

# The Future of Humans in Space

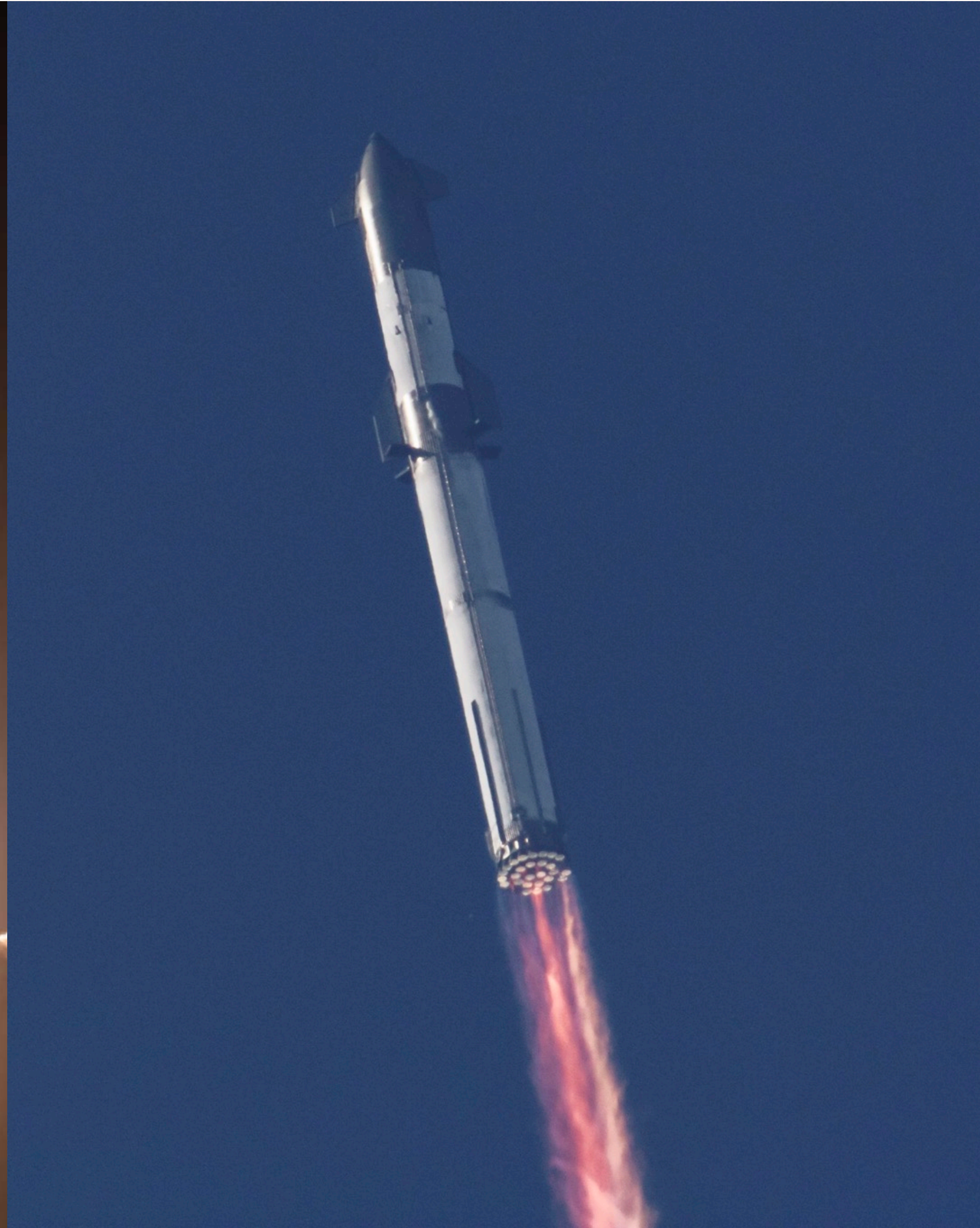
- Today
- Tomorrow
- The next ten years
- The next century
- The next millennium
- Beyond

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<http://spacecraft.ssl.umd.edu>

# Highlights of Human (Flight) History

<b>Homo Sapiens</b>	<b>200,000 yrs</b>	<b>10,000 generations</b>
<b>Agrarian Societies</b>	<b>10,000 yrs</b>	<b>500 generations</b>
<b>Writing</b>	<b>5,000 yrs</b>	<b>250 generations</b>
<b>First Human “Flight”</b>	<b>1500 yrs</b>	<b>75 generations</b>
<b>Balloon Flight</b>	<b>200 yrs</b>	<b>10 generations</b>
<b>Aircraft Flight</b>	<b>120</b>	<b>6 generations</b>
<b>Space Flight</b>	<b>60</b>	<b>3 generations</b>

