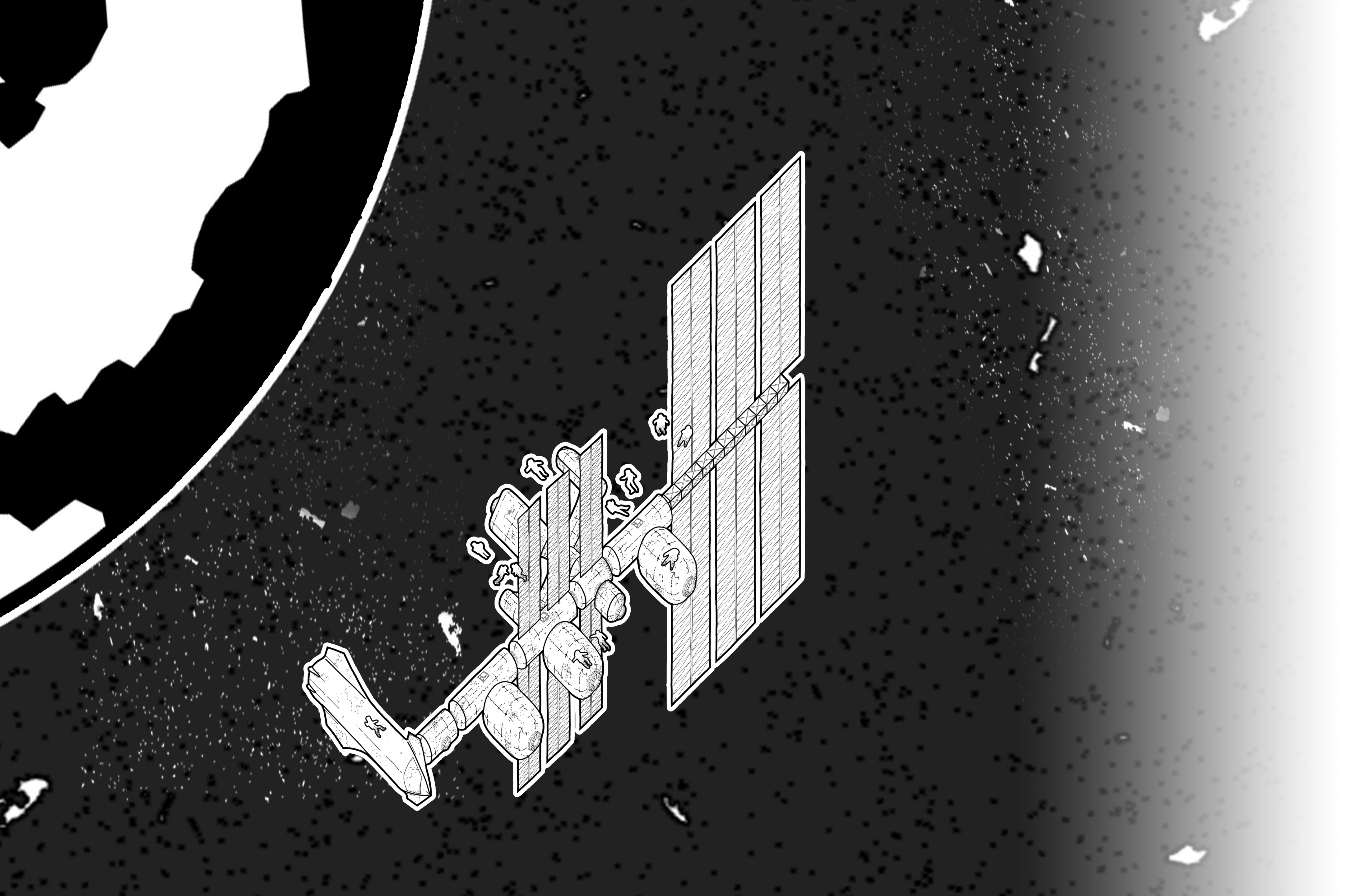


PROMETHEA STATION

project, text & images by
Beliz Bayraktar, Christopher Egg,
Luka Pejic

ABSTRACT

The primary objective of the Promethea Station is to build a modern successor to the International Space Station (ISS) in the Low Earth Orbit (LEO).

As humanity strives to explore and colonise other worlds, long missions will require reliable, self-sustaining systems. This includes an ecological life support system and artificial gravity to support crews over time.

The station enables long-term testing of these systems to ensure their dependability for long-term space travel made by mankind.

A secondary aim of the project is to introduce space tourism through a subordinate structure, offering guests a brief but authentic space experience.

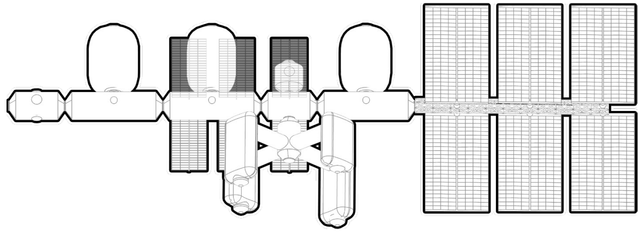
DESIGN APPROACH
INSPIRATION, IDEA, PRINCIPLES, REASONING

The Promethea Station draws inspiration from historical precedents such as the ISS, MIR and early NASA and ESA modular concepts. The central idea was to create a next-generation modular orbital station that integrates and validates (through long-term use) artificial gravity and a biological life support system, advancing humanity's technological capabilities in space. Its primary focus is to support long-duration missions while offering a livable, adaptable environment suited for both scientific research and limited commercial use.

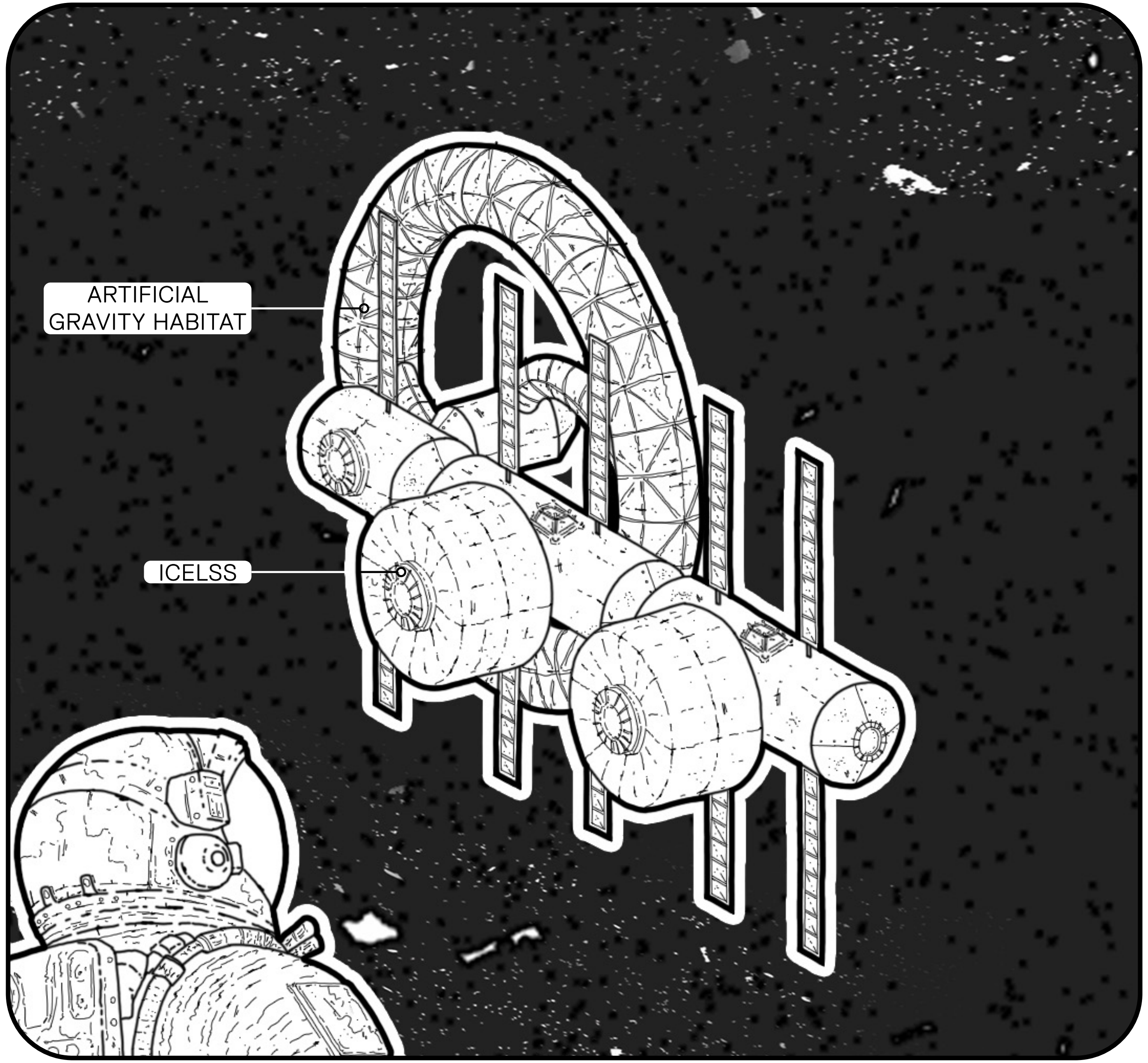
Architecturally, the design follows a human-centred design approach, balancing function-driven volume with modular adaptability. Comfort and efficiency were prioritised, where every element and design decision is based on research-driven design and scientific grounding. For example, psychological well-being was considered a foundational design element, addressed through including views of Earth, enabling plant interaction, and a layout supporting crew mental health. Furthermore, reusability was emphasised - technologies like the **ICELSS (Inflatable Controlled Ecological Life Support System)** and the **artificial gravity habitat** are designed with future deployment in long-duration missions beyond Earth orbit in mind.

The station addresses validation solutions to contemporary challenges of orbital life, such as the „absence“ of gravity and the dependency on Earth resupply. The artificial gravity habitat, named the „Space Crusader“, was implemented as a concept, based on theoretical research, to reduce bone density loss and muscle atrophy (Hall, 2000) while improving the quality of life in space. Meanwhile, the ICELSS was developed as a self-sustaining ecological life support system capable of balancing caloric and atmospheric requirements.

The spatial organisation features separate crew and commercial sectors, allowing uninterrupted functionality of the permanent crew while accommodating emerging space tourism.



Promethea Station - final



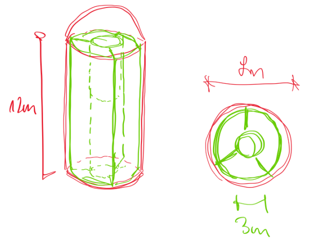
Promethea Station (version 1, launch phase 2) - part of first midterm comic

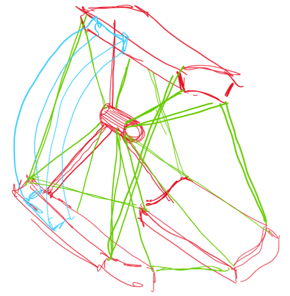
RESEARCH & DEVELOPMENT

The geometry of the station is derived from function-driven logic, shaped by the realities of launch vehicle constraints, human psychological needs, and long-term orbital operations.

