A **Design Study** for a **Rotating Space Station** to **Mitigate Microgravity Effects** during Long-Term Space Habitation

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Mission Statement

A **Rotating Space Station** to **Mitigate Microgravity Effects** during Long-Term Space Habitation

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This study outlines the design of a **rotating space station** aimed at **mitigating the physiological effects** of long-term space habitation by simulating **artificial gravity**.

By doing so, it enhances the feasibility of **extended crewed missions** in space.

AOCS: Business Model

A **Rotating Space Station** to **Mitigate Microgravity Effects**
during Long-Term Space Habitation

WHAT
- Position
- Orbit
- Gravity

HOW
- Ion Thursters
- Momentum
- Management

WHY
- The Mission

WHO
- For: Crew
- Manages: Operations
- Benefits: Clients

WHEN
- Necessity: Always
- Used: Station keeping
- Spin up: 1 or 2 hrs

WHERE
- Location: SSO/LEO
- Funds: TBC
- CS Parts: TBC

AOCS: Attitude Parameters

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```
Calculate for different target_rpms

At 1 RPM and a desired centripetal acceleration of 9.8 m/s^2:
Radius: 893.65 m, Diameter: 1787.31 m
Angular velocity: 0.1047 rad/s

At 2 RPM and a desired centripetal acceleration of 9.8 m/s^2:
Radius: 223.41 m, Diameter: 446.83 m
Angular velocity: 0.2094 rad/s

Calculate for different time periods to reach target_rpm of 2 RPM

For 1 hour to target_rpm of 2 RPM + Radius of 223.41m::
Tangential acceleration: 0.0130 m/s^2
Final tangential velocity at the edge: 46.79 m/s

