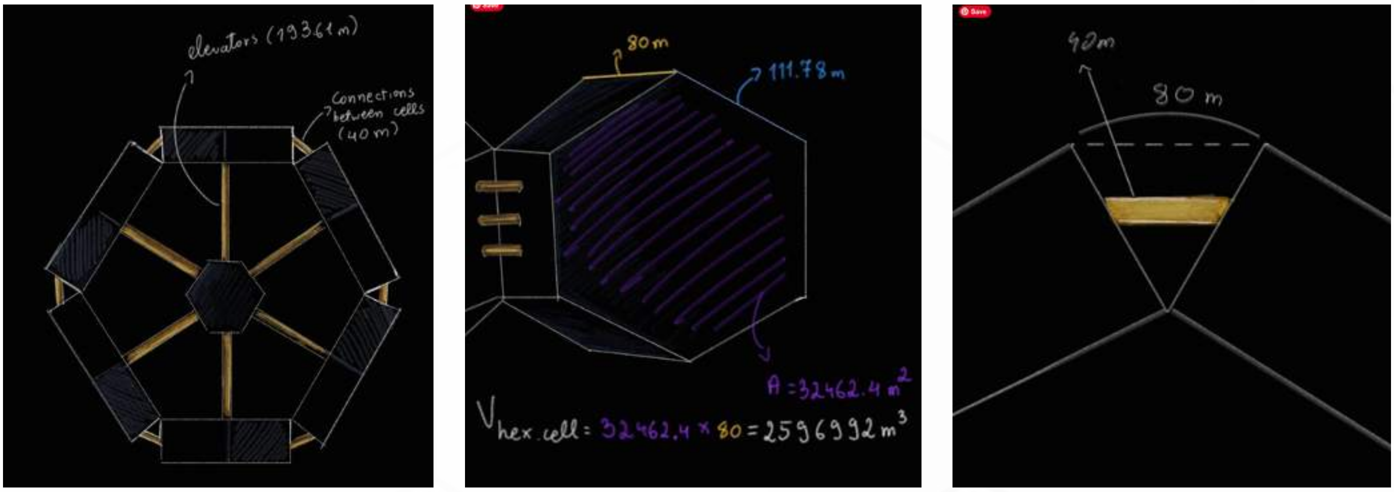
- Multi-level hydroponic systems; aquaponic nutrient recycling basins

Industrial Modules

- Additive manufacturing hubs; materials processing facilities; repair and maintenance docks

Research Modules

- Laboratories; artificial ecosystem simulations



Credit: Hive 9 Team's Initial Drawings and Calculation Notes

Materials

The materials used to construct Hive 9 have been selected so that they will withstand the extreme conditions of space while supporting long-term human habitation onboard the settlement.

Hive 9 is constructed using a combination of advanced lightweight alloys, high-strength composites and materials which aid in radiation-shielding. Materials must be resistant against the vacuum of space, radiation exposure, micrometeoroid impacts, thermal cycling and continuous mechanical stress from rotation.

The primary structural framework consists of aerospace-grade aluminium-lithium alloys and titanium reinforcements. Carbon-fibre reinforced polymer composites are used in other structural elements, while the outer hull has a built-in multi-layered shielding system combining aluminium, polyethylene radiation barriers, and regolith or water shielding to protect inhabitants from cosmic radiation and micrometeoroid impacts.

Transporting large masses from Earth is expensive, so Hive 9 is designed to rely increasingly on materials sourced from space, with materials from Earth being used for more specialised and precision components.

Structural Calculations

1) One hexagonal module: footprint (outer floor area)

Side length $s = 111.78$ m

Floor (hex face) area

$$A_{\text{hex}} = \frac{3\sqrt{3}}{2} s^2$$

$$A_{\text{hex}} = \frac{3\sqrt{3}}{2} (111.78)^2 \approx 32{,}462.4 \text{ m}^2$$

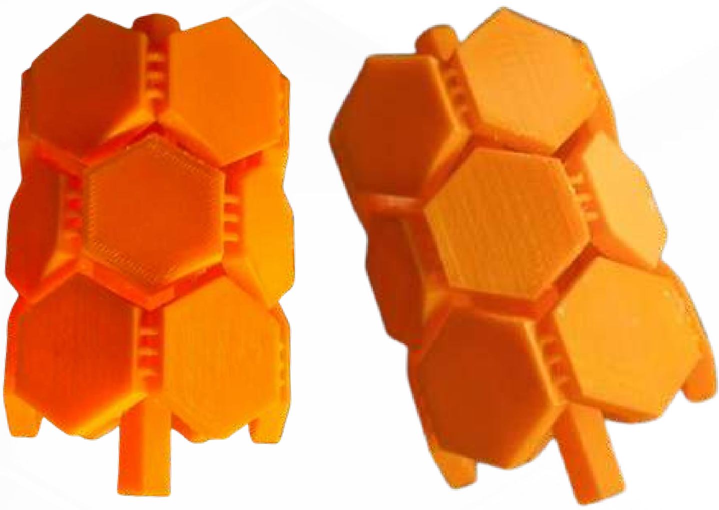
2) One module: enclosed internal volume (gross)

Given module height $h = 80$ m:

$$V_{\text{cell}} = A_{\text{hex}} \times h$$

$$V_{\text{cell}} = 32{,}462.4 \times 80 \approx 2{,}596{,}992 \text{ m}^3$$

3D PRINTS

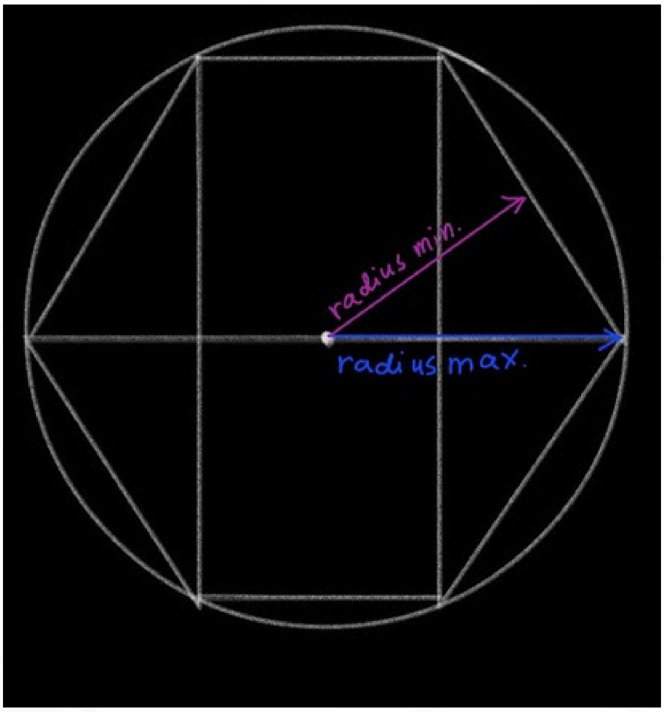


Credit: Images of 3D prints created by the Hive 9 team demonstrating the structural design

5 Artificial Gravity and Energy Generation

Hive 9 generates artificial gravity by rotating its honeycomb rings around the central hexagonal core (the core functions as a low-g hub for docking, logistics, and microgravity research). The "floor" inside each outward-facing hexagonal module is oriented so residents are pushed toward the outer hull due to the centrifugal force generated by centripetal acceleration which creates a downward force that feels like gravity.