At its core, Promethea follows a Cartesian coordinate system: the x-axis consists of a linear, non-rotating spine forming the structural and functional backbone of the station, the y-axis consists of new technological proposals, such as the Space Crusader and ICELSS.

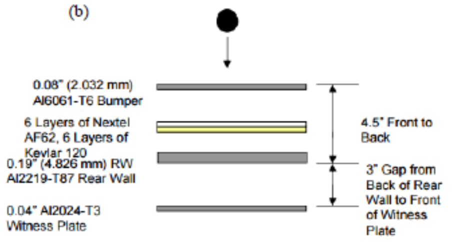
All module dimensions conform to the internal diameter of the SpaceX Starship Payload bay (~8m x 18m).





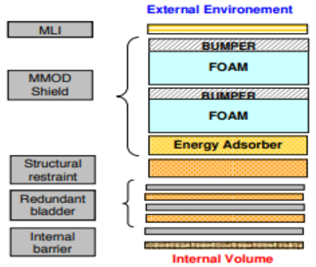
For example, the Space Crusader's design is based on geometrical constraints of the payload bay. Furthermore, the design reduced the number of required launches for the artificial gravity system from 3 to 2, while ensuring double the volume compared to the original toroidal concept.

The backbone modules feature a circular cross-section and utilise an ISS-standard stuffed Whipple shield configuration for micrometeoroid protection (Falk et al., 2021). The habitable modules of the Space Crusader adopt a bent elliptical geometry in their cross-section and are similarly equipped with stuffed Whipple Shields.



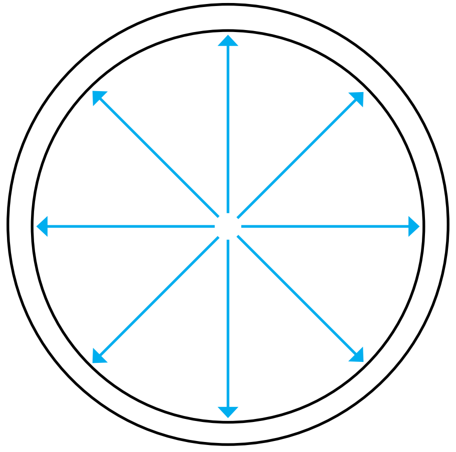
Stuffed whipple shield (Falk et al., 2021, p3)

The inflatable modules consist of multiple layers: internal barrier (Kevlar), redundant bladder (polymeric film), structural restraint (aramid fabrics), Micro-meteoroid and Orbital Debris Protection (MMOD), multi-layer insulation, and an external layer made of Teflon-coated fibreglass.



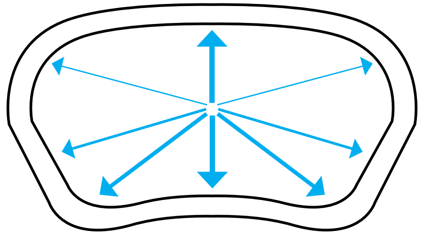
Layers of an inflatable module (Destefanis et al., 2006, p2)

The circular cross-section ensures that internal pressure is evenly distributed, exerting equal force at every point on the shell.



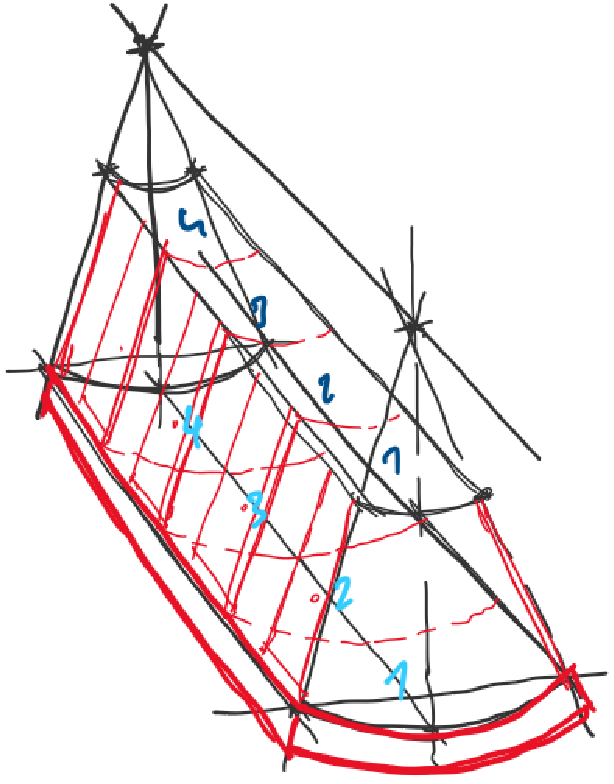
Simplified cross-section of rigid and inflatable modules

In the elliptical geometry, points with a smaller radius from the centre experience greater force from internal pressure. To counteract this, reinforcement should be added in particular areas to maintain structural integrity.

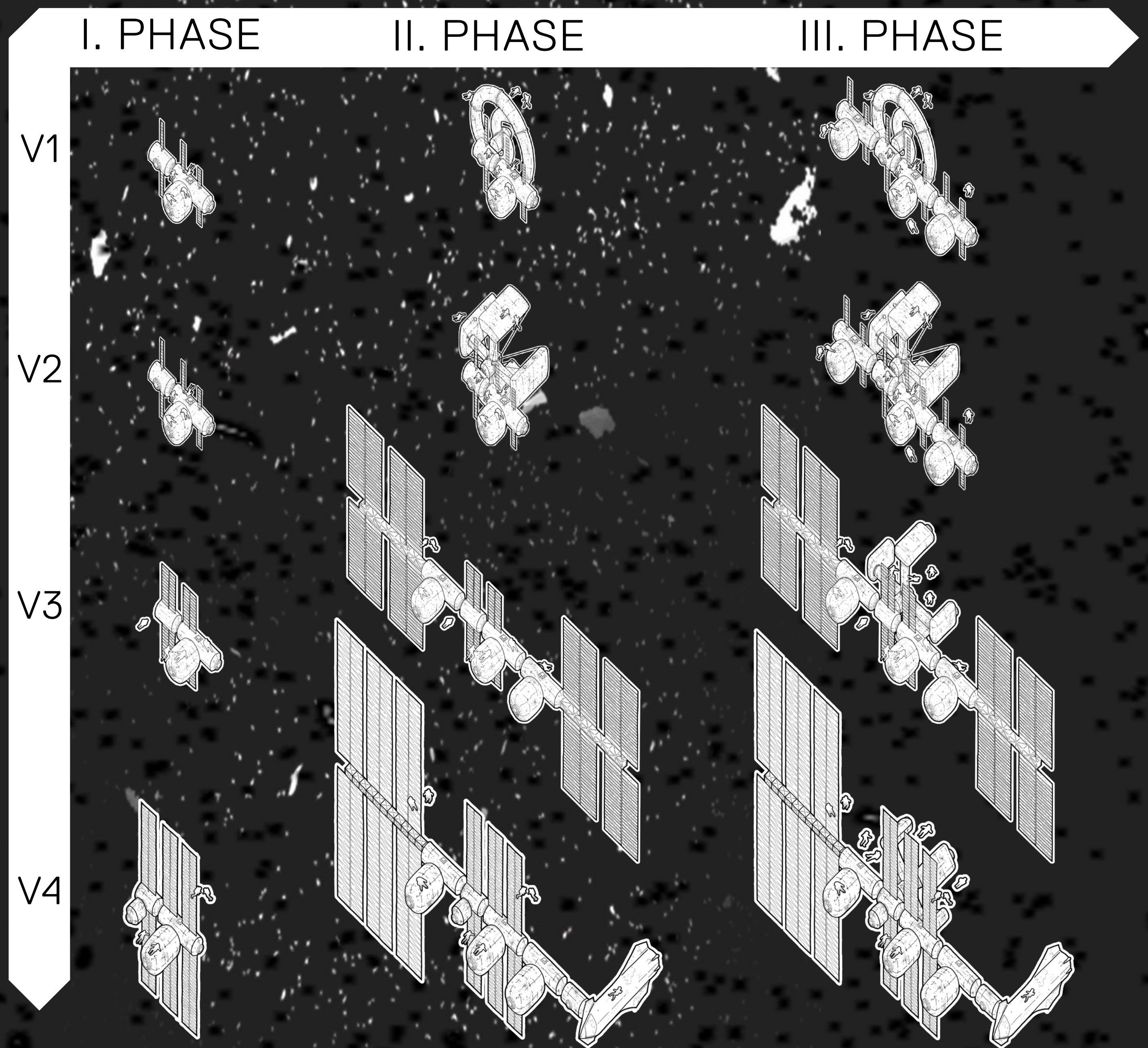


Simplified cross-section of space crusader habitable modules

The inflatable modules incorporate a biological life support system, containing multiple integrated cultivation fields. A core design intention was to maximise internal surface area usage, enabling more cultivation area within a compact volume, thereby reducing the overall dimensions of the inflatable. Further technical details and components of the ICELSS concept are presented later on.



Cultivation field organisation within ICELSS



DESIGN PROCESS AND RATIONALE

All major design iterations of the Promethea station are illustrated on the left side of the spread, depicted across 3 launch phases and 4 notable versions.

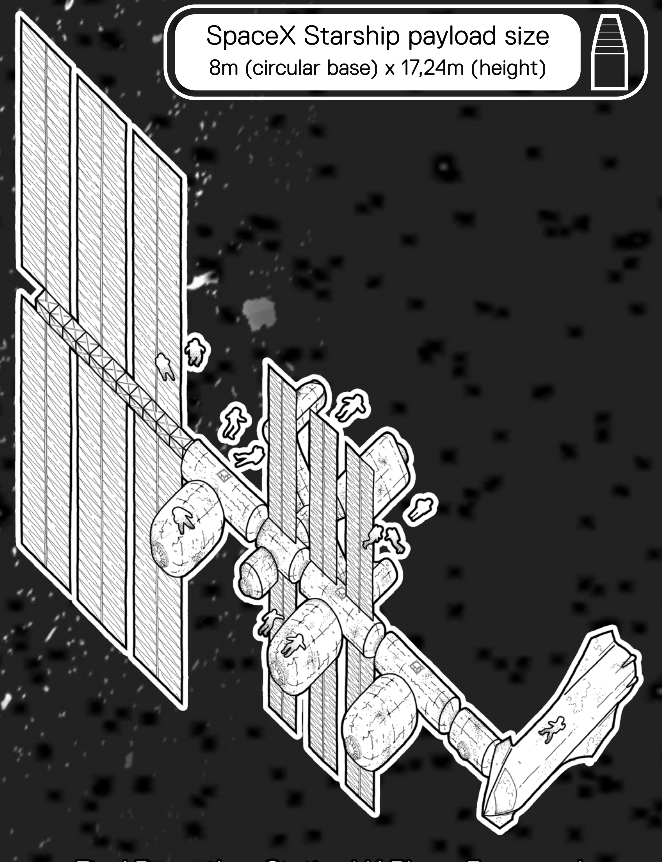
Version 1 (V1) showcases the initial configuration of the Space Crusader, at that time referred to as the "Habitat ring". The foundational theoretical framework done by Hall (1993; 1999; 2002; 2006; 2020) significantly influenced the development and refinement of the artificial gravity habitat. His research identified limitations of the toroidal geometry (V1, phases 2 and 3).

