«HUMANS IN SPACE» - EURAVIA NAPOLI 8 APRILE 2025

WHY BUILD A HABITAT IN AN EARTH-MOON LAGRANGIAN POINT"

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OVERVIEW

1. Living and working in the geo-lunar space, two alternative models
2. **SELENOPOLIS** – the **Krafft A. Ehricke** model
3. **ISLAND ONE** – the **Gerard K. O'Neill** model
4. Why the O'Neill's model is better for human life and health
5. The Earth-Moon Lagrange points
6. Alternatives and proposals

1

1. LIVING IN THE GEO-LUNAR SPACE, TWO MODELS

- **Krafft Ehricke** wrote several papers on the subject of an organic plan for Lunar industrialization, articulated on 5 stages, including the building of Selenopolis, the lunar city – 1970's

- **Gerard O'Neill** gave birth to the concept of Island One, a big rotating cilinder, designed to host thousands, or even millions of inhabitants, located at an Earth-Moon Lagrangian point – 1970's

TWO VISIONARY SCIENTISTS AND PHILOSOPERS

Krafft A. Ehricke 1917 - 1984
- Member of the Werner von Braun team at NASA
- Propulsion Engineer, Space Philosopher
- The Extraterrestrial Imperative, Author

Gerard K. O’Neill 1927 – 1992
- Princeton University, Teacher
- Space Studies Institute, Founder
- The High Frontier: Human Colonies in Space, Author

2

2. SELENOPOLIS, A PLAN FOR LUNAR INDUSTRIALIZATION

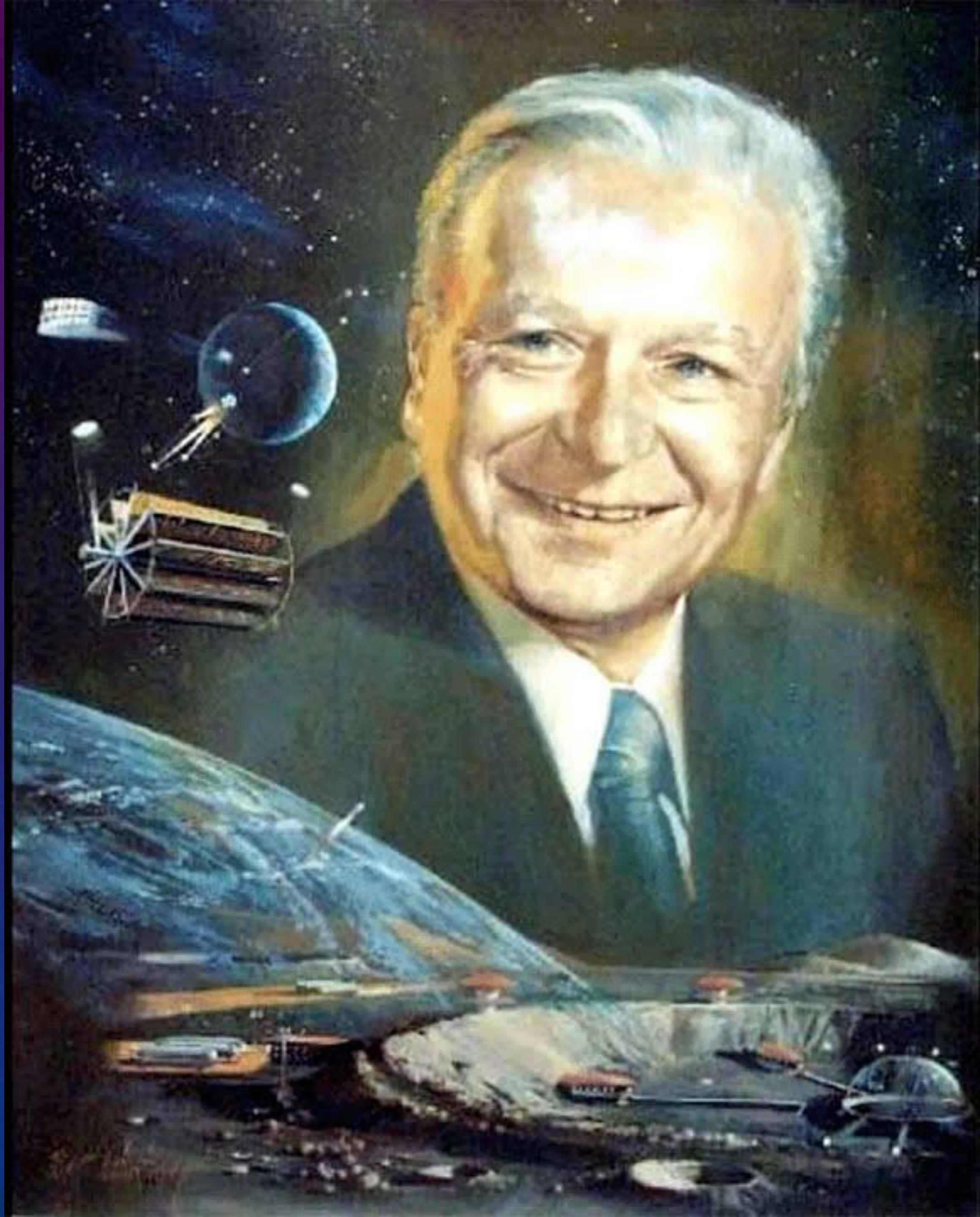
- **Krafft Ehricke: BIRTH OF A "POLYGLOBAL CIVILIZATION"**

A lunar development strategy consisting of five logical Development Stages (DS):

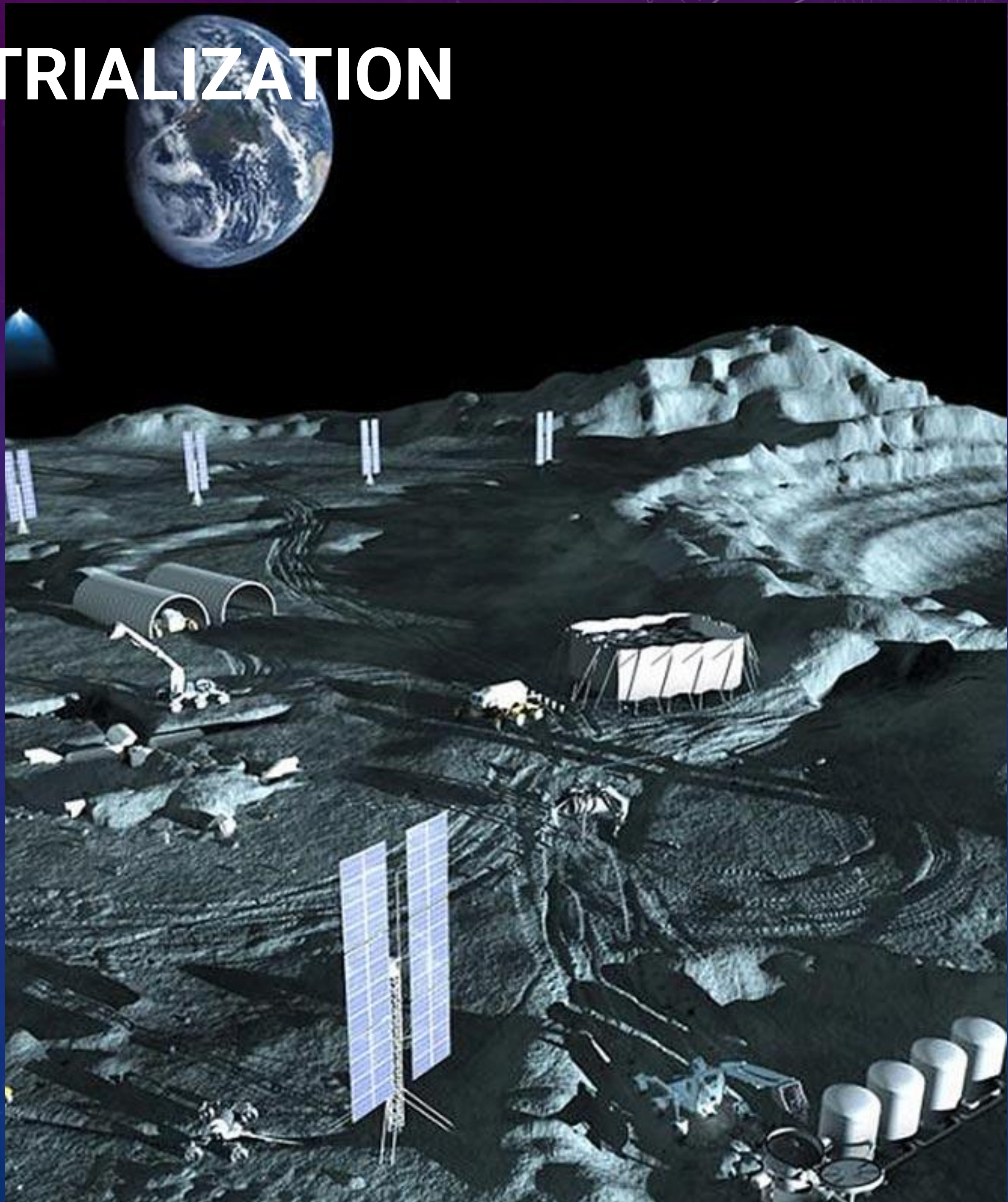
- **DS-1** synoptic prospecting for mineralogical provinces and candidate base sites.
- **DS-2** a circumlunar space station, Moon Ferry, automated laboratories, and pilot facilities including an oxygen extraction plant on the surface.
- **DS-3** a first-generation nuclear-powered Central Lunar Processing Complex, and the first large-scale industrial production.
- **DS-4** diversifies productivity by adding Feeder Stations in more distant metallogenic provinces.
- **DS-5** establishes Selenopolis, a self-sustaining lunar civilization, founded on a powerful fusion energy base.