In a rotating settlement like Hive 9, moving objects and people appear to curve sideways, causing a perceived deflection as part of what is known as Coriolis effect. The main limit for gravitational calculations then is rotation rate (rpm), because faster rotation increases Coriolis effects, which can cause dizziness and nausea when people move their head or walk. Hive 9 employs classic space settlement physics: rotation + radius determines gravity.



Credit: Hive 9 Team's Initial Notes on Structural Radius

Gravity Calculations

Artificial gravity at radius **r** (m) comes from centripetal acceleration:

a=ω2r

Where:

- a= centripetal acceleration (m/s²)
- ω= angular velocity (rad/s)
- r= radius (m)

Convert to rpm: $\mathbf{rpm} = \boldsymbol{\omega} \cdot \frac{60}{2\pi}$

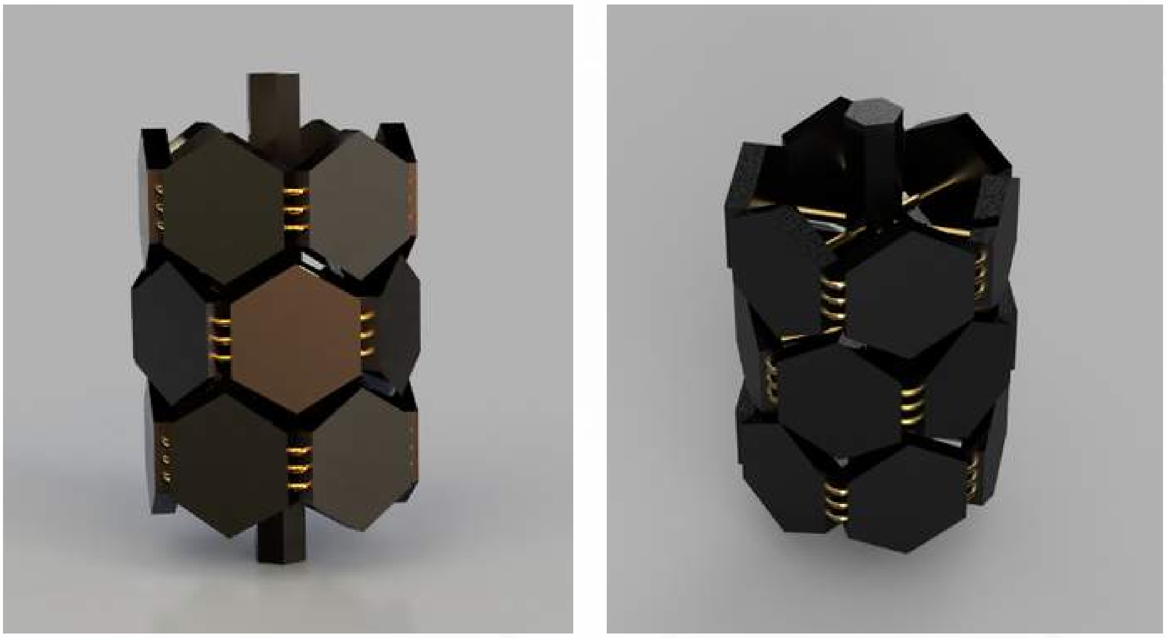
Earth gravity reference: $1g = 9.81\, m/s^2$

Gravity level in g: $g\text{-level} = \frac{a}{9.81}$

Thus, the amount of "gravity" depends on the habitat's radius and rotation rate. A larger radius allows for a slower, more comfortable spin, ensuring long-term human health while minimising structural stress and motion discomfort.

Hive 9 will aim for for ≤ 2 rpm in primary living rings, and use larger radii to achieve the required g-levels. **Baseline rotation: 1.2 rpm**

The honeycomb structure is engineered to withstand the continuous stresses produced by rotation, particularly the outward tensile forces generated at a large radius. The outer hull acts as the primary load-bearing surface, while internal walls are non-structural and oriented to align with the direction of artificial gravity. A multi-ring rotational system can further enhance stability by balancing angular momentum, allowing Hive 9 to maintain its orientation while generating consistent artificial gravity.



Source: Original Design Created in AUTO CAD 360 FUSION by the Hive 9 Team
Design demonstrates the rings and axis, gravity is created by rotating the rings around the central core

Energy systems on Hive 9

Energy systems in Hive 9 are responsible for sustaining all critical functions. including environmental control, life support, food production, lighting, communications, manufacturing and internal transportation. The settlement operates on a continual basis, so its energy system must be reliable, scalable and capable of uninterrupted energy provision. Energy generation and storage are therefore treated as critical infrastructure, with Hive 9 including multiple independent backup systems to ensure that a power source failure would not cause an interruption in essential systems.

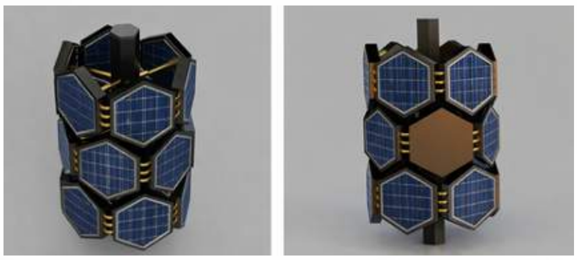
Hive 9 is located at the Earth–Sun Lagrange Point L5, where sunlight is nearly continuous and eclipses are rare. This makes solar power the most efficient and reliable primary energy source for the settlement. Large solar panels, built using high-efficiency photovoltaic cells, are incorporated into the exterior design on the hexagonal modules so as to maximise solar exposure and energy production. Power generation and storage are decentralised, meaning that each ring has its own substation, each honeycomb cluster can be isolated electrically and damaged sections can be disconnected instantly, allowing a rapid response to power supply issues and malfunctions, while supporting safe repairs and maintainence.