As a result, Version 2 (V2) evolved into a 4-module configuration connected by vertically oriented ladders (Hall, 2006), replacing the original staircases. In alignment with Hall's recommendation for minimising Coriolis-related disorientation, most of the movement within the habitats was reoriented parallel to the rotational axis (Hall, 2002).

In Version 3 (V3), the required surface area for the solar panels was calculated and integrated. Consequently, the Space Crusader was moved to the third launch phase, a deliberate choice to ensure sufficient solar power to support the artificial gravity module.

The station's backbone remained largely consistent throughout the studio. Notable additions are the EVA and docking modules added in V4. The docking module was strategically positioned on the right side of the station. consequently, relocating the solar arrays to one side. This move was intended to separate docking from solar panels and the rotating artificial gravity habitat.

The total number of launches evolved from 5 (V1) and finalised with 6 (V4) using the SpaceX Starship.



Final Promethea Station V4 Phase 3 proposal

MICROGRAVITY MODULES

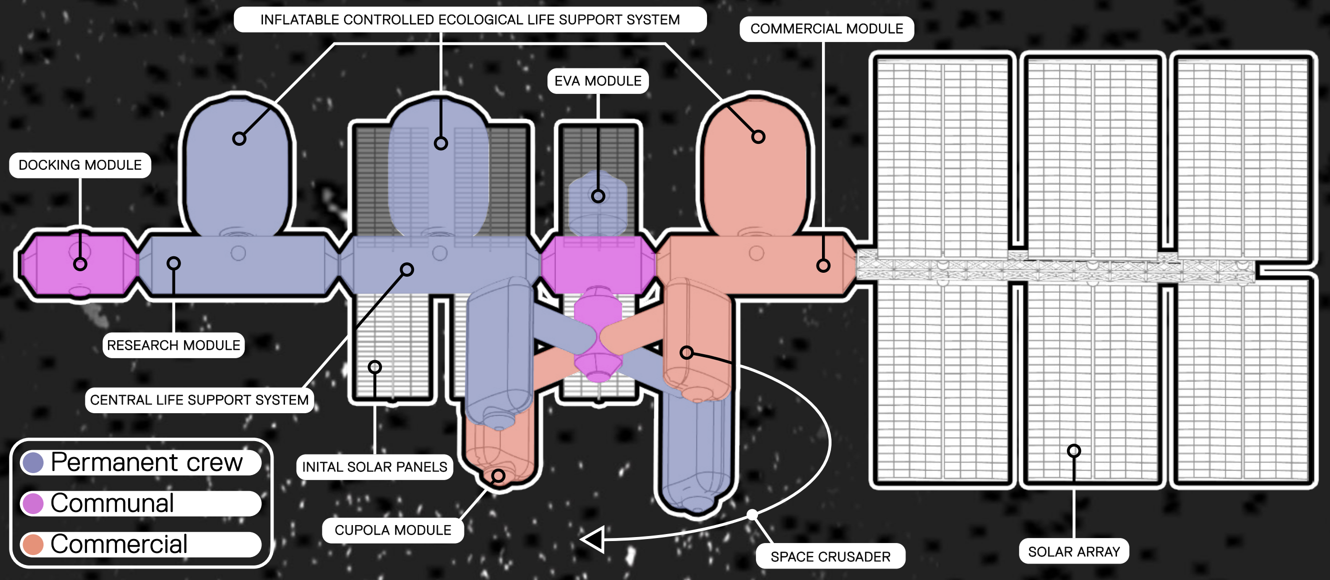
The station operates using two types of gravity; microgravity and artificial gravity (provided solely within the Space Crusader).

The microgravity modules form the structural backbone of the Promethea Station, housing essential systems such as docking, EVA operations, life support systems, and research modules.

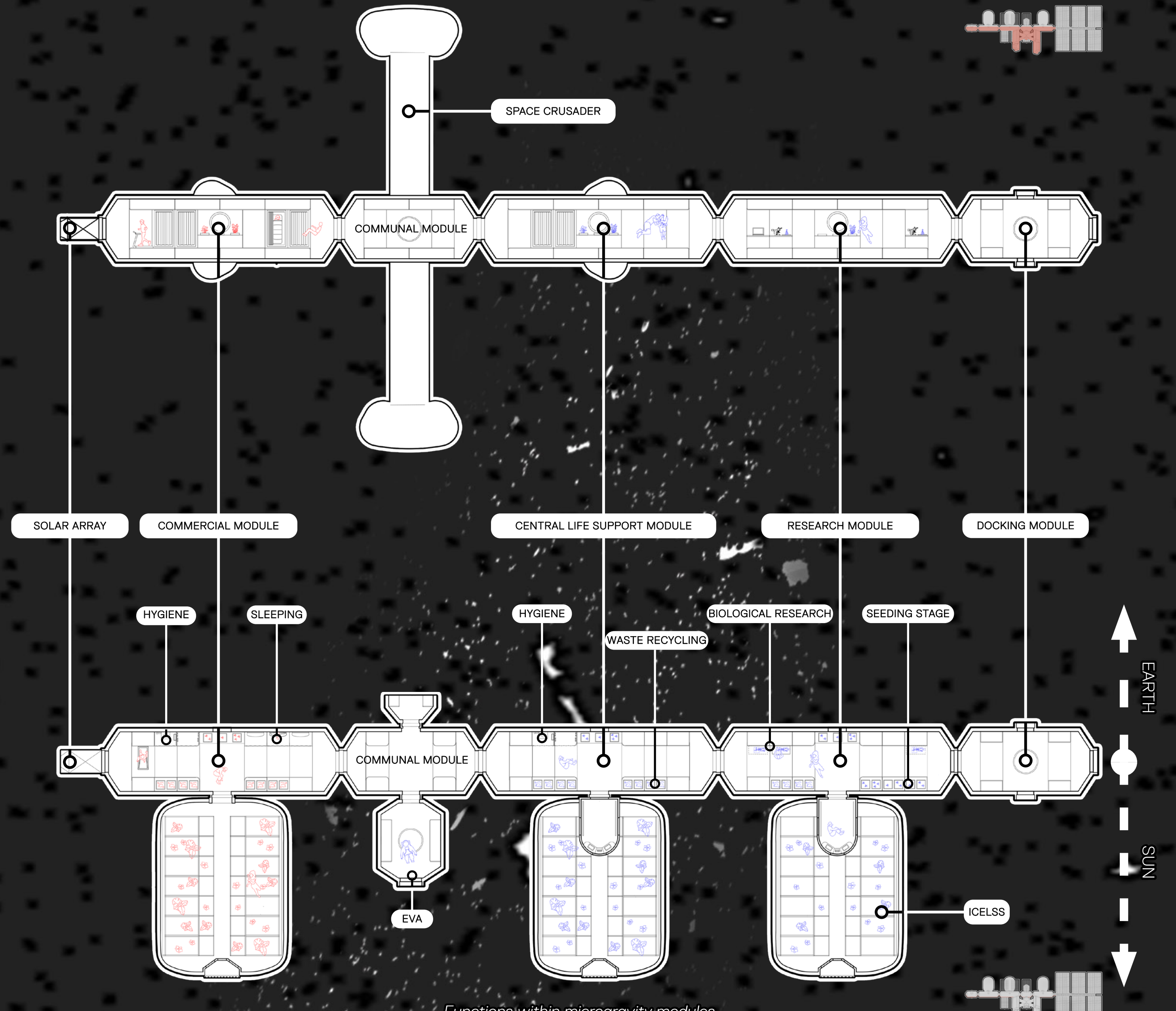
The station is organised into 3 user clearance zones: permanent crew, commercial users, or communal areas. These zones are distributed across 2 types of modules: inflatable or rigid. The separation of users allows a more tailored space experience for the personnel and commercial occupants.

The strategic placement of Cupola modules served dual functions: enhancing crew mental health through Earth visibility, and enabling natural sunlight to support plant cultivation within the ICELSS (Zabel, 2016; Drysdale, 1994), thus reducing power consumption.

Two major architectural structures define the station: the ICELSS and the artificial gravity habitat. These systems are covered in further detail on the following spreads.



Functions diagram



Functions within microgravity modules

„SPACE CRUSADER“
ARTIFICIAL GRAVITY HABITAT - DESCRIPTION

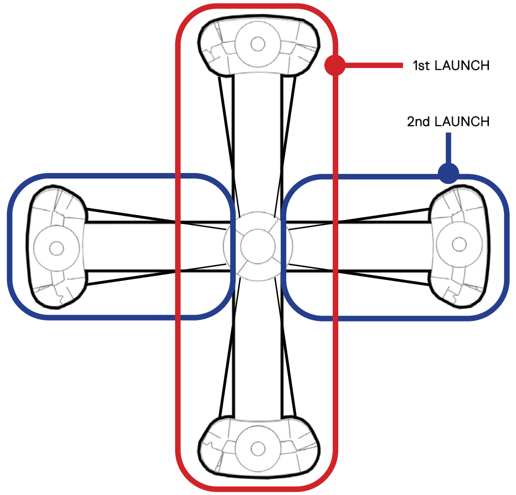
The artificial gravity habitat, named the “Space Crusader” for its cross-like appearance from the front, consists of a central microgravity module, 4 connecting ladder modules, and 4 habitable modules.

The design maximises available cargo volume within the SpaceX Starship, requiring a total of 2 launches to fully assemble. Accordingly, the resulting radius is 10.8 meters, with a rotation rate of 5.612 rpm and a rim velocity of 6.34m/s. The parameters give out a centripetal force equal to that of Martian gravity (0.38g). Detailed calculations related to the Space Crusader are included at the end of the “Promethea Station” book section.

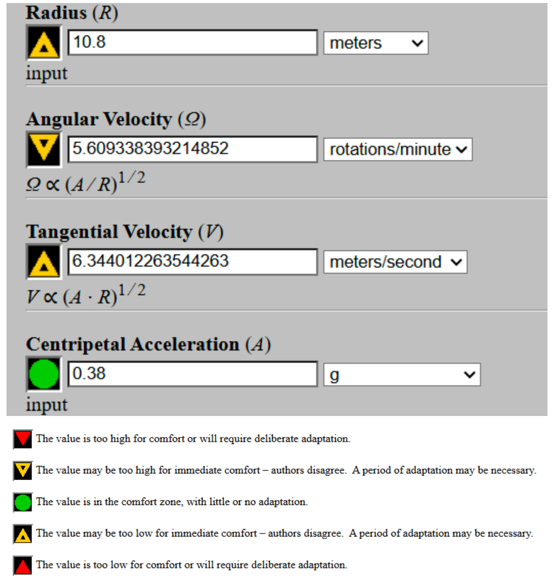
The first launch delivers the microgravity module, 2 connecting modules, and the 2 smaller (commercial) modules. Due to the symmetrical design, the Space Crusader becomes operational after the first launch.

The second launch completes the structure by adding the remaining 2 connecting modules and 2 research modules.

The Space Crusader is designed to accommodate 12 individuals in total (8 crew members and 4 tourists). Each habitable module contains private sleeping quarters, a research area, dining space, bathroom, and storage.