For 2 hour to target_rpm of 2 RPM + Radius of 223.41m:s:
Tangential acceleration: 0.0065 m/s^2
Final tangential velocity at the edge: 46.79 m/s
Plot for gravity gradient at 2 RPM generating 1 G with the outer diameter being 223.41
Acceleration at station edge: 9.82 m/s²
Distance for Earth-like gravity: 223.41 m
```

Constraints:

- Max RPM of 2
- Tangent Acceleration
- 1 G of Earth's gravity
- Spin Acceleration Time

Questions + what's next?

- Orientations
- Spin mitigation for central hub
- Gravity gradient

AOCS: Gravity Gradient

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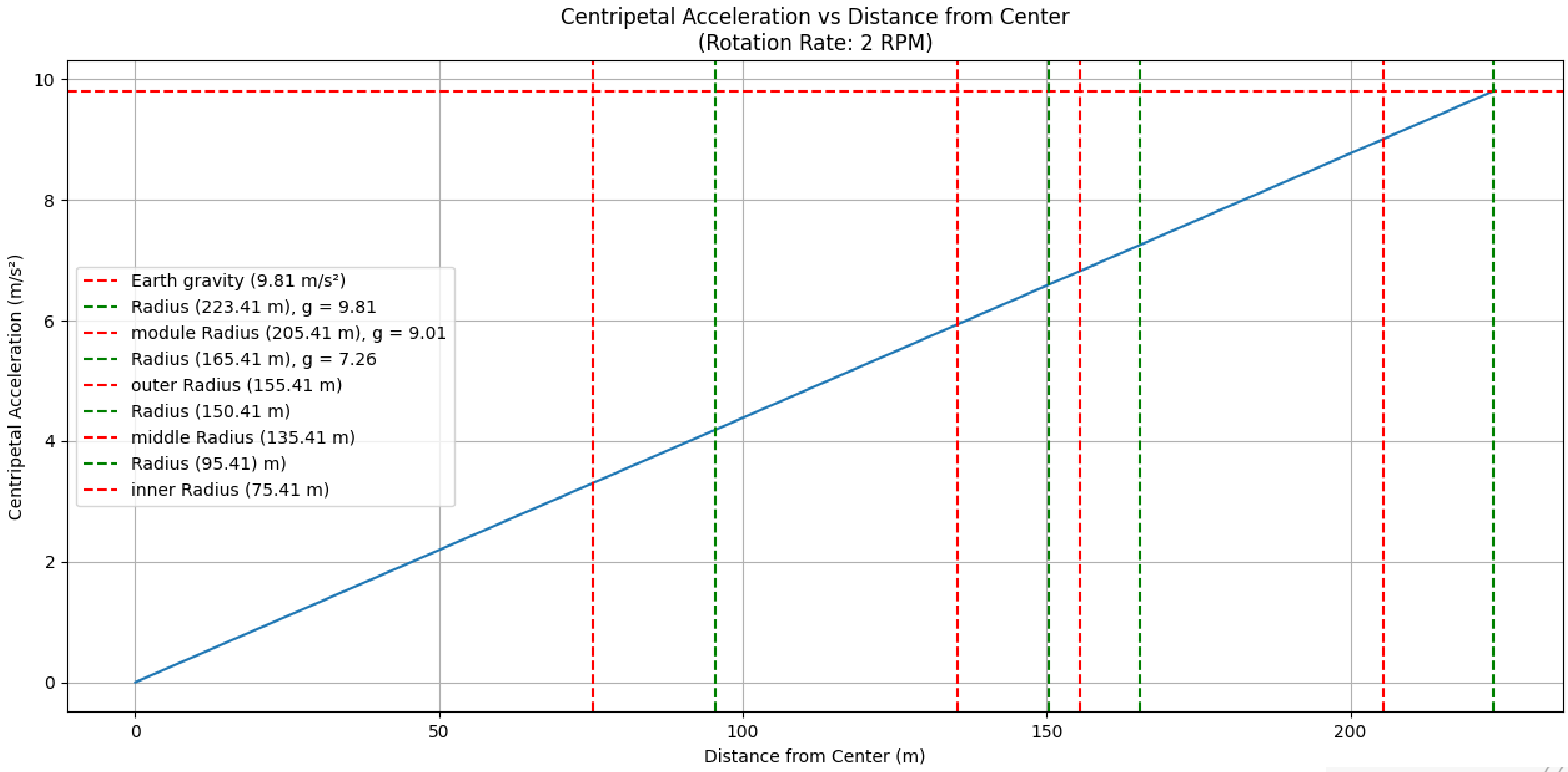

AOCS: Orbital Parameters

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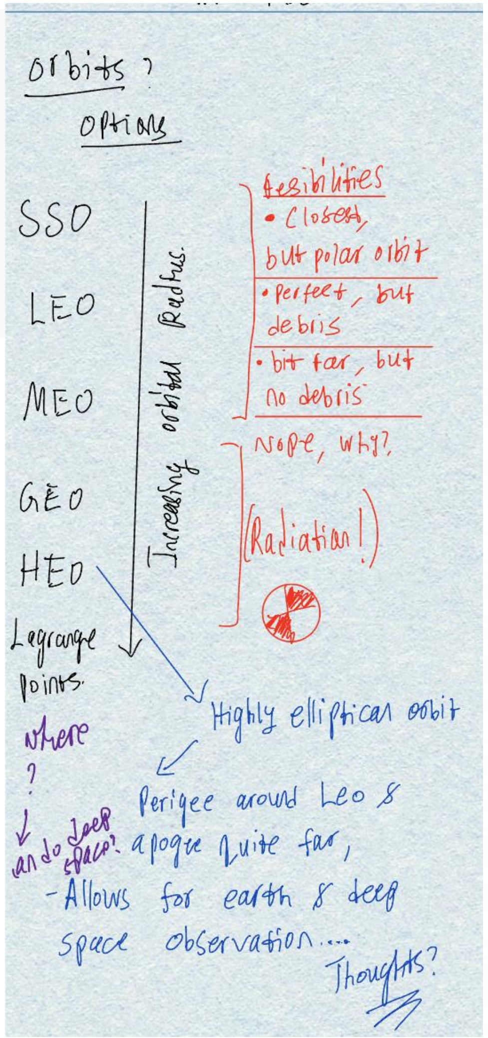

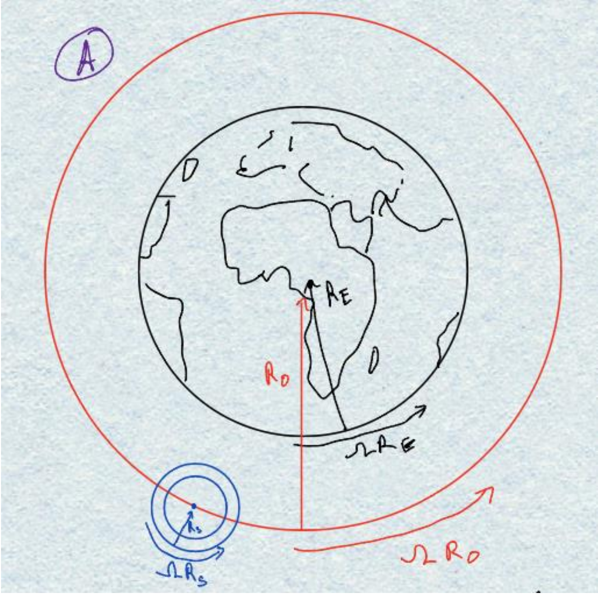

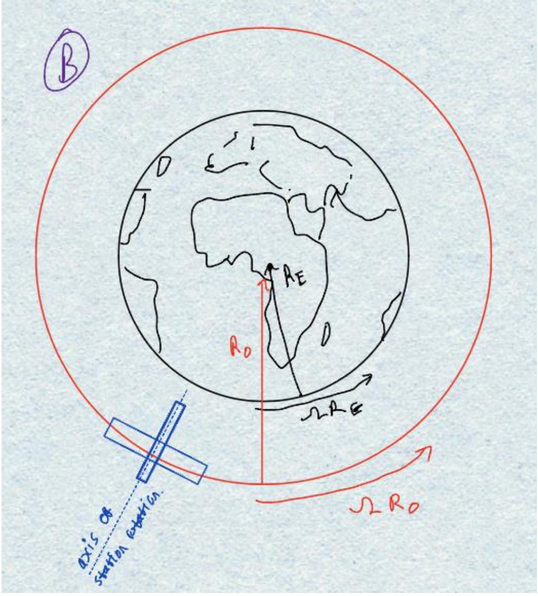

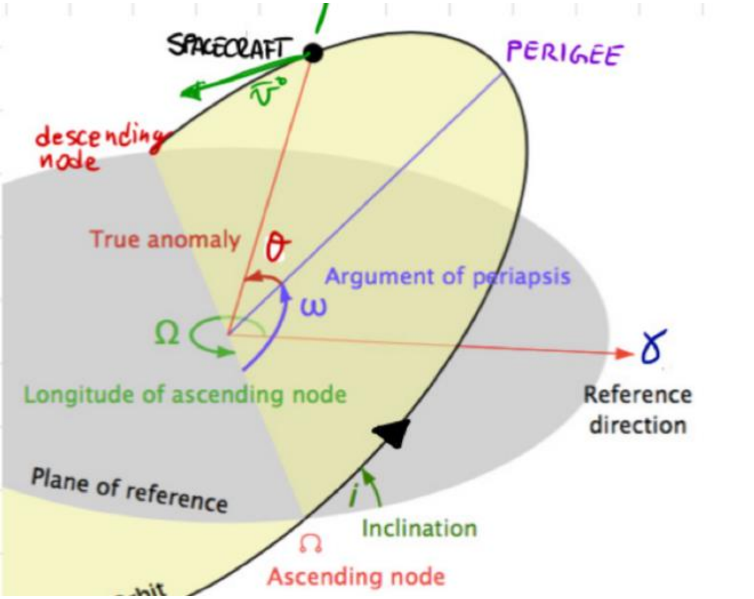

Constraints:

- LEO
- Orbit Size
- Station mass/ gravity
- J2 Pertubations

Questions + what's next?

- Spin stabilisation
- Station – keeping