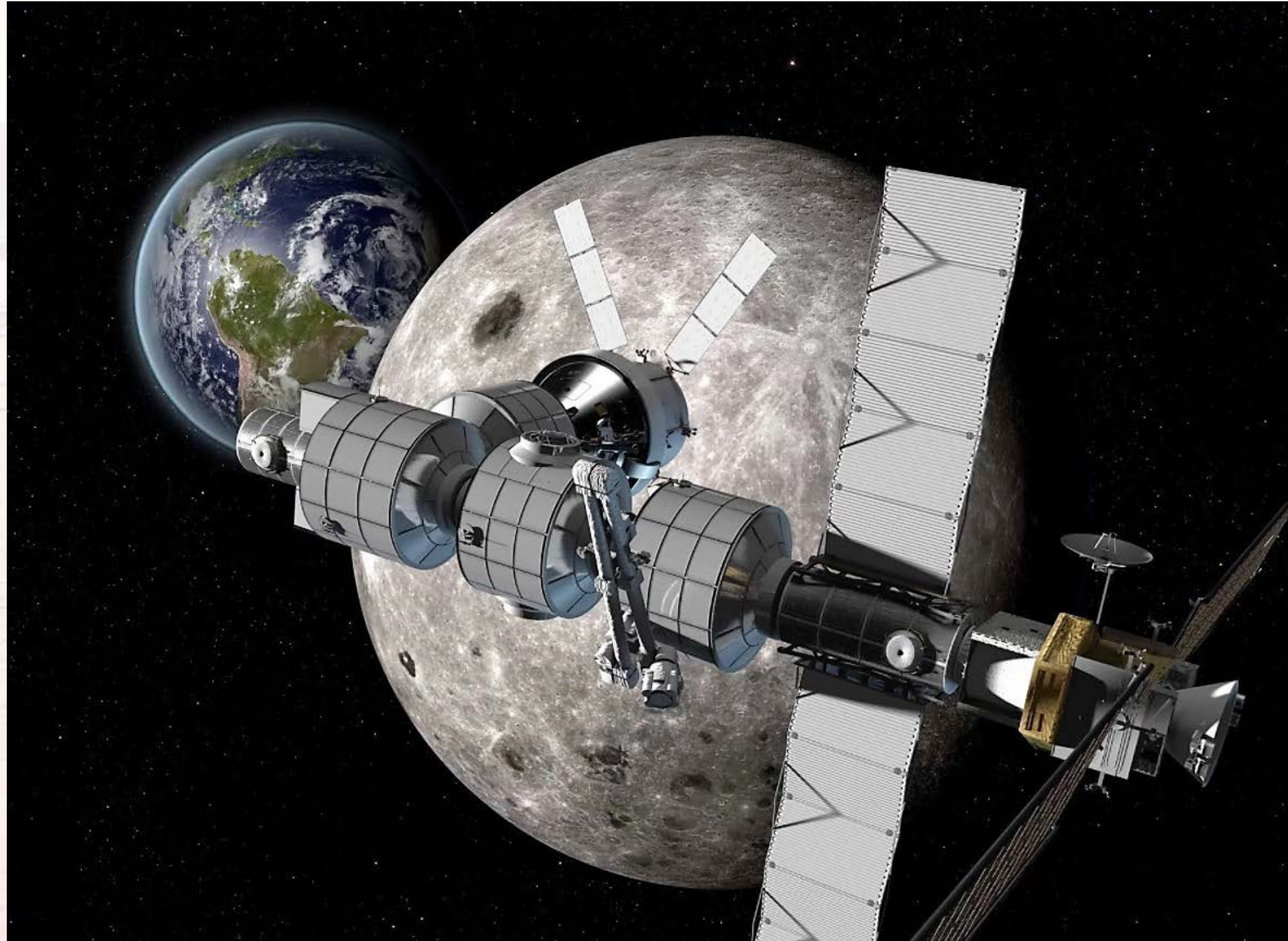
# Today/Near Future - Launch Vehicles



# Today/Near Future - Crewed Vessels



# The Near Future - Gateway



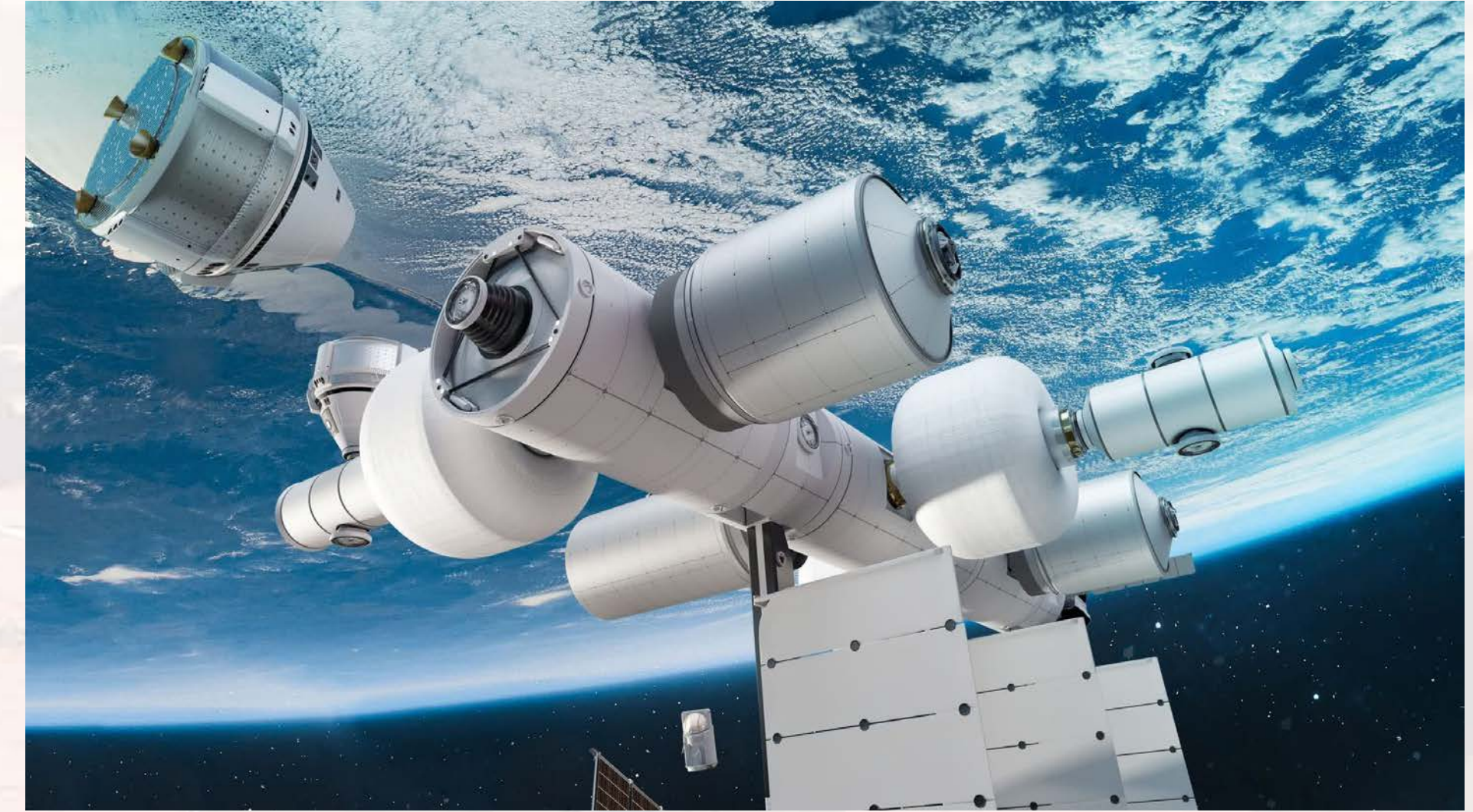
# Today(?) – Suborbital Tourism



MarsScientif



# Today/Near Future – Orbital/Cislunar Tourism



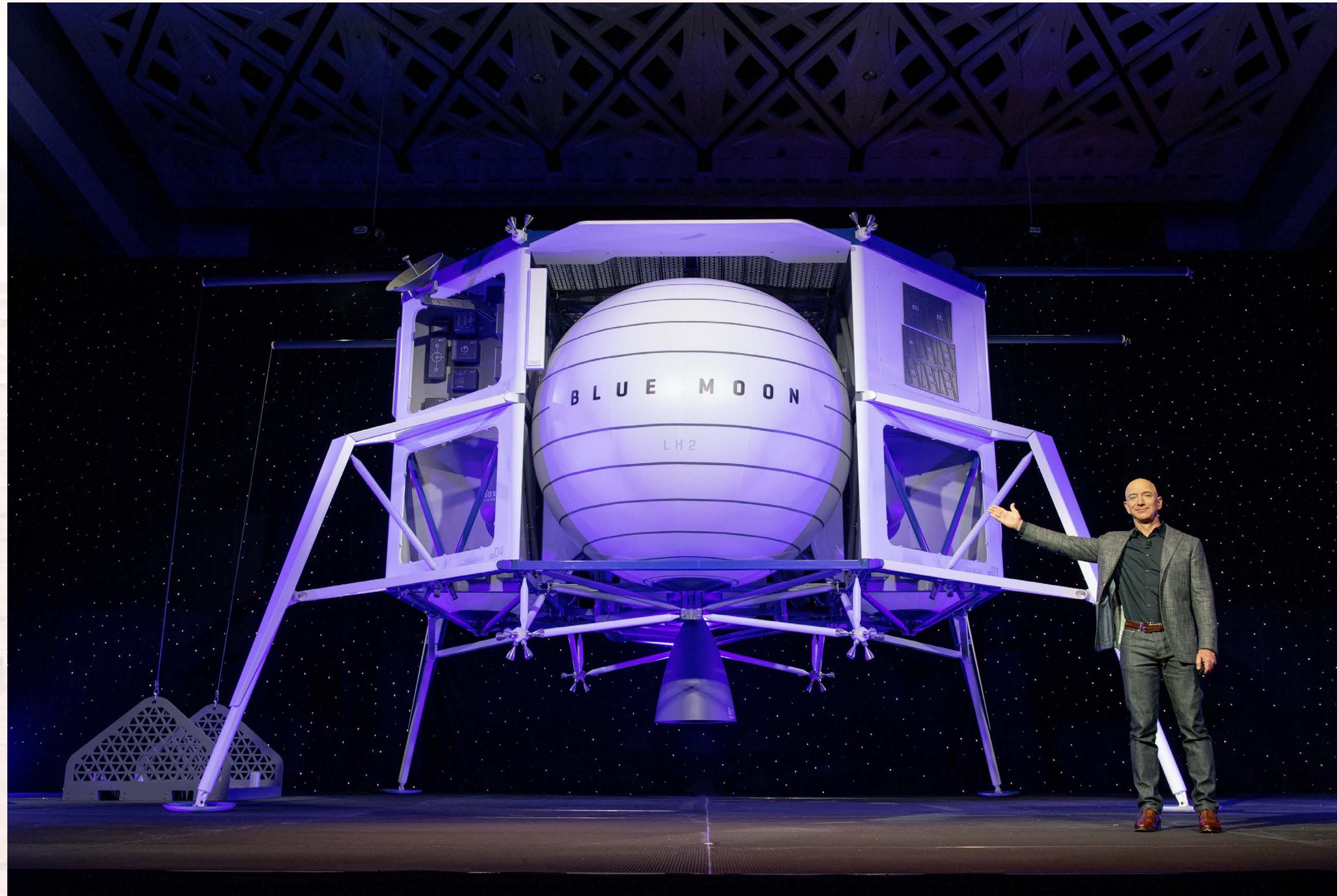
# Economics of Space Tourism

- \$20M (current)  $Customers/year \approx \frac{1000}{(cost < \$M >)^2}$

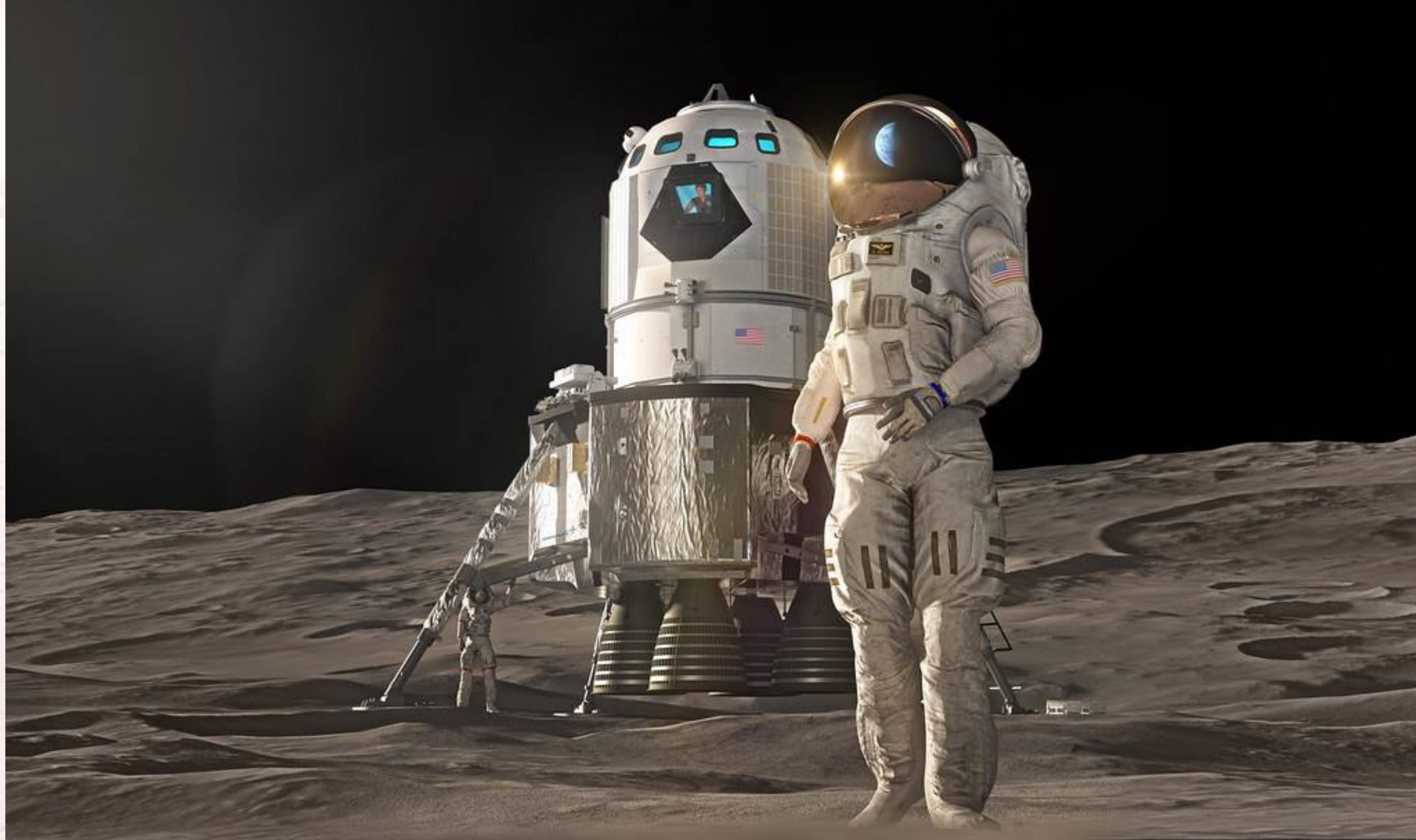
Ticket Cost	Cost/kg	Passengers/year	Annual Revenue
\$20M (current)	\$200,000	2.5	\$50M
\$5M	\$50,000	40	\$200M
\$1M	\$10,000	1000	\$1B
\$250K	\$2500	16K	\$4B
\$50K	\$500	400K	\$20B
\$10K	\$100	10M	\$100B