Energy storage

During peak sunlight hours, extra energy is stored in advanced lithium-based or solid-state battery banks. This stored energy can then be used during maintenance periods, temporary shadowing or emergency situations.

Power Distribution and Prioritisation
Level 1 - Critical: Oxygen supply; CO_2 removal; pressure control; emergency lighting; medical systems. **Level 2** - Essential: Food production; water recycling; communication systems; temperature control. **Level 3** - Non-essential: Manufacturing; recreational systems; decorative lighting. (Shut down in emergency scenarios.)

Estimated Power Demand
If each person uses approximately 5 - 10 kW of power (including industrial and agricultural demand), a population of 3,378 residents would require an estimated 17 - 34 MW of continuous power.



Source: AI Generated Images by the Hive 9 Team - Demonstration of solar panels on the hexagonal modules (not to scale)

6 Radiation Protection and Structural Safety Systems

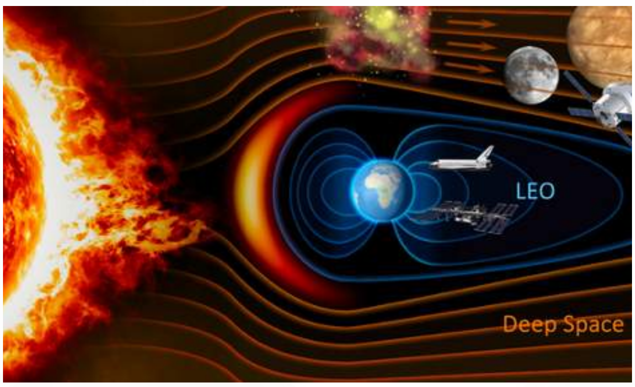
Radiation is energy travelling in the form of waves and it can be harmful to biological systems such as human beings. Ionising radiation, for example, has enough energy to break chemical bonds in human cells, damage DNA and increase the risk of cancer and genetic mutations.

Radaiation is measured in millisieverts (mSv). In space, an astronaut on a long-term mission can be exposed to cumulative doses ranging from 50 to over 2000 mSv, a much stronger dose than the usual 2 - 3 mSv an average person is exposed to each year on earth.

Radiation exposure is one of the most significant challenges facing permanent human settlement in deep space. While Earth is protected by a dense atmosphere and strong magnetic field, the location of Hive 9 lies outside any planetary magnetosphere, resulting in residents facing exposure to higher levels of space radiation. Hive 9 would therefore require extensive, highly-effective, long-term protective measures.

Radiation Environment at L5

Hive 9 is exposed to two forms of space radiation, Galactic Cosmic Rays, which originate outside the solar system, and Solar Energetic Particles, which is released during solar flares and coronal mass ejections.



Credit: STEMRAD Radiation in Space

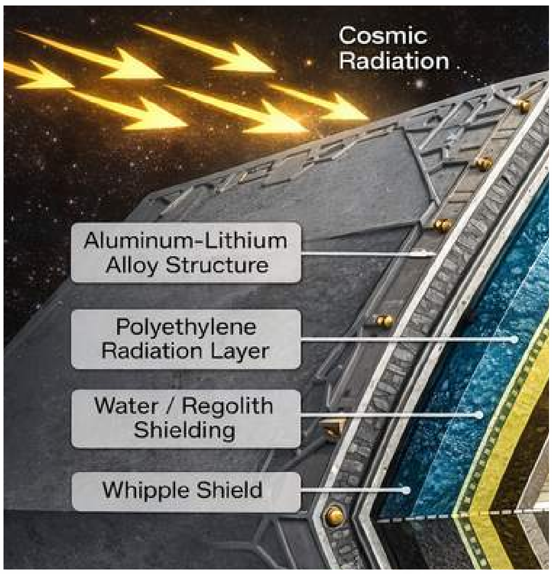
Material-based shielding strategy

Hive 9 uses a layered radiation protection strategy based on materials proven to be effective against ionising radiation. Hydrogen-rich materials are particularly effective because hydrogen atoms are effective at slowing down and absorbing high-energy particles.

1. Water is a key shielding material which is used throughout the settlement. Large volumes of water are stored within and around the walls of living areas, providing drinking water and feeding into life-support systems, while simultaneously acting as a radiation absorber, reducing exposure to harmful particles.
2. Polyethylene is also included in the structure of the habitat, due to it being lightweight, flexible, chemically stable and mechanically strong.
3. Liquid hydrogen is a core component of fuel and energy systems and, where stored safely, provides additional radiation shielding.

Whipple shield

The outer hull of Hive 9 includes a Whipple shield to protect against micrometeoroids and space debris, while aluminium-lithium structural layers help mitigate internal pressure and rotational stress.



Credit: AI Generated Image by the Hive 9 Team - Demonstration of layering as part of the hexagonal module design

7 Life Support and Environmental Control

Hive 9 requires sustainable life support systems. The settlement is therefore designed to operate as a closed-loop system, so that essential resources such as air, water and nutrients are continuously recycled. Waste products from one process are reused as inputs for another to improve efficiency and crating a self-sustaining ecosystem onboard.

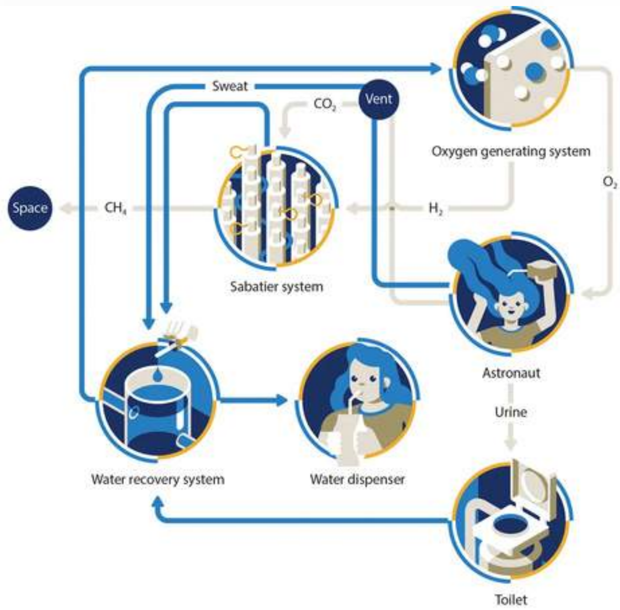
The life-support architecture of Hive 9 combines mechanical systems with biological processes, in a hybrid approach which includes:

- CO_2 scrubbers, oxygen generators and water processors.
- Plants, algae and microbial processes for naturally recycling carbon dioxide into oxygen, purifying water, and contributing to food production.