LUNAR PRODUCTS

- Sheet metal and trusses of aluminum, magnesium, titanium, iron, or alloys;
- castings, bars, wires, powders of pure or alloyed materials;
- glasses; glass wool; ceramics; refractories; fibrous and powdered ceramics; insulation; conductors; anodized metals; coatings, including almost perfectly reflective sodium coating
- thin film materials, silicon chips, solar cells, entire structures of various metals and alloys for lunar and orbital installations
- compound and fibrous materials; heat shields and insulation materials, as well as radiation shielding materials for space stations; propellant containers; entire orbiting facilities, such as space station and factory modules and liquid lunar oxygen depots; large portions of cislunar and interplanetary spacecraft; and so on
- where 0 g is required for manufacturing, easily reached facilities in circumlunar orbit (CLO) can make crystal bole, fibers, solar cells and other special materials and products
- parts, components, subassemblies, and full assemblies can be integrated in CLO before being shipped to geosynchronous or other distant circumterrestrialorbits via electric freighters (which will eventually use lunar sodium as propellant)



EHRICKE'S FOCUS: LUNAR INDUSTRIALIZATION



- Ehricke priority was to develop the Moon enormous industrial potential
- His vision included the Moon and the surrounding space region, orbit and Lagrange Points – i.e. the Cislunar space
- The main industrial processes to be placed on the Moon surface, e.g. raw materials extraction and processing
- Energy supply by nuclear plants – see also the SELENE project, an ENEA initiative to bring small nuclear reactors on the Moon
- Orbital industrial facilities taking profit of zero-G
- Earth-Moon quick and low-cost transport systems
- Industrial production for Moon, Earth orbit and Earth customers
- Goal: lunar community self-sufficiency in due time

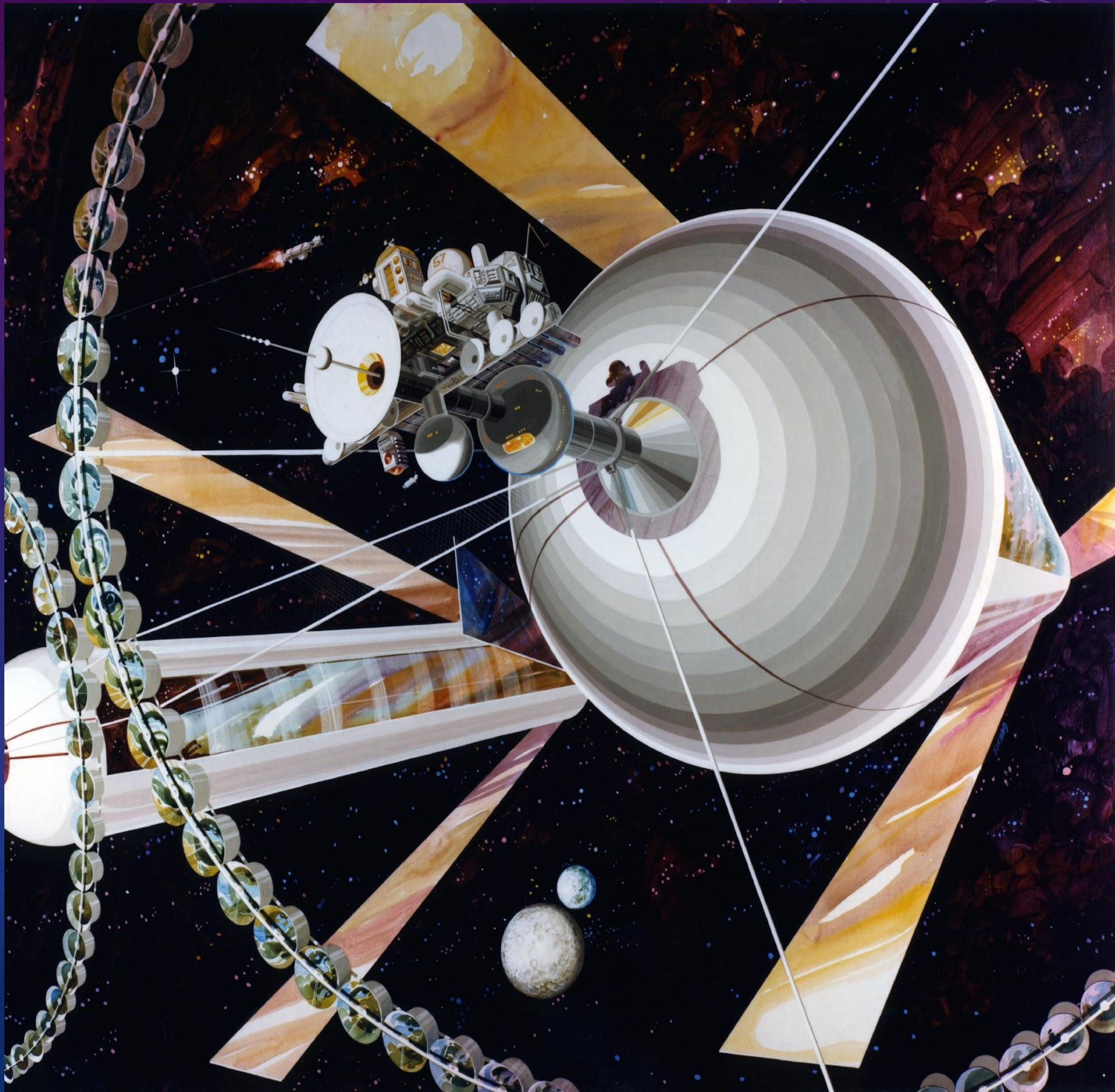
3

3. ISLAND ONE – THE GERARD K. O'NEILL MODEL

- **Gerard O'Neill** asked his students at Princeton University (1969):

  "Is a planetary surface the right place for an expanding technological civilization?"

