SKYPIA

The design of an artificial gravity space station

BEYOND THE BLUE, ABOVE THE REST



RENDER Skypia in low Earth orbit: two 200 m truss arms spinning at 2.11 RPM around a still central hub.

1.00 g	200 m	2.11 RPM	7.5 MN
AT THE RIM	SPIN RADIUS	SPIN RATE	TENSION PER ARM

YANQUIEL BOSQUES

Aerospace Engineering, Georgia Institute of Technology, Class of 2028

Personal design project, January 2026 to present

yanquielbosques.com

yanquielbosques@gmail.com

linkedin.com/in/yanquielbosques

01 · OVERVIEW

A STATION THAT MAKES ITS OWN GRAVITY

Long stays in microgravity cost the human body bone, muscle and eyesight. Skypia answers with rotation instead of medicine.

Skypia is a space station that makes its own gravity. Habitat clusters ride at the ends of two 200 meter truss arms, and spinning the whole structure at 2.11 revolutions per minute presses everyone inside against the floor with a full Earth g. The central hub never turns, so ships can dock to it the same way they dock to the ISS today.

At the hub, Skypia doubles as a gas station in orbit, with a propellant depot for visiting ships. Elevators carry crew and cargo between the still hub and the spinning habitats, and a counterweight system keeps the station balanced every time they move.

It is my dream project, the one I work on when nobody has assigned me anything. I started it in January 2026 to answer one question: could the numbers actually work? So far, every subsystem I have worked through says yes, as long as one joint, the hub bearing, can be solved.

MY ROLE

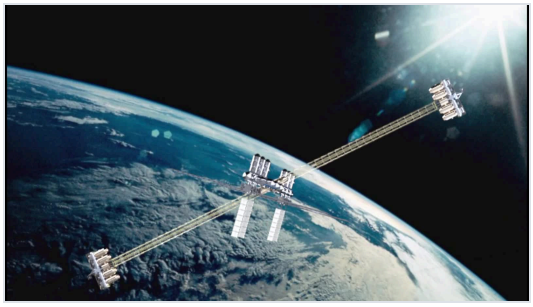
I own the concept, the requirements and the analysis: orbital and rotational dynamics, the structural sizing of the arms, the counterweight system and the MATLAB scripts behind it. The CAD, renders and animations were built with my ME 1670 team (Kartik Menke, Paige Brewer, Liza Polgul and Ian Delcher). Within the model, I built the trusses, the center hull, the cloud habitats and the connectors.

THE PLAN: THREE DESIGNS

- **Design I, understand it.** Orbital mechanics, rotational dynamics, the counterweight system, propulsion and structures, worked out from first principles. *(In progress)*
- **Design II, make it real.** Cut cost and mass, design for manufacture and maintenance, plan the assembly, and stress test the rare events: solar storms, meteor showers and collisions.
- **Design III, build it.** Assembled within ten years, with a crew of ten aboard within five, a propellant depot for visiting ships, gravity tuned for research, and room for visitors.

KEY PARAMETERS

SPIN RADIUS	200 m
SPIN RATE	2.11 RPM
RIM GRAVITY	1.00 g
RIM SPEED	44.2 m/s
ONE ROTATION	28.4 s
DESIGN MASS PER TIP	765 t
ARM TENSION	7.5 MN
TRUSS	7075-T6 aluminum
SAFETY FACTOR	1.5
HABITATS	8 m × 15 m
ELEVATOR SPEED	0.75 m/s
ORBIT	LEO, ISS path
TOOLS	SolidWorks, AutoCAD, MATLAB



ANIMATION Spin up sequence over Earth, built in SolidWorks.

02 · ARTIFICIAL GRAVITY

GRAVITY IS A RADIUS

Spin a station and the floor pushes back. Choosing the radius and the spin rate is choosing what the crew will feel.

A person standing on the rim is carried in a circle, and the floor has to push on them to keep them turning. That push is what they feel as weight. It depends on only two numbers, the spin radius and the spin rate:

$a = \omega^2 r \quad \rightarrow \quad \omega = 2.11 \text{ RPM} = 0.221 \text{ rad/s} \quad \rightarrow \quad a = 0.221^2 \times 200 = 9.77 \text{ m/s}^2 \approx 1.00 \text{ g}$

Rim speed $v = \omega r = 44.2$ m/s, one full turn every 28.4 s

The same gravity can come from a small, fast station or a large, slow one. Small stations are cheaper, but fast spin makes people dizzy when they turn their heads, and the difference in gravity between head and feet grows. A 200 m radius keeps the spin near 2 RPM while keeping the structure buildable.