Hive 9 incorporates controls for monitoring and maintaining optimal levels of oxygen and atmospheric pressure on the settlement. Other essential systems focus on temperature control and thermal regulation; humidity and air circulation; and air filtration and contamination control. Together, these systems form an integrated environment which supports a variety of core functions for comfortable life on Hive 9.

Water: An essential resource

Water is an important resource on Hive 9, as it is required for a number of key roles, including: drinking; hygiene; food production; thermal control; humidity regulation; and radiation shielding. The settlement uses advanced water recycling systems to capture moisture from breath, sweat, wastewater and urine, purify it and return it to the system for use. High recovery rates drastically reduce the need for resupply and make long-term habitation feasible.



Credit: Popular Science
How the ISS recycles its air and water

Oxygen and Water Demand Calculations

1) Oxygen demand (kg/day)

Average metabolic rate: **0.85 kg O_2 / person / day**

Total O_2 per day for 3,378 people: $\mathbf{0.85 \times 3378 = 2871.3}$ **kg O_2/day**

Hive 9 requirement: **2.87 tonnes of oxygen per day**

2) Water demand and recovery (kg/day)

Cautious estimate: **4.19 kg of water per crew member per day**

Total water loop flow/day:

$\mathbf{4.19 \times 3378 = 14156.8}$ **kg/day ≈ $\mathbf{14.16}$ tonnes/day**

A note on recycling urine into water: This is a multi-stage system, primarily involving vacuum distillation to separate water vapour from urine in the Urine Processor Assembly (UPA), followed by further filtration with high temperature in the Water Processor Assembly (WPA) to eliminate contaminants, producing ultra-pure water that's cleaner than Earth's tap water, achieving nearly 98% recovery.

Green spaces

Green spaces are integrated into the interior of Hive 9, supporting air revitalisation while simultaneously contributing to the wellbeing of residents. These areas improve mental health, reduce stress and help regulate circadian rhythms.

Hive 9 has been designed to include natural, multi-functional zones, with each hexagon able to include layered vertical garden, hydroponic farming systems, small trees, walking paths, and communal park areas.

Some modules function as agricultural greenhouses for food production, while others are designed as open recreational parks with seating areas, water features, and playground spaces for children.

Credit: NASA
Corps grown onboard the ISS

Credit: NASA
Solid-State Light Assemblies (SSLAs) on the International Space Station

Notes: Crops grown on the ISS and their use of lighting systems inspired the Hive 9 team in their design of green spaces and the day night system.

Credit: AI Generation by the Hive 9 Team

Night / Day Cycle

Hive 9 does not experience a natural planetary day/night cycle, making it necessary to create an artificial lighting system which simulates a 24 hour circadian rhythm.

Adjustable LED lighting panels are installed in the interior spaces of the settlement to replicate the colour temperature and intensity of natural sunlight, gradually shifting from bright white light during "daylight" hours to softer tones in the evening. This controlled lighting schedule helps regulate the sleep patterns, hormone production, mood and overall psychological wellbeing of the Hive 9 population, by replicating a key element of life on Earth.

Credit: AI Generation by the Hive 9 Team - Illustration of the Day / Night Cycle

8 Food Production and Closed Ecosystems

Long- term human habitation in space requires a reliable and sustainable food supply that does not depend on frequent resupply missions from Earth. In Hive 9, food production is full integrated into the settlement's life support system and designed to operate as a closed-loop ecosystem, ensuring food security, reducing resource waste and supporting both physical and psychological wellbeing.

Soilless Crop Production Systems

The primary methods of plant cultivation on Hive 9 are hydroponics and aeroponics. In hydroponic systems, plants are grown without soil, by suspending their roots in a nutrient-rich water solution. Aeroponic systems take this further by misting plant roots with a fine pray containing water and dissolved nutrients. Both methods allow Hive 9 staff to control nutrient delivery, oxygen levels and growth conditions, so as to ensure a continuous supply of food for the settlement's 3378 residents.

These systems have been selected due to their effectiveness in meeting settlement needs in a sustainable way, with a notable feature being the recycling of water, which is used in a much lower quantity than traditional farming because it is not lost to soil absorption and evaporation.

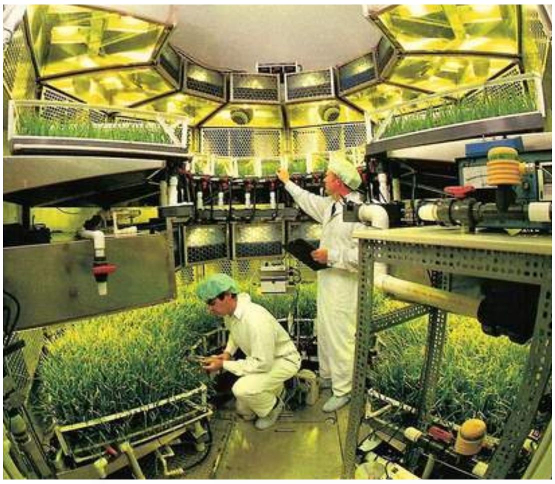
Food Production Requirements
Each resident requires approximately
2,000–2,500 kcal per day.
For the full population of **3,378 people**,
Hive 9 must produce:
6.8–8.4 million kcal per day
2.5–3.1 billion kcal per year
Using hydroponic and aquaponic systems, this equals approximately:
5–7 tonnes of food per day
1,800–2,500 tonnes per year

Credit AI Generated Imaginings of Hydroponic and Aquaponic Systems by the Hive 9 Team

Food production onboard Hive 9 is designed to provide a balanced diet with carbohydrates for energy, proteins for muscle repair and immune function and healthy fats for brain and hormone regulation. Essential vitamins and minerals, including iron, calcium, and vitamin D are carefully monitored onboard to prevent deficiencies and maintain long-term physical health.

Hydroponics

Hydroponic systems grow plants without soil, using nutrient-rich water solutions. This method uses up to 90% less water than soil farming and allows for the production of large quantities of product within a comparatively small space, by using vertically stacked layers. This technique is suitable for producing staple crops such as leafy greens, herbs, tomatoes, beans and some root crops.