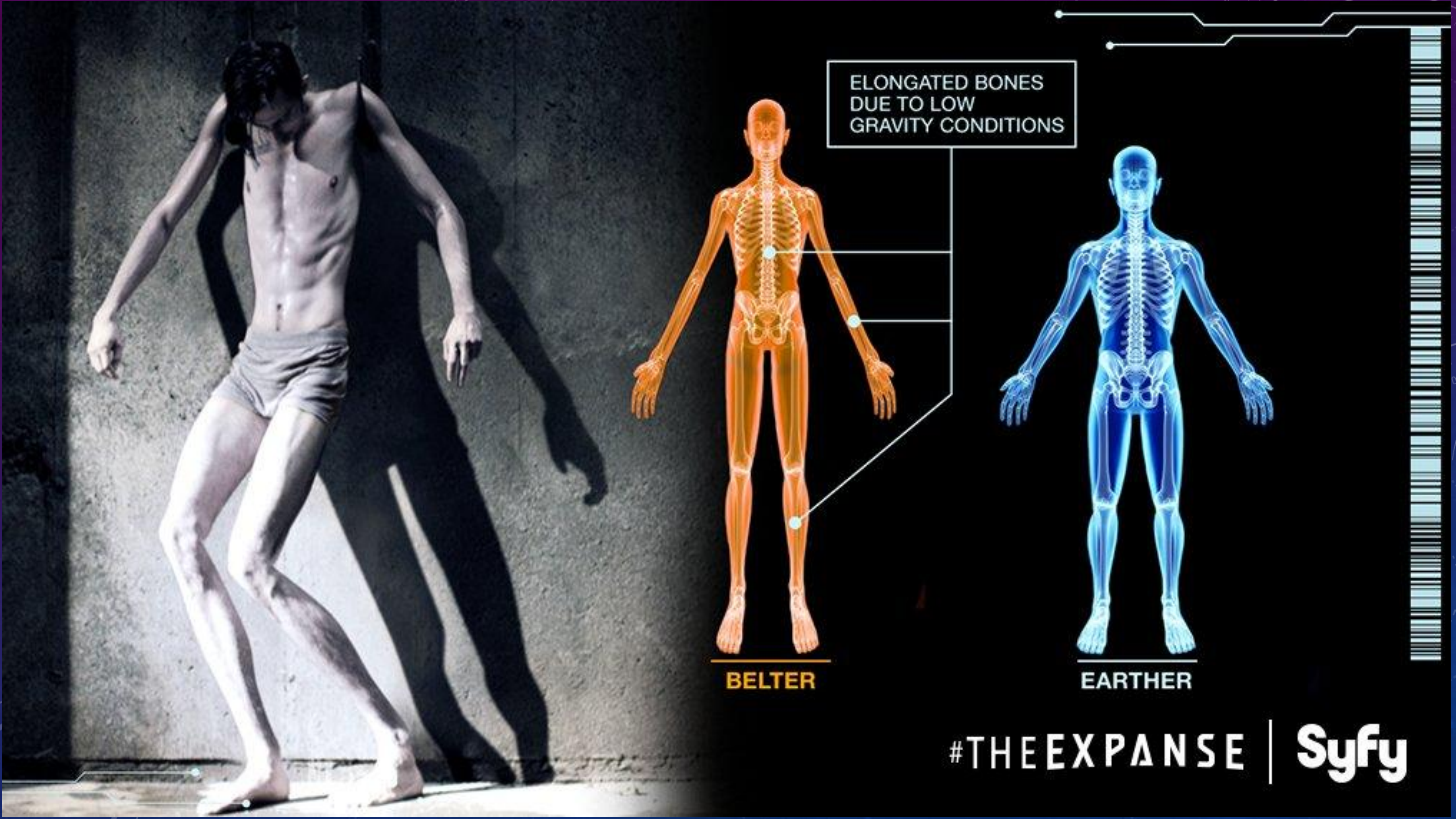
- The students replied: **NO**
- Planetary surfaces in the Solar System do not have the same gravity of Earth (1g)
- Migrants to the Moon or Mars will experience dramatic biological and physiological changes in a few years
- Health may suffer heavy damages
- They could go back to Earth only in a wheelchair
- That's a heavy limitation to freedom
- Gerard O'Neill conceptualized a big rotating habitat, for thousands, or even millions of inhabitants, to be placed at an Earth-Moon Lagrangian point – 1970's



DIFFERENT MISSION REQUIREMENTS

- 3 different mission scopes are to be considered:
  - Space Exploration
  - Scientific Research
  - Space Settlement

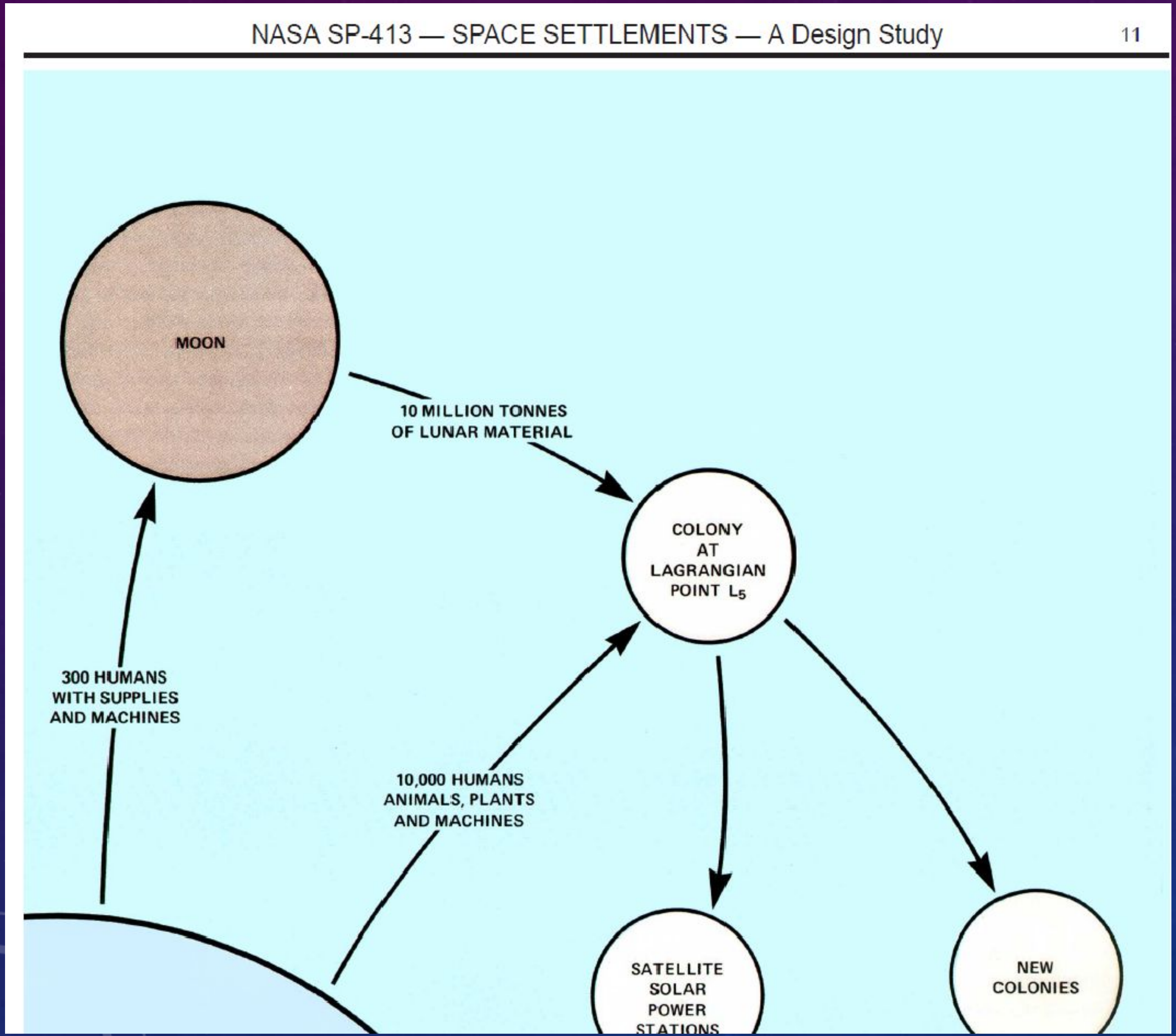
- As far as space settlement is concerned, the living systems' (including humans) requirements need higher relevance and priority, e.g.:
  - Contrasting effects of zero or reduced gravity
  - Protecting life and health from ionizing space radiation
  - Providing an environment similar to the Earth's environment, including flora and fauna


ELONGATED BONES
DUE TO LOW
GRAVITY CONDITIONS
BELTER
EARTHER
#THEEXPANSE

WHY LIVING IN L5 IS BETTER THAN ON THE MOON

- Gravity lower than 1G will cause heavy changes to human physiology
- Lunars, Martians, Belters, Ganimedians, etc… will become not only new ethnic groups,
- Likely they might be defined as new variants of the human genetic strain – as Sapiens and Neanderthal
- Likely humans will adapt – think about the differences between Equatorians and Eskimo
- Yet too fast changes and adaptations will generate heavy problems, three main orders at least:
    - biology, health, reproduction
    - freedom of movement and migration
    - social problems, due to diversity – think about skin colors on Earth