Structural Design: A look at the ISS

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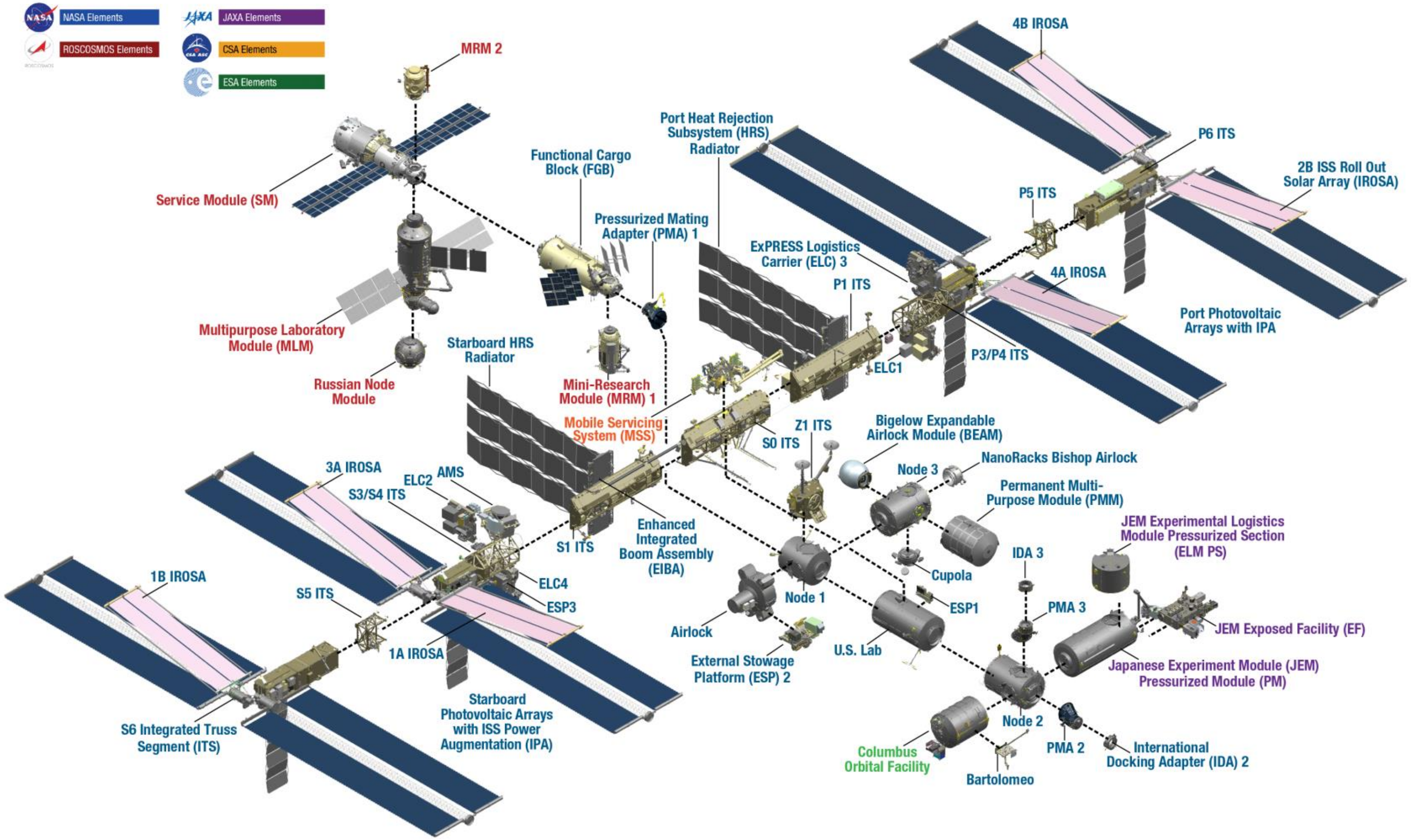

Facts and Figures

- Pressurised Module Length: 67 m along major axis
- Truss Length: 94m
- Habitable Volume: 388m^3 (not including visiting vehicles)
- Pressurised volume: 1,005m^3
- Lines of computer code: approximately 1.5 million

Structural Design: A look at the ISS

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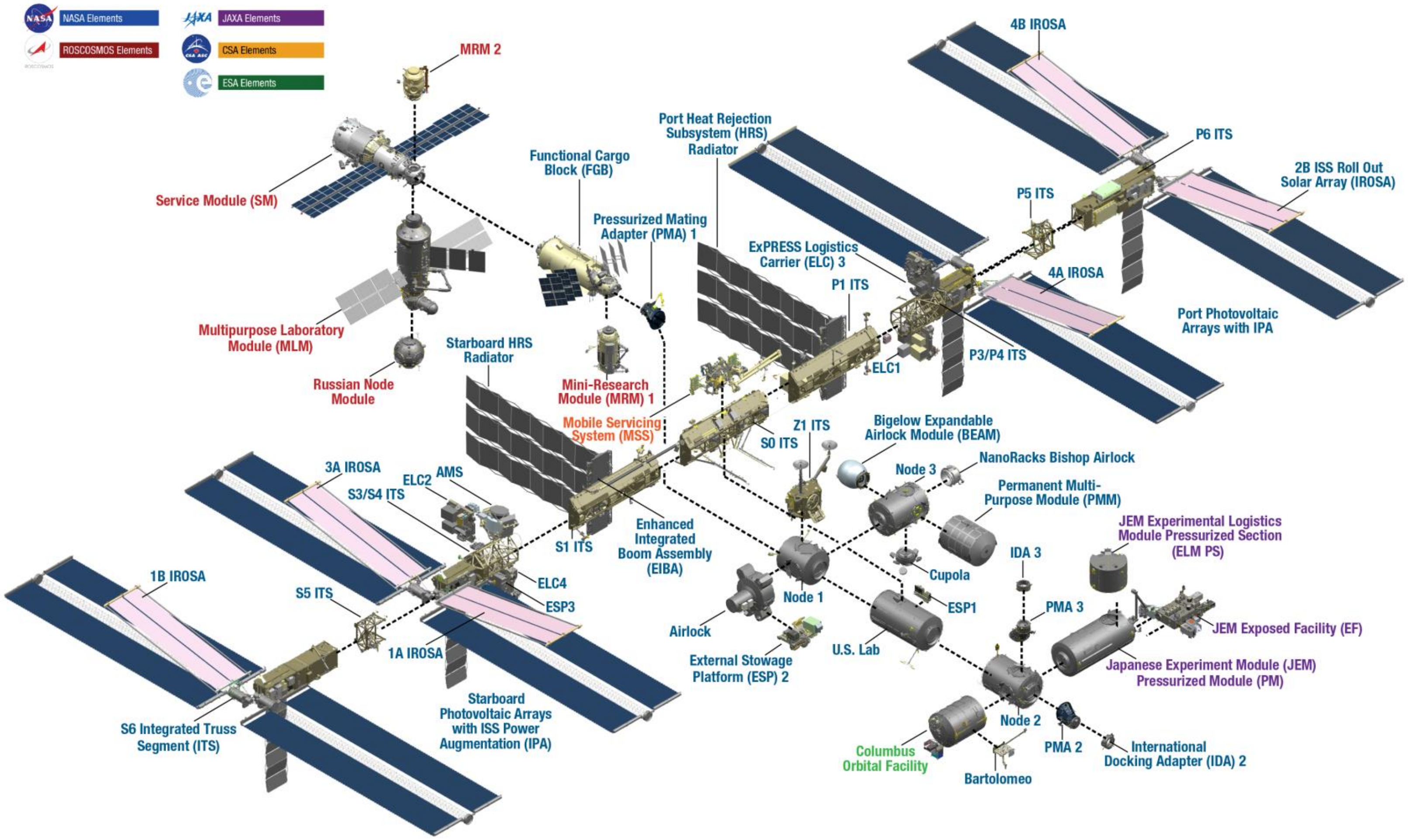

Facts and Figures

- Delivered on 42 assembly flights
- Measures 109m end to end
- 55-foot robotic arm Canadarm2 is used to move modules, deploy science experiments and transport spacewalking astronauts
- Eight spaceships can be connected to the spaceship at once

Structural Design: Net Habitable Volume

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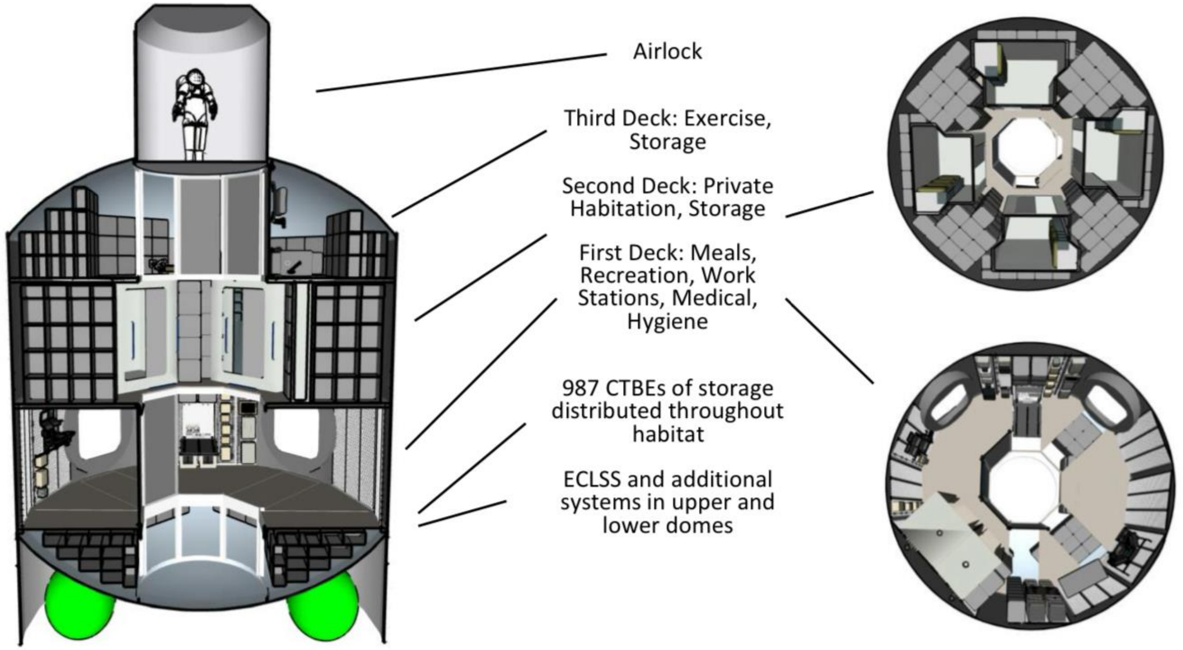

Figure 3: Case Study Habitat

Research

- NASA study
- 28.36 - 28.96 m^3 per crew member