Space Crusader frontal view



Radius (R)

△ 10.8 meters

input

Angular Velocity (Ω)

▽ 5.609338393214852 rotations/minute

$\Omega \propto (A/R)^{1/2}$

Tangential Velocity (V)

△ 6.344012263544263 meters/second

$V \propto (A \cdot R)^{1/2}$

Centripetal Acceleration (A)

● 0.38 g

input

▼ The value is too high for comfort or will require deliberate adaptation.

▽ The value may be too high for immediate comfort – authors disagree. A period of adaptation may be necessary.

● The value is in the comfort zone, with little or no adaptation.

△ The value may be too low for immediate comfort – authors disagree. A period of adaptation may be necessary.

▲ The value is too low for comfort or will require deliberate adaptation.

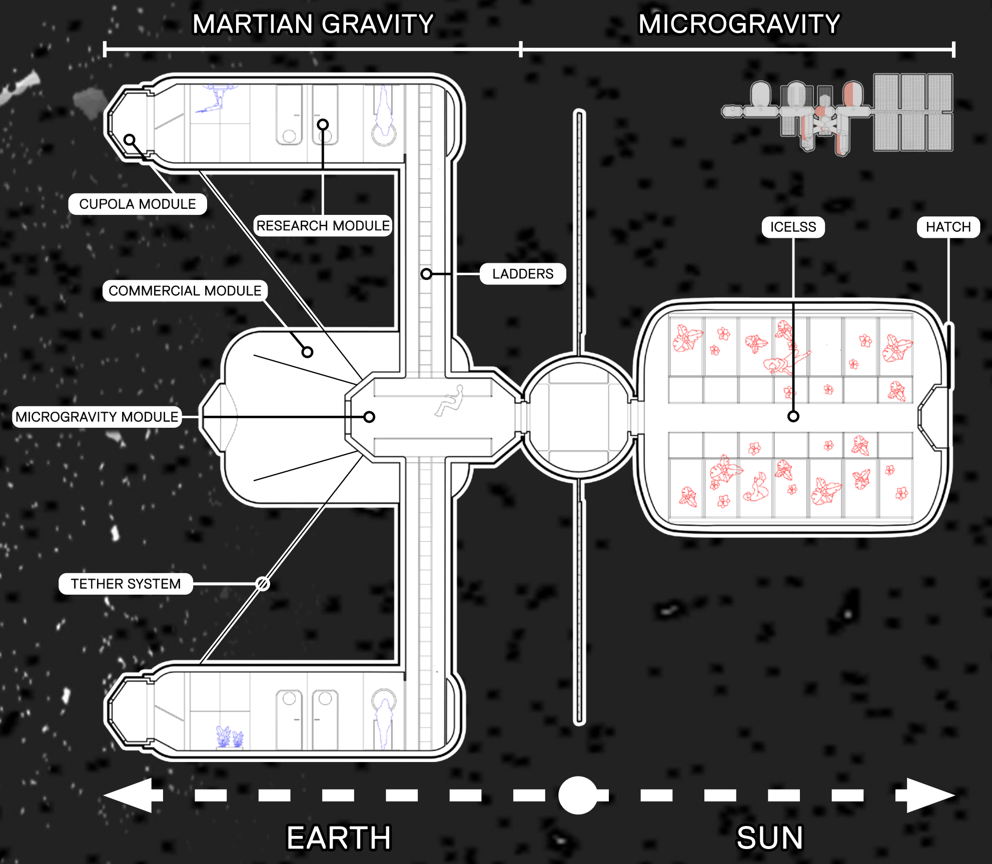
SpinCalc - artificial gravity value calculator

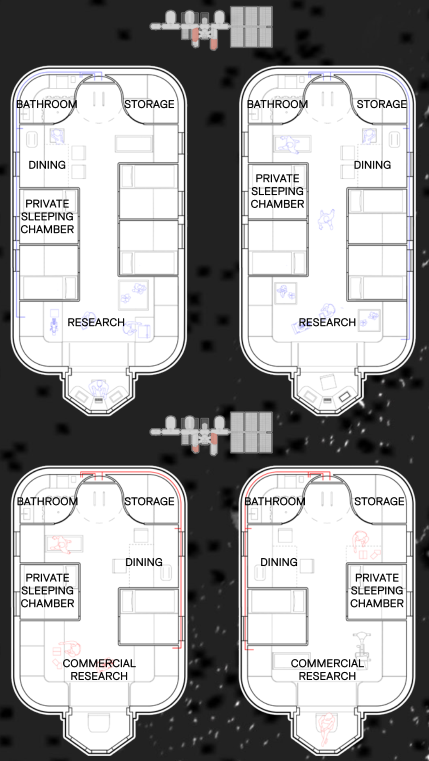
„SPACE CRUSADER“
ARTIFICIAL GRAVITY HABITAT - PLANS

Design decisions are informed not only by physical constraints and rotational forces but also by the goal to create a consistent and enjoyable experience.

Each connecting module features two ladders, one for ascending and one for descending. This configuration leverages the Coriolis force to the user’s advantage, allowing the ladders to “press onto” the body during movement, improving stability (Hall, 2006).

Creating a comfortable living environment in artificial gravity was of high priority. Therefore, the Space Crusader always faces the Earth, allowing the inhabitants to enjoy viewing the Earth from the Cupola module.





Space Crusader reserach and commercial modules

„SPACE CRUSADER“
ARTIFICIAL GRAVITY SYSTEM DETAIL

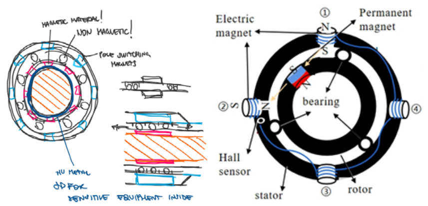
Rotation is initiated via thrusters, located at the ends of the Space Crusader. Furthermore, they can additionally be used to slow down in case of need. A system of electromagnetic pole-switching motors continues the rotation whilst using electricity generated by the station's solar panels. Samarium cobalt (SmCo) magnets (rotators) are built around the electromagnetic pole-switching system (stators). SmCo was preferred for its radiation resistance and thermal stability, enduring high temperatures without demagnetising, ensuring constant performance.

At the core of the mechanical interface is a multi-ring bearing system, comprised of concentric arrays of 50mm ceramic bearings to support both radial and axial loads, but also allow the outer shell to rotate. Ceramic bearings were used so as not to magnetically interfere with the electromagnetic drive system.

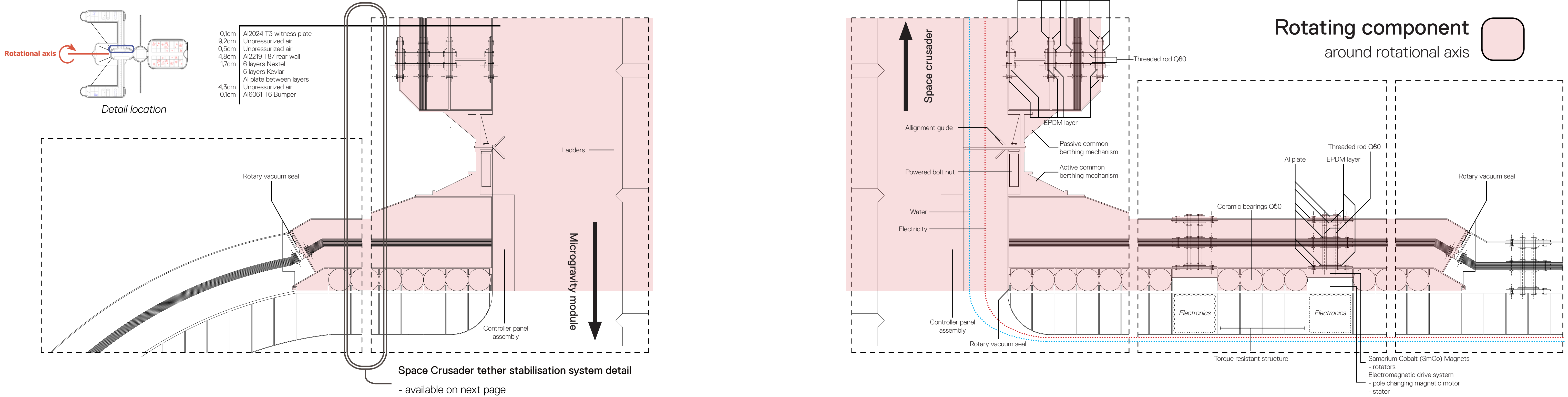
Between the rotating and non-rotating shells lies a torque-resistant frame, acting both as a structural anchor and as a pass-through channel for connections, such as cabling, and the electromagnetic drive system itself.

Multiple layers of rotary vacuum seals were used where the ends of the non-rotating and rotating shells meet, preserving the station's pressure integrity.

The connecting modules, leading to the habitable modules of the Space Crusader, are connected using the CBM (Common Berthing Mechanism).



Left:
conceptual idea of system before designing
Right:
Diagram of rim-driven magnetic propulsion (Liu et al., 2023)



Detail location

0,1cm	Al2024-T3 witness plate
9,2cm	Unpressurized air
0,5cm	Unpressurized air
4,8cm	Al2219-T87 rear wall
1,7cm	6 layers Nextel
	6 layers Kevlar
	Al plate between layers
4,3cm	Unpressurized air
0,1cm	Al6061-T6 Bumper

Samarium Cobalt (SmCo) Magnets
- rotators

Electromagnetic drive system
- pole changing magnetic motor
- stator

Space Crusader tether stabilisation system detail

- available on next page

„SPACE CRUSADER“
TETHER STABILISATION SYSTEM DETAIL

The tether stabilisation system consists of three key components: a tether deployment profile based on OEDIPUS-C (Cosmo et al., 1997), a motorised friction wheel for controlled release and tensioning (Lansdorp et al., 2012) and a custom-designed tether connection profile, mounted on the outer shell (facing the rotational axis) of the rotating Space Crusader.

The main purpose of the stabilisation system is to control and stabilise rotational imbalances and prevent tangential misalignment of the floor due to centrifugal force during rotation. Furthermore, given that the Space Crusader rotates, the stabilisation system must be anchored to the outer rotating shell of the microgravity module.

A 50cm x 0,1cm Teflon-coated Dyneema tether was selected for the deployment system. Dyneema is a strong, lightweight synthetic fibre capable of withstanding high tensile loads. The Teflon coating provides thermal stability and UV resistance. The compact measurements ensure efficient storage, low mass, and a lower likelihood of being damaged by space debris (Lansdorp et al., 2012).

