

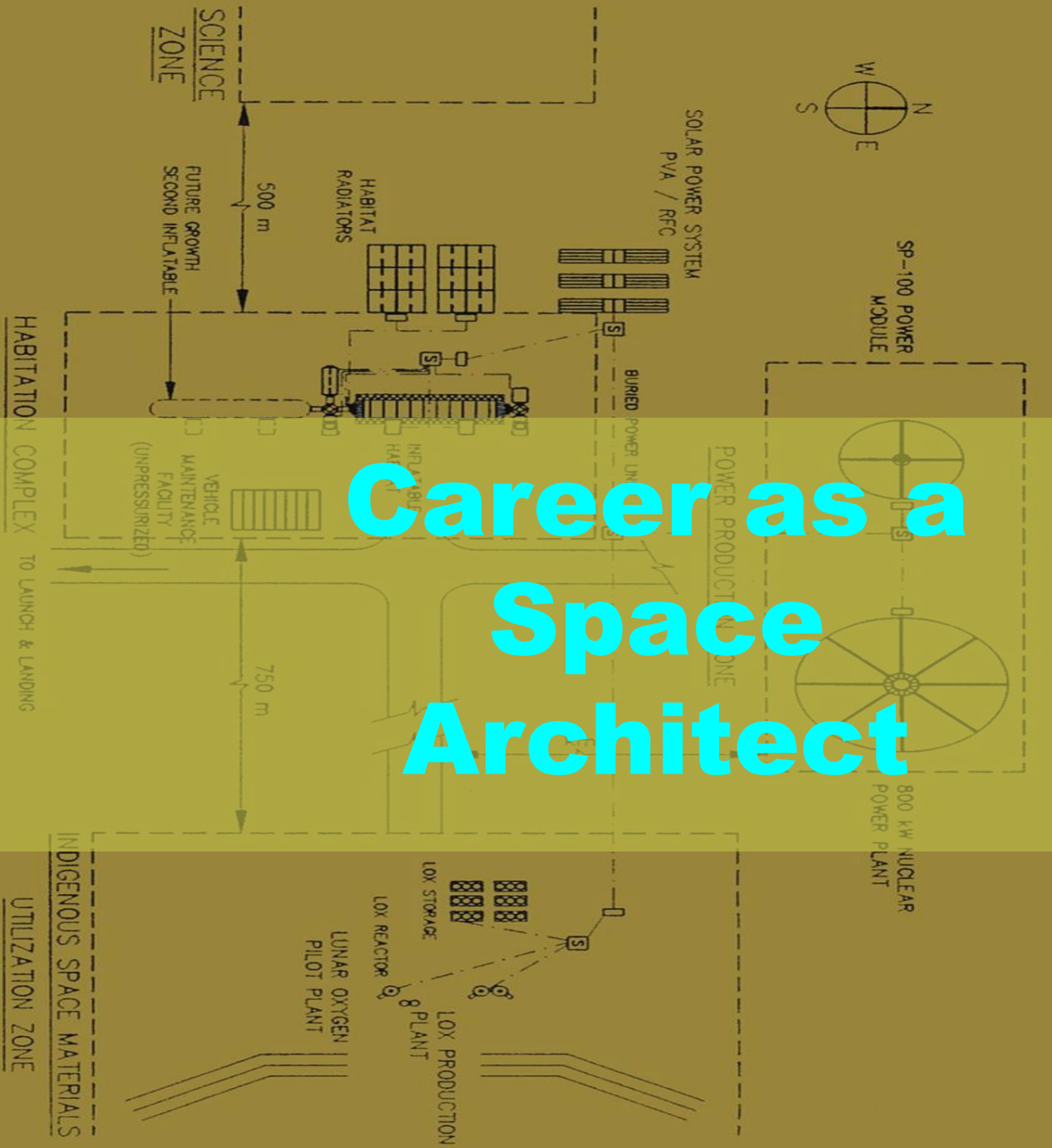
# SPACE ARCHITECTURE

## Systems Architecting

*Kriss J. Kennedy*

*Space Architect*

*NASA - JSC*



# Career as a Space Architect

**Three (3) degrees in Architecture**

**Worked on over 45 designs and projects**

**Written over 50 publications, papers, or chapters in books**

published in numerous magazines, periodicals & books

**Has two patents and numerous NASA Technology Brief Awards**

Recognized by his architect peers as one of the new upcoming architects in Texas as published in the millennium issue January 2000 Texas Architect magazine.