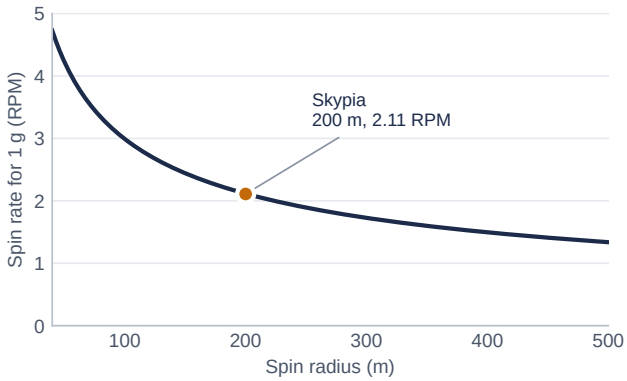
INSIDE THE HABITAT

Because gravity scales with radius, every meter closer to the hub is about 0.5% lighter. Each 15 m habitat therefore has a built in gradient: the floor nearest the rim sits at a full g, and the upper floors are a few percent lighter. For a 1.8 m tall person, the difference between head and feet is under 1%, small enough not to notice. "Down" always points straight out from the hub.

GRAVITY IS TUNABLE

Changing only the spin rate turns Skypia into a research platform for other worlds:

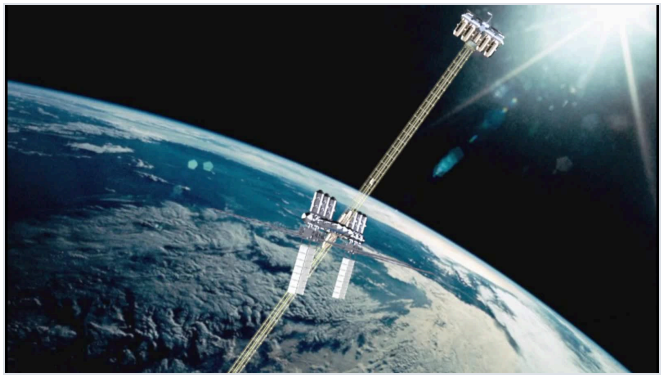
MOON GRAVITY (0.17 G)	**0.86 RPM**
MARS GRAVITY (0.38 G)	**1.30 RPM**
EARTH GRAVITY (1.00 G)	**2.11 RPM**
TWO G	**2.99 RPM**



TRADE Spin rate needed for one Earth g at each spin radius. Halving the radius raises the spin rate by about 40%.

WHY 200 M

- Spin stays near 2 RPM, a commonly cited comfort range for crews.
- Head to foot gravity difference stays under 1%.
- Arm tension of 7.5 MN can be carried by an aluminum truss at a 1.5 safety factor.
- Rim speed of 44 m/s keeps docking and elevator loads manageable.

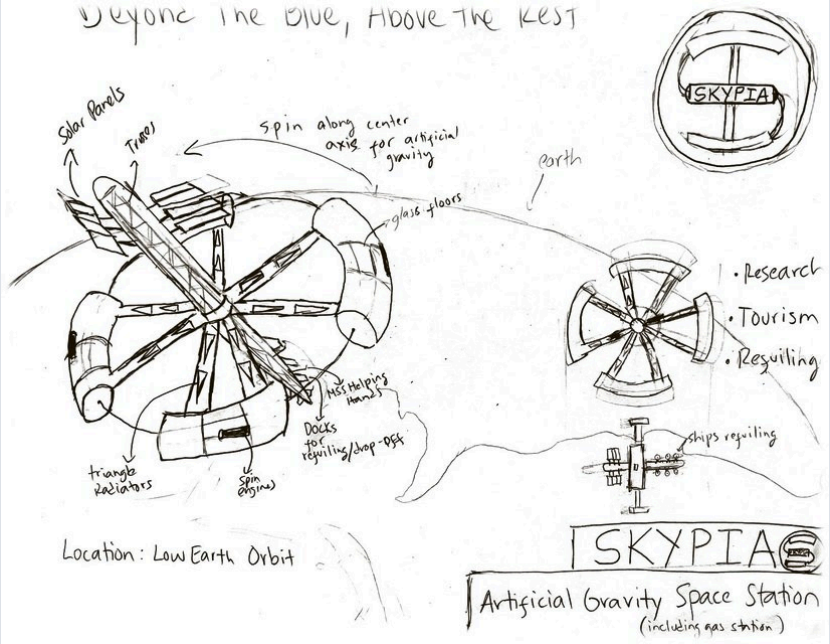


ANIMATION Arms sweeping through a rotation, one turn every 28.4 seconds.