Academic references and theoretical framework, used to draw the two details and design the Space Crusader:

Cosmo et al., 1997

Ding et al., 2024

Hall, 2006

Hall, 2020

Hall, 1999

Hall, 1993

Hall, 2002

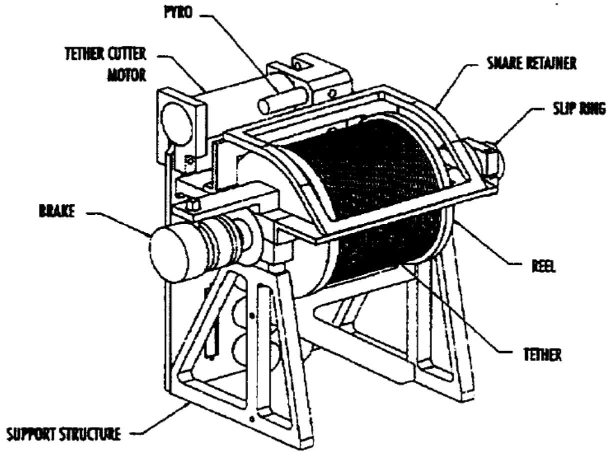
Lackner et al., 2003

Lansdorp et al., 2012

Liu et al., 2023

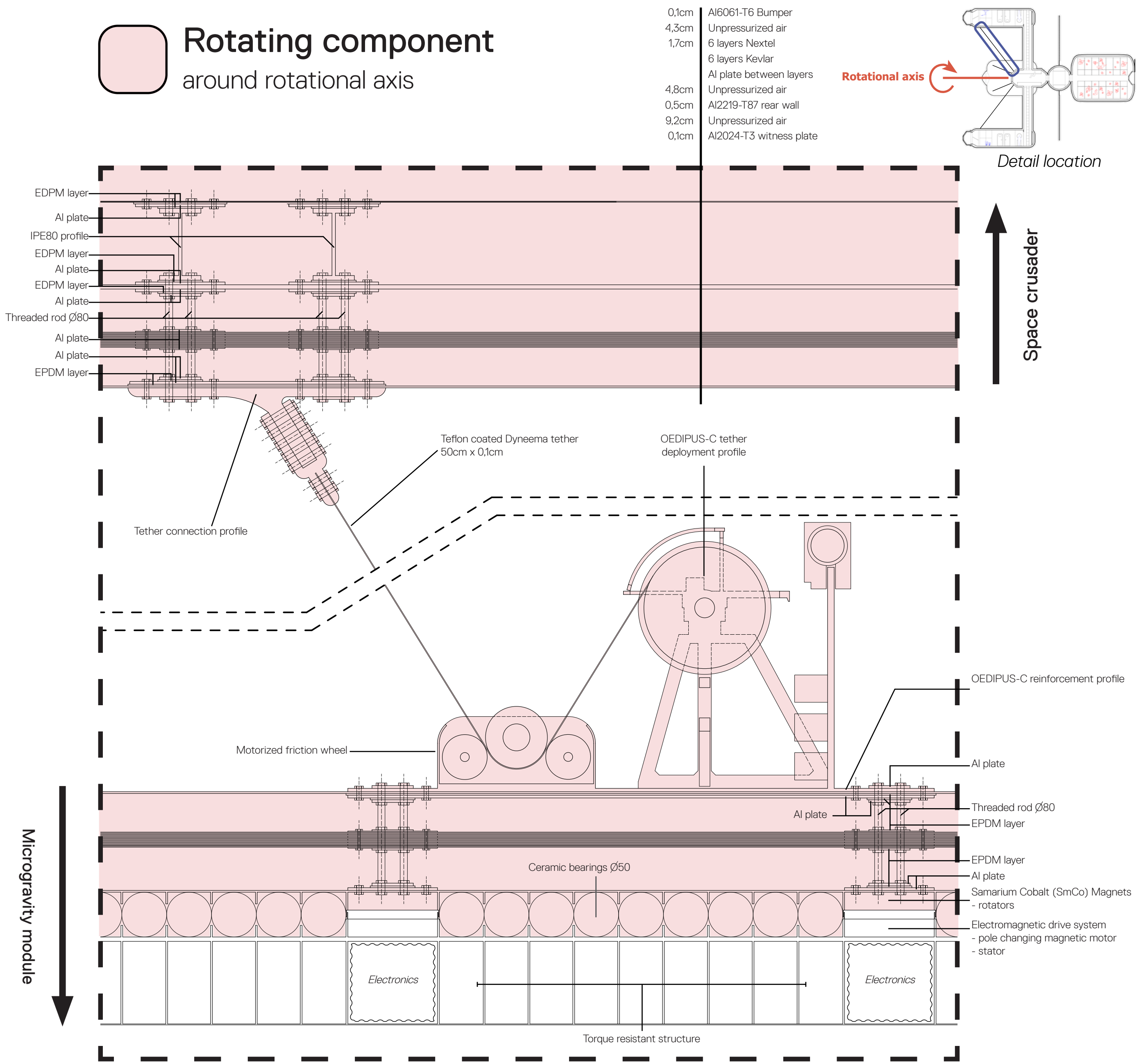
Liu et al., 2021

Wang et al., 2006



OEDIPUS-C tether deployment system

Cosmo et al., 1997, p34



0,1cm	Al6061-T6 Bumper
4,3cm	Unpressurized air
1,7cm	6 layers Nextel
	6 layers Kevlar
	Al plate between layers
4,8cm	Unpressurized air
0,5cm	Al2219-T87 rear wall
9,2cm	Unpressurized air
0,1cm	Al2024-T3 witness plate

INFLATABLE CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEM (ICELSS)

The Inflatable Controlled Ecological Life Support System (ICELSS) is a self-sustaining support system designed to support human life in space independently of Earth-based resupply. Such a system provides several key benefits (Zabel et al, 2016): independent food production, CO_2 reduction, O_2 generation, waste recycling, water management, and positive impact on crew psychological health.

A limited number of notable studies have addressed the spatial requirements per individual necessary to meet caloric demands while also maintaining a photosynthetic balance. A notable reference is the study by Wheeler (2003), which served as the basis of the spatial requirement for the Promethea Station crew. According to the findings, $40m^2$ per individual is required in order to provide an average of 2500 daily kilocalories, while simultaneously maintaining CO_2 and O_2 balance within a CELSS system. Each ICELSS system is designed to support 4 individuals.

A central design goal was to optimise the use of limited interior space, while also ensuring various fruitage in order to satisfy diverse metabolic needs (Salisbury et al, 1996; De Pascale et al, 2021; Polutchko et al, 2022). To guide crop selection, two reference tables were developed (one for each cultivation system), presenting scientific data on plant types, growth cycles, photosynthetic performance, and nutritional output. These tables are presented on the following spread.

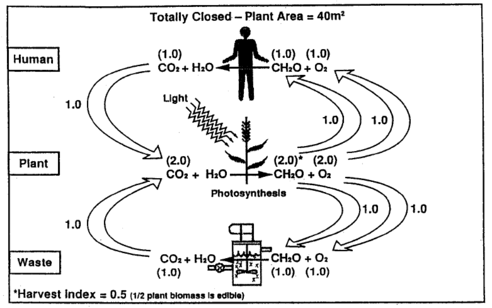


Fig. 1. Comparison of O_2, CO_2, and biomass (CH_2O) fluxes in a bioregenerative life support system that supplies all the gas exchange and dietary energy needs for one person. In this case, the system is closed, half the biomass is edible (i.e., harvest index = 0.5), and all waste biomass is oxidized to retrieve CO_2 and H_2O.

Illustration of fluxes within a $40m^2$ CELSS - Wheeler (2003)

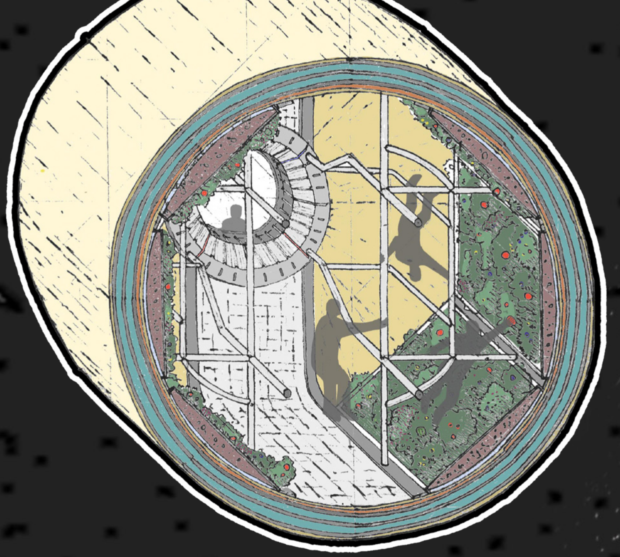
Further literature research revealed a promising topic regarding diet-based GCR protection. Several sources highlight the potential of antioxidant-, vitamin-rich crops mitigating physiological effects from high-energy, charged particles. (Polutchko et al, 2022; Skrizweski et al, 2024; Mitrea et al, 2018; Ushakov et al, 2011; Escobar et al, 2017; Yuan et al, 2016). Thus, a diet rich in antioxidants (ie, lutein and zeaxanthin) and essential vitamins (notably C and E), critical for mitigating radiation damage and chronic inflammation in long-term space missions (Polutchko et al, 2022), would be prioritised.

ORIGINAL ICELSS CONCEPT

Through literature review of past astronaut experiences, (Häuplik-Meusburger et al., 2016; Nixon, 2016), the importance of psychological wellbeing in past space experiences was identified as a recurring challenge.

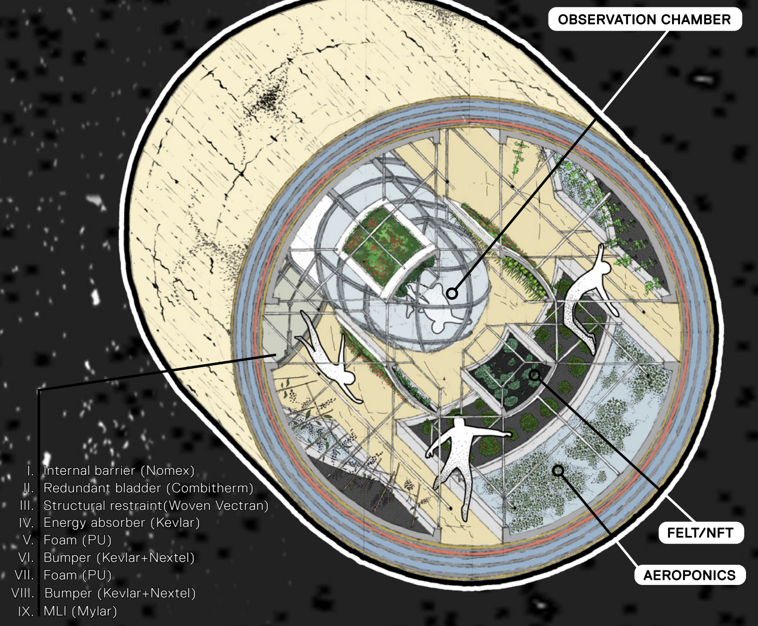
The ICELSS should not only serve as a life support system, but also as a habitat module with positive impact on crew psychological health (Zabel et al., 2016).

Particular importance was placed on enabling crew members to interact with plants in the ICELSS, as this interaction has been shown to offer psychological benefits (Zabel et al., 2016).



Original ICELSS concept illustration

Final ICELSS concept illustration



FINAL ICELSS CONCEPT

Further literature research revealed an important factor that influenced the final design of the ICELSS: transmission of pathogens within a closed-loop agricultural system can not only risk plant-, but also, more importantly, human health (Salisbury et al., 1997; Wheeler et al., 2003; Coughlan et al., 2022).

As a result, it was decided that harvesting would be carried out autonomously by robotic systems. Human interaction should be reserved in only critical scenarios, with sterile suits and equipment (Salisbury et al, 1997).

Accordingly, the cultivation fields were more exactly dimensioned and spatially organised.