Credit: NASA

Demonstration of a closed growing environment

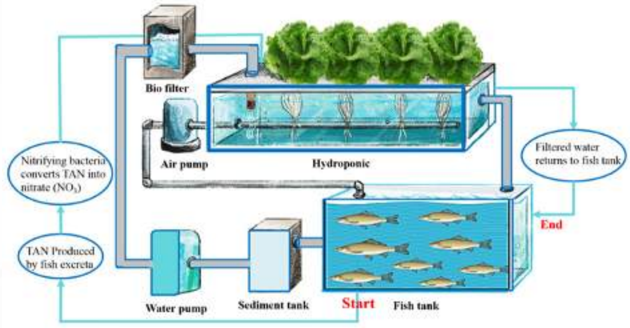
HYDROPONICS & LIGHTING

Credit: TG Hydroponics

Credit: Eden Green Technology

Aquaponics

Aquaponics combines growing plants with fish farming. Fish waste provides nutrients for plants, while plants help filter the water for reuse by the fish. This system provides fish as a key source of protein for residents, while simultaneously supporting natural nutrient recycling and reducing the need for synthetic fertilisers.



Credit: Verified Market Reports

Credit: The Aquaponics Association

Notes: The agricultural projects on Hive 9 use artificial lighting to support plant growth, with energy-efficient LED systems providing plants with the wavelengths needed for photosynthesis.

Waste management

Waste management in Hive 9 is carefully managed by a closed-loop nutrient cycle. Organic waste, food scraps and human waste are all processed through microbial digestion systems, converting them into usable nutrients for hydroponic and aquaponic farming. By transforming waste into a resource, Hive 9 is able to use less external fertilisers and minimise system waste, supporting both continuous food production and long-term sustainability.

9 Transport, Logistics and Communication

Hive 9 has developed a safe and efficient transportation system, to ensure that that people, goods and resources can move easily throughout the settlement and between Hive 9 and external destinations.

Internal transportation

Internal movement between adjacent hexagonal modules is supported by low-speed conveyor walkways within structural tunnels. For longer horizontal travel across each ring, enclosed electric rail systems provide automated, low-acceleration transport for passengers and cargo, minimising travel time. Vertical transport between rings and the central spine is achieved through elevator systems designed to operate against artificial gravity, ensuring smooth and controlled movement throughout the settlement.

Credit: AI Generated Images by the Hive 9 Team

External transportation

Docking facilities are located on the non-rotating central core, allowing spacecraft to dock safely without the risks that would arise from docking on the complex rotating mechanisms (the rings). These standardised ports accommodate crew vehicles, cargo ships, maintenance modules and emergency evacuation craft. All incoming supplies and equipment will be inspected and sorted, before being distributed throughout the settlement, using the internal elevator and railway systems.

Resource collection logistics

Hive 9 is designed to prioritise in-space resource utilisation, with the objective of developing self-sufficient systems which reduce reliance on Earth. Thus, while specialised equipment, medical supplies and advanced technologies would be transported to the L5 zone from Earth during the initital development stages, the settlement would then actively shift towards a reliance on materials sourced from the moon and nearby asteroids. Materials such as regolith, metals, silicates and water ice could be extracted and used for radiation shielding, structural maintenance and expansion, fuel production and manufacturing. An automated cargoship system is used in conjunction with a robotic handling system for maximim safety and efficiency.

Communication Systems

Hive 9 communicates with Earth using radio frequency (RF) technology, which is the most reliable long-distance space communication method currently available. It operates across S-band (2–4 GHz) for highly reliable backup communication, X-band (8–12 GHz) for deep-space telemetry and Ka-band (26.5–40 GHz) for high-data-rate transmission.

Due to the fact that Hive 9 is located at the Earth–Sun L5 point, approximately 150 million km from Earth, radio signals travelling at the speed of light experience a one-way delay of about 250 seconds (around 4 minutes), meaning real-time communication is not possible and systems must function autonomously, without requiring an immediate response from Earth.

Multiple antennas, transmitters, receivers and independent power supplies ensure communication reliability on Hive 9, while emergency modes allow the station to transmit signals during during system failures.

10 Society and Wellbeing

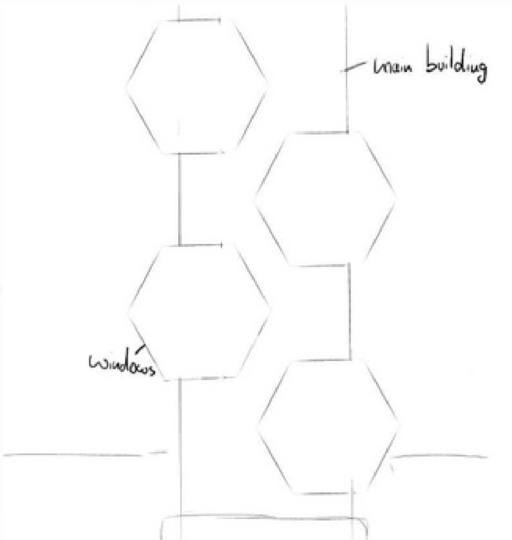
Community living environment

Residential areas have been established within the hexagonal modules of the Hive 9 structure and provide approximately 30 m^2 of personal living space per resident, ensuring comfort and privacy. Apartments are arranged in clusters that include shared green spaces and recreational areas to promote social interaction. Each apartment will include an open-plan living space, kitchen, bedroom and built-in storage.

Workplaces, laboratories, schools and community facilities are distributed throughout the settlement to reduce travel time and support efficient daily routines. As families form and the population grows, larger housing units can be provided, ensuring healthy and stable living conditions for future generations.

The living environment is also maintained in a manner which supports societal wellbeing due to the use of artificial day-night cycles and climate regulation. Programmable full-spectrum lighting systems are integrated into ceilings, walls, and reflective panels to replicate sunrise, midday, sunset, and night by adjusting brightness and colour temperature, for a stable circadian rhythm.

Gentle air circulation systems simulate natural breezes, improving comfort and air quality. Humidity levels are balanced to prevent dryness, keeping skin, eyes and respiratory systems healthy. Each system is integrated to ensure that the indoor environment remains comfortable for all Hive 9 residents, supporting their health and long-term life on the settlement



Credit: Sketch by Hive 9 Team
Consideration of the Hive 9 Apartment Structures

Credit: AI Generated Image by the Hive 9 Team - Rendition of the Tiered Living Quarters

Note: As both the physical and psychological health of Hive 9 inhabitants is a priority, all workplaces and schools, are equipped with "rest pods", which people can use to to rest, sleep, read or just enjoy a break from the usual activities of the day.