# Blue Moon Lander Mockup



# Return to the Moon - ~~2024~~ ~~2025~~ 2026???



# Renewed Lunar Exploration



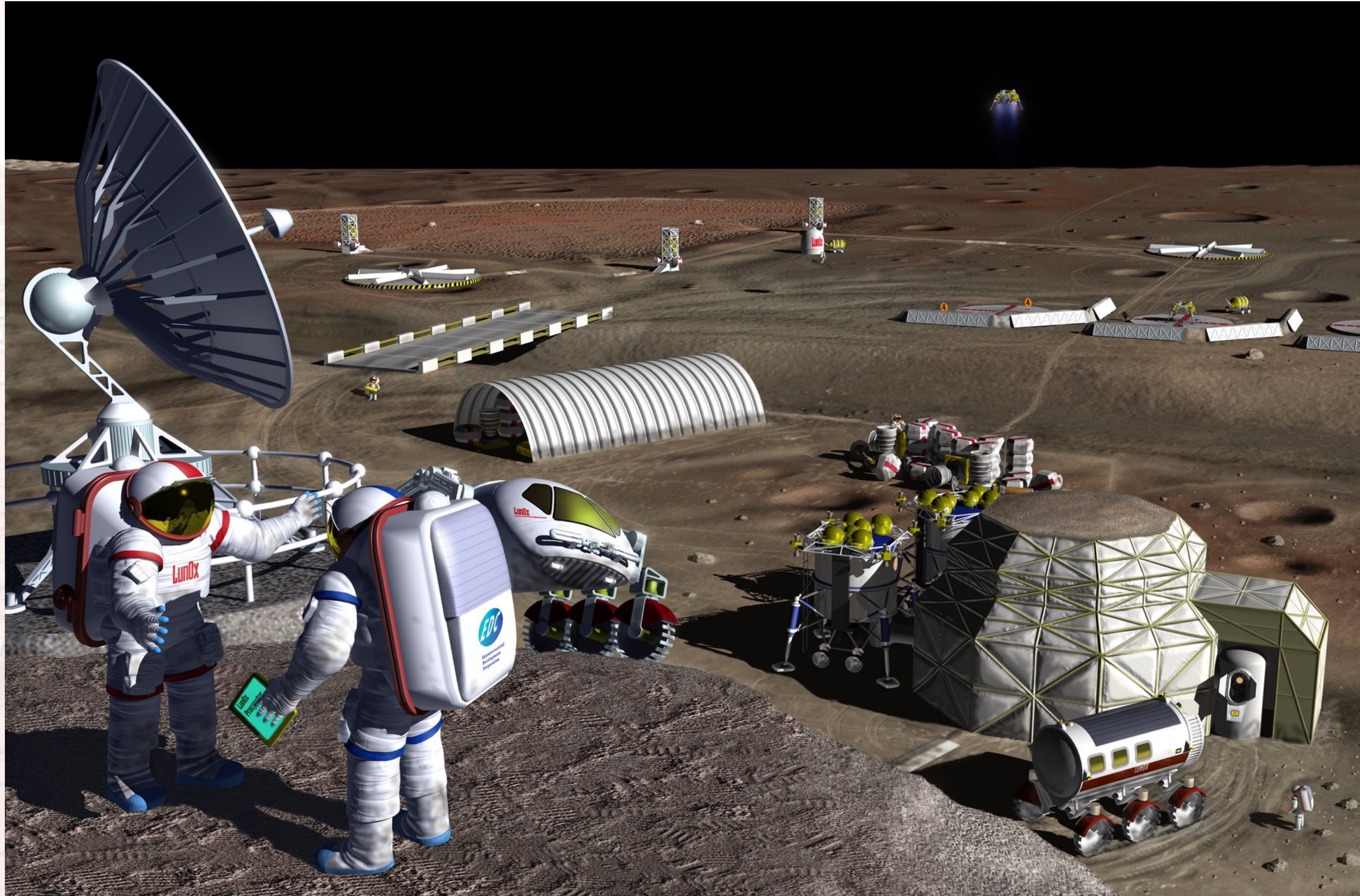
# Starship on the Moon



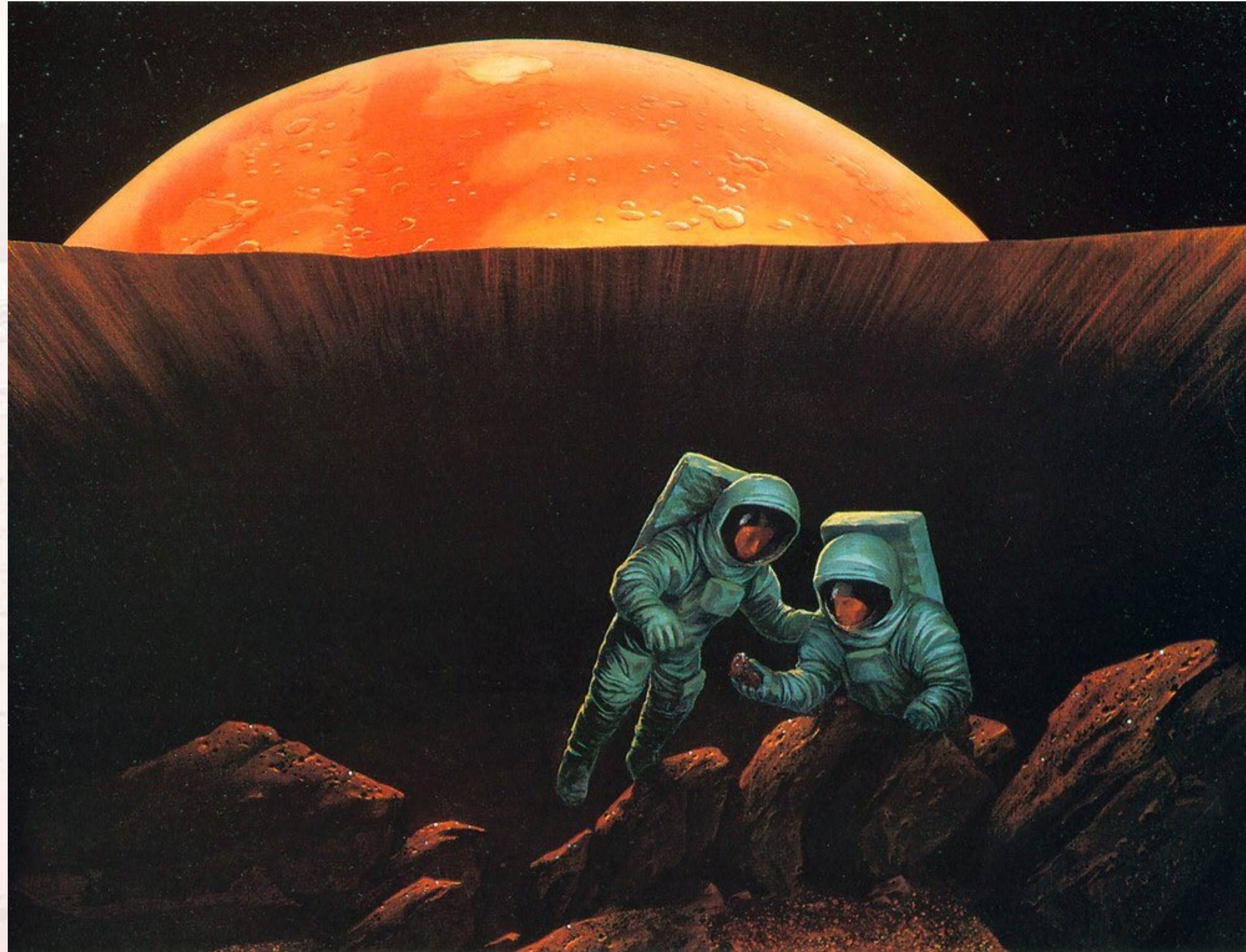
# Lunar Terrain Vehicles



# The Moon as an Industrial Center



# Exploring Phobos



# Mars Exploration

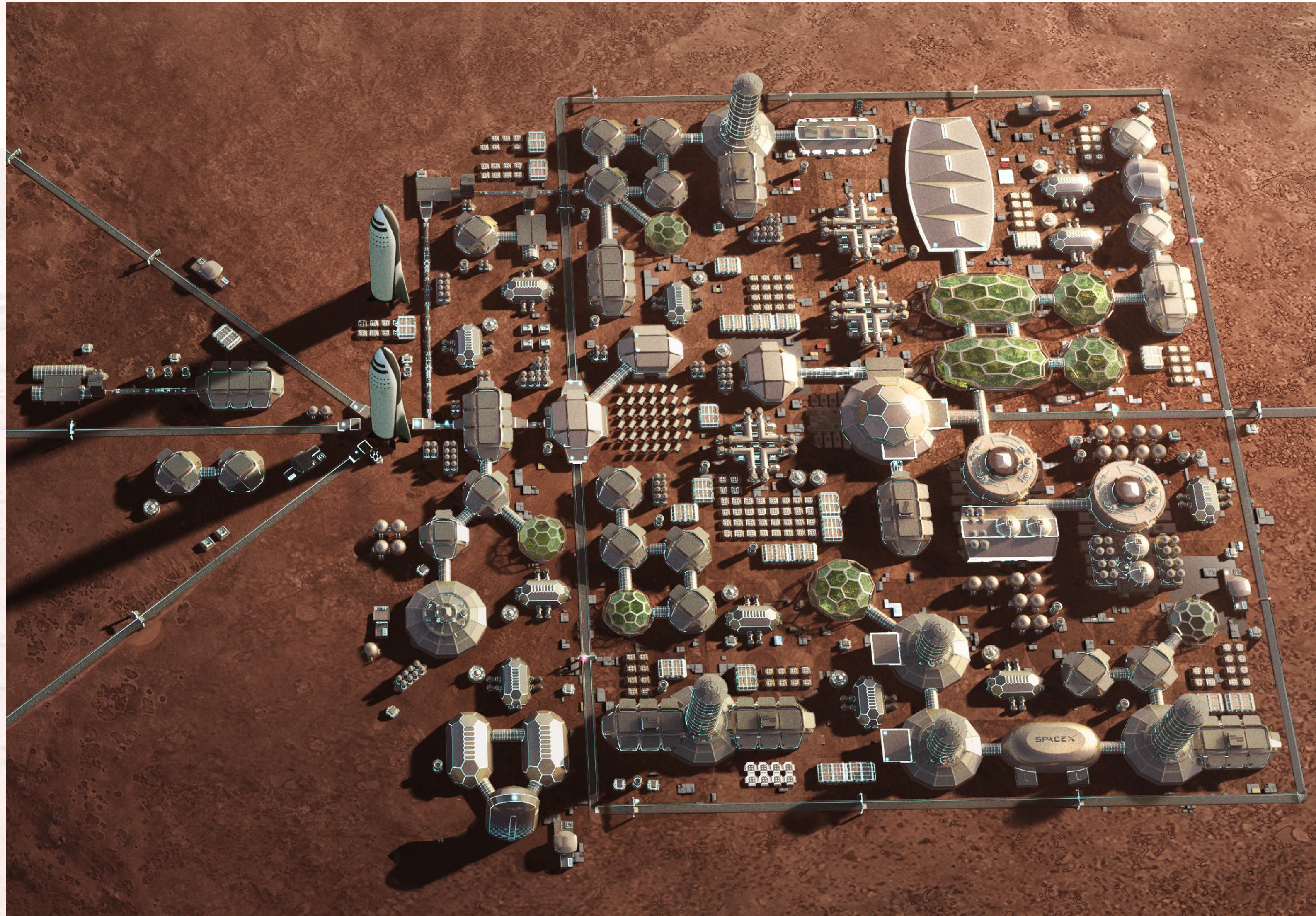




# The First Base on Mars



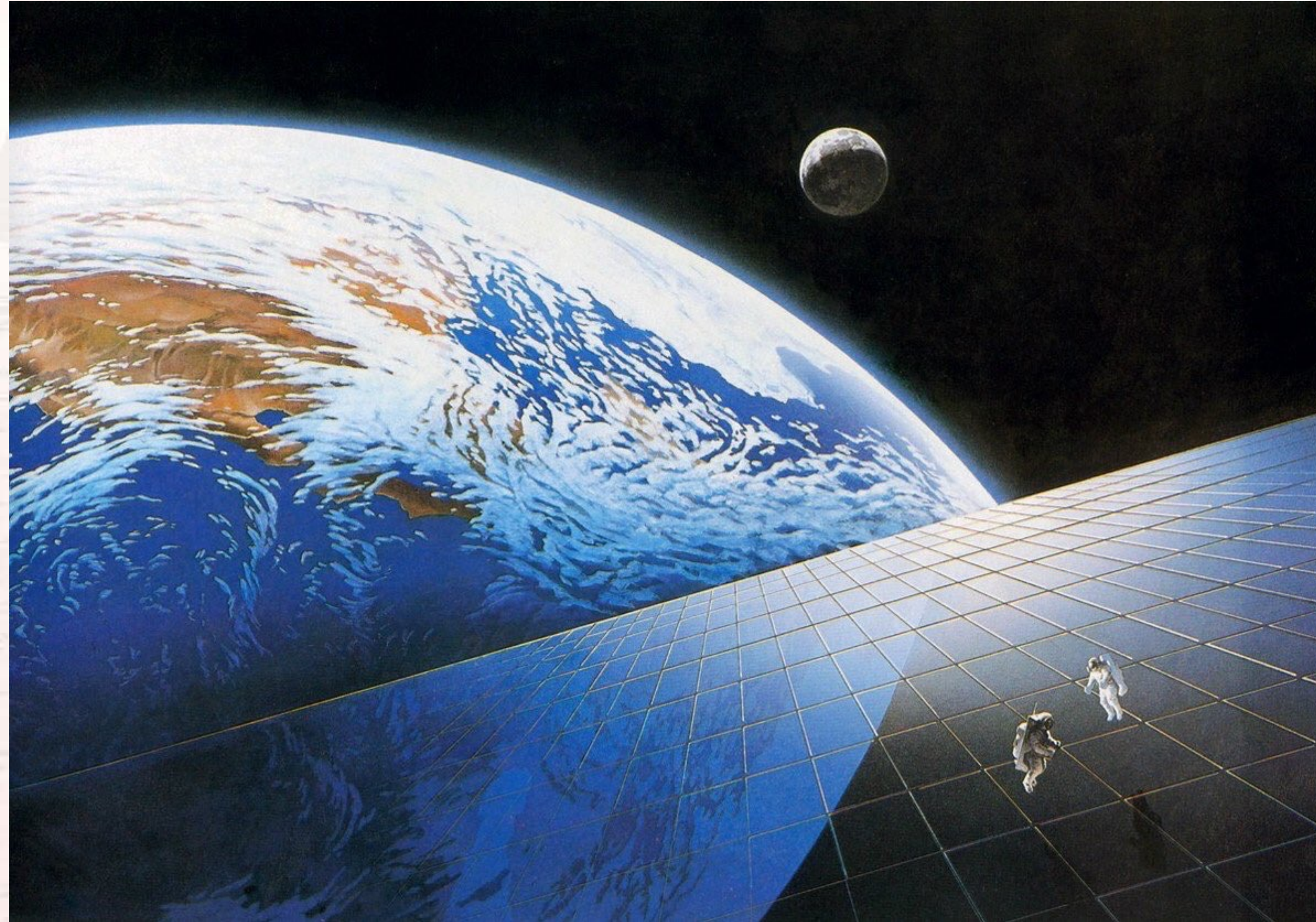