Minimum acceptable net habitable volume for long-duration exploration missions subject matter expert consensus session report - NASA technical reports server (NTRS) (no date) *NASA*. Available at: https://ntrs.nasa.gov/search.jsp?R=20140016951

Structural Design: Next Steps

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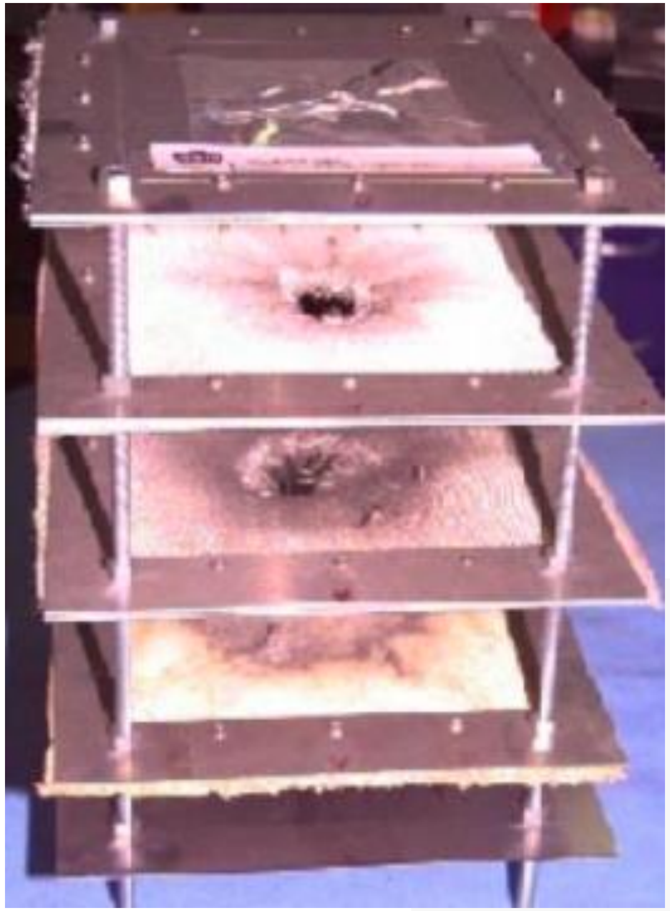
- How can we adapt the spaceship design so that it has **maximum use of the size** we are proposing currently?
- How many **wheels** are we going to have?
- What else will be affected by our design?
- How many **launches** will we need?
- How far in the **future** is concept proposition?

1. **Outer Layer (Bumper/Shield Layer)**
   - Material: Aluminium or Nextel (a ceramic fabric).
   - **Thickness**: Usually about **1 to 3 mm**

2. **Gap (Space Between Layers)**
   - Function: Debris fragments after impact, dissipating energy before hitting the inner layer.
   - **Thickness**: Vary from **10cm to more than 30cm**, (depending on the location and expected debris threat level).

3. **Inner Layer (Pressure Hull)**