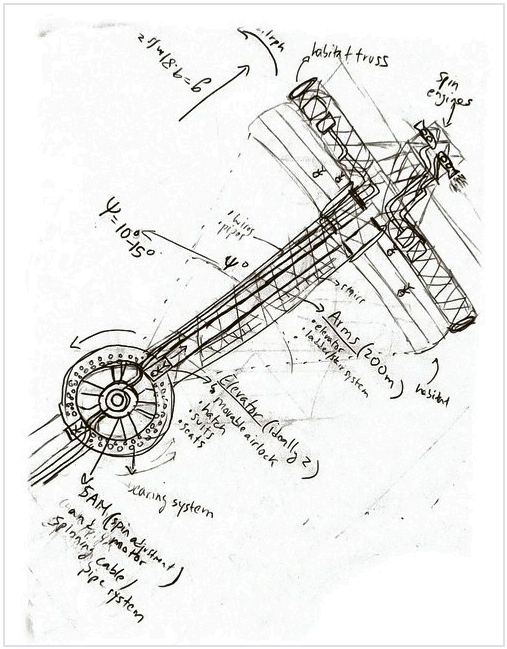
03 · CONCEPT TO CAD

FROM SKETCHBOOK TO ORBIT

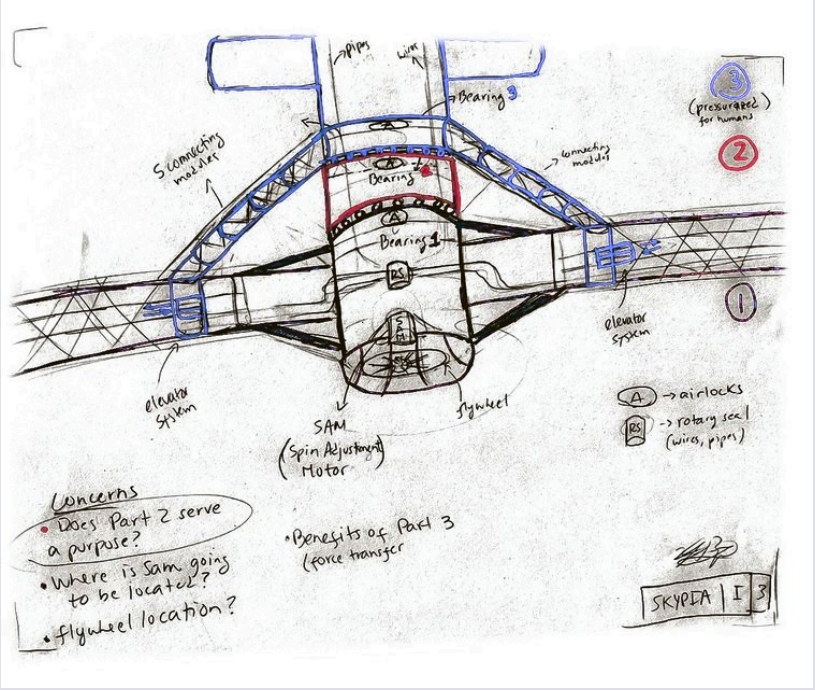
Skypia started as pencil on printer paper, then went into SolidWorks and out over the Earth.



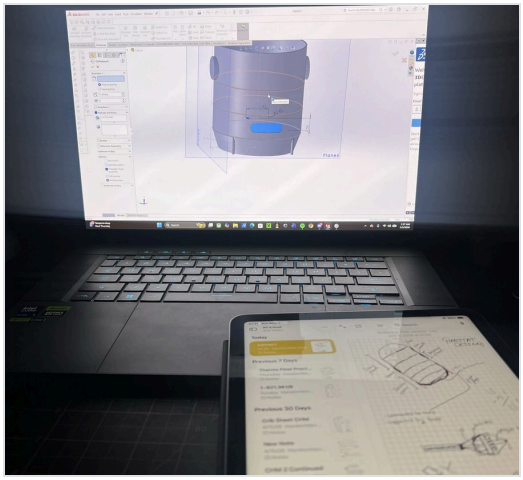
SKETCH 1 The first concept page: hub, two arms and habitat clusters.