# The First City on Mars



# Mars as a Second Abode for Humans



# Satellite Solar Power Stations



# The Moons of Saturn



# A Future Winter's Day?



# Humans on Titan



# Humans on Venus

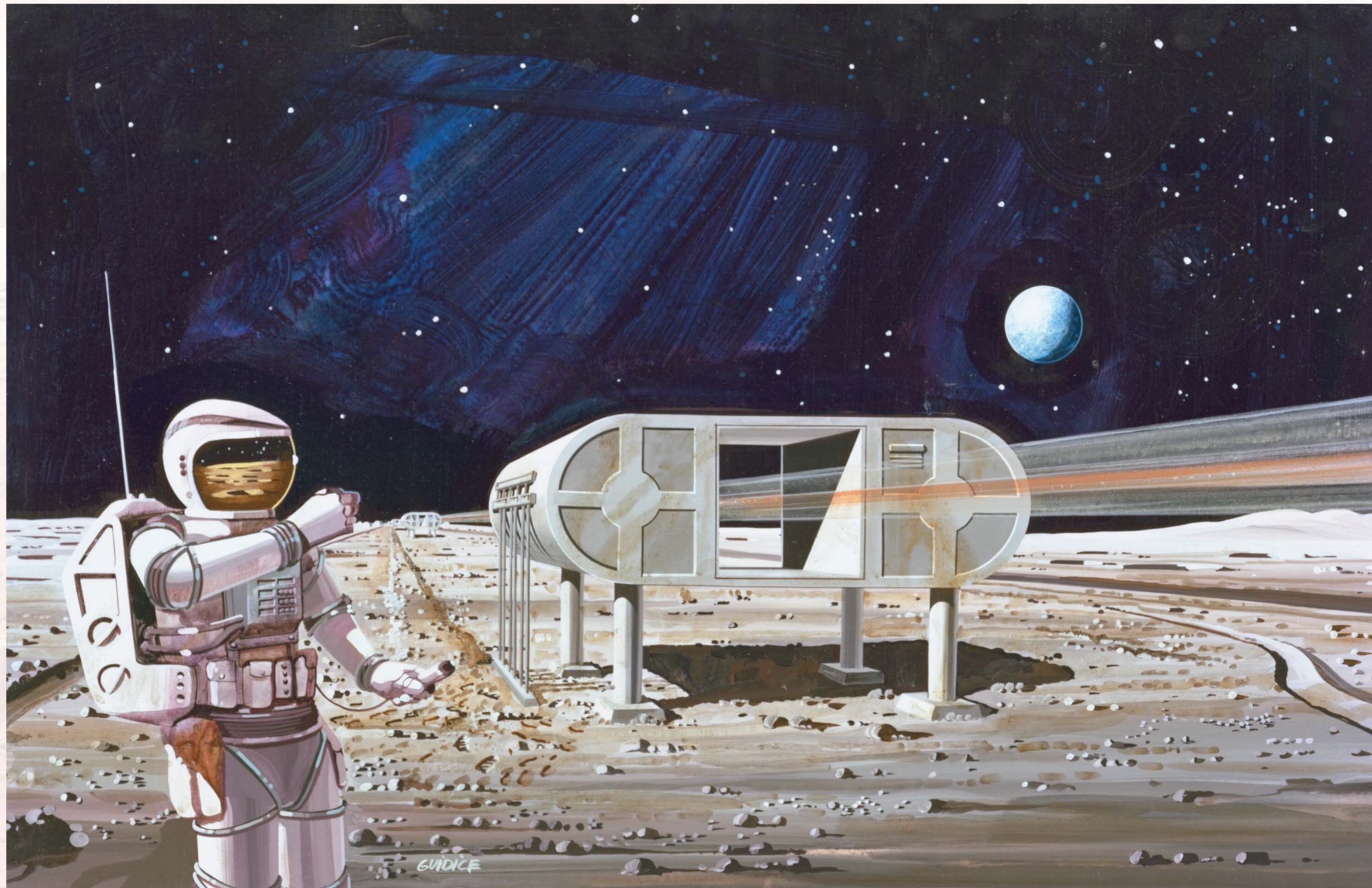




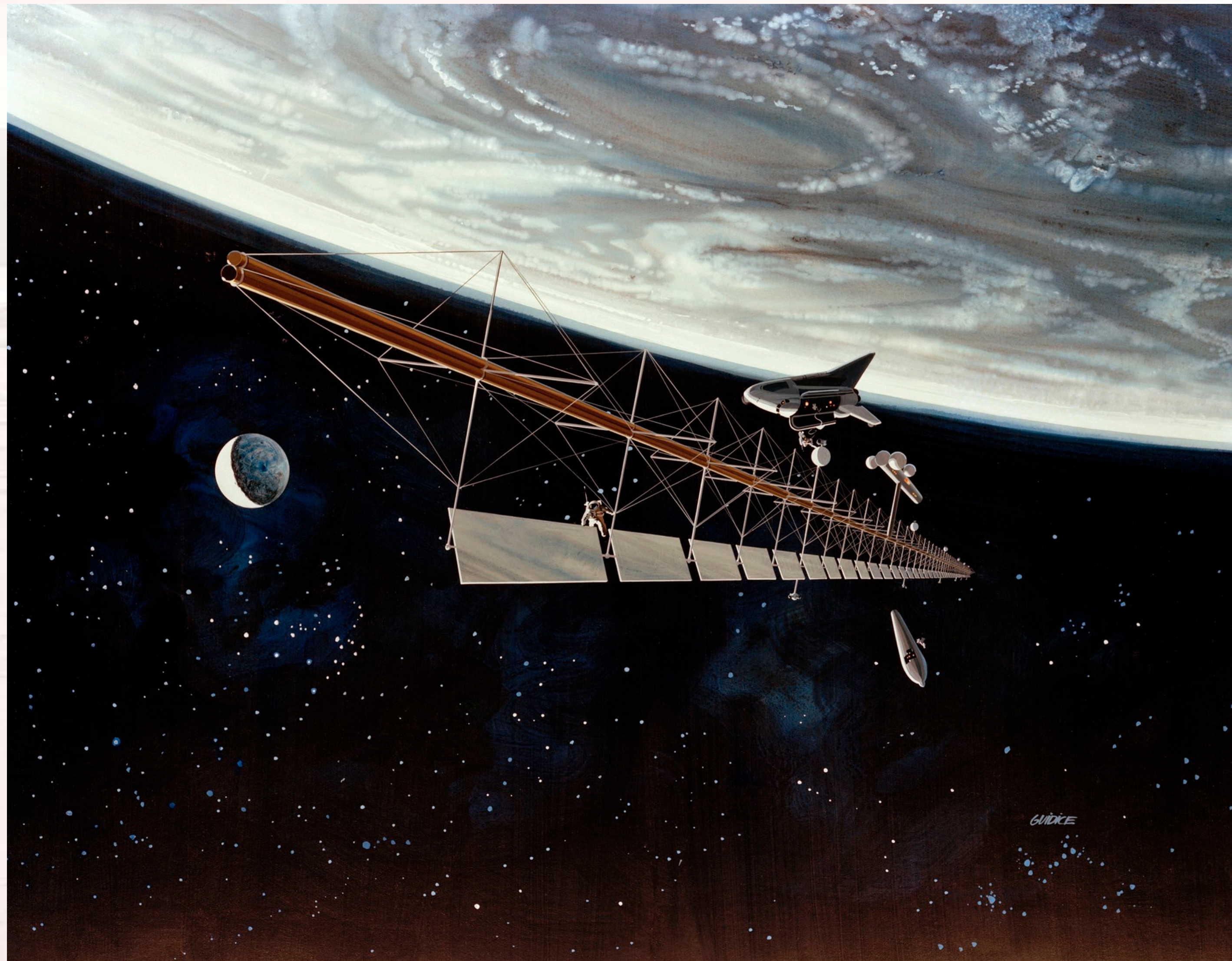
# Lunar Industrialization



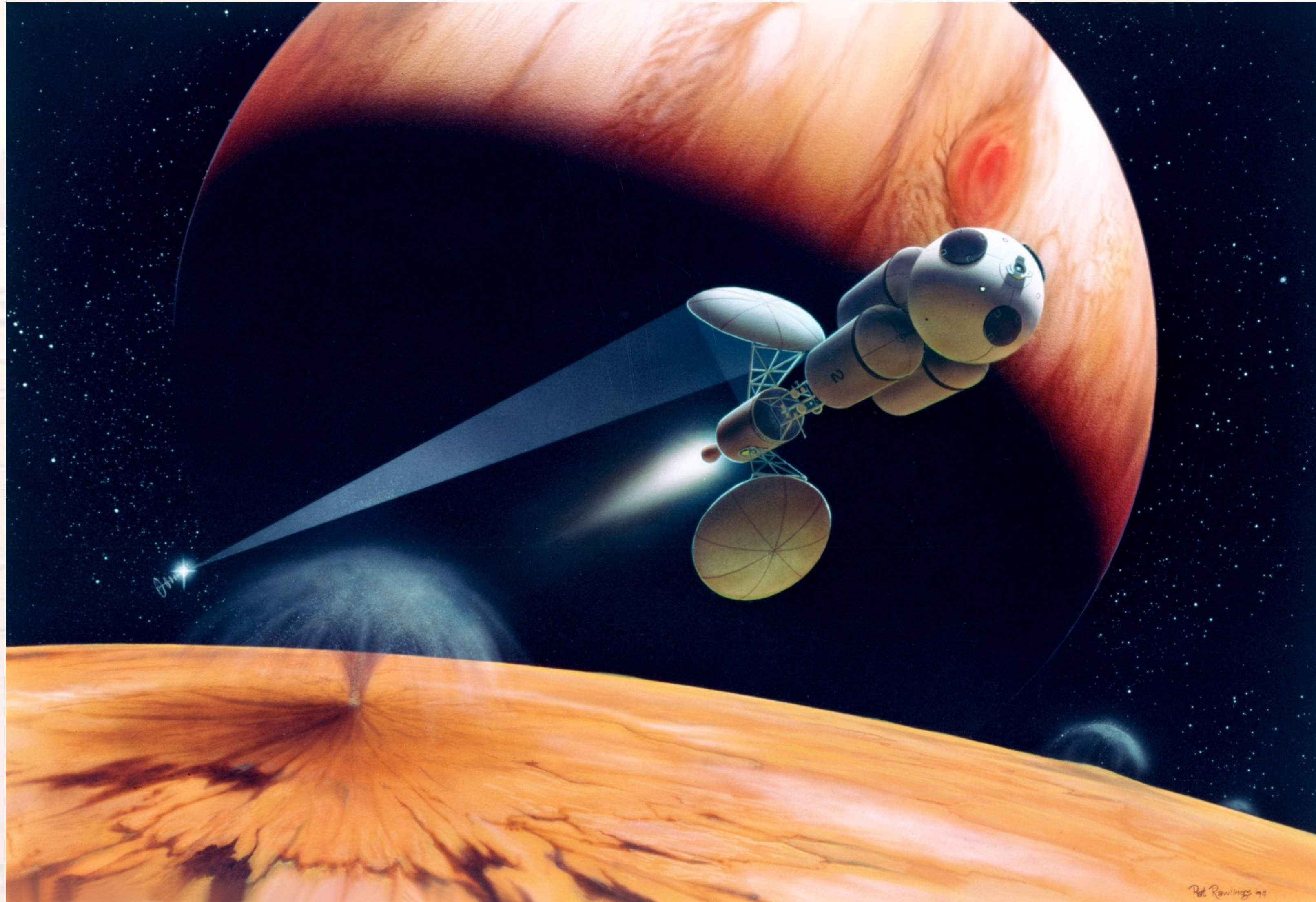
# Lunar Mass Driver



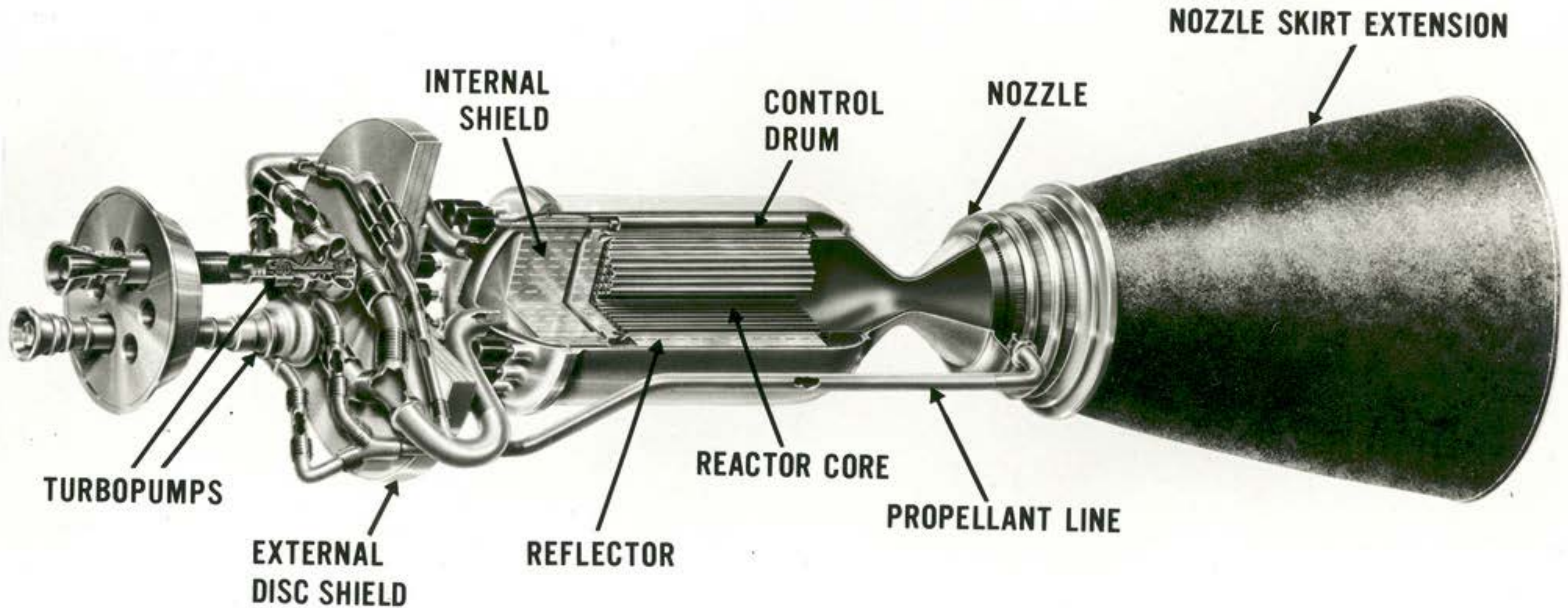
# Mass Driver Vehicle



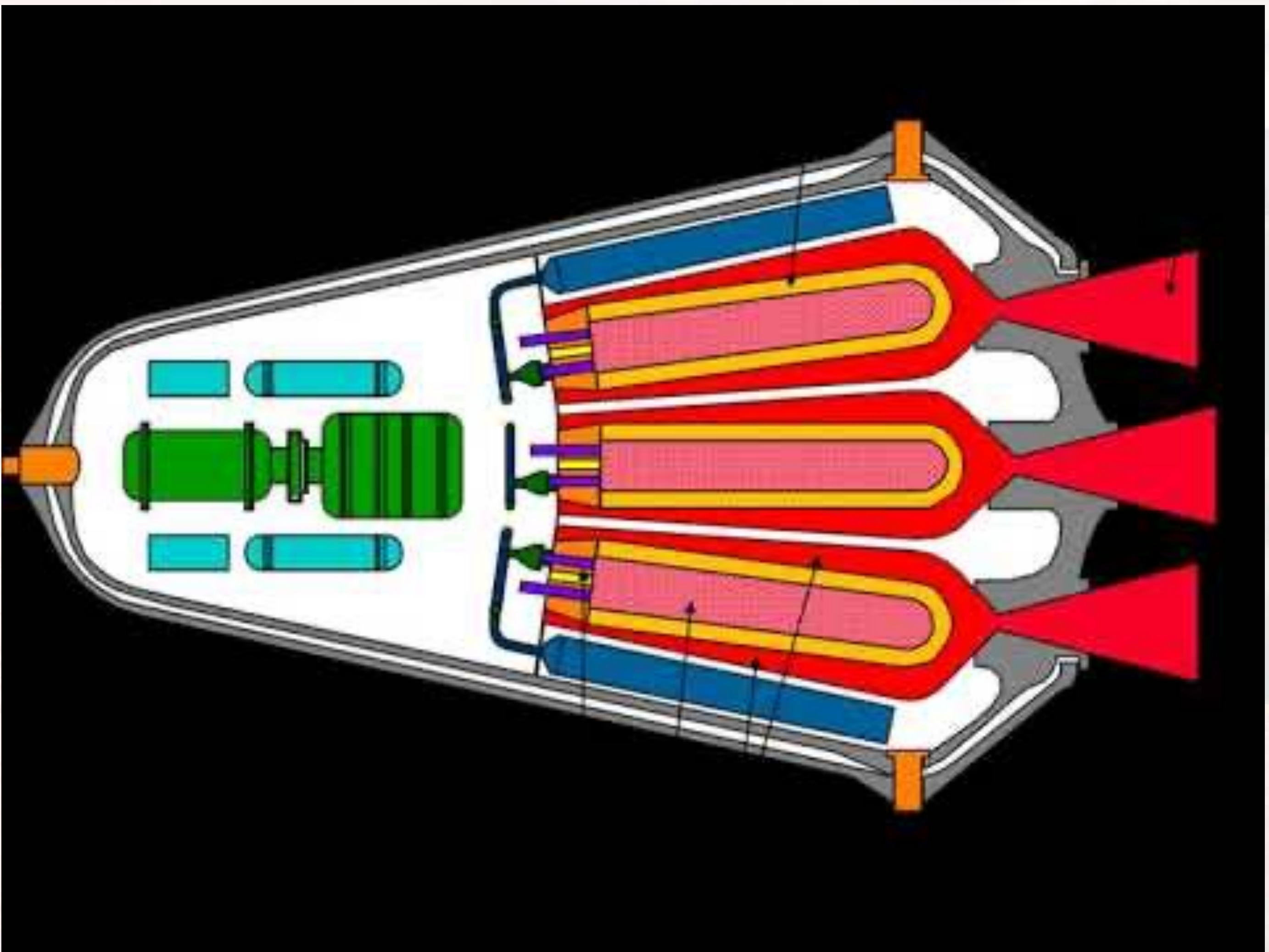
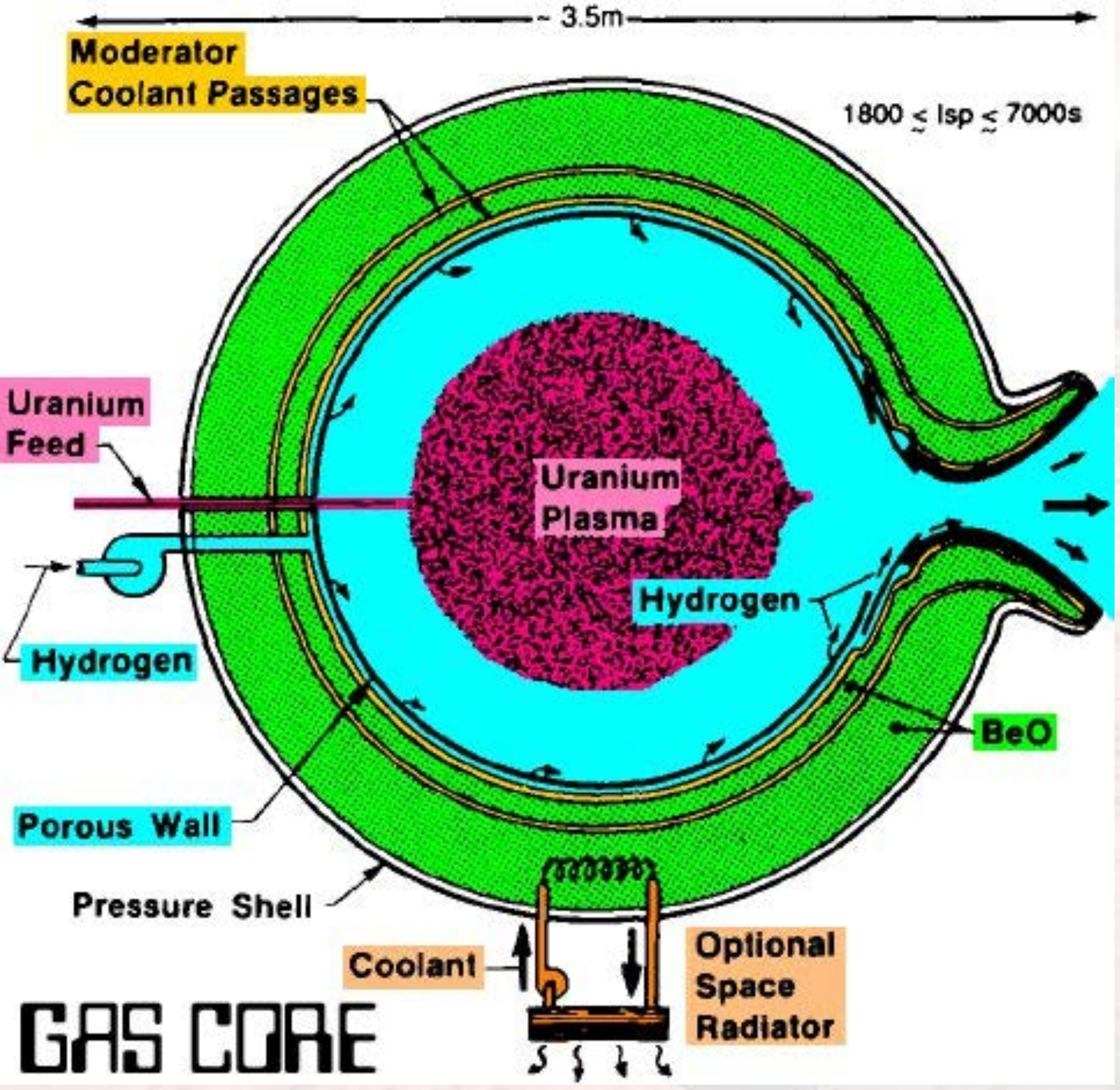
# Laser Propulsion System