**First space architect awarded the prestigious Rotary National Award for Space Achievement in March 2000**

**Registered licensed architect in the State of Texas**

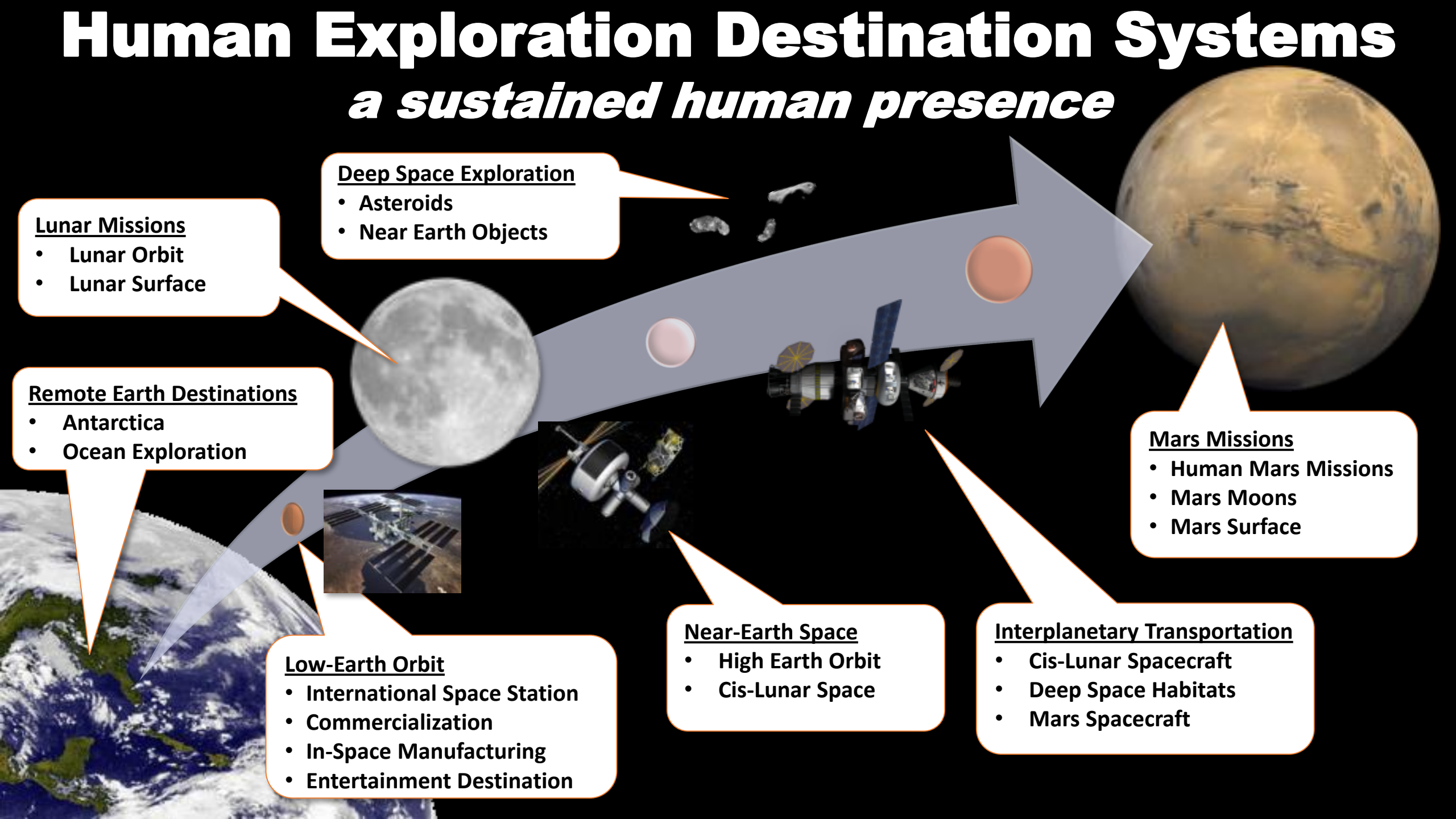
# Space Architecture...

...theory and practice of designing and building inhabited environments in outer space...