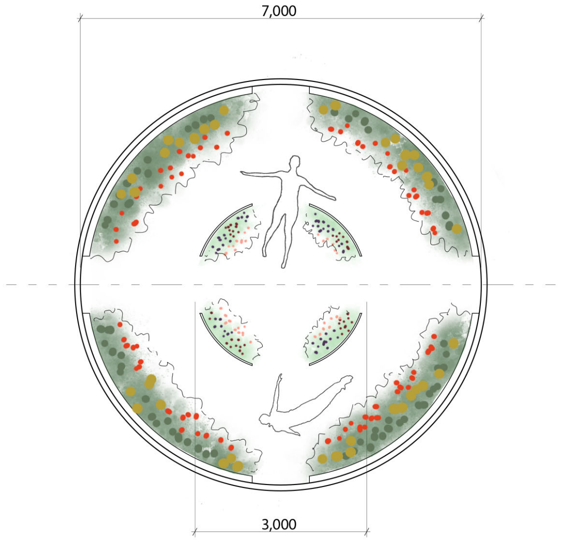
INFLATABLE CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEM (ICELSS) - CULTIVATION

AEROPONICS CROP CHOICE TABLE

CATEGORY	Name (EN)	Name (LA)	Key nutrients	plant density/m^2	plant density/gu	CO$_2$ absorption g/gu/d	O$_2$ production g/gu/d	kcal/gu/harvest	days to maturity	harvest cycle (days)	notes
Leafy greens											
	Cabbage	*Brassica oleracea*	Vit C, Vit K, Fiber, Folate	4	5,36	32,22	0,00	1.608,00	70-100	Single harvest	
	Chinese cabbage	*Brassica rapa*	Vit A, Vit C, Ca, Fe	6	8,05	34,60	0,00	1.610,00	50-80	10-14	
	Collards	*Brassica oleracea var. acephala*	Vit A, Vit C, Vit K, Ca, Fiber	6	8,05	26,05	0,00	515,20	60-85	7-14	
	Dandelion	*Taraxacum officinale*	Vit A, Vit C, Vit K, Ca, Fe	10	13,41	17,48	0,00	905,18	85-95	10-15	
	Endive	*Cichorium endivia*	Vit A, Vit C, Vit K, Fiber	10	13,41	23,31	0,00	341,96	45-95	10-15	
	Kale	*Brassica oleracea Acephala*	Vit A, Vit C, Vit K, Antioxidants	8	10,73	36,91	0,00	751,10	55-75	7-14	
	Lettuce	*Lactuca*	Vit A, Vit K	10	13,41	40,27	0,00	301,73	30-55	5-10	
	New Zealand spinach	*Tetragonia tetragonioides*	Vit A, Vit C, Ca, Fe	6	8,05	31,64	0,00	354,20	55-70	7-10	
	Red mustard	*Brassica juncea*	Vit A, Vit C, Vit K, Antioxidants	15	20,12	44,29	0,00	784,68	30-50	7-10	
	Spinach	*Spinacia oleraceae*	Vit A, Vit C, Vit K, Fe, Folate	20	26,82	44,29	0,00	925,29	35-50	7-10*	*regrows once or twice*
	Swiss chard	*Beta vulgaris cicla*	Vit A, Vit C, Vit K, Mg, K	8	10,73	42,59	0,00	407,74	50-65	7-14	
	Turnip greens	*Brassica rapa*	Vit A, Vit C, Vit K, Ca	15	20,12	55,37	0,00	603,60	30-40	7-10	
Herbs/spices											
	Chives	*Allium schoenoprasum*	Vit A, Vit C, Antioxidants	25	33,53	18,46	0,00	502,95	60-90	14-21	
	Dill	*Anethum graveolens*	Vit C, Mn	20	26,82	18,46	0,00	576,63	60-90	7-14	
	Fennel	*Foeniculum vulgare*	Vit C, Fiber, K	10	13,41	18,46	0,00	415,71	60-90	14-21	
	Oregano	*Origanum vulgare*	Vit K, Vit E, Antioxidants	8	10,73	16,61	0,00	853,04	80-100	14-28	
	Parsley	*Petroselinum crispum*	Vit A, Vit C, Vit K	20	26,82	18,46	0,00	772,42	70-90	14	
	Saffron	*Safranum*	Vit C, Mn, Antioxidants	100	134,10	0,01	0,00	13,41	180-210	90	
	Sage	*Salvia officinalis*	Vit K, Antioxdiants	8	10,73	18,46	0,00	675,99	75-90	28-42	
	Thyme	*Thymus vulgaris*	Vit A, Vit C, Antioxidants	8	10,73	18,46	0,00	216,75	70-90	21-28	
Grains											
	Barley	*Hordeum vulgare*	Vit B, Se, Fiber	250	335,25	19,38	0,00	47.471,40	80-100	Single harvest	
	Flax	*Linum usitatissimum*	Omega-3 acids, Fiber, Lignans	800	1.072,80	18,46	0,00	2.219.150,08	90-120	Single harvest	
	Millets	*Milium*	Vit B, Mn, P	200	268,20	17,23	0,00	30.413,88	60-90	Single harvest	
	Oats	*Avena sativa*	Vit B, Fe, Fiber	250	335,25	16,15	0,00	52.164,90	90-120	Single harvest	
	Quinoa	*Chenopodium quinoa*	Mg, Fe, Protein	100	134,10	12,92	0,00	14.804,64	90-120	Single harvest	
	Rice	*Oryza*	Vit B, Fiber	50	67,05	16,79	0,00	9.789,30	100-150	Single harvest	
	Sorghum	*Syrucum*	Vit B, Fe, Antioxidants	80	107,28	16,15	0,00	17.647,56	100-120	Single harvest	

FELT/NFT CROP CHOICE TABLE

CATEGORY	Name (EN)	Name (LA)	Key nutrients	plant density/m^2	plant density/gu	CO$_2$ absorption g/gu/d	O$_2$ production g/gu/d	kcal/gu/harvest	days to maturity	harvest cycle (days)	*notes*
Tubers & roots											
	Beet	*Beta vulgaris*	Mn, Nitrates, Folate	25	110,53	33,22	0,00	7.129,19	50-70	Single harvest	
	Carrot	*Daucus carota subsp. sativus*	Beta-Carotene	40	176,84	29,07	0,00	10.875,66	60-80	Single harvest	
	Garlic	*Allium sativum*	Vit C, Vit B6, Allicin	25	110,53	8,61	0,00	8.234,49	120-180	Single harvest	
	Ginger	*Zingiber officinale*	Gingerol, Anti-inflammatory properties	10	44,21	6,46	0,00	2.829,44	240-300	Single harvest	
	Horseradish	*Armoracia rusticana*	Vit C, Glucosinolates	10	44,21	9,69	0,00	1.697,66	160-200	Single harvest	
	Kohlrabi	*Brassica oleracea var. gongylodes*	Vit C, K, Fiber	16	70,74	32,30	0,00	3.819,96	45-60	Single harvest	
	Nut sedge	*Cyperus rotundus*	Fiber, Starch	40	176,84	9,69	0,00	70.736,00	90-120	Single harvest	
	Onion	*Allium cepa*	Vit C, Vit B6, Quercetin	25	110,53	19,38	0,00	6.631,80	90-120	Single harvest	
	Radish	*Raphanus sativus*	Vit C, Antioxidants	50	221,05	48,45	0,00	3.536,80	25-40	Single harvest	
	Sweet potato	*Ipomoea batatas*	Beta-Carotene, K, Fiber	6	26,53	18,09	0,00	5.703,95	90-150	Single harvest	
	Taro	*Colocasia esculenta*	Vit E, Fiber, Starch	4	17,68	11,63	0,00	5.940,48	150-200	Single harvest	
	Turnip	*Brassica rapa subsp. rapa*	Vit C, Fiber	25	110,53	38,76	0,00	6.189,68	30-60	7-10	
	White potato	*Solanum tuberosum*	Vit B6, Vit C, K	6	26,53	22,61	0,00	7.149,84	90-120	Single harvest	
	Young potato	*Solanum tuberosum*	Vit B6, Vit C, K	8	35,37	29,07	0,00	6.808,73	60-80	Single harvest	
Fruiting crops											
	Butternut squash	*Cucurbita moschata*	Vit A, Vit C, K, Mg, Fiber, Antioxidants	1	4,42	30,20	0,00	2.983,50	90-110	Single harvest	
	Cucumber	*Cucumis sativus*	Vit C, Vit K, K, Antioxidants	2	8,84	39,55	0,00	565,76	50-70	3-5	
	Gac	*Momordica cochinchinensis*	Vit A, Vit C, K, Fe, Fiber, Antioxidants	1	4,42	10,55	0,00	7.072,00	180-210	7-14	
	Pumpkin	*Cucurbita pepo*	Vit C, Vit K, Fe, Mn, Fiber, Folate, Protein	1	4,42	27,68	0,00	2.298,40	90-120	Single harvest	
Ultra dwarf fruit trees											
	Banana	*Musa × paradisiaca*	Vit B6, Vit C, K	1	4,42	11,07	0,00	5.900,70	270-450	Single harvest	
	Grape	*Vitis vinifera*	Vit K, Antioxidants	1	4,42	3,54	0,00	1.829,88	730-1095	90	
	Melon	*Cucumis melo*	Vit C	1	4,42	33,22	0,00	2.254,20	70-100	Single harvest	
	Papaya	*Carica papaya*	Vit A, Vit C, Digestive enzymes	4	17,68	19,38	0,00	15.204,80	150-200	7-14	
	Spicy peppers	*Capsicum annuum*	Vit C, Capsaicin	10	44,21	27,68	0,00	2.652,60	60-100	7-10*	*for 4-8 weeks*
	Strawberry	*Fragaria × ananassa*	Vit C, Antioxidants	20	88,42	18,46	0,00	4.244,16	90-120	3-5*	*for 2-6 weeks*
	Tomatillo	*Physalis philadelphica*	Vit C, Niacin	2	8,84	27,68	0,00	424,32	70-100	5-7*	*for 2-4 weeks*
	Tomato	*Solanum lycopersicum*	Vit C, K, Lycopene	2	8,84	39,08	0,00	636,48	60-85	5-7*	*for 4-8 weeks*
Legumes											
	Chickpea	*Cicer arietinum*	Fe, Folate, Fiber, Protein	25	110,53	17,62	0,00	14.081,52	90-110	Single harvest	
	Cowpea	*Vigna unguiculata*	Fe, Folate, Protein	20	88,42	19,38	0,00	3.890,48	60-100	7-10	
	Graden pea	*Pisum sativum*	Vit A, Vit C, Vit K, Fiber, Protein	20	88,42	25,84	0,00	7.162,02	55-75	3-5*	*for 2-3 weeks*
	Green bean	*Phaseolus vulgaris*		20	88,42	27,68	0,00	4.111,53	50-70	2-4*	*for 2-4 weeks*
	Lentil	*Lens culinaris*	Fe, Folate, Fiber, Protein	150	663,15	14,09	0,00	70.028,64	80-110	Single harvest	
	Pinto bean	*Phaseolus vulgaris*	Fe, Folate, Fiber, Protein	25	110,53	16,15	0,00	15.341,56	90-120	Single harvest	
	Snow pea	*Pisum sativum var. saccharatum*	Vit C, Fiber	15	66,32	27,68	0,00	2.785,44	60-70	3-5*	*for 2-3 weeks*
	Soybean	*Glycine max*	Fe, Ca, Protein	20	88,42	19,38	0,00	23.661,19	80-120	Single harvest	
	Winged bean	*Psophocarpus tetragonolobus*	Vit A, Vit C, Protein	4	17,68	19,38	0,00	7.231,12	80-100	3-7	
Oil-storing crops											
	Canola	*Brassica napus*	Omega-3 acids	150	663,15	16,15	0,00	234.489,84	90-120	Single harvest	
	Flax (oil)	*Linum usitatissimum*	Omega-3 acids, Lignans	800	3.536,80	18,46	0,00	755.460,48	90-120	Single harvest	
	Peanut	*Arachis hypogaea*	Folate, Niacin, Protein, Healthy fats	15	66,32	16,61	0,00	18.801,72	100-140	Single harvest	
	Sunflower	*Helianthus annuus*	Vit E, Healthy fats	10	44,21	19,38	0,00	15.491,18	90-120	Single harvest	
Special crops											
	Green tea extract	*Camellia sinensis*	Catechins, Antioxidants	1	4,42	1,52	0,00	-	730-1095	7-14	
	Duckweed	*Lemna*	Protein, Antioxidants, Amino acids	whole gu	4,42	166,10	0,00	4.327,18	7-14	3-5	