   - Materials: thicker Aluminium or Kevlar (Ensures the station's pressurised environment is maintained)
   - **Thickness**: Typically, **4 to 10 mm**



Shielding & Protection

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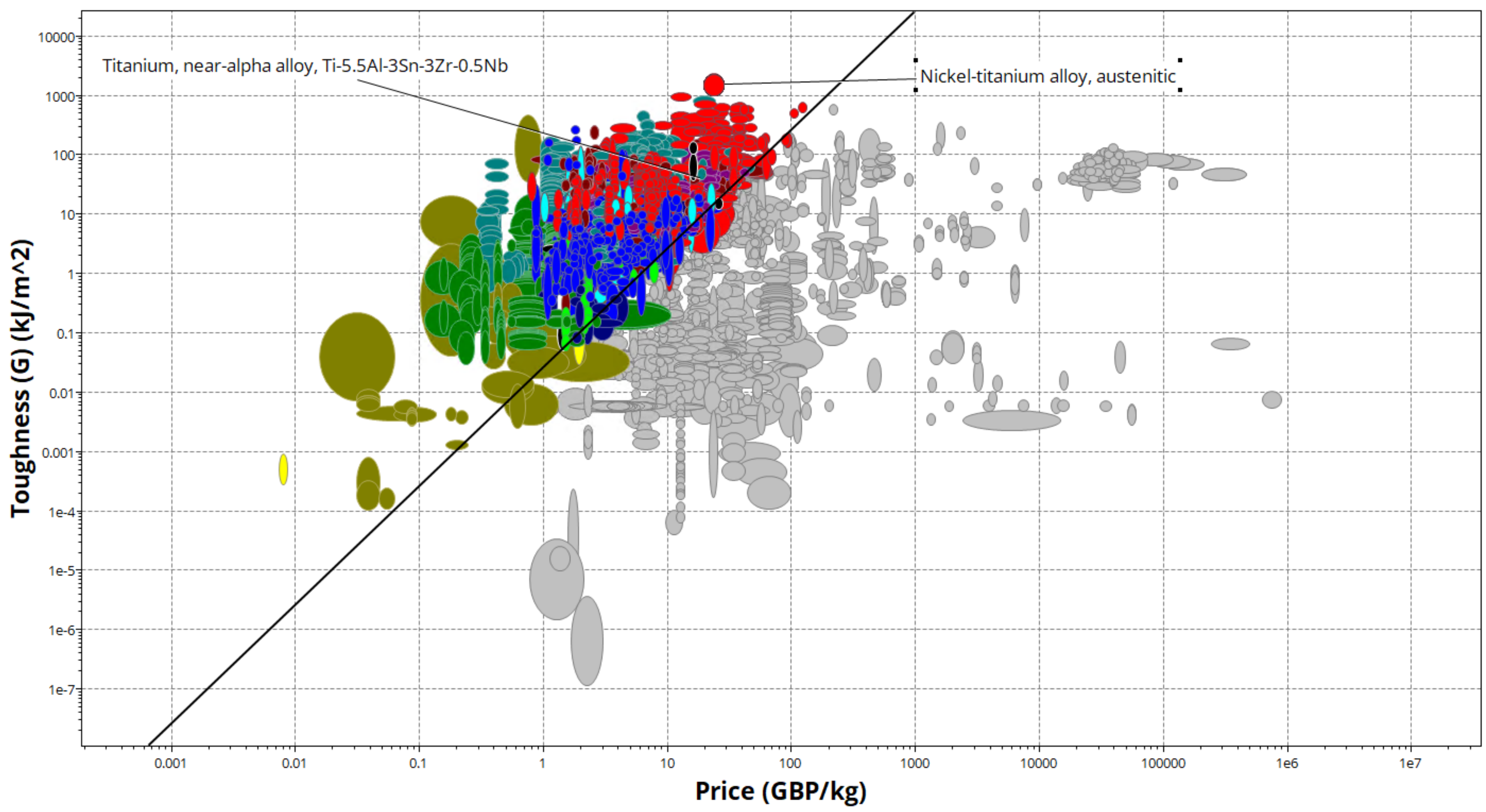
Toughness (G) (kJ/m^2) vs. Price (GBP/kg)



Materials	Benefits	Drawbacks
Ti	• High strength-to-weight ratio • Excellent corrosion resistance • Can withstand extreme temperatures and stress	• Expensive • More difficult to machine and fabricate
Al	• Lightweight • Good corrosion resistance • Relatively inexpensive	• Less heat-resistant • Prone to cracking under long-term stress in space
Nylon like material (Kevlar)	• High tensile strength • Lightweight & resistant to abrasion & wear	• Heavier than pure nylon • Prone to degradation (UV)

Shielding & Protection

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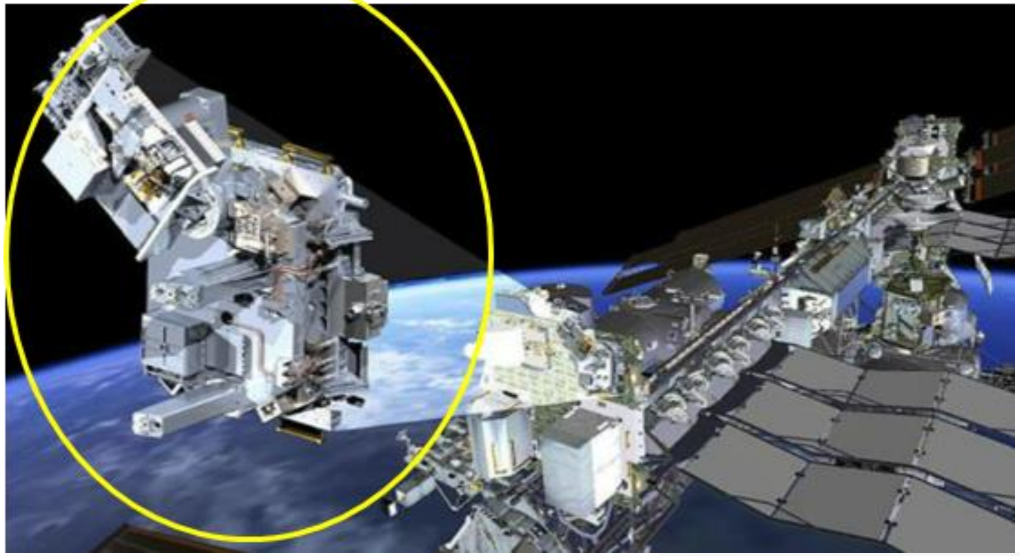

The **SDS** can **detect debris** between the sizes of 0.05 millimetres and 0.5 centimetres.