1976: NASA DEVELOPS A STUDY ON SPACE HABITATS



- O’Neill published his paper on Space Colonies in 1974
- In 1976 NASA published a comprehensive design study, on space habitats
- The O’Neill’s model was estimated the best, to fit the requirements of living systems, including humans
- http://large.stanford.edu/courses/2016/ph240/martelaro2/docs/nasa-sp-413.pdf

HUMAN REQUIREMENTS, ACCORDING TO NASA

- WEIGHTLESSNESS: PSEUDO GRAVITY IS NEEDED
- ATMOSPHERE: LESS IS ENOUGH
- FOOD AND WATER
- COMBINED ENVIRONMENTAL STRESSES
- ENVIRONMENTAL DESIGN TO REDUCE STRESS
- SMALL SIZE AND ISOLATION
- PSYCHOLOGICAL AND CULTURAL CONSIDERATIONS
    - The Solipsism Syndrome in Artificial Environment
    - Different types of Social Organization: Hierarchial and Homogenistic, Individualistic and Isolationistic, heterogenetic, Mutualistic and Symbiotic
    - The Problem of Matching
    - Self-Sufficiency of an Extraterrestrial Community
    - Turnover of Personnel
    - International Participants
- SPACE REQUIREMENTS OF VARIOUS ACTIVITIES
    - Residences
    - Schools and hospitals
    - Assembly halls
    - Open space
    - Light industry
    - Storage
    - Mechanical Subsystems
    - Transportation

DESIGN CRITERIA

- Physiological Criteria
- Environmental Design Criteria
- Organizational Criteria

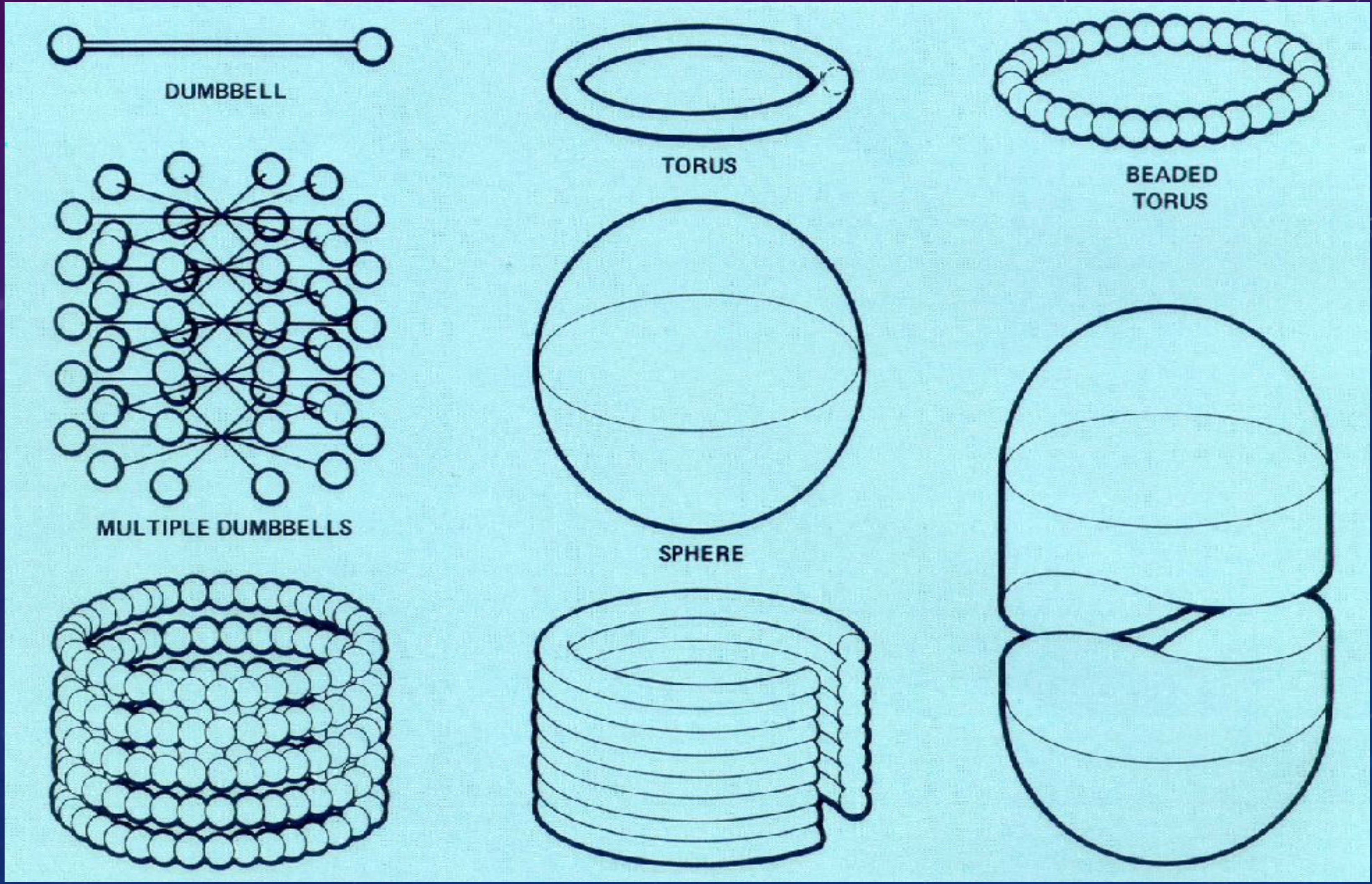
HUMAN REQUIREMENTS: PEOPLE

- Size and Suitability of Population
- Ethnic and National Composition
- Age and Sex Distributions
- Export Workers
- Social Organization and Governance

- **LIFE SUPPORT**
  - Food
  - Recycling Wastes
  - Composition and Control of the Atmosphere
  - Light and dark
  - Comfort
  - Ergonomics
  - Beautiness

THE SHAPE OF THE HABITAT

- The Habitat Must Hold an Atmosphere (size - internal pressure)
- A Rotating System With 1 g at Less Than 1 rpm (radius – speed)