ICELSS illustrative section

ICELSS - CO$_2$ AND O$_2$ CALCULATION METHOD

C = carbon

O$_2$= oxygen

CO$_2$ = carbon dioxide

Y_{ed} = edible yield per square meter

M_b = biomass multiplier

A = area

T = days to maturity

45% of dry biomass is carbon

I. Dry biomass to carbon — $C = Y_{ed} * M_b * 0,45$

1g C = 3,67g of CO$_2$ absorbed

II. Carbon to CO$_2$ absorbed — $CO_2 = C * 3,67$

III. CO$_2$ absorbed per day — $CO_2/m^2/d = CO_2 / T$

IV. CO$_2$ absorbed per day per growth unit — $CO_2/d/gu = CO_2 * A / T$

V. Simplified formula — $CO_2/d/gu = 1,6515 * Y_{ed} * M_b * A / T$

molecular weight ratio

VI. O$_2$ calculation — $O_2=CO_2 * 0,727$

The Inflatable Controlled Ecological Life Support System (ICELSS) features two types of cultivation methods: aeroponics and felt/NFT (Nutrient Film Technique) system.

As mentioned before, each inflatable was designed to accommodate the life support needs of 4 individuals. The total surface area required per individual (40m^2) was separated into 14 parts: 7 being aeroponics-based (4,421m^2 each), 7 felt/NFT-based (1,341m^2 each). This amounts to a total of 28 aeroponics cultivation units and 28 felt/NFT units per inflatable module.

Furthermore, to support resource management, two detailed crop selection tables were developed, one for each system. These tables provide key data regarding harvest cycles, calories, photosynthetic rate, plant density, and key nutrients. All of the listed crops were either tested or proposed in prior studies related to CELSS.

List of reviewed literature, used to gather crops from:

Coughlan et al., 2022
Escobar et al., 2017
Hava et al., 2019
Meinen et al., 2018
Mitrea et al., 2024
Nelson et al., 2009
Olson et al., 1984
Polutchko et al., 2022
Romano et al., 2021
Salisbury et al., 1996
Salisbury et al., 1997
Schwartzkopf, 1922
Skoog, 1984
Ushakov et al., 2011
Wheeler, 2003
Wheeler, 2021
Wheeler et al., 2003
Wilks, 1962
Yuan et al., 2016
Zabel et al., 2016

VERSATILITY & PROGRAMMING

The Promethea Station is based on a modular and reprogrammable architectural logic, allowing for a wide range of mission objectives, ranging from long-duration research habitation to short-term commercial stays.

It features clearly defined zones for scientific operations, private habitation, tourism, and ecological life support, separated by clearance-based access levels.

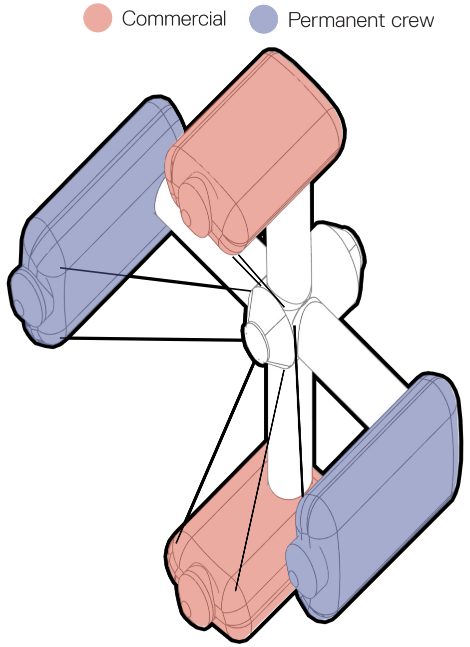
A key aspect of versatility is the dual-gravity environment: the Space Crusader provides artificial gravity for comfort and physiological benefits, while the microgravity backbone supports EVA, docking, and proven microgravity research.

The ICELSS and Space Crusader modules not only further enhance versatility by both being integrated orbital systems but also modular units that can be detached, redeployed, or integrated into other stations, if proven to function well.

Environmental systems within the ICELSS modules are programmable - lighting, humidity, and air composition can be adjusted to meet specific plant cultivation needs, depending on mission and research goals.

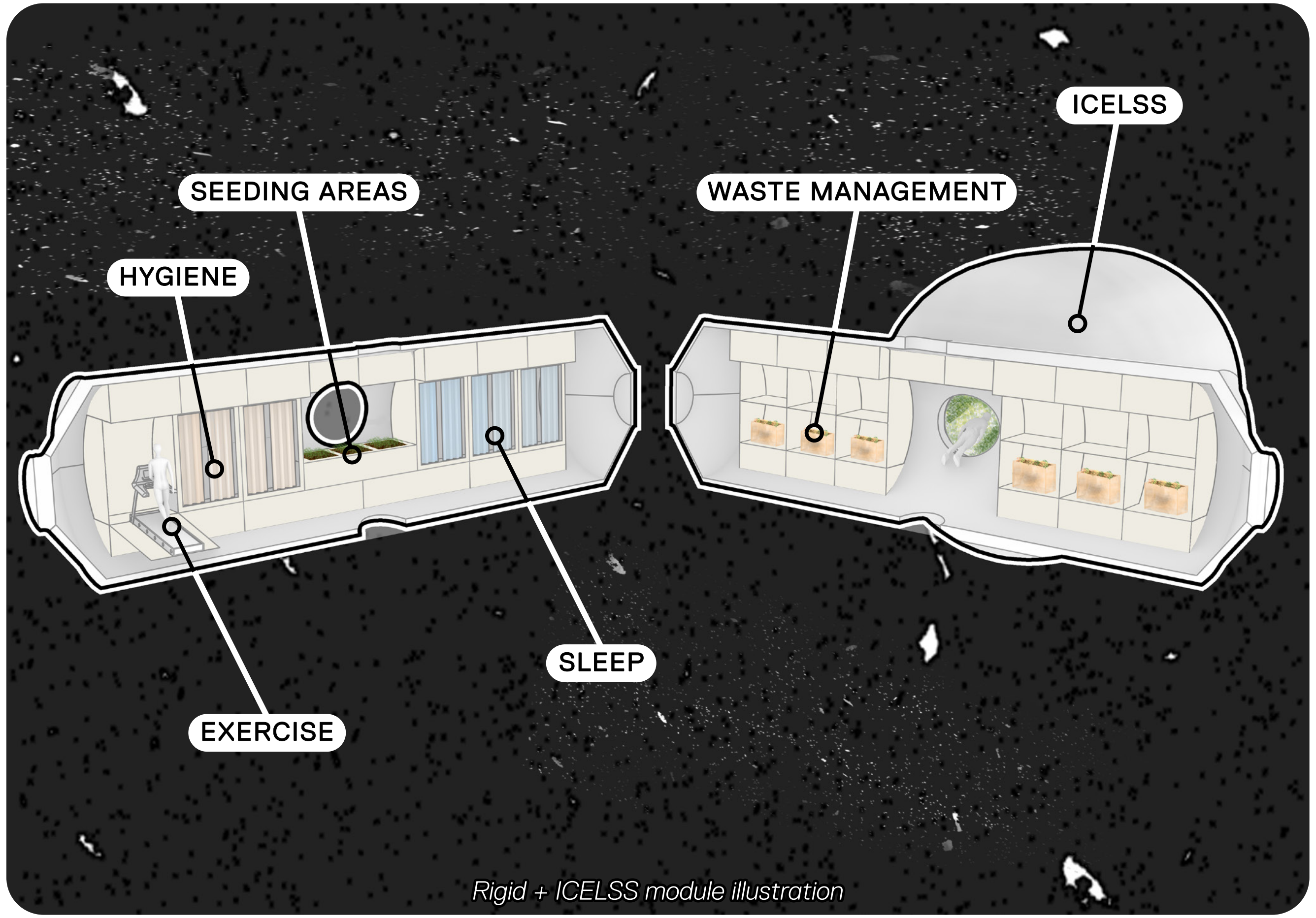
The permanent crew aboard the station operates on a rotation cycle similar to that of the ISS, which is equal to 6 months. In contrast, commercial or tourist occupants are scheduled for shorter stays, typically around 2 weeks.

Furthermore, the commercial modules of the Space Crusader, while designed for tourism, can also be used for commercial scientific research. This possibility not only provides a unique opportunity to study the effects of artificial/Martian gravity, offering valuable insight into the effects of Martian gravity on the tested subject, but also enhances the scientific value of the station.



Space Crusader axonometric view

The rigid modules connected to the ICELSS offer a wide range of possible configurations, depending on their level of interconnection with the adjacent ICELSS units. For example, the image below illustrates how a rigid module can complement an ICELLS module, providing functions such as seeding areas and waste management for the biological life support. In contrast, it also supports familiar systems such as exercise and sleep in microgravity, whose effects on human psychology are well understood and reliable.