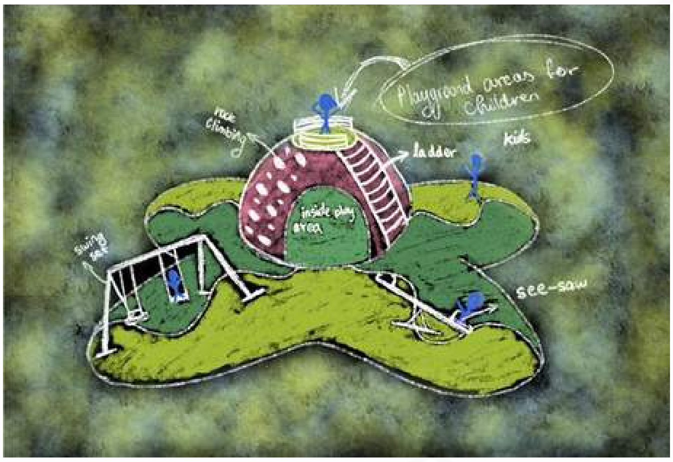
Credit: AI Generated Image by the Hive 9 Team - Rest pods in use

Education on Hive 9

Hive 9 treats education as essential infrastructure, equal in importance to life support and energy systems. As a multi-generational settlement, it must ensure that knowledge, skills and culture are passed on without relying entirely on Earth.

Education supports all age groups, from early childhood to advanced professional training. The curriculum prioritises science, engineering, medicine, agriculture, environmental management and governance, while also including arts and humanities to support creativity and critical thinking.

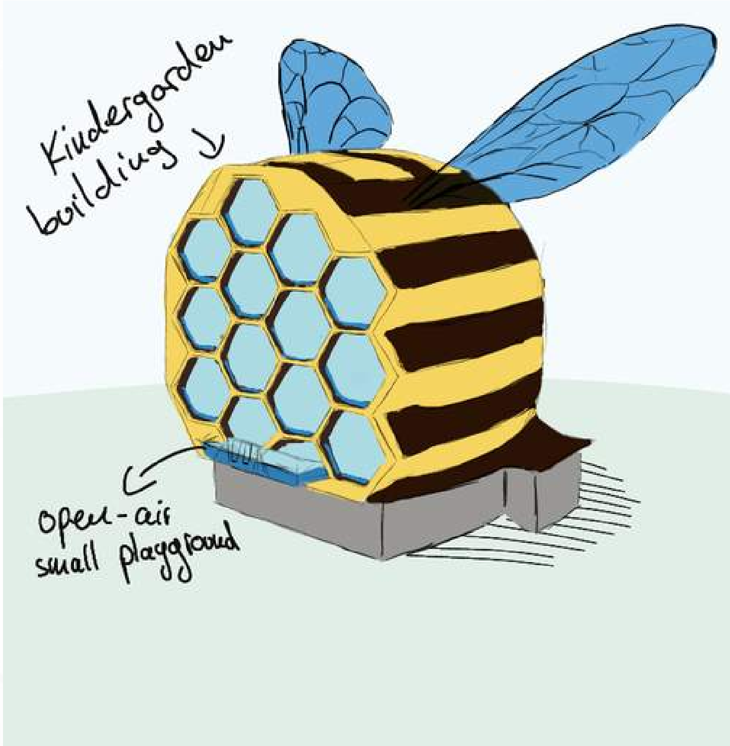
Learning is practical and systems-based, with programmes requiring students to interact directly with aspects of their surrounding environment, such as agricultural systems to learn about scientific principles involved with food production and waste management. This approach ensures that every resident understands how Hive 9 functions and can grow to become a contributing member of society.



Credit: Hive 9 Team Sketch of a Playground

Culture and identity

Hive 9 is home to a diverse population thus, developing a shared sense of identity as a Hive 9 community, while maintaining treasured aspects of culture from Earth will be an important task. Cultural life onboard therefore includes shared celebrations, festivals, artistic performances and community gatherings, with facilities such as libraries, digital archives, art studios, music rooms and performance spaces allowing residents to express themselves creatively.



Credit: Drawing by Hive 9 Team
Nature inspired Kindergarten

Psychological wellbeing

Living in space for an extended period of time will present challenges such as confinement stress and social tension. Hive 9 addresses these challenges through mental health support systems, ensuring that residents have access to confidential counselling, peer support programmes and regular psychological assessments. The Hive 9 habitat has also been designed natural lighting cycles, green spaces and a variety of recreational environments to reduce stress and maintain emotional stability.

Facilities

Hive 9 includes numerous facilities to support the physical and mental health of its residents.
These include:

- Gyms
- Fitness centres
- Walking and cycling paths integrated into rotating rings
- Sports facilities
- Indoor parks
- Cafés
- Theatres
- Game rooms
- Relaxation and meditation zones

11 Economy and Governance

Trade and economic activity

Hive 9's primary industries include asteroid resource extraction, scientific research, advanced manufacturing, agricultural production, life-support maintenance and fuel generation. Water ice mined from asteroids can be processed into hydrogen and oxygen, which are used for life support and rocket fuel and may also be exported to support other space missions as expansion further into space begins.

Inside the settlement, an internal digital credit system helps support trade and provides residents with a way to access to goods and services, so that they can receive essential resources such as food, water and healthcare, while also rewarding specialised skills and contributions to the community.

The Hive 9 workforce

Jobs in Hive 9 range from doctors, engineers, agricultural specialists and life-support technicians to educators, researchers, artists and entertainers. Essential services such as healthcare, environmental control, agriculture and waste management are prioritised to ensure survival and stability.

There is a workforce plan for Hive 9 to prevent a shortage of workers in critical roles, while education and training systems prepare residents for entry into the workforce.

Conflict resolution

Hive 9 prioritises mediation and restorative justice. Trained mediators and ethical oversight committees assist in resolving disputes before they escalate. Formal legal procedures exist for serious violations but emphasis is placed on dialogue, transparency, and maintaining trust.

Governance and law

Governance within Hive 9 is guided by the principle that human dignity, safety and collective wellbeing are central to long-term sustainability. A representative council, supported by scientific, technical and ethical advisory boards, oversees major decisions related to life-support systems, resource management, expansion and community policy.

Laws are designed not only to ensure operational safety but also to protect individual rights, promote fairness, and guarantee equitable access to essential resources. In a confined habitat where cooperation is essential for survival, legal structures prioritise transparency, accountability and shared responsibility.

Leadership Structure

Residents of Hive 9 elect their leaders through a democratic voting system. During the first four years of settlement, presidential terms last one year. This shorter term allows the community to evaluate leadership performance in a real operational environment and replace ineffective leadership quickly if necessary.

The first round of candidates are recommended by a founding committee based on expertise, psychological suitability and community trust. Nominees must voluntarily accept candidacy and final selection is decided by a vote by Hive 9 residents. Presidents during this initial period may stand for re-election up to four times.

After the initial four years of development, governance adjusts to the usual democratic terms from Earth, with a standard four-year election cycle.