SKETCH 2 An arm with its elevator and spin motor.



SKETCH 3 The hub stacked on three bearing stages, the part of the design I trust least.



CAD Habitat modeling in SolidWorks next to the notebook it came from.

04 · STRUCTURE AND SPIN

HOLDING 765 TONNES AT THE RIM

The arms do not carry weight the way a building does. They carry pure tension, the pull of each habitat trying to fly away.

01

Uniform truss arms

Each tip is sized for a design mass of 765 t, about 30% above its current estimate (see the mass budget). Holding it on a circle at 200 m and 2.11 RPM takes a steady pull through the arm:

$$T = m\,\omega^2\,r = 765{,}000\ \text{kg} \times (0.221\ \text{rad/s})^2 \times 200\ \text{m} \approx 7.5\ \text{MN}$$

Sizing the load bearing section with 7075-T6 aluminum (yield strength about 500 MPa) and a safety factor of 1.5:

$$A = SF \times T / \sigma_y = 1.5 \times 7.5\ \text{MN} / 500\ \text{MPa} \approx 224\ \text{cm}^2$$

Plus about 1% for the truss's own weight: ≈ 228 cm², root to tip

Each 200 m arm is a uniform square truss: one adapter bay flares from the 12 m hub collar to 5.5 m, then about 28 identical bays run to the tip. The truss's own weight adds only about 1% to the tension, so a taper would save about 70 kg per arm. Identical bays mean one design, interchangeable spares and bays that launch pre-assembled. Eight radial carbon fiber cables and four crossed ones share the load, wrapped in multilayer insulation against thermal swings in and out of sunlight.

02

The hub

The spinning arms meet the still station on three stacked bearing stages, with airlocks between them so the crew can pass from the still core to the turning structure. A rotary seal carries power and fluids across the joint. Ferrofluidic seals, with almost no friction, are one option under study. Whether the middle stage earns its place is still an open question.

03

Spin up and attitude

Liquid engines at the arm tips spin the station up and down quickly. Ion thrusters then trim away the slow losses to drag and bearing friction. To show why both are needed, I estimated the spin up time for ion propulsion alone:

$$L = m\,r^2\,\omega = 765\ \text{t} \times (200\ \text{m})^2 \times 0.221\ \text{rad/s} \approx 6.8 \times 10^9\ \text{kg·m}^2\text{/s}$$

$$\tau = F\,r = 5.4\ \text{N} \times 200\ \text{m} = 1{,}080\ \text{N·m}$$

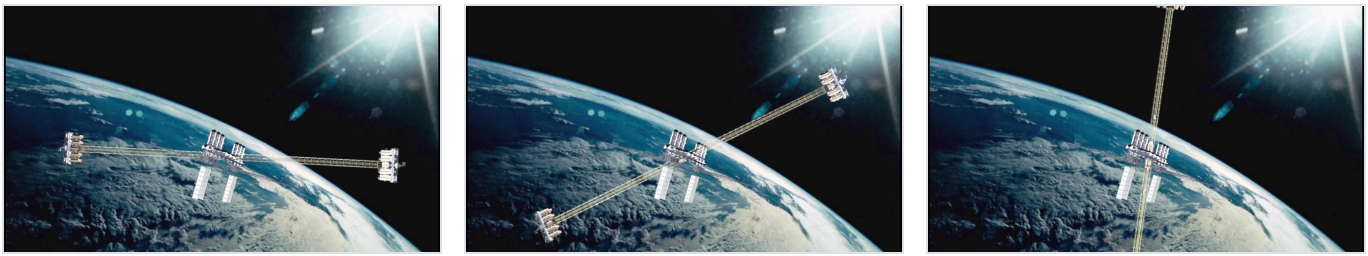
$$t = L / \tau \approx 6.3 \times 10^6\ \text{s} \approx 72\ \text{days}$$

One 5.4 N ion thruster per tip, 765 t at 200 m

More than two months is fine for trimming, but far too slow for spin up or an emergency spin down, so the chemical engines stay.