SHELDING

- Active shields
- Passive shields

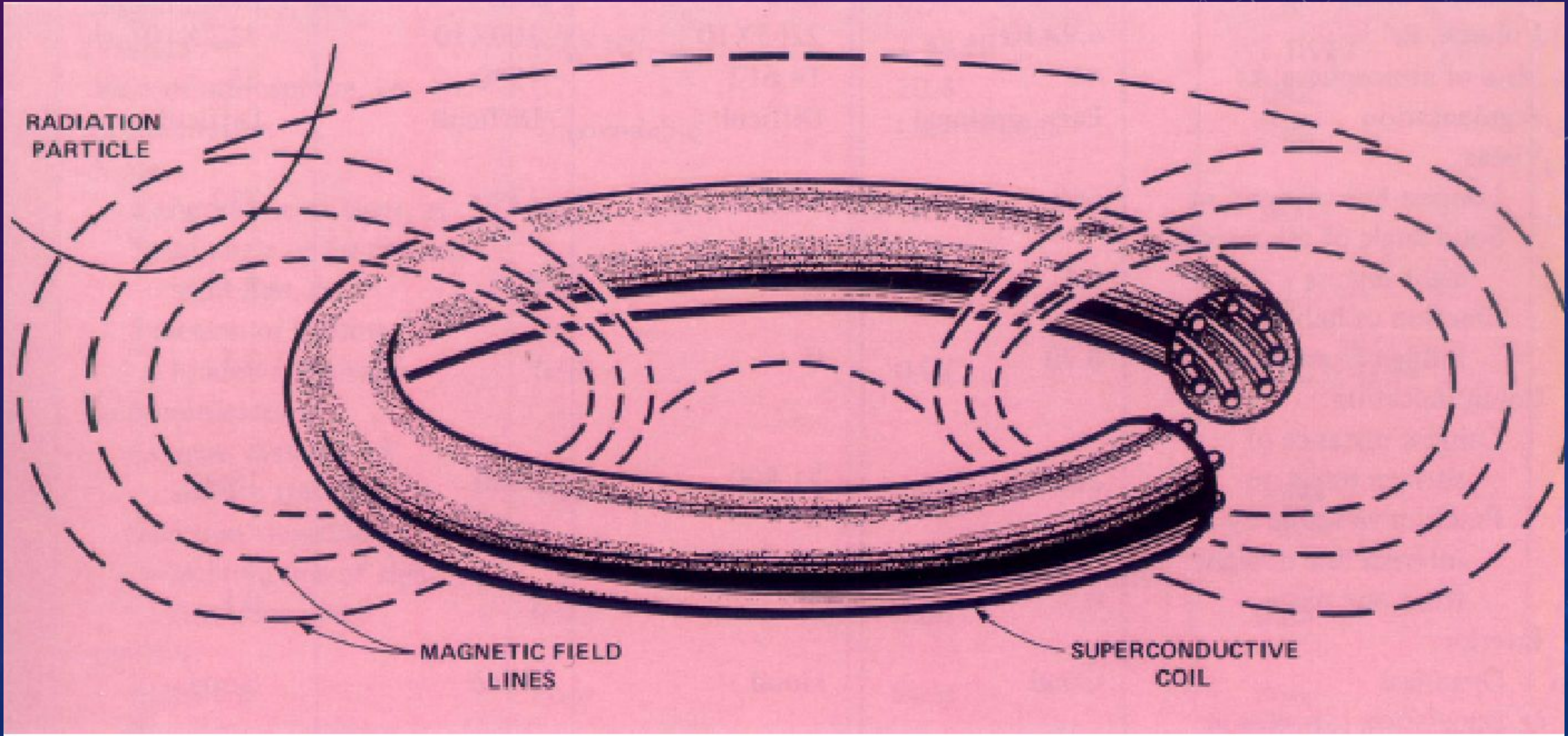


Figure 4-5 — *Magnetic shield around a torus.*

MAIN REFERENCES

- GERARD K. O'NEILL «Colonies in Space»
- «Space Settlement» - A Design Study NASA SP-413 (Technical Director: Gerard K. O'Neill)
- «Space Resources and Space Settlement» - A Design Study NASA SP-428 (Study Director: Gerard K. O'Neill)

5

WHERE? IN FREE SPACE AT L5, OR L4

- The colony could be located in any one of a number of orbits in free space: around the Earth, or the Moon, or both the Earth and the Moon.

- Near either the Earth or the Moon are not suitable, because of the frequency and duration of solar eclipses which deprive the colony of its light and energy.
- Large orbits around the Earth make it difficult to deliver the large mass of material needed from the Moon.
- There remain the orbits about the five Lagrange libration points.
- L1, L2, and L3, are known to be unstable, to maintain orbits around any of these points for long time requires appreciable expenditures of mass and energy for station keeping.

- There do exist, however, large orbits around both of the remaining libration points, L4 and L5.
- These have been shown to be stable.
- A colony in either of these orbits would be reasonably accessible from both Earth and Moon.

- We might arbitrary choose L5, for the location of the first space colony, though the differences between L4 and L5 are very slight.

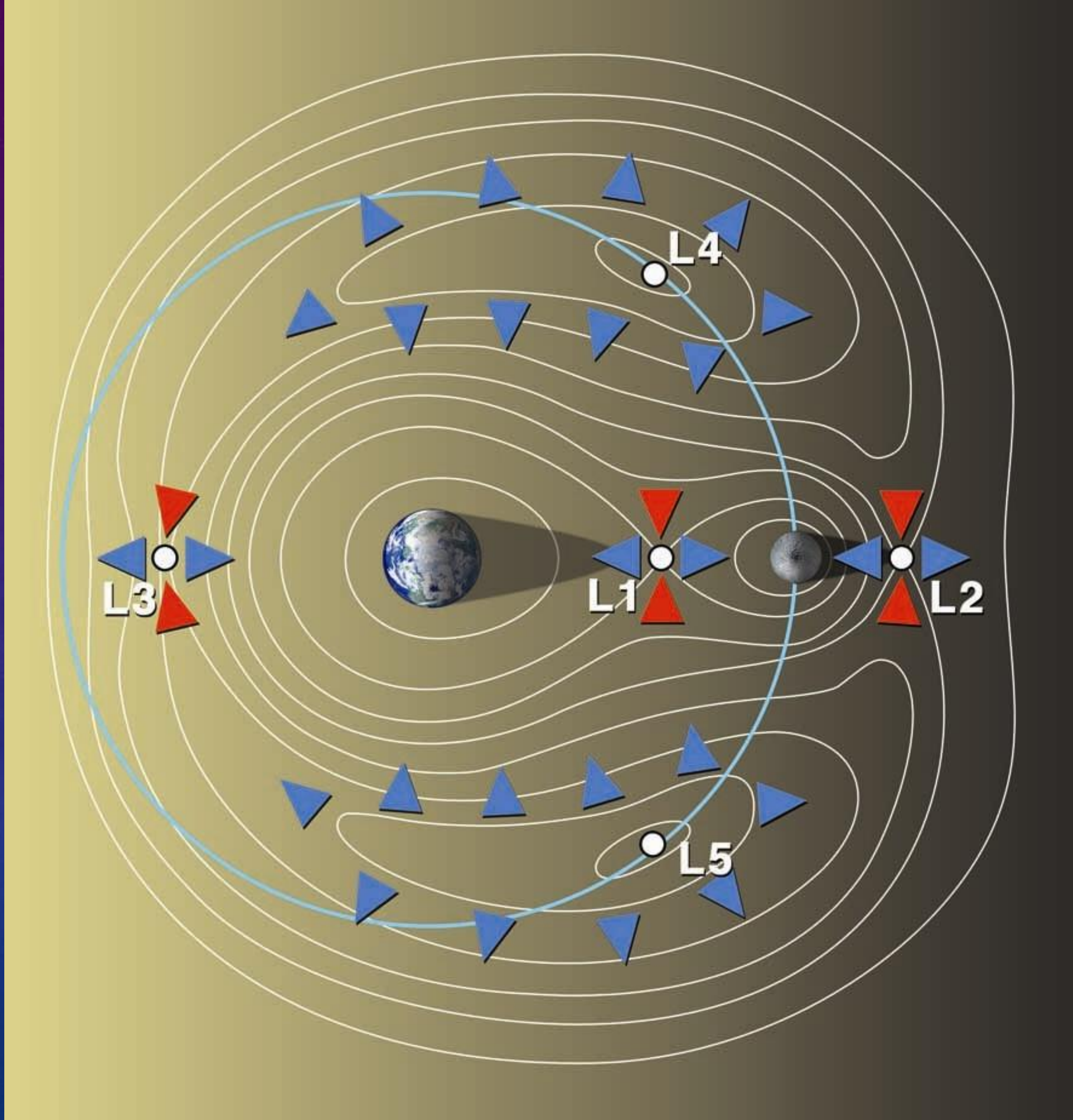
5. THE 5 LAGRANGE LIBRATION POINTS OF THE EARTH-MOON SYSTEM

On the Earth-Moon axis:

- **L1** about 5/6 of the Earth–Moon distance - 325,000 km from the Earth, 56,000 from the Moon
- **L2** in front of the far side of the Moon - 447,000 km from the Earth and 67,000 from the Moon
- **L3** directly opposite the Moon - 380,000 km from the Earth and 760,000 from the Moon

At 60° from the Earth-Moon axis:

- **L4** 380,000 km from the Earth and 380,000 from the Moon
- **L5** 380,000 km from the Earth and 380,000 from the Moon