12 Risk Management and Expansion

Hive 9's expansion strategy

Hive 9’s honeycomb architecture allows for controlled and scalable expansion of the original settlement structure. Rings can be fitted to rotate around the core systematically, with each ring capable of functioning without reliance on the others. The modular design of Hive 9 therefore ensures that growth occurs gradually and sustainably, as the first, second and all subsequent rings are added to the core in a controlled manner.

Plans for future expansion reflect the understanding that as the settlement expands physically, it also expands economically. Additional rings which are added in the future can facilitate advanced manufacturing, research laboratories and agricultural zones, capable of boosting trade due to increased production capacity. In time, Hive 9 aims to become a regional hub at the Earth–Sun L5 point, supporting exploration missions and other space settlement initiatives.

Expansion also opens opportunities for space tourism with hospitality modules that could include observation decks, cultural centres and short-term accommodation for visitors from Earth or other space habitats.

Credit: AI Generated Image by the Hive 9 Team - Green Spaces and an Educational / Cultural Space on Hive 9

SWOT anlysis

Strengths

- Stable L5 orbital location
- Modular, expandable architecture
- Closed-loop life-support systems
- Renewable solar energy supply

Weaknesses

- High construction and launch costs
- Complex technological systems
- Dependence on early-stage infrastructure reliability

Opportunities

- Space-based fuel production
- Scientific research
- Asteroid resource utilisation
- Expansion into larger interplanetary networks

Threats

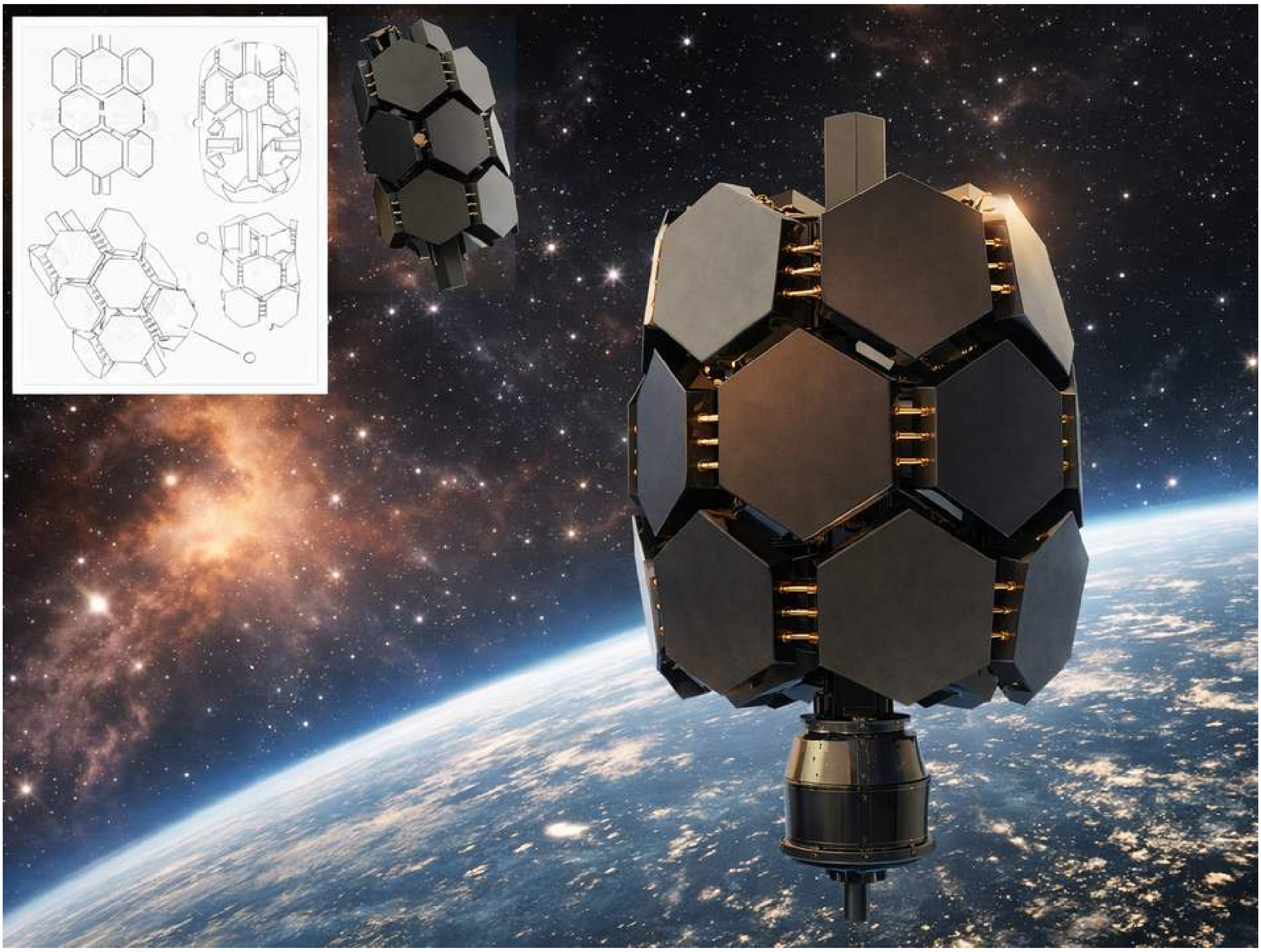
- Solar storms and radiation events
- Micrometeoroid impacts
- Long-term psychological isolation
- Technological malfunction

Risk management and systems failure

Operating in space requires proactive risk assessment. Hive 9 anticipates potential system failures such as structural damage, power loss, life-support malfunction or communication interruption. To address these risks, critical systems (power, water, air, communication) are all fully redundant, while modules can be isolated instantly to prevent one system failure from affecting other modules. Backup life-support systems are available in multiple sections of the settlement and emergency shelters provide additional radiation and impact protection for extreme scenarios. Finally, autonomous repair drones assist in maintenance, in order to ensure that Hive 9 is well maintained and operating at optimal efficiency.

13 Conclusion: Hive 9, the Answer to Humanity's Future

Hive 9 represents a sustainable vision for humanity's future beyond Earth. Located at the Earth–Sun L5 point, the settlement combines advanced engineering with ecological responsibility, operating as a closed-loop system that recycles air, water and nutrients to support long-term habitation. Inspired by the planet we originated from, the name and design reflect the honey bees of Earth, working together for the greater good. The settlement's modular honeycomb design allows safe expansion, artificial gravity ensures human health and layered radiation shielding protects inhabitants from space hazards. By integrating education, governance, industry, agriculture and cultural development, Hive 9 becoms a thriving society in space. Through innovation, cooperation and sustainability, Hive 9 offers a practical pathway for humanity to expand, adapt and flourish beyond our home planet.