Measures the velocity, size, direction, and time of debris impacts.

Measures the amount of solar energy (power per unit area) received from the Sun in the form of electromagnetic radiation.

Irradiance $(Wm^{-2}) = \frac{Power\ (W)}{Area(m^2)} = \frac{P}{A}$

Shielding & Protection: Next Steps

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Find a way to integrate **non-Newtonian fluids** and **beta cloth** within the Whipple shield

What other **materials** can help regulate the thermal energy received

Thickness of both the **outer and inner layer** of the Whipple shield

Solar Panels

Total Solar Irradiance ≈ 1361 W/m^2

Current peak efficiency IS 38%

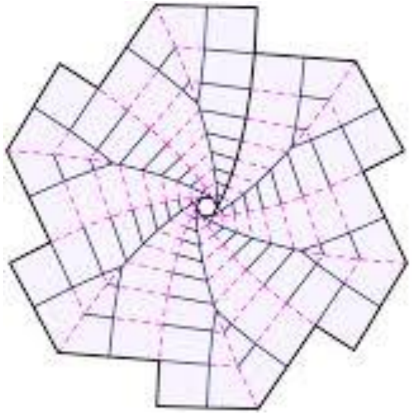
ISS uses 75-90kW for 7 people

~720kW for 56 people

Min. area of solar panels needed ≈ 1400 m^2

Power down non-essential systems during strong solar flares

Image Source: nasaspaceflight.com



Power Systems: Thorium Reactor

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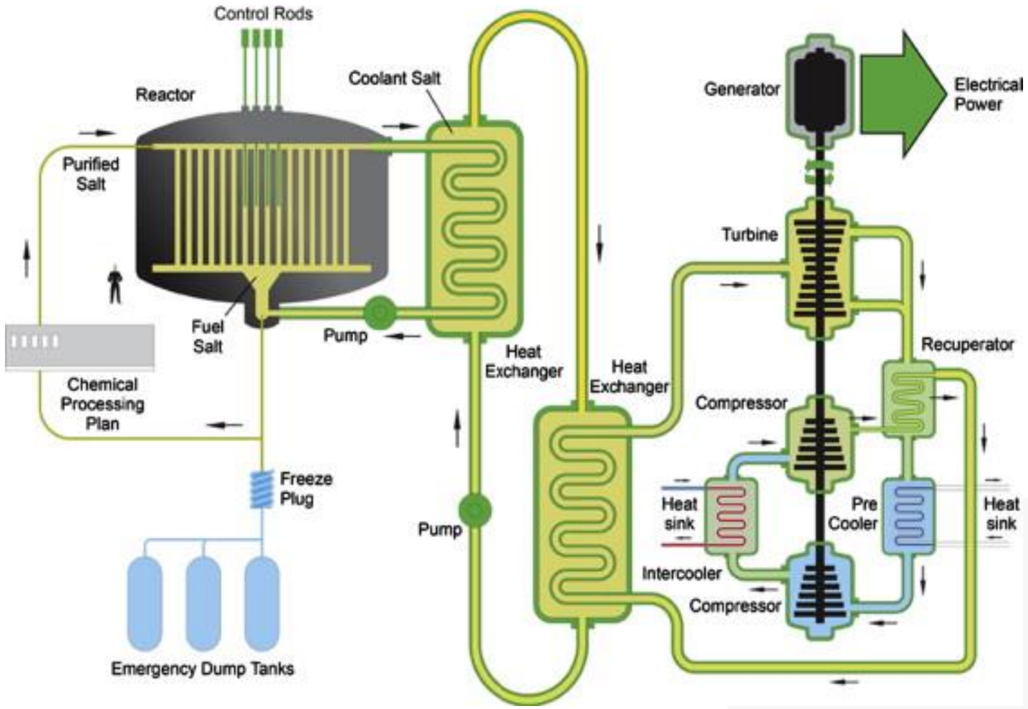