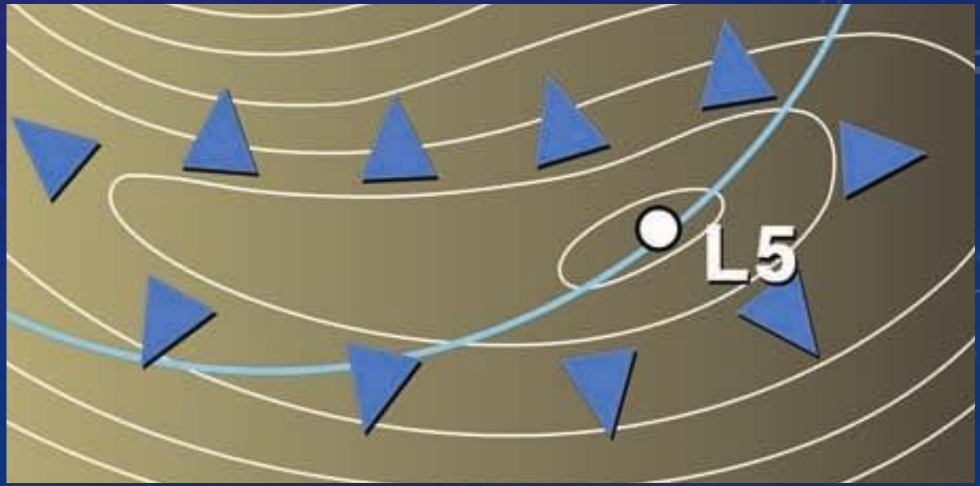
CHARACTERISTICS OF LAGRANGE LIBRATION POINTS

On the Earth-Moon axis:

- they are comparable to «hills»
- objects placed on top tend to «fall» off
- they are unstable and require correction of attitude
- they can however be placed in orbit around the point

At 60° from the Earth-Moon axis:

- they are comparable to «valleys»
- objects placed in the valley tend to «fall» to the center of the valley
- they are stable and do not require attitude correction
- they can also be placed in orbit around the point



6

REDISCUSSING EHRICKE AND O'NEILL

TWO INSUFFICIENT MODELS?

- The Ehricke solution might solve the problem of **cosmic radiation protection**, building Selenopolis in the lunar subsurface.
- But there remains the problem of the **Moon's gravity**, which is one-sixth that of Earth.
- Fatal for the inhabitants that, once addicted to the lower gravity, would suffer inevitable physiological mutations.
- O'Neill's solution, on the other hand, would solve the problem of gravity, but how to shield a large structure, the size of the magnitude of kilometers, from cosmic radiations?

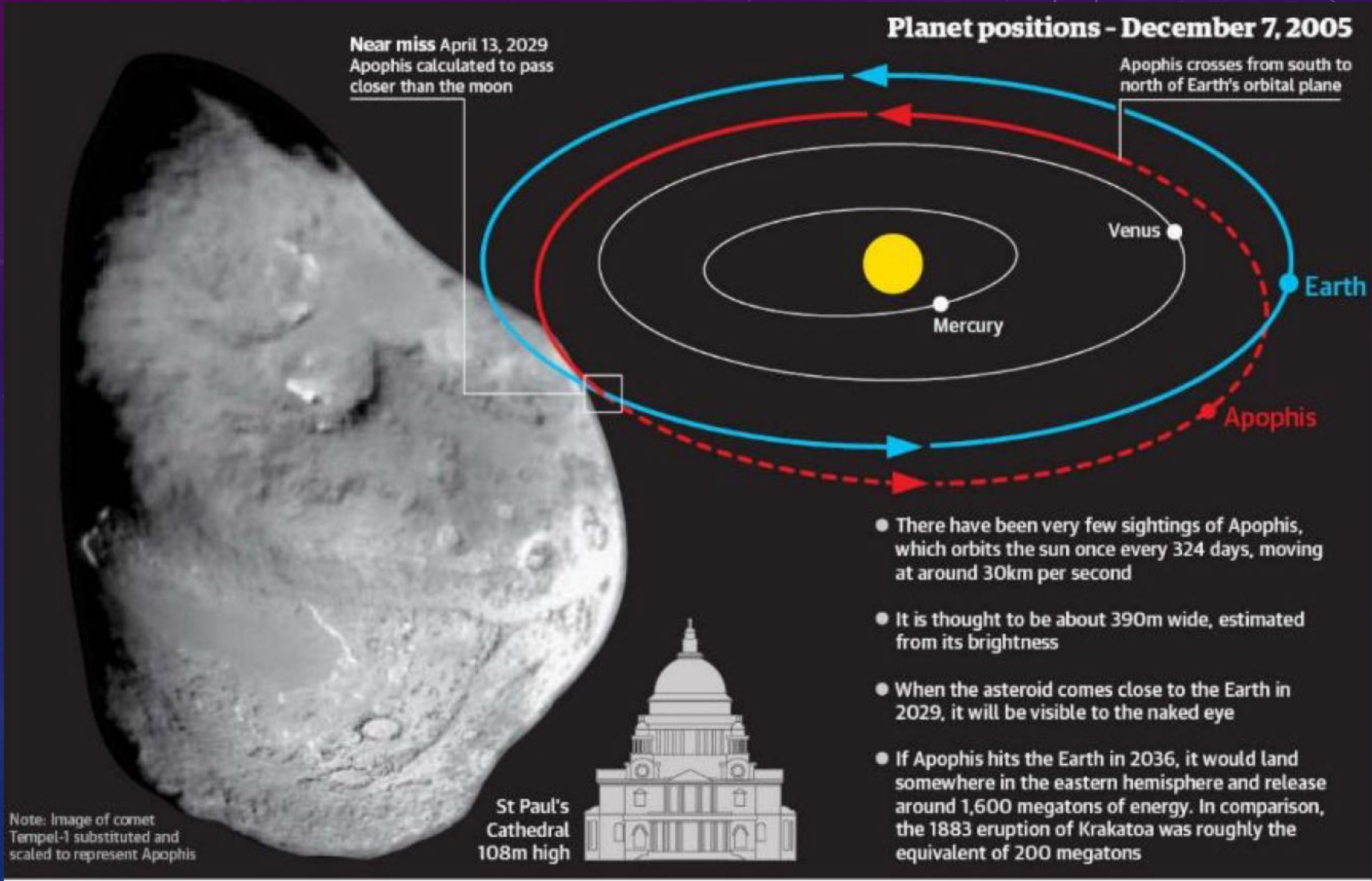
SOLVING BOTH ISSUES

- A solution for both problems could be using near-Earth asteroids.
- Some of them, e.g. Apophis, have a low Delta V; they could be "captured" and taken, for example, in L5 (NASA).
- The asteroid could be dug inside, obtaining an enormous spheroidal space.
- The resulting materials may be used to construct dwellings and all urban, industrial and agricultural infrastructures for settlement by thousands or millions of people.
- The complex may be imprinted rotation, to generate **simulated gravity**.
- Several meters of rock would interpose between the habitat and the outer space, **protecting against radiations** and micrometeorites.

AN ALTERNATIVE: ASTEROPOLIS

Concept:
a city carved inside an asteroid

Note: this option was also discussed by G. O'Neill, in his late studies



THREE CANDIDATE ASTEROIDS

- **APOPHIS**
  - passing quite close, and relatively slowly, several launch windows
  - mass 27 million tons, roughly twelve times larger than the minimum useful capture size
- **2005 YU55**
  - three times as massive as Apophis,
  - approaches Earth, Venus, and Mars,
  - multiple possibilities for gravity assists,
  - approaches about every 11 years, with relatively close approaches
  - possibility of incremental approach every 11 years
- **1999 AN10**
  - a large (50x Apophis), fast, and dangerous asteroid passing as close as the Moon in 2027
  - large enough to house 2 million people in a 3 km diameter habitat.
  - hard to capture, might be worth after experience with smaller ones.