Skypia keeps its spin axis fixed in space and lets the solar arrays swivel to follow the Sun. Turning the whole axis 1° a day would take 2.7 kN·m nonstop, far more than control moment gyroscopes can absorb or magnetic torque bars can make. When the axis must move, about 14 N per tip, pulsed once per turn out of the spin plane, does it, and gyroscopes on the still hub damp any wobble.

765 t DESIGN MASS PER TIP	**7.5 MN** ARM TENSION	**228 cm²** CHORD SECTION, SF 1.5
5.5 m UNIFORM BAYS, 28 PER ARM	**12** CARBON FIBER CABLES PER ARM	**~72 days** ION ONLY SPIN UP

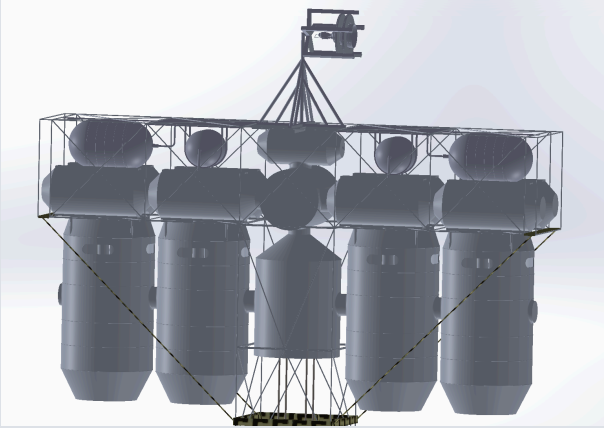


ANIMATION Spin sequence rendered from the SolidWorks model: the tip engines bring the arms up to 2.11 RPM.

05 · MASS BUDGET

WHAT 765 TONNES IS MADE OF

Every load in Skypia scales with the mass at the tips, so the tip mass has to be earned line by line.



BASELINE CAD One tip: four habitats, eight service modules, the central elevator hub, propellant and counterbalance tanks, and the truss frame that ties them to the arm.

ASSUMPTIONS

- 4 habitats, 8 m × 15 m, 3+ floors each (about 750 m³).
- 8 service modules, 4 m × 9 m (about 113 m³), sized like the ISS Tranquility node at about 15 t each.
- Floors carry real 1 g loads, so habitats are heavier than microgravity modules.
- Light radiation shielding: in the ISS orbit, Earth's magnetic field blocks much of it.
- Spin propellant for three events: spin up, spin down and one emergency spin down.

ITEM	RANGE (T)	EST. (T)
Habitat shells, debris shielding, insulation	60 to 90	**80**
Habitat floors (1 g rated)	35 to 60	**48**
Habitat outfitting: quarters, labs, furniture	120 to 180	**150**
Crew, supplies, research payload	20 to 50	**28**
8 service modules: life support, thermal, AC, water	96 to 160	**120**
Central elevator hub module	30 to 60	**40**
Tip truss frame, cables, arm end platform	45 to 80	**60**
Spin propellant, tanks, liquid engines	30 to 40	**35**
Ion thrusters, power units, xenon	3 to 6	**5**
Counterbalance water tank	3 to 6	**4**
Elevator car and cargo when docked	0 to 4	**4**
Batteries, avionics, wiring	3 to 8	**5**
Current estimate	**445 to 805**	**≈ 580**
With 20% concept stage margin	**535 to 965**	**≈ 700**
Design mass used for sizing		**765**

~30%
GROWTH MARGIN, 765 T VS 580 T

2/3
OF THE MASS IS HABITATS AND SERVICE MODULES

<5%
SPIN PROPELLANT

WHY SPIN PROPELLANT IS SMALL

With the engines at the tips, the 200 m lever arm cancels out of the impulse. Each tip only needs to reach the rim speed: $F \times t = m\, v_{tip} = 765$ t × 44.2 m/s ≈ 3.4×10^7 N·s, or about 10 t of methalox per spin event. A one hour spin up needs only about 9.4 kN per engine.

WHERE I WOULD OPTIMIZE FIRST

Pressurized volume drives the mass. Eight habitats give about 6,000 m³, more than six times the ISS. Removing one habitat per tip would save about 75 t per tip and lower the arm tension, truss section and bearing loads with it.

06 · COUNTERWEIGHT SYSTEM

KEEPING THE BALANCE

Every elevator ride moves mass along the arm, which shifts both the balance and the spin. I designed a two part system so neither one changes.