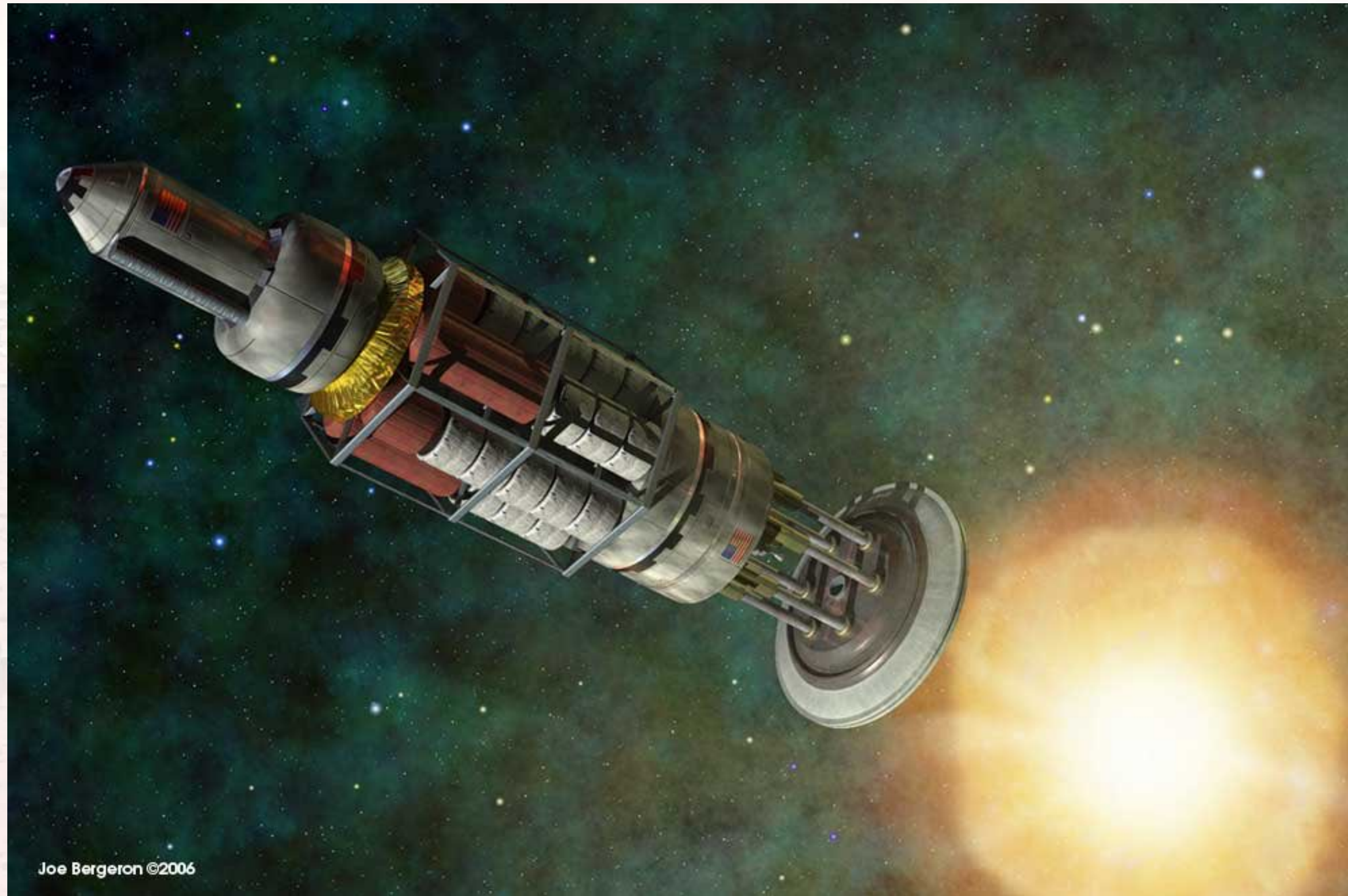
# Nuclear Thermal Rocket Engine



# Gas Core Nuclear Rocket Engines



# Orion Nuclear Impulse Drive



# Benefit to a Multiplanetary Species

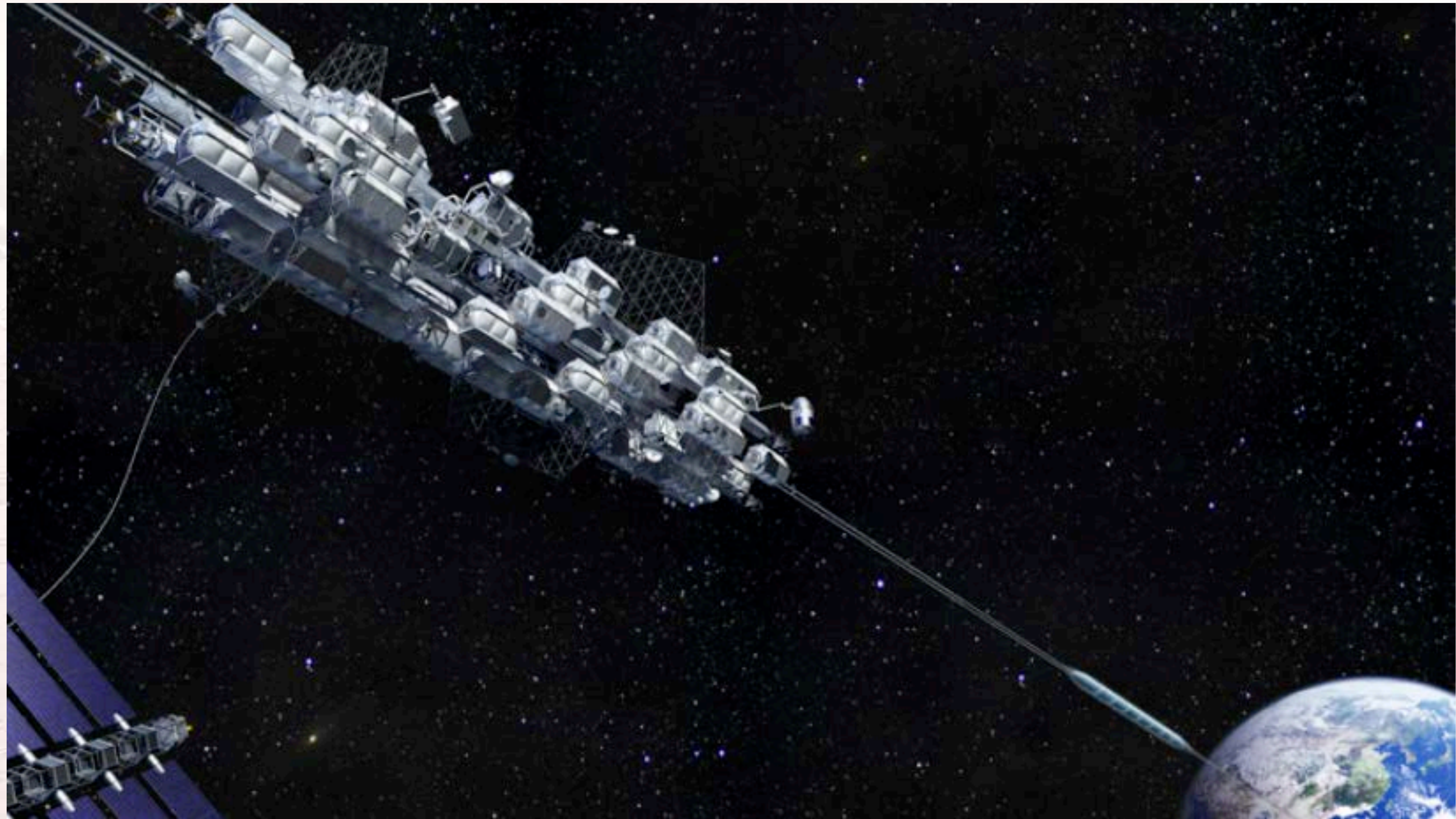




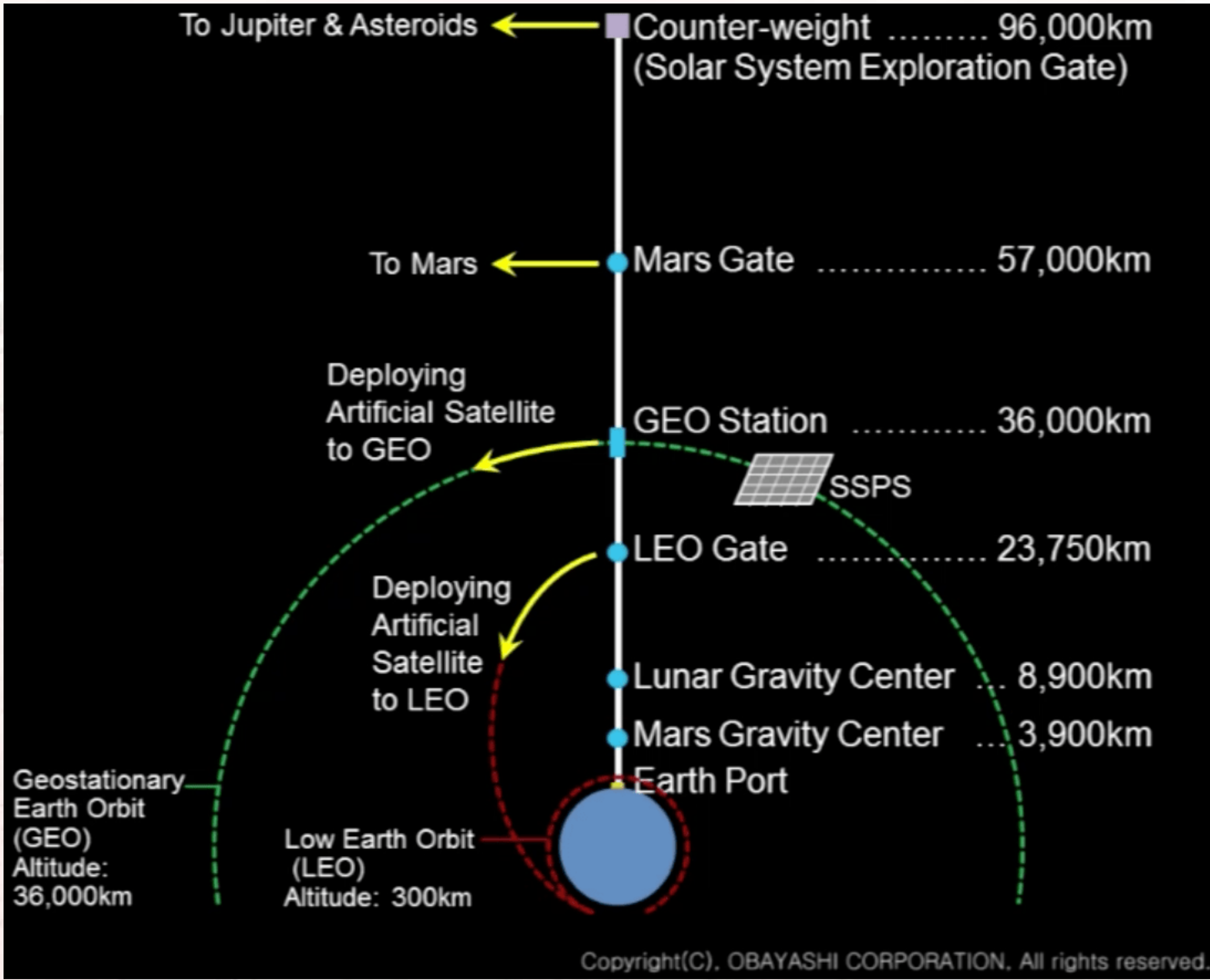
# Laser Launch Systems



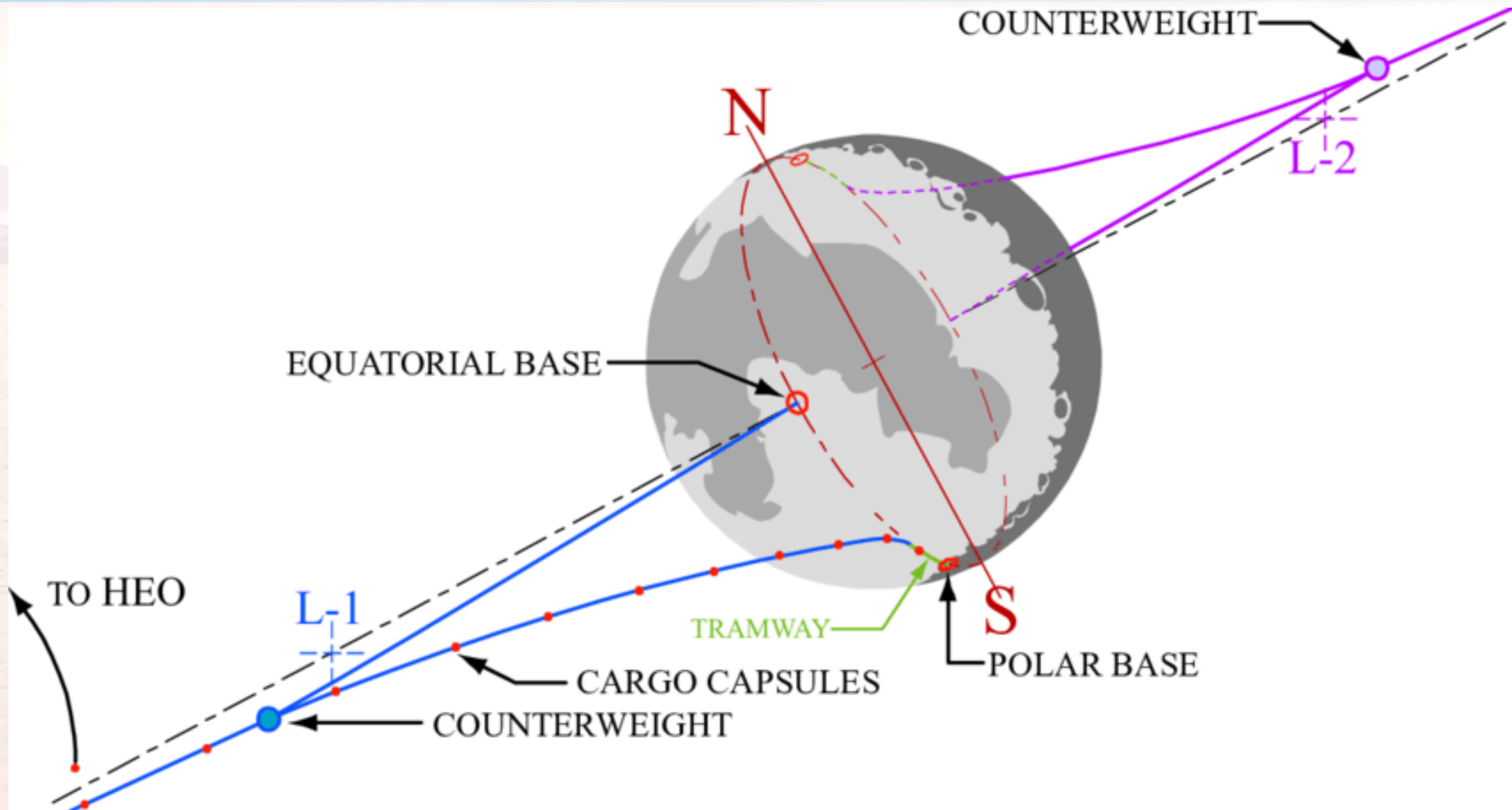
# Space Elevators



# Space Elevator Schematic



# Lunar Space Elevator Concept



# The Origins of Space Settlements

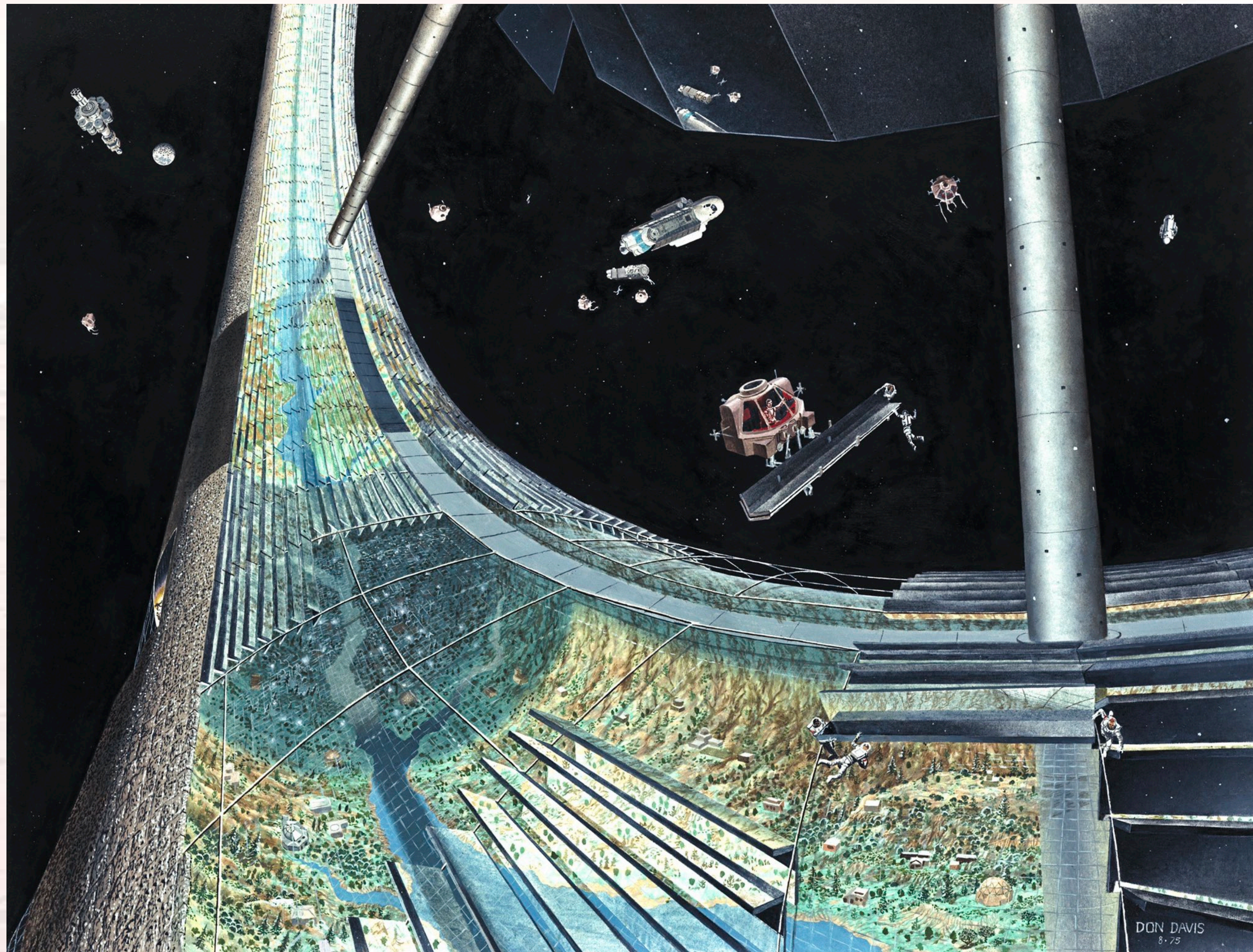
“A number of rockets orbiting the Earth, with all the equipment needed to enable rational beings to exist, might serve as a base for the further dissemination of humanity.”

– Konstantin Tsiolkovskiy, 1911

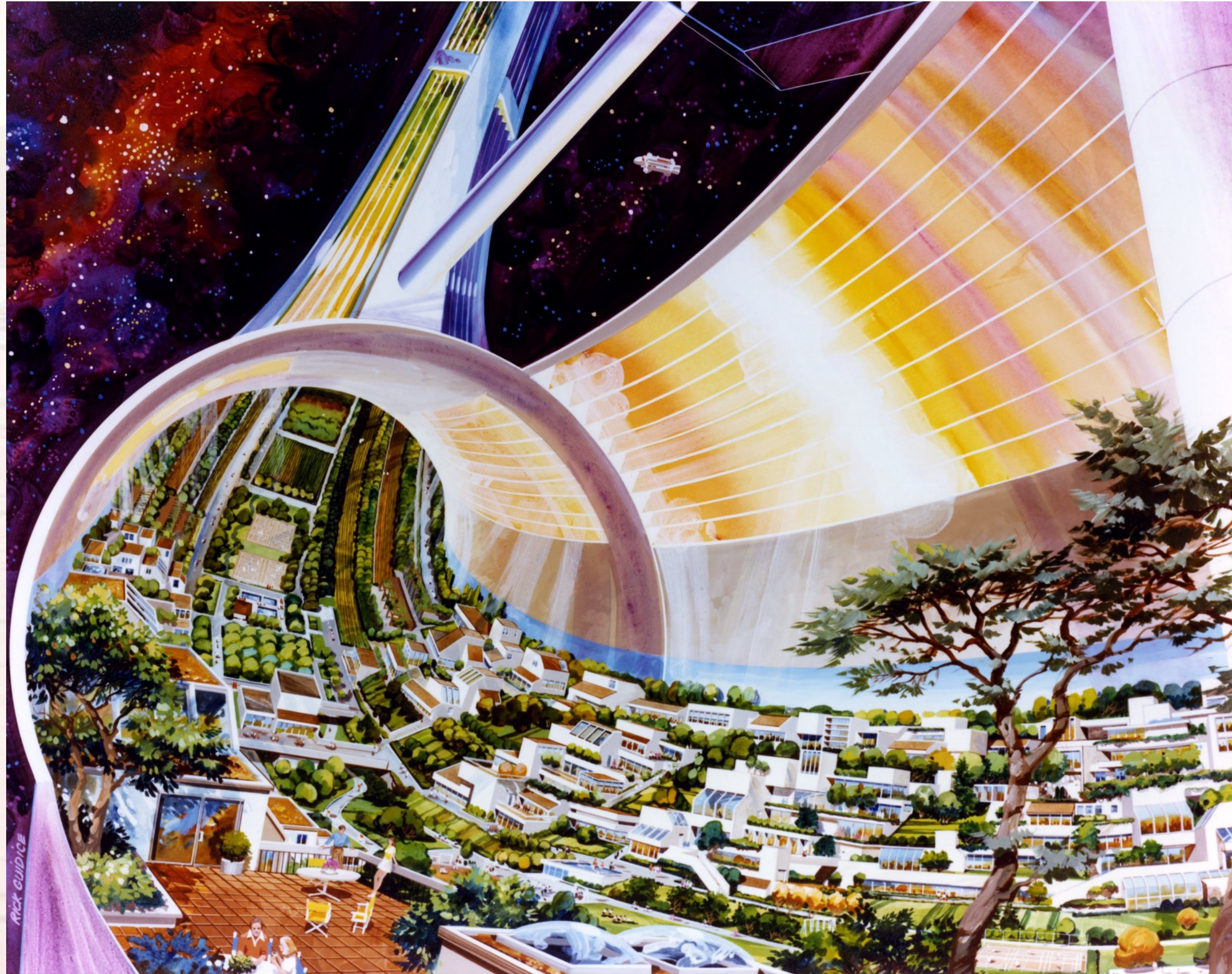
“Is the surface of a planet the best place for human civilization?”