LAGRANGE ASTEROID CITY STRUCTURAL LAYOUT

- The central body hosts the large 1G gravity cylindrical habitat
- At the extremities, some smaller ZeroG cylindrical infrastructures
- Cargo spaceport
- Passengers spaceport
- Industrial settlements
- Hospital and medical research
- Zero/Low G Sport and Arts

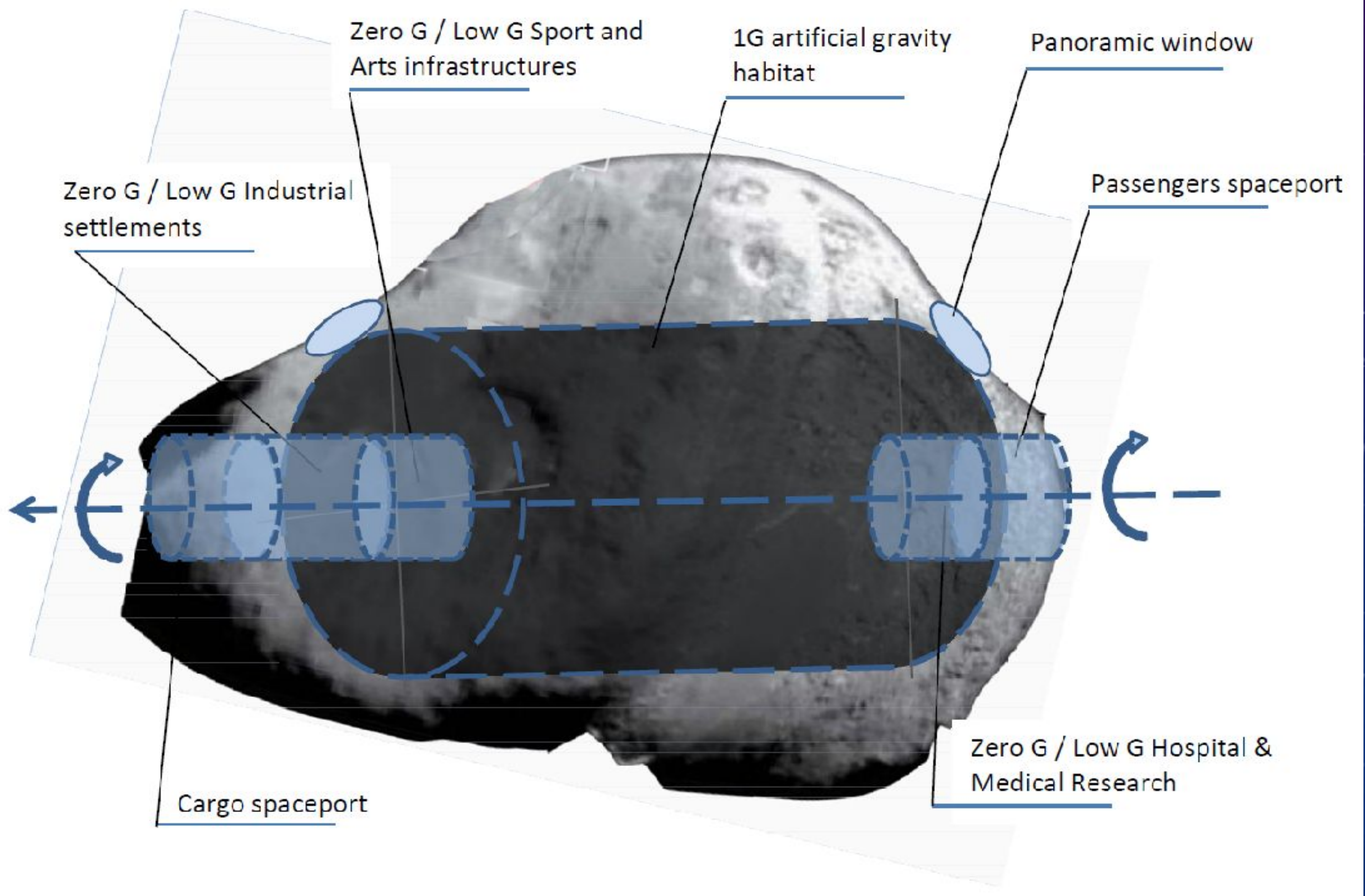
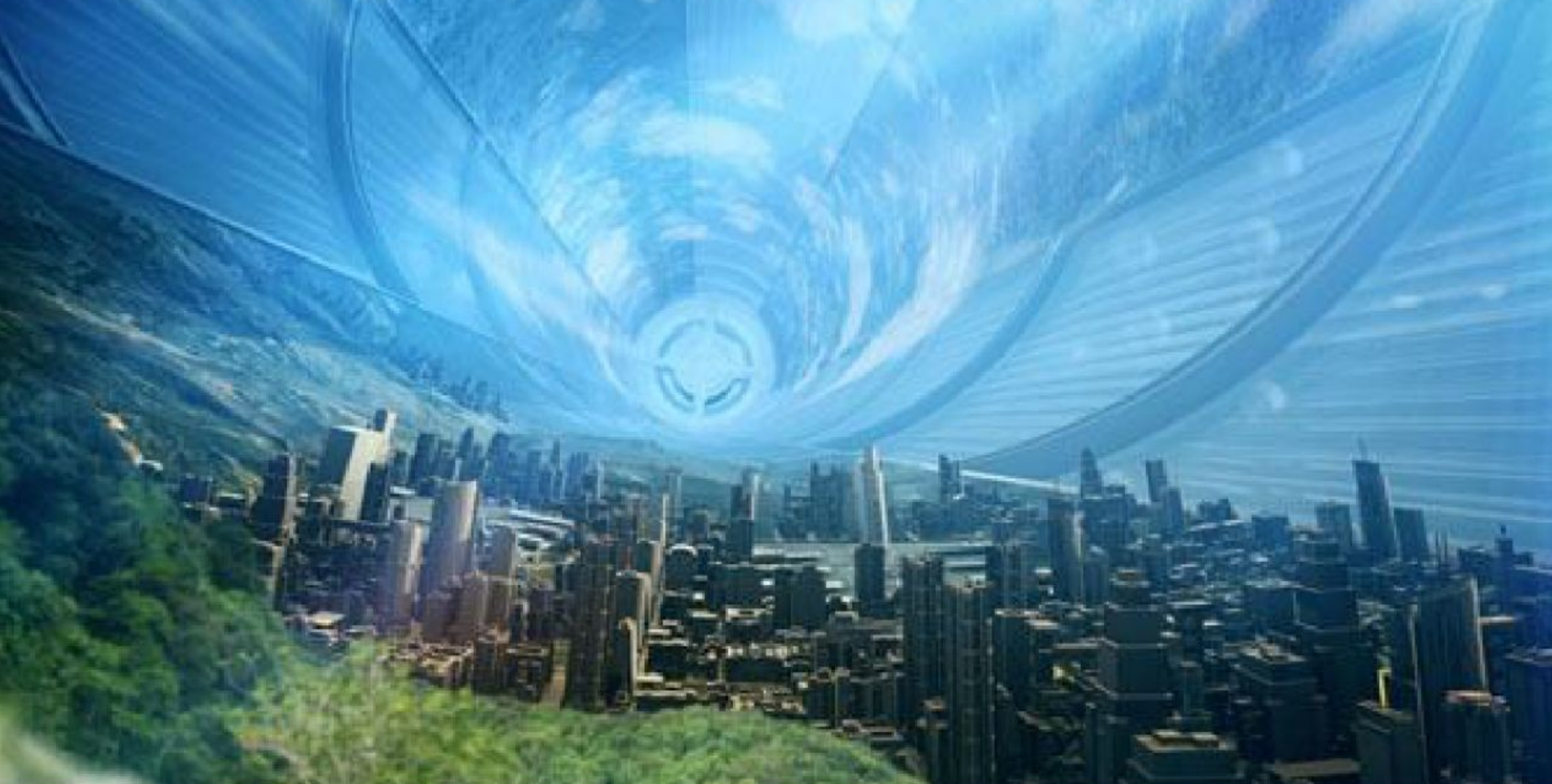