Thorium Reactor

- Thorium is cheaper and more abundant than Uranium
- Waste is substantially less radioactive and long-lived
- Meltdown is very unlikely – negative feedback loop
- U233 is contaminated with U232 which can damage electronics



Power Systems: Next Steps

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- How will the solar cells handle **rotational stress**?
- How to **disperse excess heat**
- Use of **AC vs DC** power

Life Support: Waste Management

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Key Objective

Transform waste into useful resources during long-term space habitation.

A part of the Life Support System

Recycles waste to provide **CO_2**, **water**, and **compost** for growing crops.

Importance

Minimises resupply needs from Earth by reusing waste.

Waste Management: How does it work?

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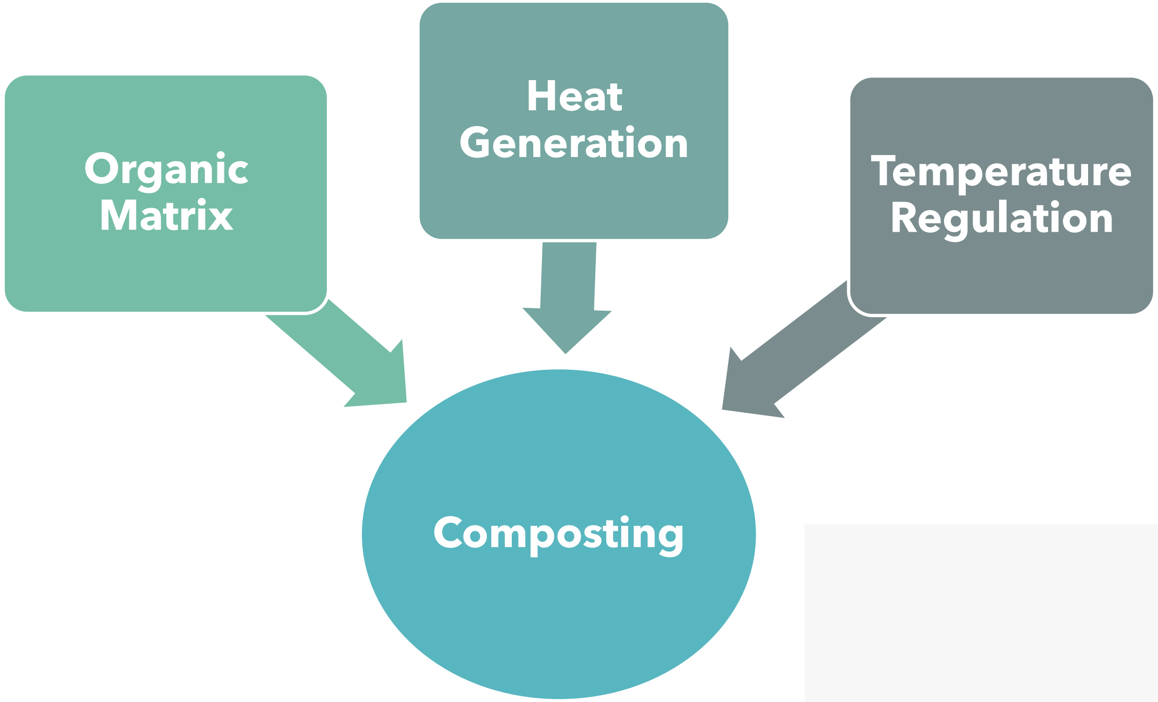
Composting relies on the natural heat generated by microorganisms as they break down organic matter.