– Dr. Gerard K. O’Neill, 1969

# Stanford Torus



# Stanford Torus Interior

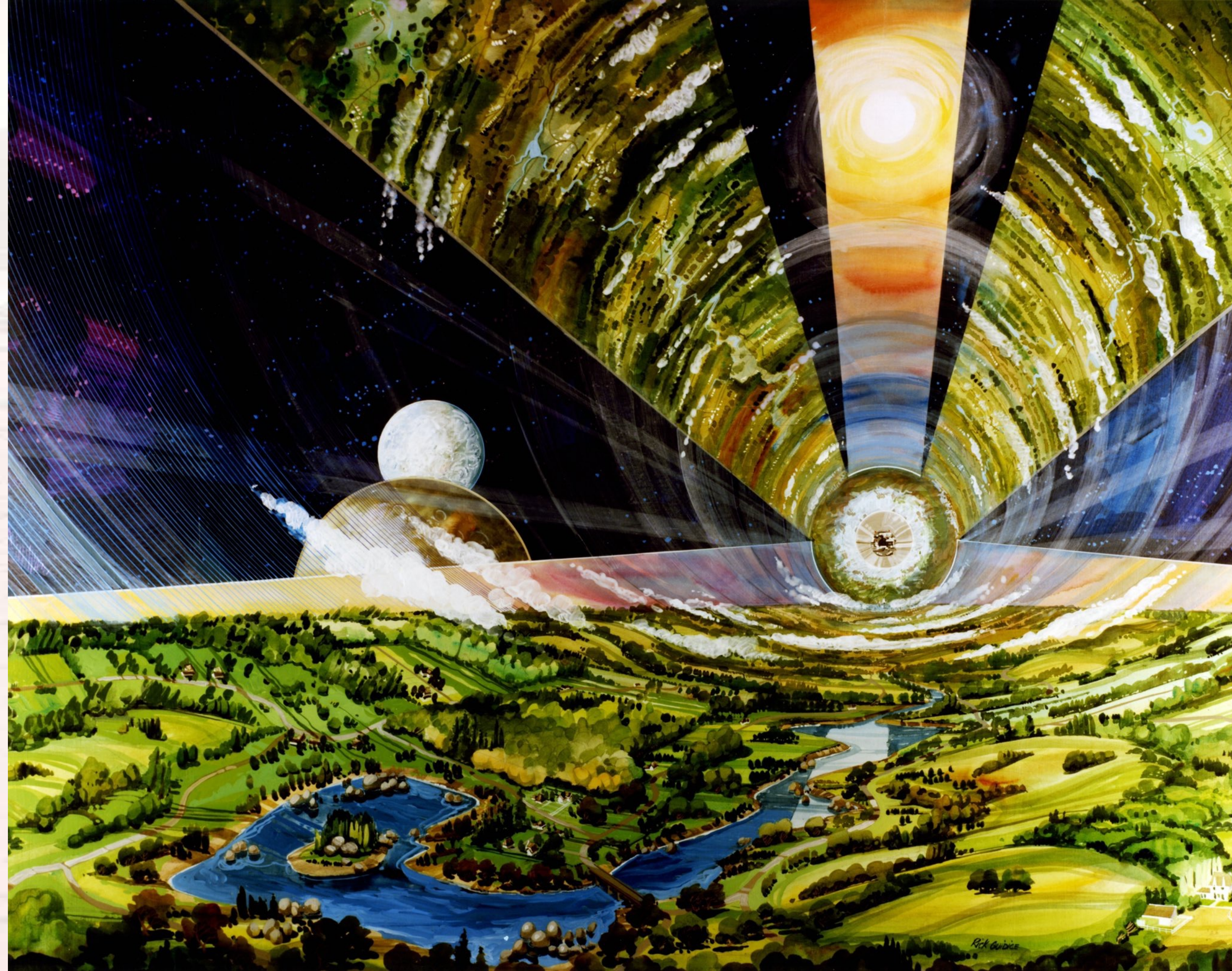


# Interior of Stanford Torus





# Interior of O'Neill Cylinder

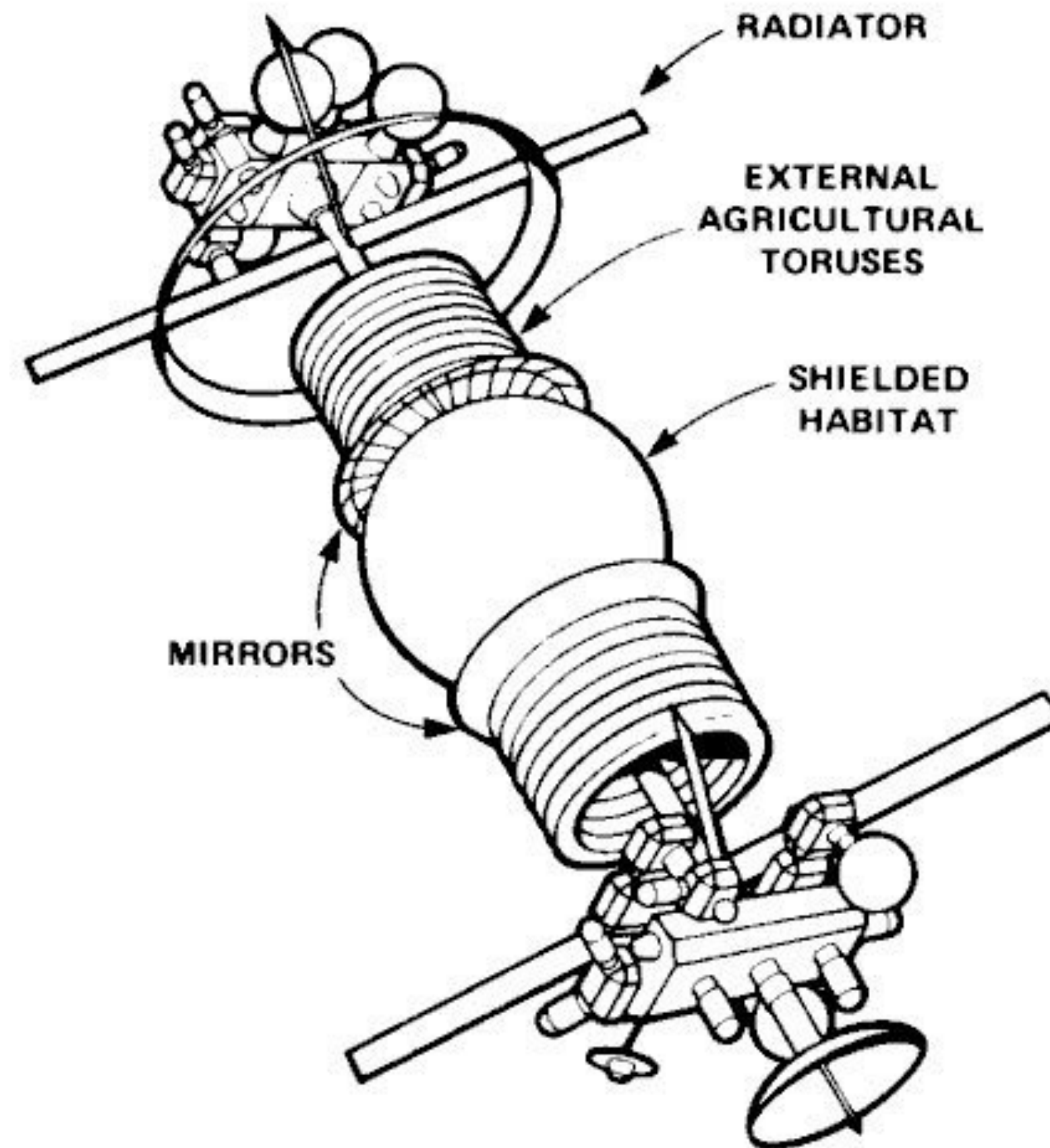


# Interior of O'Neill Cylinder

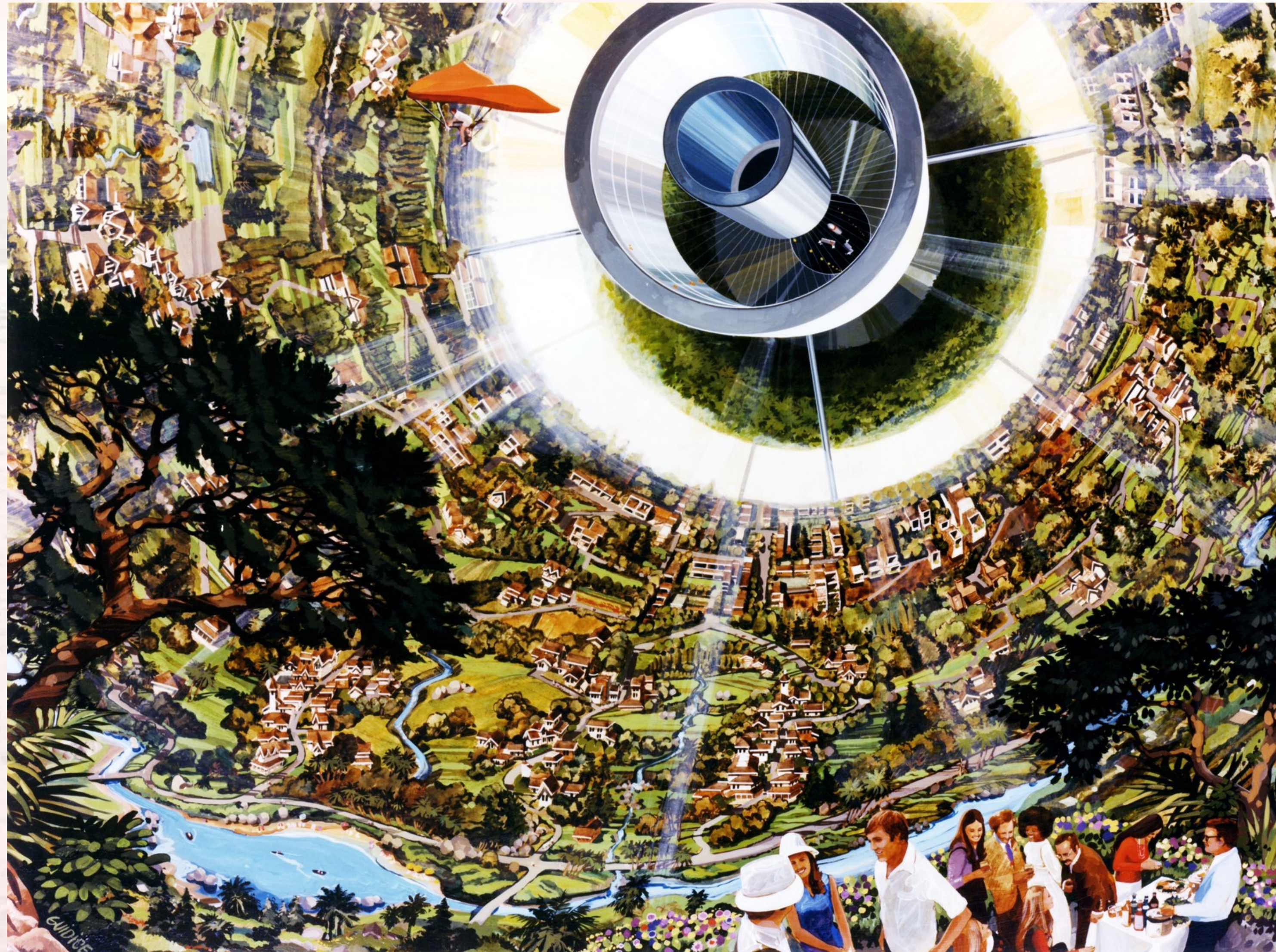


DON DAVIS  
8.75

# Bernal Sphere

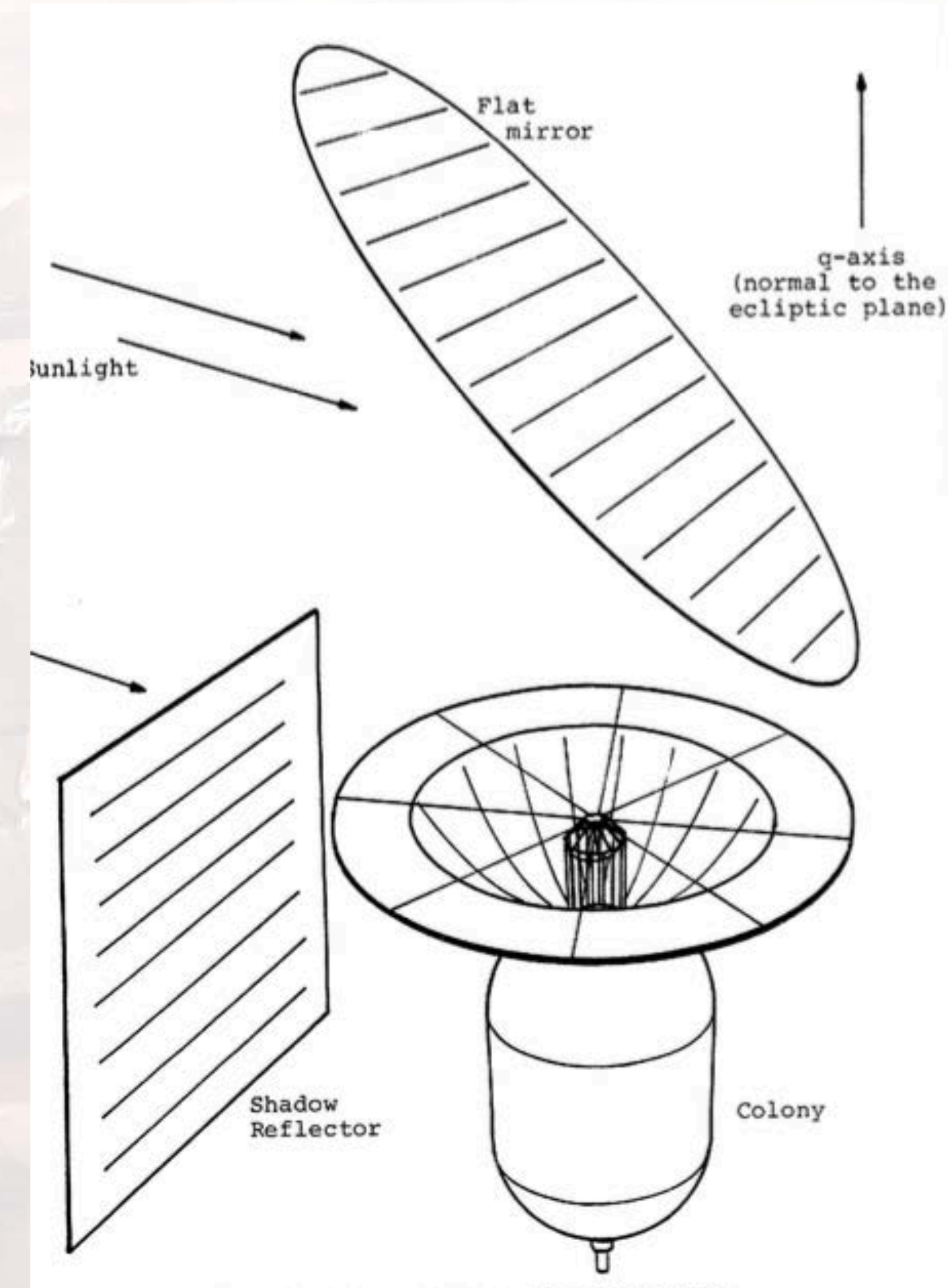


# Interior of Bernal Sphere

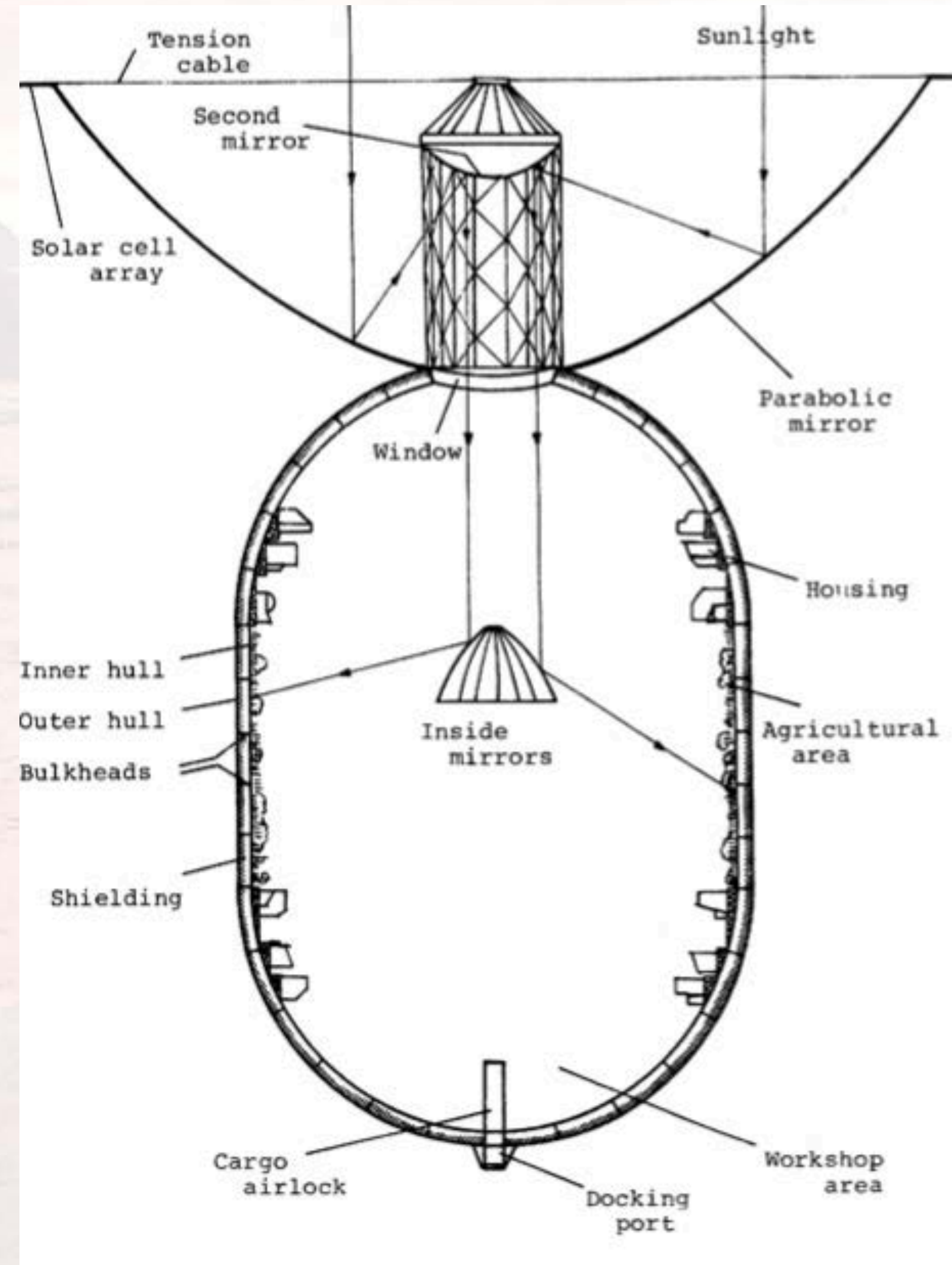
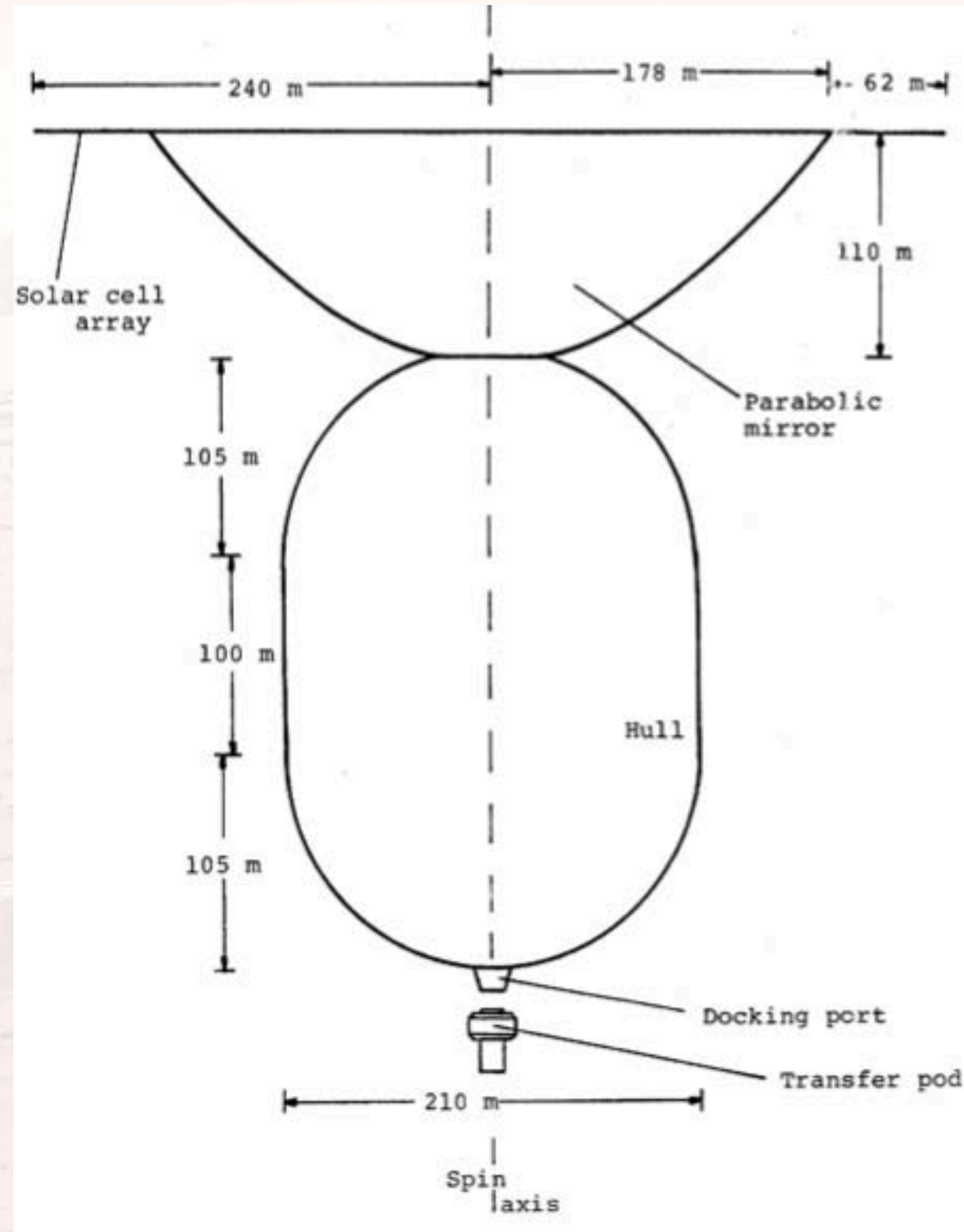