Credit: AI Generated Concept Art by the Hive 9 Team

The Settlement in Space - Based on the Team's Original Structural Drawings

14 Bibliography

Amol Sanap (2024). Top Companies In The Aquaponics - Verified Market Reports. Verified Market Reports. Available at: https://www.verifiedmarketreports.com/blog/top-companies-in-the-aquaponics/
[Accessed 15 January 2026].

Audrey, M. and Emery, M., 2017. Silicate phases on the surfaces of Trojan asteroids. AAS/Division for Planetary Sciences Meeting Abstracts #49, 49, p.110.34. Available at: https://ui.adsabs.harvard.edu/abs/2017DPS....4911034M/abstract
[Accessed 5 December 2025].

Bolt, O., 2024. Average water usage and wastage stats per person per day. Energy Theory, 4 April. Available at: https://energytheory.com/average-water-usage-per-person-per-day-liters/
[Accessed 7 December 2025].

Davis, J., 2018. Exploring Jupiter's Trojan Asteroids. Astronomy Magazine. Available at: https://www.astronomy.com/science/exploring-jupiters-trojan-asteroids/
[Accessed 10 December 2025].

Dorais, G., n.d. An artificial-gravity space-settlement ground-analogue design concept.

Ehinger, B., 2024. How much waste does a human produce per day? Waste Removal USA, 20 May. Available at: https://wasteremovalusa.com/blog/how-much-waste-does-a-human-produce-per-day/
[Accessed 12 December 2025].

Emery, J.P., et al., 2015. The complex history of Trojan asteroids. In: Asteroids IV. Available at: https://www-n.oca.eu/morby/papers/Rev39.pdf
[Accessed 5 December 2025].

Energy Theory, 2024. Average water usage per person per day. Available at: https://energytheory.com
[Accessed 10 December 2025].

ESA, 2024. MELiSSA life-support system. Available at: https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Melissa
[Accessed 25 November 2025].

Funk, B., n.d. How Hydroponic Lights Work. Eden Green. Available at: https://www.edengreen.com/blog-collection/how-hydroponic-lights-work
[Accessed 27 November 2025].

garden, T., 2025. The Importance of LED Lights in Hydroponics: A Cost-Effective and Efficient Lighting Solution. TG-Hydroponics. Available at: https://tghydroponics.com.au/blogs/tg-hydroponics/the-importance-of-led-lights-in-hydroponics-a-cost-effective-and-efficient-lighting-solution
[Accessed 27 November 2025].

Hall, L., 2021. NASA Research Launches a New Generation of Indoor Farming. NASA. Available at: https://www.nasa.gov/technology/tech-transfer-spinoffs/nasa-research-launches-a-new-generation-of-indoor-farming/
[Accessed 28 November 2025].

Lea, R., 2022. Artificial gravity: definition, future tech and research. Space.com, 20 May. Available at: https://www.space.com/artificial-gravity
[Accessed 5 November 2025].

NASA, 2017. Why space radiation matters. Available at: https://www.nasa.gov/missions/analog-field-testing/why-space-radiation-matters/
[Accessed 12 November 2025].

NASA, 2023. Growing Plants in Space. Available at: https://www.nasa.gov/exploration-research-and-technology/growing-plants-in-space/
[Accessed 10 December 2025].

NASA, 2023. Human health countermeasures. Available at: https://www.nasa.gov/hrp/human-health-countermeasures
[Accessed 14 November 2025].

NASA, 2023. Human integration design handbook. Available at: https://www.nasa.gov/humans-in-space/human-integration-design-handbook/
[Accessed 10 December 2025].

NASA, 2025. Environmental control and life support systems (ECLSS). Available at: https://www.nasa.gov/reference/environmental-control-and-life-support-systems-eclss/
[Accessed 12 November 2025].

NASA, n.d. Ion propulsion. Available at: https://science.nasa.gov/mission/dawn/technology/ion-propulsion/
[Accessed 10 December 2025].

National Academies of Sciences, Engineering, and Medicine, 2026. Dietary reference intakes for water, potassium, sodium, chloride, and sulfate. Available at: https://nap.nationalacademies.org/catalog/10925/dietary-reference-intakes-water-potassium-sodium-chloride-and-sulfate
[Accessed 14 January 2026].

Pomeroy, R., 2020. 3 ways to make artificial gravity in space, including a “holy grail” method. RealClearScience, 29 October. Available at: https://www.realclearscience.com/blog/2020/10/29/3_ways_to_make_artificial_gravity_in_space_including_a_holy_grail_method.html
[Accessed 16 December 2025].

Southwest Research Institute, 2018. The Lagrange points – Lucy mission. Available at: https://lucy.swri.edu/2018/03/13/Lagrange-Points.html
[Accessed 15 October 2025].

Study, Q., 2021. The Aquaponics Association. The Aquaponics Association. Available at: https://aquaponicsassociation.org/articles/aquaponics-amp-local-food-systems-hawaii-study-xeh4g
[Accessed 23 November 2025].

Sullivan, K., 2019. How the ISS recycles its air and water. Popular Science. Available at: https://www.popsci.com/how-iss-recycles-air-and-water/
[Accessed 4 December 2025].

United States Environmental Protection Agency, 2023. US EPA. Available at: https://www.epa.gov [Accessed 2 November 2025].

USDA, 2020. Dietary guidelines for Americans. Available at: https://www.dietaryguidelines.gov [Accessed 12 December 2025].

Weiner, L., 2021. Radiation Shielding in Space. StemRad. Available at: https://stemrad.com/blocking-space-radiation-in-deep-space/ [Accessed 4 December 2025].

Wevolver, n.d. Falcon Heavy Block 5 specifications. Available at: https://www.wevolver.com/specs/falcon-heavy-block-5 [Accessed 10 December 2025].

Wikipedia, 2020. Ion thruster. Available at: https://en.wikipedia.org/wiki/Ion_thruster [Accessed 3 December 2025].

Wikipedia, 2021. SpaceX Raptor. Available at: https://en.wikipedia.org/wiki/SpaceX_Raptor [Accessed 3 December 2025].

Wikipedia, 2022. Delta-v. Available at: https://en.wikipedia.org/wiki/Delta-v [Accessed 10 December 2025].

www.esa.int, n.d. What are Lagrange points? Available at: https://www.esa.int/Enabling_Support/Operations/What_are_Lagrange_points [Accessed 15 October 2025].