This **self-heating** is a critical feature that **drives the composting process**.

Near-maximal decomposition rate preferred!



Assumptions:
1. The system assumes artificial gravity
2. Integration with wastewater purification and air purification systems
3. Soil-Based Crop Growth

Waste Management: Process

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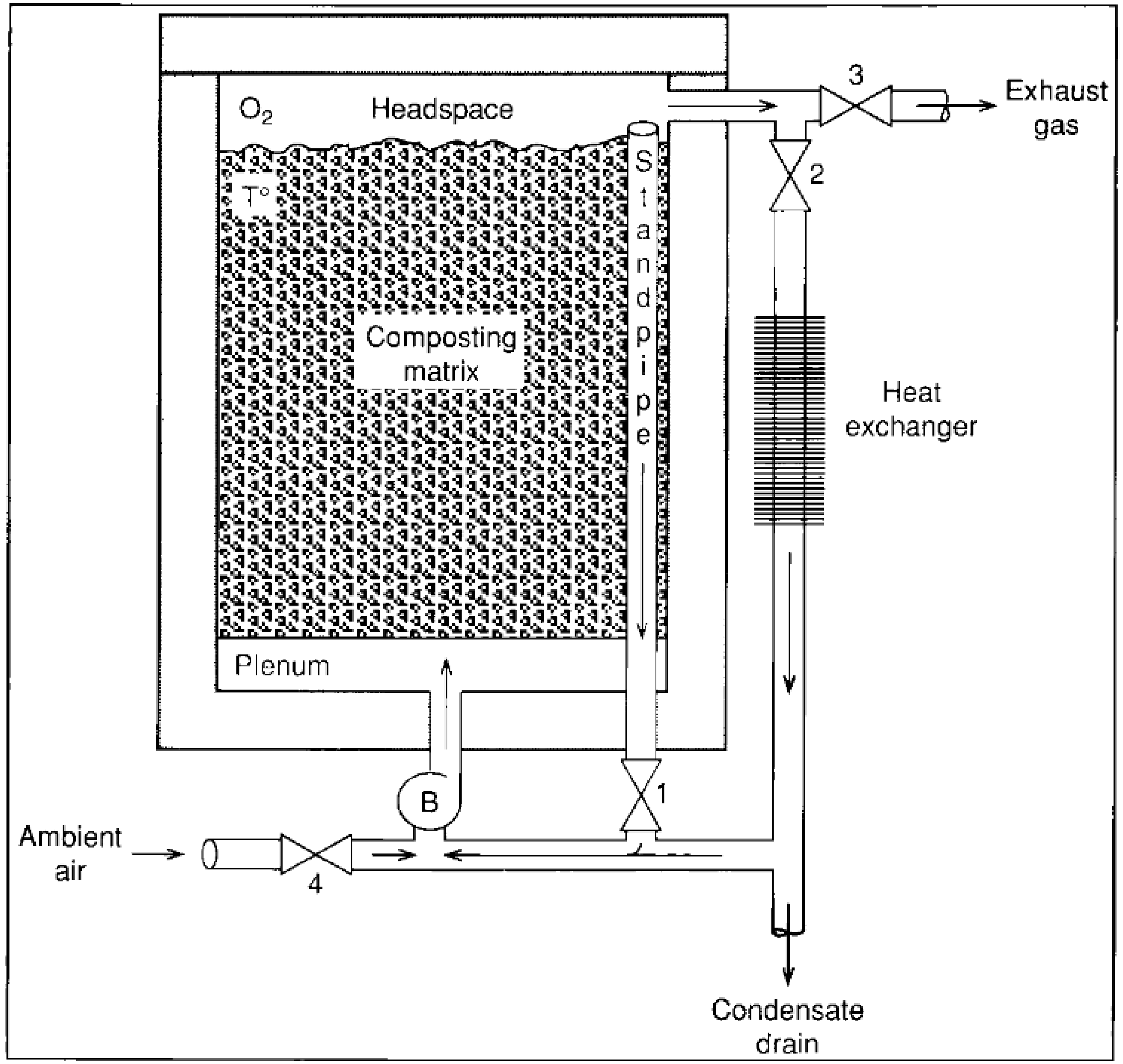

Process control regimen	Process gas condition		Control valve position			
	O_2 (% v/v)	Temp (°C)	1	2	3	4
#1	> 15	< 56	Open	Closed	Closed	Closed
#2*	< 15	< 56	Closed	Closed	Open	Open
#3	> 15	> 56	Closed	Open	Closed	Closed

Once the composting process is complete:

- **Condensate** management
- **Vented process gas** management

Figure and Table: J. A. Hogan and M. S. Finstein, 'Composting of Solid Waste During Extended Human Travel and Habitation in Space', *Waste Manag Res*, vol. 9, no. 1, pp. 453–463, Jan. 1991, doi: 10.1177/0734242X9100900164.

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