# MIT Prototype Space Colony (1976)

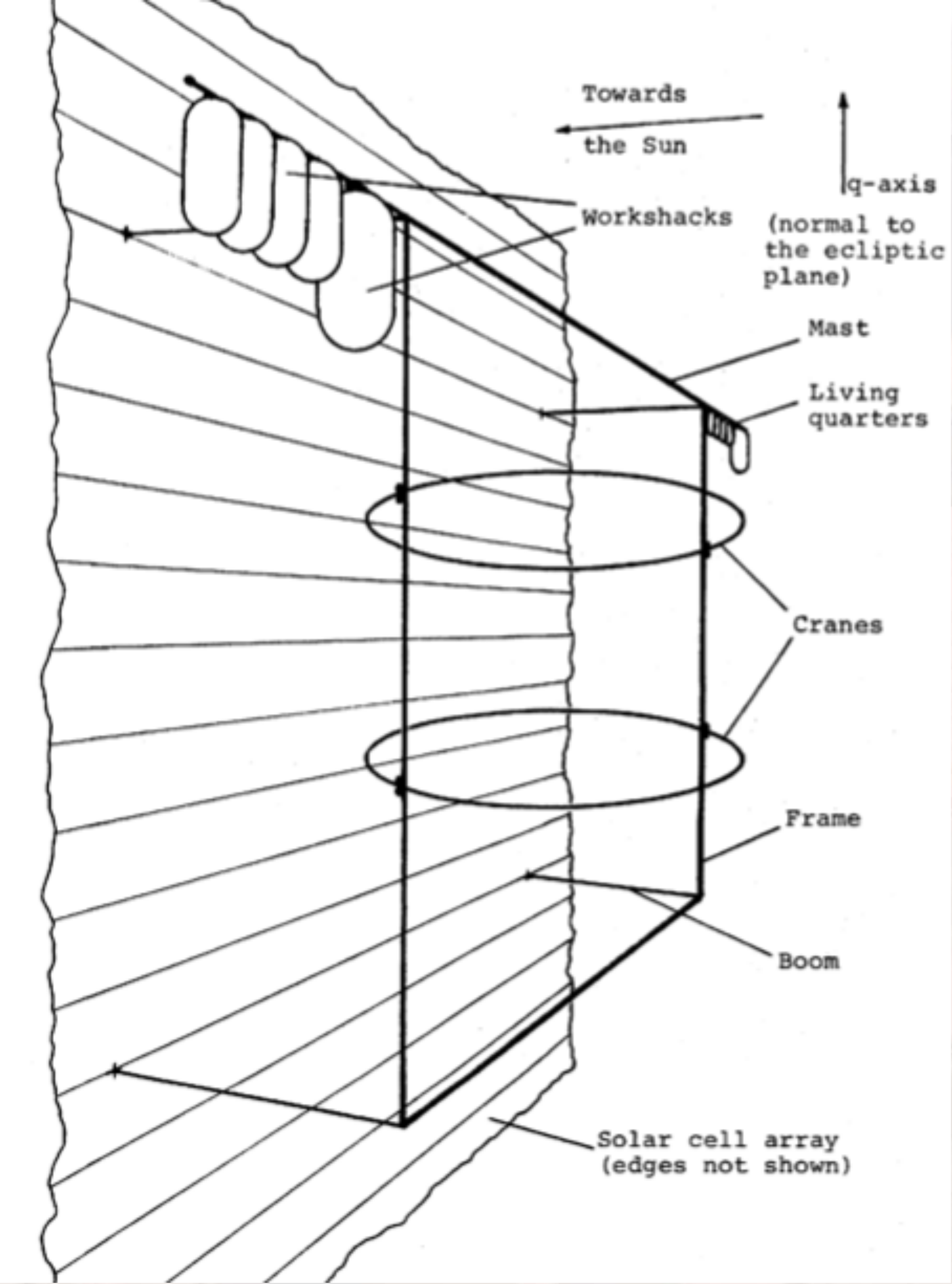
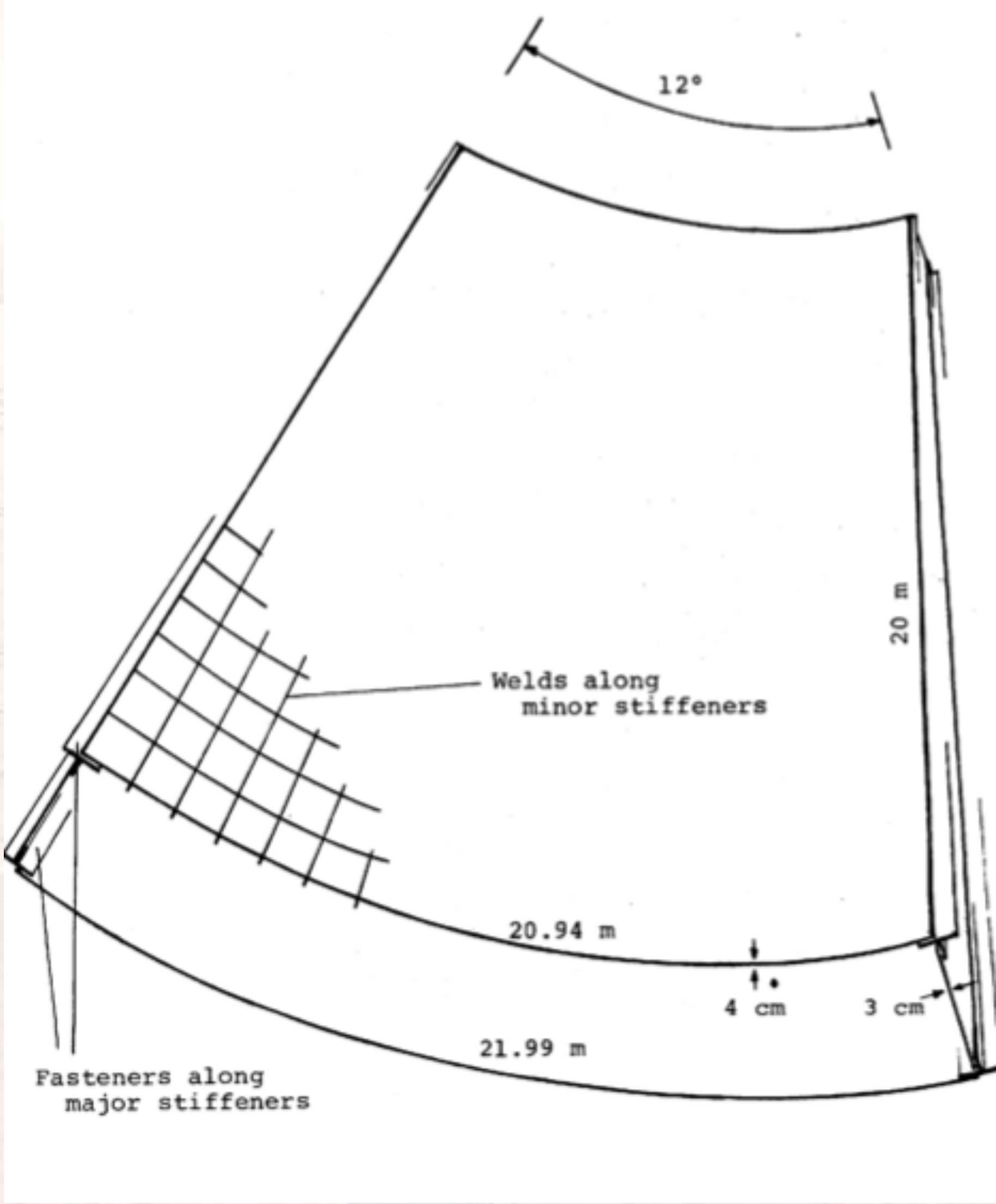
- Complement: 1000 people
- Located at E-M L5
- Focus on detailed design and fabrication scenarios
- Intended as “engineering check” on large habitats being envisioned at the time



# Habitat Dimensions and Layout



# Basic Structure and Construction Site



# Habitable Space Allocations (1)

	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total	Comments	
I.	Housing	Dwelling	Housing Stock Unit	300	117.75	(35325)	See text for explanation
II.	Education	School	Library	1	100	100	Accessible to entire colony
			Seminar Rooms	6	50	300	Media equipment
			Laboratories	4	5/person	100	Life and physical sciences
			Cafetorium	1	1/person	150	Seats 150
			Offices	5	10/each	50	Preparation, administration
			Toilets	6	20/each	120	Three sets of two
			Counseling	4	50	200	Accessible to entire colony
			Kitchen	1	40	40	For school lunches
			SUBTOTAL			1060	
			Storage	1		150	
			Circulation	15%		190	
			SUBTOTAL			1400	
		Town Meeting	Plaza and Stage		.75/person	750	In Colonyville Center
			TOTAL			2150	
III.	Active Sports	Tennis	Courts	8	12x35	3360	
		Track	Gravel Path	2	5	10	At edge of agriculture area
		Swimming	Pool	2		100	One wading, one full size
		Basketball	Gym Area	1	35x20	800	Multipurpose
		Volleyball	Gym Area	1	10x20		Gym area for 4,5
		Squash	Court	3	6x10	180	
		Handball	Court	3	8x15	360	
		Weightlifting	Lifting Area	1	50	190	Subdividable
		Wrestling	Room	1	100		Gym area for 8,9,10
		Fencing	Room	1	80		
			SUBTOTAL			5000	
			Storage			150	
		Clubhouse	Lockers	2	2/capita	250	
			Lounge/Spectator	2	1/person	50	
			Circulation	15%		850	
			TOTAL			6300	

6.127



# Habitable Space Allocations (2)

	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total Area	Comments	
IV.	Spectator	Ballet, Opera	1		450	Seats 300, full stage.	
		Drama,					
		Chamber Music	1	1/person	150	Seats 150	
		Movies,					
		Lectures					
			Cafetorium*				listed in school program, see II
			Dressing Areas	2	2/person		One per sex, adjacent to 1,2
			Theatre Shop	1	200	200	Adjacent to 1,2
			Stage Control	1	10	10	Lighting, curtains, for 1,2
			SUBTOTAL			810	
			Storage			90	
			Toilets	4	20	80	Two sets of two
			Lobby-Tickets	1	1/person	25	Adjacent to 1,2
			Projection Room	1	10	10	For 3.
	Circulation	5%		50			
	TOTAL			1065			
V.	Active Cultural	Ballet,	1	20x10	200	Mirrors, etc.	
		Opera	1	75	75	Piano, audio visual	
			1		25	For 1,2	
		TV	1	100	100		
			1		10		
			2	10/each	20		
		Radio	2	10/each	20		
			1		20		
		Movies	1		20		
			1	10/each	10		
			1		15	For 3,4,5,6	
			5	10/each	50	For 1-5	
		Newspaper	1		20		
			1		20		
		Photography				Uses TV studio	
			3	5/each	15		
			1	2.5/person	10	4 enlargers	
			1	5	5	Movies, etc.	
			1	10	10		
			1	20	20	For exhibition	
	SUBTOTAL			665			
	Sculpture	1	50	50			
	Painting	1	50	50			

6.128



# Habitable Space Allocations (3)

	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total Area	Comments	
V.	Active Cultural	Ceramics	Studio	1	50	50	
			Kiln	1	5	5	For 10
			Welding Shop	1	10	10	For 8
			Storage	1		20	For 8,9,10
			Gallery	1			Same as photography
		Gardening	Greenhouses	3	50	150	Adjacent to agriculture area
			Storage	3	5	15	For 11
			SUBTOTAL				1015
		Restaurateur	Restaurant	3	1.5/person	115	Three types of earth-regional cuisine
		Baker	Bakery	2	25	50	Two types of earth-regional bakeries
		Architecture	Studio -				
		Int. Design	Office	1	25	25	Reproduction services
		Carpenter	Shop	1	40	40	Storage
		Electrician	Shop	1	25	25	Storage
TOTAL					1270		
VI.	Religion	Worship	Chapel	3	40	120	Some interdenominational
			Offices	3	10	30	For clergy
			Storage	3	5	15	Separate compartments
		Education	School*				Uses spaces of II
		Funeral	Viewing	1	15	15	
			Holding	1	20	20	Coordinate with mortician
		TOTAL					200
VII.	Entertainment	Disco	Nightclub	1	1/person	100	
			Toilets	2	5/each	10	One set of two
		Drinking	Bar	2	50	100	
			Toilets	4	5/each	20	Two sets of two
		Pool	Pooltable	3	25	75	
			Storage	1		40	For 3,4,5,6 .
		Pingpong	PP Table	3	50	150	
			Toilets	4	10/each .	40	Two sets of two for 3-6
		Bowling	Bowling Lanes	4	30	120	
			Lobby			10	For 3,4,5,6
Shuffleboard	Court	2	35/each	70			
Bingo	Cafetorium*				Uses space in II		

6.129

# Habitable Space Allocations (4)

	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total Area	Comments		
VII.	Entertainment	Plants	1	25	25	Storage & refrigerators Differing lines of apparel Storage included Storage included Three meditation rooms along with general observation deck		
		Clothing	3	35	105			
		Health	1	25	25			
		Beauty	2	35	70			
		Lookout	1	3@5, 1@20	35			
		TOTAL					995	
VIII.	Service Professionals	Inpatient Treatment	Hospital	1	15	15		
			Library	10	12/bed	120		
			Beds	2	5/each	10		
			Nurse	4	30	120		
			Emergency	4	20	80		
			Radiology Room	4	40	160		
			Surgery-OBS	4	12/bed	50		
			ICU-Recovery	4	5/person	20		
			Laboratories	1	1/person	15		
			Dining Room	1	10	10		
			Kitchen	1	50	50		
			Administration Area	1	50	50		
			Materials Handling	1	50	50		
			PT/OT	1	50	50		
			Offices	5	10	50		
		SUBTOTAL				800		
		Outpatient Treatment	Clinic	4	10	40		In program for Inpatient Two sets of two In program for Inpatient
			Diagnostic	2	10	20		
			Dental	1	5	5		
			Administration*	4	5	20		
			Files	2	15	30		
Toilets								
Eye Laboratories*								
SUBTOTAL				915				

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# Habitable Space Allocations (5)

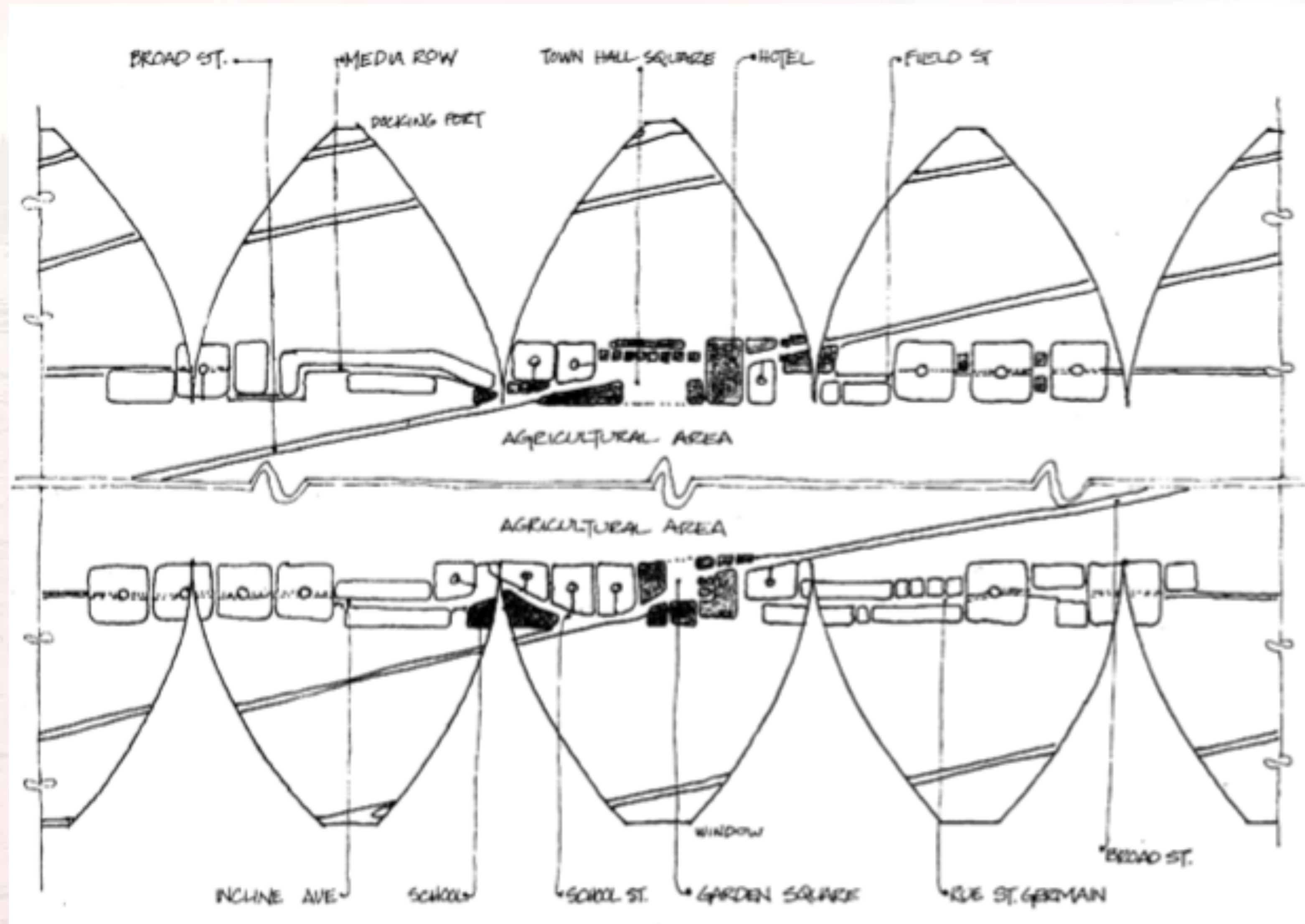
	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total Area	Comments	
VIII. Service Professionals	Emergency	Equipment Room	1		20		
		Control Room	1		10		
		Detention	1		10		
		Toilets	2	5	10	One set of two	
		Fire Suppression Equipment Room	1		30	One per 10 housing units	
		Oxygen Stock	40	5	200	Agriculture area	
		SUBTOTAL				1195	
		Guest Housing	Hotel				
	Guest Rooms		50	32/room	1600	100 people total	
	Desk/Lobby		1	20	20		
	Restaurant/Bar		1	1.5/person	310		
	Housekeeping				150		
	SUBTOTAL				3275		
	Communication	Radio/Telephone/Teletype	1		20	For personal communications coordinated w/colony control	
		SUBTOTAL				3295	
	Mortician	Prep Room	1	15	15		
		Refrigeration	1	30	30		
		Housekeeping	1	5	5		
		Storage	1	10	10		
		SUBTOTAL				3355	
	Sanitation	Collection Areas	50	5	250	One per 10 housing stock units plus others	
		Processing Area	1		100		
		Storage	1		10		
Disposal Room		1		40			
SUBTOTAL				3755			
Maintenance	Shops	2	40	80			
	Storage	2	10	20			
SUBTOTAL				3855			
Tailoring	Shop	1	25	25	Storage included		
SUBTOTAL				3880			
Cleaning	Shop	1	35	35			
	Laundries	10	25	250	One per 30 housing stock units		
	Control Shop	1		35	For hotel, hospital, public facilities		
SUBTOTAL				4200			