The problem

When an elevator carrying 2,000 kg of cargo climbs from 180 m to 20 m, two things go wrong. The center of mass moves off the spin axis, so the hub bearing feels a load that turns with the arms. And the station's moment of inertia drops, so by conservation of angular momentum the spin rate rises and the gravity everyone feels changes.

The solution

- **Mirror counterweight.** A counterweight on the same arm moves opposite the elevator, always at $r_{cw} = 200\ \text{m} - r_e$. The balance point stays fixed at 100 m.
- **Rim tanks.** Water tanks at the 200 m rim take on or drain water so the total moment of inertia never changes, which keeps the spin rate, and the gravity, constant.

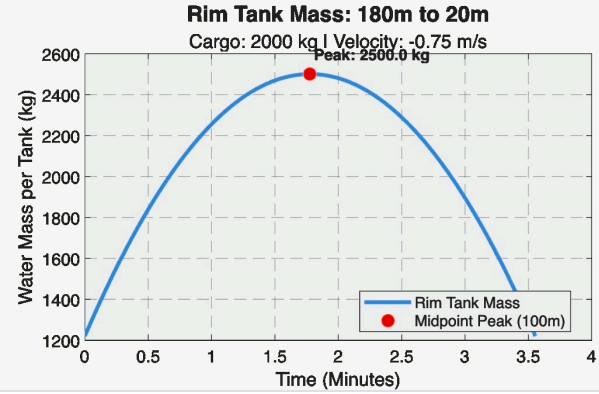
$$m_{rim} = (m_e / R^2)\ [\ 200^2 - (r_e^2 + r_{cw}^2)\ ] + m_{buffer}$$

Water needed per rim tank as the elevator moves (R = 200 m, 500 kg safety buffer)

The result

With 2,000 kg of cargo, each rim tank starts and ends the ride at 1,220 kg and peaks at 2,500 kg as the elevator passes the 100 m mark. Without the mirror counterweight, my second script shows each tank would have to start at 4,460 kg and drain 3,200 kg during the ride. **The mirror cuts the peak water mass per tank by 44%.**

2,500 kg	4,460 kg	3:33
PEAK PER TANK, WITH MIRROR	PER TANK, WITHOUT MIRROR	RIDE, 180 M TO 20 M AT 0.75 M/S



MATLAB Water mass per rim tank during a 180 m to 20 m ride with the mirror counterweight. Peak at the 100 m midpoint.

```
%% Skypia_Counterweight_Psync.mlx (excerpt)
m_cargo = 2000;       % cargo mass (kg)
r_initial = 180;      % elevator start (m)
r_final   = 20;       % elevator end (m)
V_e = 0.75;           % elevator speed (m/s)
m_e = 2000 + m_cargo; % elevator plus cargo (kg)
R_rim = 200; m_buffer = 500;

t   = linspace(0, abs(r_initial-r_final)/V_e, 500);
r_e = r_initial + (r_final-r_initial)/t(end)*t;
r_cw = 200 - r_e;     % mirror counterweight

numerator = 200^2 - (r_e.^2 + r_cw.^2);
m_rim = (m_e/R_rim^2)*numerator + m_buffer;

% Output: start 1220 kg | peak 2499.99 kg | end
1220 kg
```

07 · THE BOTTLENECK

WHERE STILL MEETS SPINNING

Of everything in the design, this is the part I trust least and the one I most want to solve.

Every system on Skypia eventually crosses one joint: the bearing between the still hub, where ships dock, and the arms turning at 2.11 RPM. It has to carry the loads, leak nothing, pass power, data and fluids, and keep turning for decades without a stop. If it seizes, the station loses its gravity.

What the bearing has to survive

7.5 MN

Arm tension. The pull of each habitat cancels across the hub when the arms are balanced, so the bearing only feels what does not cancel.

9.8 kN per t

Imbalance. Every tonne out of balance at 200 m weighs a full Earth tonne on the bearing, and that load turns with the arms. This is why the counterweights exist.

15.3 MN·m

Gyroscopic torque if Skypia turned once per orbit like the ISS. Holding the spin axis fixed and only following the Sun, about 1° a day, drops it to 2.7 kN·m.