Figure 3. LAC structural layout

LAGRANGE ASTEROID CITY INTERIORS

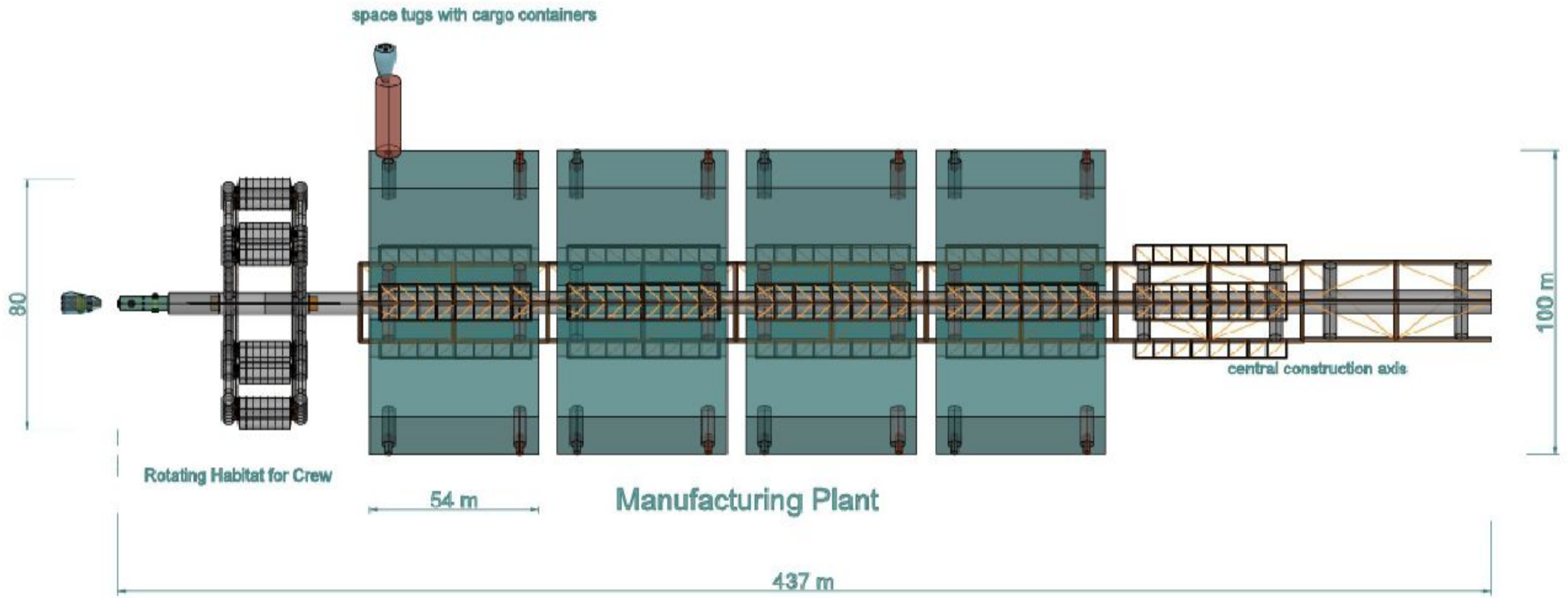


CONCEPT: LAGRANGE SPACE FACTORY (LSF) IN L5

The structure starts with a rotating habitat for the crew (48 persons).

Along the central construction axis the non-rotating manufacturing modules are built.

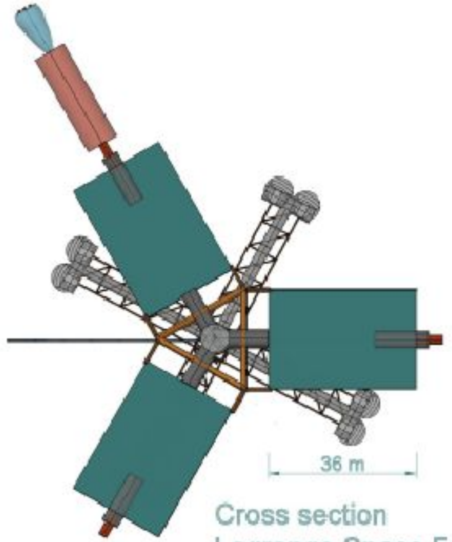
The structure can be extended along the central axis.



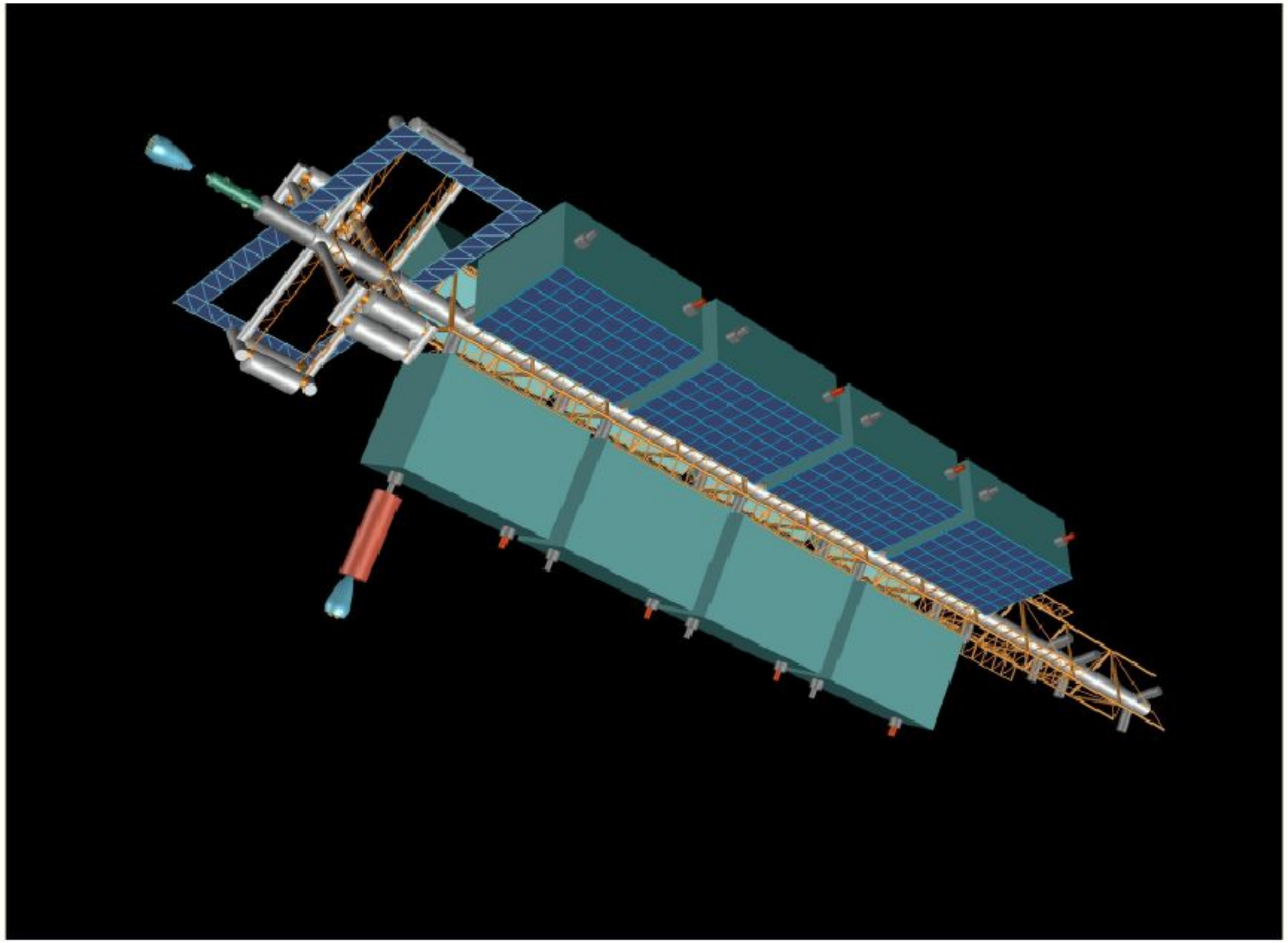
Presented by Werner Grandl (SRI, Austria) to IAC 2024, Milano, October 2024

CONCEPT: LAGRANGE SPACE FACTORY (LSF) IN L5

cross section and *perspective view* (red cargo ship docking)



Cross section
Lagrange Space Factor



CONCEPT: LAGRANGE SPACE FACTORY (LSF) IN L5

To establish the proposed Lagrange Space Factory (LSF) some precursory steps are necessary within the next years:

- A new orbital station in LEO (succeeding ISS) preferably with simulated gravity 2035
- A manned lunar base with electromagnetic mass driver 2040
- LSF 1st *stage* to process lunar material and space debris from Earth orbit 2045
- Mining of NEAs 2060
- LSF 2nd *stage*, processing asteroid material 2065

In the long run all mining and heavy industry could be shifted into space to minimize pollution and climate warming on Earth!

7

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  introduzione a programmi di tirocinio presso agenzie spaziali ed aziende aerospaziali worldwide

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- **Networking:**

  inserimento nel contesto internazionale, mondo accademico, ricerca, ONG

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