Rigid + ICELSS module illustration

CALCULATIONS - SPACE CRUSADER

Radius

$$rpm = 5,9\ rotations/min$$

$$F = m * \omega^2 * r$$

$$\omega = \frac{2\pi}{T}$$

$$F = m * g_{mars}$$

$$m * g_{mars} = m * \left(\frac{2\pi}{T}\right)^2 * r$$

$$g_{mars} = \left(\frac{2\pi}{T}\right)^2 * r$$

$$r = \frac{g_{mars}}{\left(\frac{2\pi}{T}\right)^2}$$

$$r = \frac{9,81 * 0,38}{\left(\frac{2\pi}{\frac{60}{5,9}}\right)^2}$$

$$\boxed{r = 9,77m}$$

Gravity gradient

$$\frac{\Delta a}{a} < 20\%$$

$$h_{human} = 1,8m$$

$$\Delta a = h * \omega^2$$

$$\Delta a = 0,69m/s^2$$

$$a = r * \omega = 3,77m/s^2$$

$$\boxed{\frac{\Delta a}{a} = 18\%}$$

Rim velocity

$$v_{rim} = \sqrt{g_{mars} * r}$$

$$\boxed{v_{rim} = 6,03m/s}$$

+1m to radius in order to ensure better comfort
r = 10,8m

New rpm

$$g_{mars} = \left(\frac{2\pi}{T}\right)^2 * r$$

$$g_{mars} = \left(\frac{2\pi}{\frac{60}{rpm}}\right)^2 * r$$

$$\frac{g_{mars}}{r} = \left(\frac{2\pi}{\frac{60}{rpm}}\right)^2$$

$$\sqrt{\frac{g_{mars}}{r}} = \frac{2\pi}{\frac{60}{rpm}}$$

$$\sqrt{\frac{g_{mars}}{r}} = \frac{2\pi * rpm}{60}$$

$$\frac{60 * \sqrt{\frac{g_{mars}}{r}}}{2\pi} = rpm$$

$$\boxed{rpm = 5,612\ rotations/min}$$

Angular momentum and torque

$$r_1 = 49,27\ m$$

$$r_2 = 40\ m$$

$$m_1 = 36947,91\ kg$$

$$m_2 = 64836,81\ kg$$

$$L = I * \omega$$

$$I = \frac{1}{3} * m * r^2$$

$$L = \frac{1}{3} * m * \omega * r^2$$

$$\boxed{\begin{gathered}\boldsymbol{L_1 = -3130857,65\ Nms}\\ \boldsymbol{L_2 = -3621178,78\ Nms}\\ \boldsymbol{L_{total} = -6752036,43\ Nms}\end{gathered}}$$

$$\tau = \frac{L_{total}}{t}$$

$$t = 1\ day = 24h = 86400s$$

$$\tau = \frac{L_{total}}{t}$$

$$\tau = \frac{6752036,43Nms}{86400s}$$

$$\boxed{\boldsymbol{\tau = 78,15\ Nm}}$$

Coriolis : centripetal

$$a_{coriolis} = 2 * \Omega * v_{rim}$$

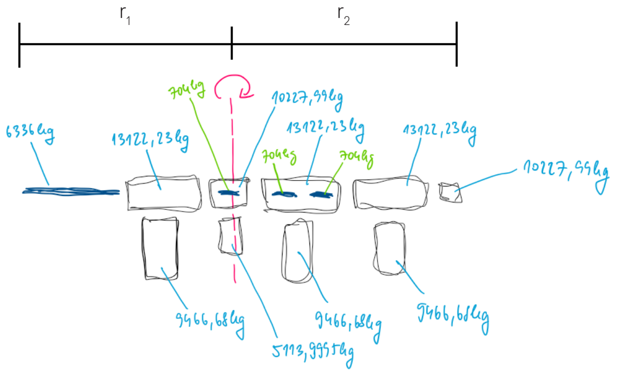
$$a_{coriolis} = 2 * 0,10472 * 6,03$$

$$a_{coriolis} = 1,263m/s^2$$

$$\boxed{\boldsymbol{\frac{a_{coriolis}}{a_{centripetal}} = \frac{1,263}{3,73} = \frac{1}{2,95} \approx \frac{1}{3} = \frac{0,13g}{0,38g}}}$$

The calculation above indicates that within the Space Crusader there is a constant Coriolis force approximately equivalent to that of lunar gravity.

Momentum and torque simplified illustration



CALCULATIONS - SOLAR PANEL AND RADIATOR AREA

Necessary double sided solar panel surface area

$$S = ?$$

$$S = \frac{\Delta P}{V}$$

$$\Delta P_{iss} = 90kW = 90\,000W$$

$$V_{iss} \sim 900m^3$$

$$\boldsymbol{S = 100\frac{W}{m^3}}$$

We'll take a higher value to provide more power

$$\boldsymbol{S = 110\frac{W}{m^3}}$$

$$P_{promethe} = ?$$

$$P_{promethea} = S * V_{promethea}$$

$$P_{promethea} = 110\frac{W}{m^3} * 1320,092m^3$$

$$\boldsymbol{P_{promethea} = 145210,12W}$$

Theoretical solar panel surface area

$$A_{solar} = \frac{P_{promethea}}{P_{effective}}$$

$$P_{effective} = G_{sc} * \vartheta_{front} * (1 + \vartheta_{back}) + \vartheta_{daylight\ fraction}$$

$$G_{sc} = 1377\frac{W}{m^2}$$

$$\vartheta_{front} = 20\%$$

$$\vartheta_{back} = 10\%$$

$$\vartheta_{daylight\ fraction} = 60\%$$

$$\boldsymbol{P_{effective} = 181,76\frac{W}{m^2}}$$

$$A_{solar} = \frac{P_{promethe}}{P_{effective}}$$

$$A_{solar} = \frac{145210,12}{181,76}$$

$$\boldsymbol{A_{solar} = 798,911m^2}$$

How does the ISS function?

$$P_{effective\ iss} = \frac{P_{iss}}{A_{solar\ iss}}$$

$$P_{effective\ iss} = \frac{90\,000W}{2500m^2}$$

$$\boldsymbol{P_{effective\ iss} = 36\frac{W}{m^2}}$$

According to ISS standards

$$A_{solar} = \frac{P_{promethea}}{P_{effective\ iss}}$$

$$A_{solar} = \frac{145210,12\ W}{36\frac{W}{m^2}}$$

$$\boldsymbol{A_{solar} = 4033,61m^2}$$

New, modern panels

$$\sim \vartheta = 30\%$$

$$P_{effective} = 70\frac{W}{m^2}$$

$$A_{solar} = \frac{P_{promethe}}{P_{effective\ iss}}$$

$$A_{solar} = \frac{167330,9\ W}{70\frac{W}{m^2}}$$

$$\boldsymbol{A_{solar} = 2074,43m^2}$$

20% buffer for degradation and outages

$$A_{solar\ final} = A_{solar} + A_{solar} * 0,2$$

$$\boldsymbol{A_{solar\ final} = 2489,316m^2}$$

Round up to a nice number

$$\boxed{\boldsymbol{A_{solar\ final} = 2500m^2}}$$

Necessary radiator surface area

$$Q = \epsilon * \sigma * A * T^4$$

$$Q = heat\ [W]$$

$$\epsilon = emissivity\ (of\ the\ radiator\ surface)$$

$$\sigma = stefan - boltzmann\ constant\ [5,67 * 10^{-8}W/m^2K^4]$$

$$A = surface\ area\ [m^2]$$

$$T = temperature\ [K]$$

$$Q = Q_{crew} + Q_{system} + Q_{margin}$$

$$Q_{crew} = n_{crew} * Q_{crewmember}$$

$$Q_{crew} = 12 * 120$$

$$\boldsymbol{Q_{crew} = 1440\ W}$$

$$Q_{system} = V_{promethea} * S_{power\ systems}$$

$$Q_{system} = 1320,092 * 50$$

$$\boldsymbol{Q_{system} = 66004,6\ W}$$

$$Q_{margin} = (Q_{crew} + Q_{system}) * 0,2$$

$$Q_{margin} = (1440 + 66004,6) * 0,2$$

$$\boldsymbol{Q_{margin} = 13488,92W}$$

$$\boldsymbol{Q = 80933,52\ W}$$

$$\epsilon = 0,9$$

$$T = 300K$$

$$A = \frac{Q}{\epsilon * \sigma * T^4}$$

$$A = \frac{80933,52}{0,9 * 5,67 * 10^{-8} * 300^4}$$

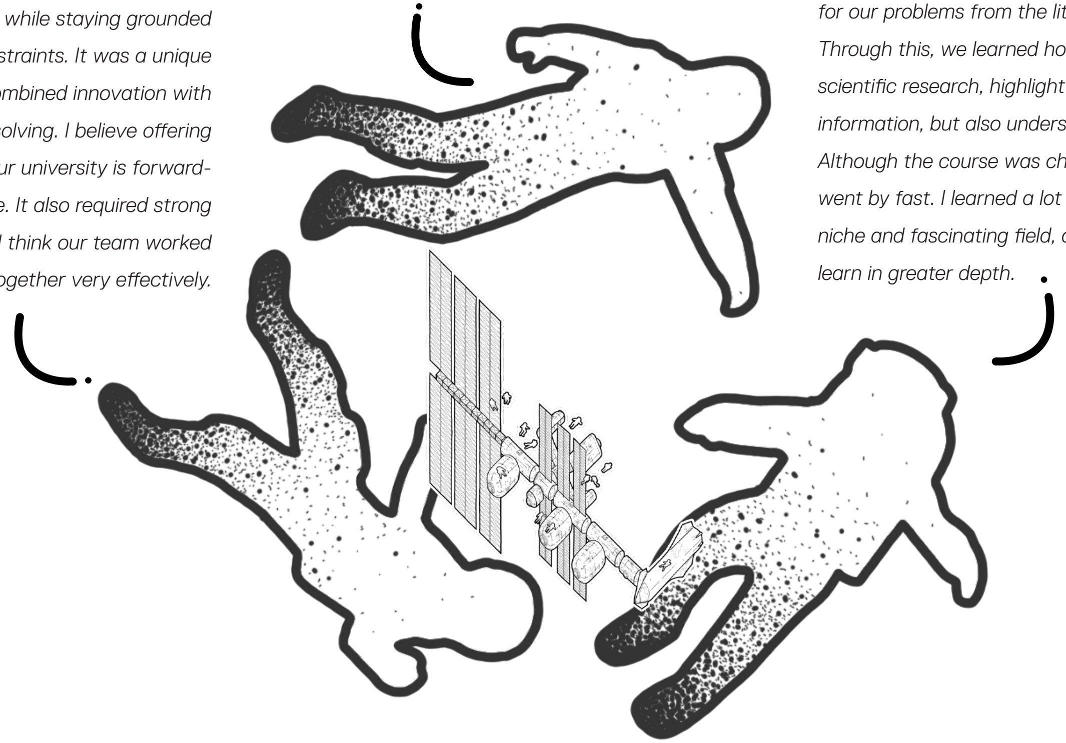
$$\boxed{\boldsymbol{A = 195,802\ m^2}}$$

REFLECTION

This design studio was a challenging yet rewarding experience. The most difficult aspect was finding the right balance between creative freedom and the need for scientific accuracy. Designing a space station pushed us to explore bold, imaginative ideas while staying grounded in real-world constraints. It was a unique opportunity that combined innovation with practical problem-solving. I believe offering such a course at our university is forward-thinking and valuable. It also required strong collaboration, and I think our team worked together very effectively.

I appreciated learning about the interdisciplinary collaboration between architects, astronauts, and engineers. Integrating the physics of outer space into our design added an exciting and complex layer to the project. It was a unique challenge that pushed us to think beyond traditional architectural boundaries. The feedback sessions with professionals like David Nixon and Peter Schattschneider were especially valuable, offering us practical insights and helping us refine our ideas.

The design studio was an outstanding experience. The integration of different disciplines such as basic biology, psychology, physics, engineering, and architecture made the process genuinely enjoyable. The greatest challenge was finding and extracting the right answers for our problems from the literature. Through this, we learned how to approach scientific research, highlight important information, but also understand it better. Although the course was challenging, it went by fast. I learned a lot about a highly niche and fascinating field, one I hope to learn in greater depth.



Internal atmospheric view - part of first midterm comic

REVIEWS

this is the place where the external and internal reviews will evaluate your proejct.„Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.“

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