33 million

Turns over a 30 year life, about 1.1 million a year, under a load that never rests.

$$H = I\omega = (2 \times 765\ \text{t} \times 200^2) \times 0.221 \approx 1.35 \times 10^{10}\ \text{kg·m}^2\text{/s}$$

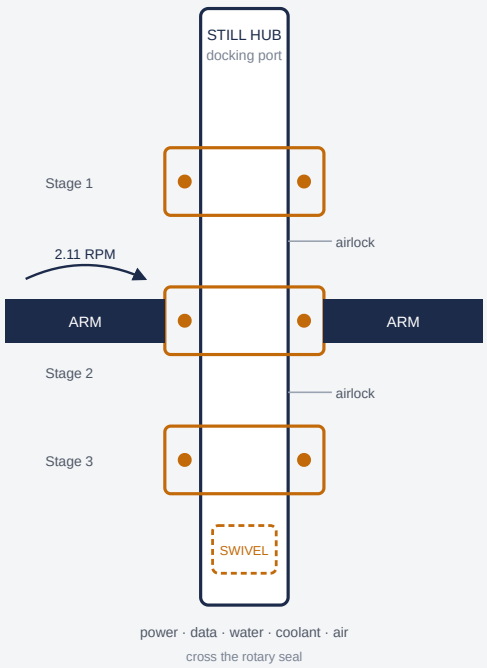
$$\tau = H\,\Omega: \quad \Omega_{\text{orbit}} = 1.13 \times 10^{-3}\ \text{rad/s} \rightarrow 15.3\ \text{MN·m} \mid \Omega_{\text{Sun}} = 1°/\text{day} \rightarrow 2.7\ \text{kN·m}$$

Why Skypia keeps its spin axis fixed in inertial space instead of facing Earth

Open questions I am working on

- Five flows cross the joint: power, data, water, coolant and air. Cryogenic propellant is colder than most rotary seals can serve, so refueling the spin engines is still unsolved.
- Does the middle bearing stage add enough redundancy to justify its mass?
- Can ferrofluidic seals hold atmosphere across a joint this large for decades?

HUB BEARING STACK (SCHEMATIC)



SCHEMATIC Three stacked bearing stages join the still hub to the spinning arms, with airlocks between stages and a swivel carrying five flows across the joint.

08 · KEEPING PEOPLE ALIVE

LIFE SUPPORT, POWER AND WHAT COMES NEXT

01

Life support and thermal

Electrolysis splits water into oxygen and hydrogen. A Sabatier reactor then combines that hydrogen with the CO_2 the crew exhales, returning water and producing about 0.36 kg of methane per person per day. Around 90% of the water is recycled. Heat follows the ISS pattern: water loops inside, ammonia loops and radiators outside.

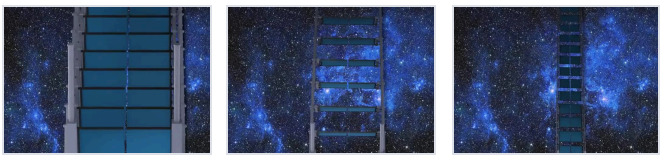
$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Sabatier reaction, closing the oxygen loop

02

Power

Sun tracking solar arrays unfold from the truss. Nuclear power was ruled out early: rejecting its waste heat would take radiators covering acres.



MOTION STUDY Solar array deployment from the truss, SolidWorks.

03

Spin stability

A spinning body only holds steady about its axis of greatest inertia. A two arm station barely qualifies: the spin axis and the axis across the arms both come to about $2mr^2$. With the habitats laid out in the spin plane, the spin axis wins by only about 1%.

Heavy still mass stacked along the axis adds to the tumbling inertia but not to the spin. A full propellant depot 44 m below the arms could make the spin axis the intermediate one and flip the station in about a minute. So the depot stays close to the spin plane, and the still hub carries wobble dampers.

$$I_{spin} > I_{tumble}, \text{ depot full or empty}$$

Required for every depot fill and elevator position

NEXT STEPS IN DESIGN I

- Bearing load model with imbalance, gyroscopic and thermal loads together.
- Truss FEA under spin, docking and elevator loads.
- Power and thermal budget for a crew of ten.
- Propellant storage and transfer at the still hub.
- Assembly sequence and launch count.

Why Skypia

One day, I want to build it for real. I hope to eventually start a company that makes artificial gravity space stations a reality: places in orbit where people can live, work and visit without giving up the weight of their own bodies.

Design I is how I am learning what that will take. The best place to keep learning is next to the people already building the first commercial stations.

YANQUIEL BOSQUES

Aerospace Engineering, Georgia Tech, Class of 2028

yanquielbosques.com · yanquielbosques@gmail.com