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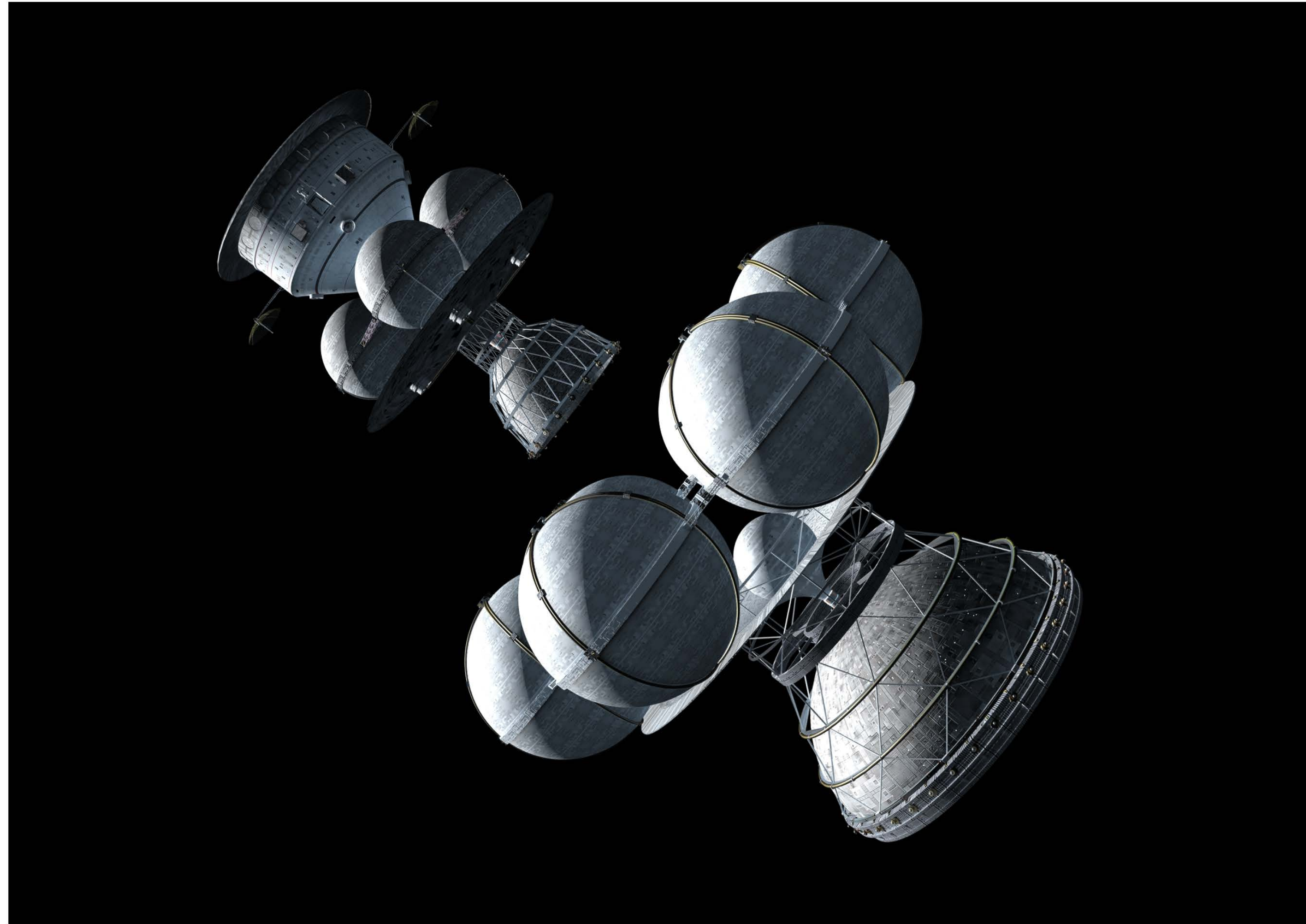
# Habitable Space Allocations (6)

	Activity	Facility	Number Needed	Size (m <sup>2</sup> )	Total Area	Comments	
VIII.	Service Professionals	Lawyer	1	15	15		
		Library	1	10	10		
			SUBTOTAL		4225		
		Accountant	Office	1		25	Storage included
			SUBTOTAL		4250		
		Financial Planner	Office	1		25	Storage included, accessible to computer systems
			TOTAL			4275	
							Category 1 35325
							2 2150
							3 6300
						4 1065	
						5 1270	
						6 200	
						7 995	
						8 4275	
						GRAND TOTAL 51580 - within 10% of design program V.3.2	

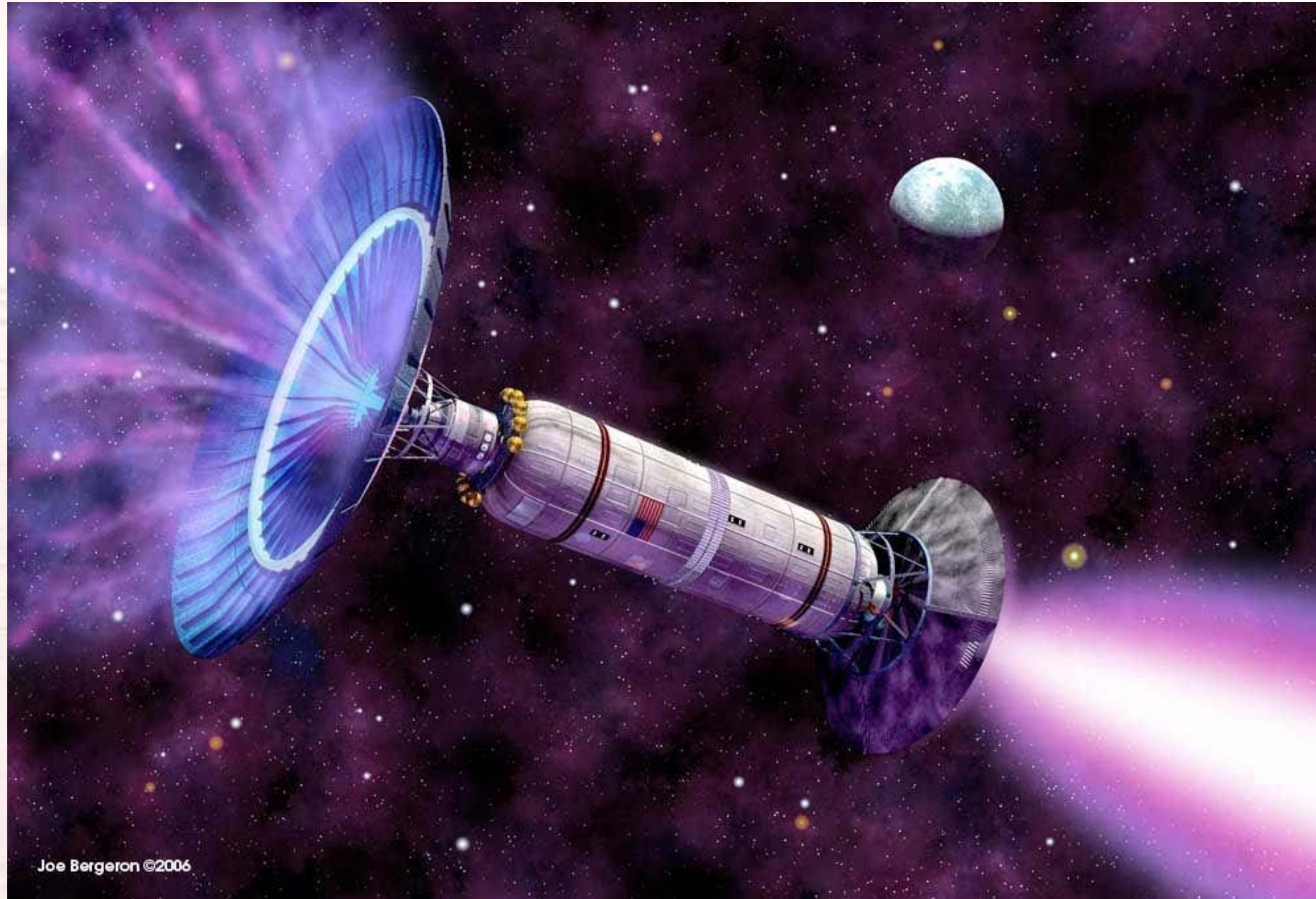
# Land Use Plan



# Laser Confined Fusion Interstellar Spacecraft



# Bussard Ramjet





# Interstellar Travel, Optimized

$$E_{travel} = 2 \times \frac{1}{2}mv^2 = mv^2$$

$$E_{living} = Pt = P\frac{d}{v}$$

$$E_{total} = E_{travel} + E_{living} = mv^2 + \frac{Pd}{v}$$

$$\frac{\partial E_{total}}{\partial v} = 2mv - \frac{Pd}{v^2} = 0 \implies v_{opt}^3 = \frac{Pd}{2m}$$

$$v_{opt} = \left( \frac{Pd}{2m} \right)^{1/3}$$



# MIT Colony to Alpha Centauri

$$d = 4.1 \times 10^{16} \text{ m}$$

$$P = 9.35 \times 10^6 \text{ W}$$

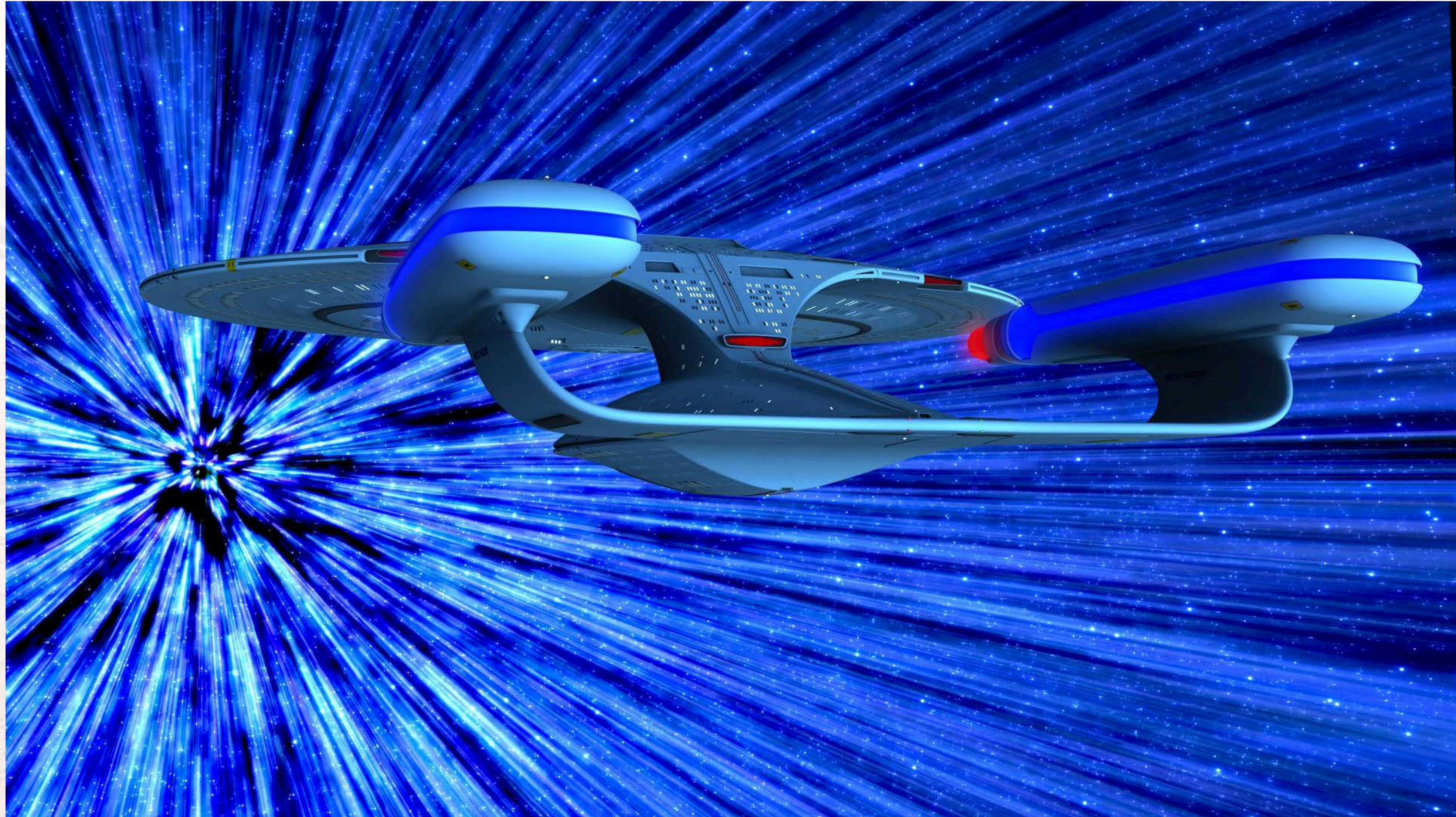
$$m = 6 \times 10^8 \text{ kg}$$

$$v_{opt} = \left( \frac{9.35 \times 10^6 (4.1 \times 10^{16})}{2(6 \times 10^8)} \right)^{1/3} = 68,200 \text{ m/sec}$$

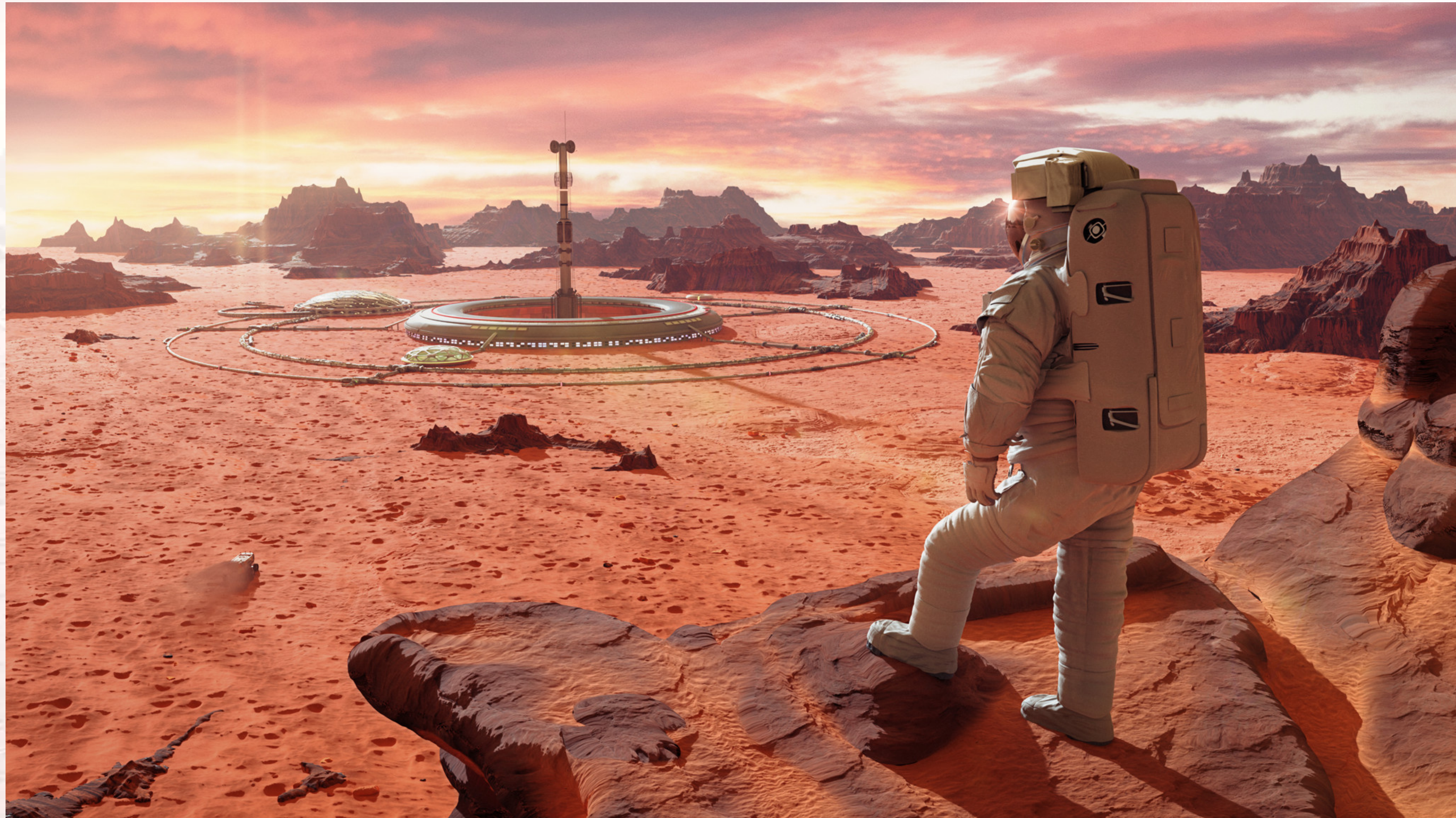
(0.02 % *lightspeed*)

*Trip duration = 19,000 years*

# Warp Drive???



# The Future is What We Make It...



# The Future is What We Make It...



Artwork by  
Michael Whelan