...design of living and working environments in space related facilities, habitats, surface outposts and bases, and vehicles...

# Human Exploration Destination Systems

*a sustained human presence*



## Lunar Missions

- Lunar Orbit
- Lunar Surface

## Deep Space Exploration

- Asteroids
- Near Earth Objects

## Remote Earth Destinations

- Antarctica
- Ocean Exploration

## Low-Earth Orbit

- International Space Station
- Commercialization
- In-Space Manufacturing
- Entertainment Destination

## Near-Earth Space

- High Earth Orbit
- Cis-Lunar Space

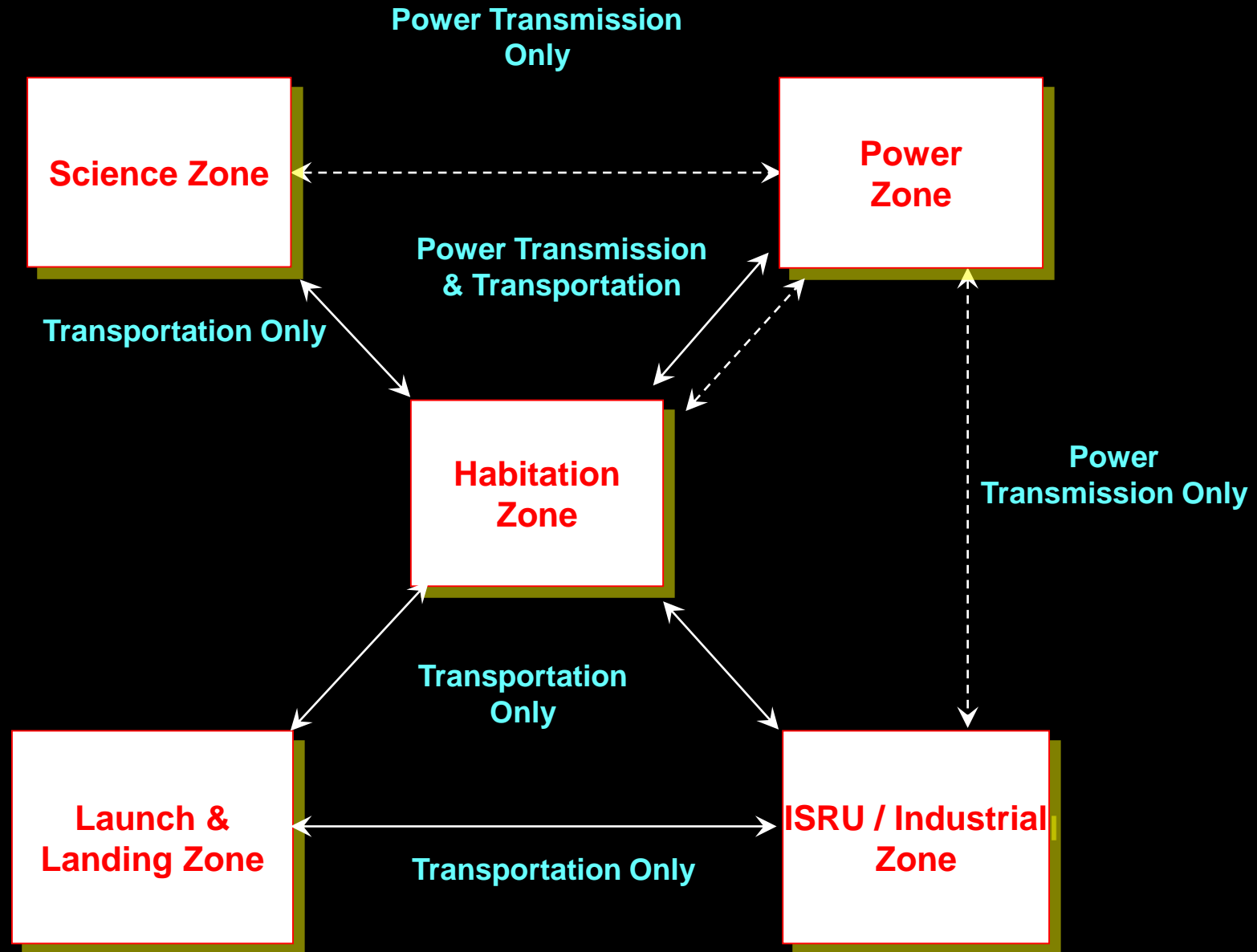
## Interplanetary Transportation

- Cis-Lunar Spacecraft
- Deep Space Habitats
- Mars Spacecraft

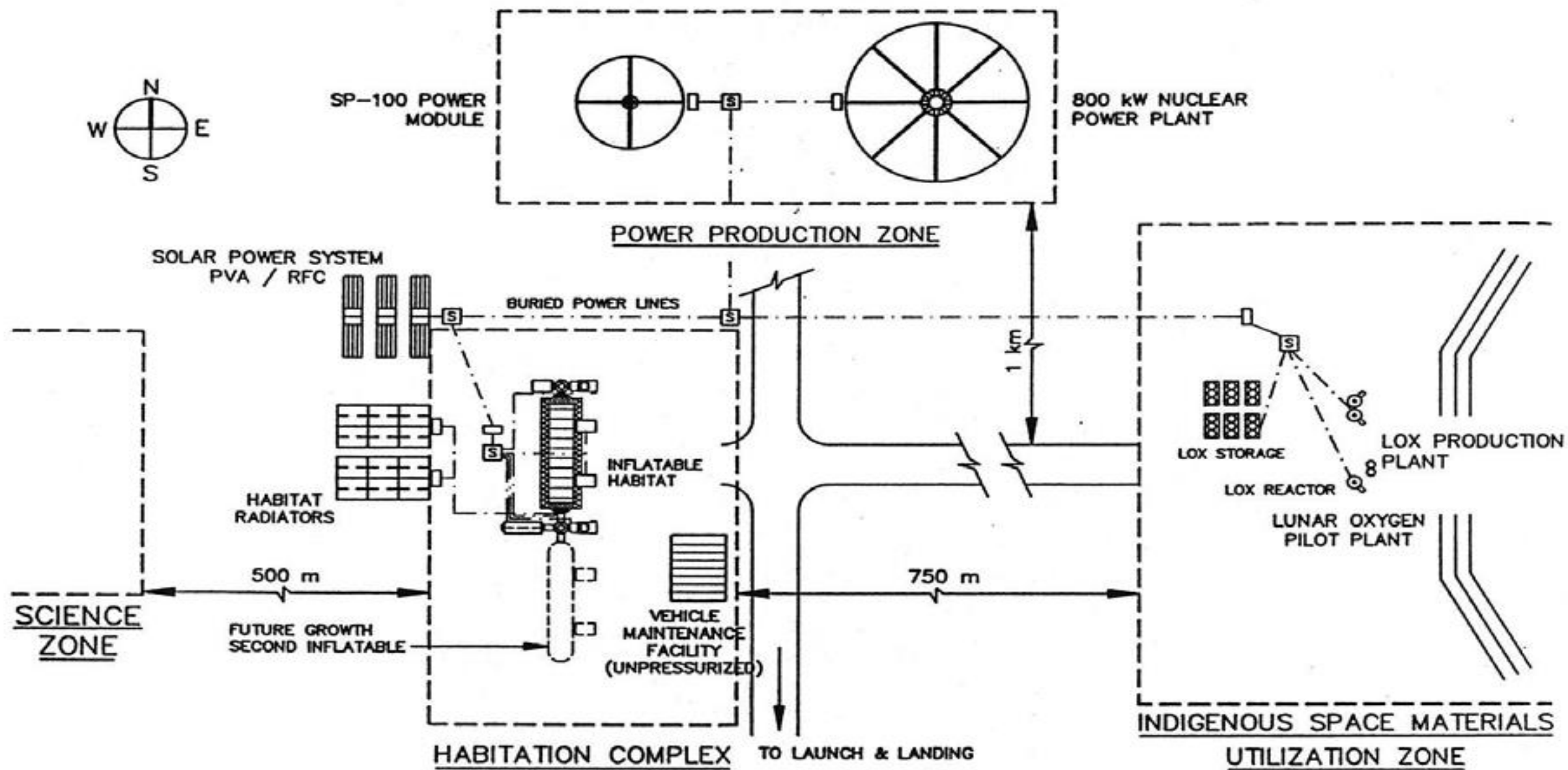
## Mars Missions

- Human Mars Missions
- Mars Moons
- Mars Surface

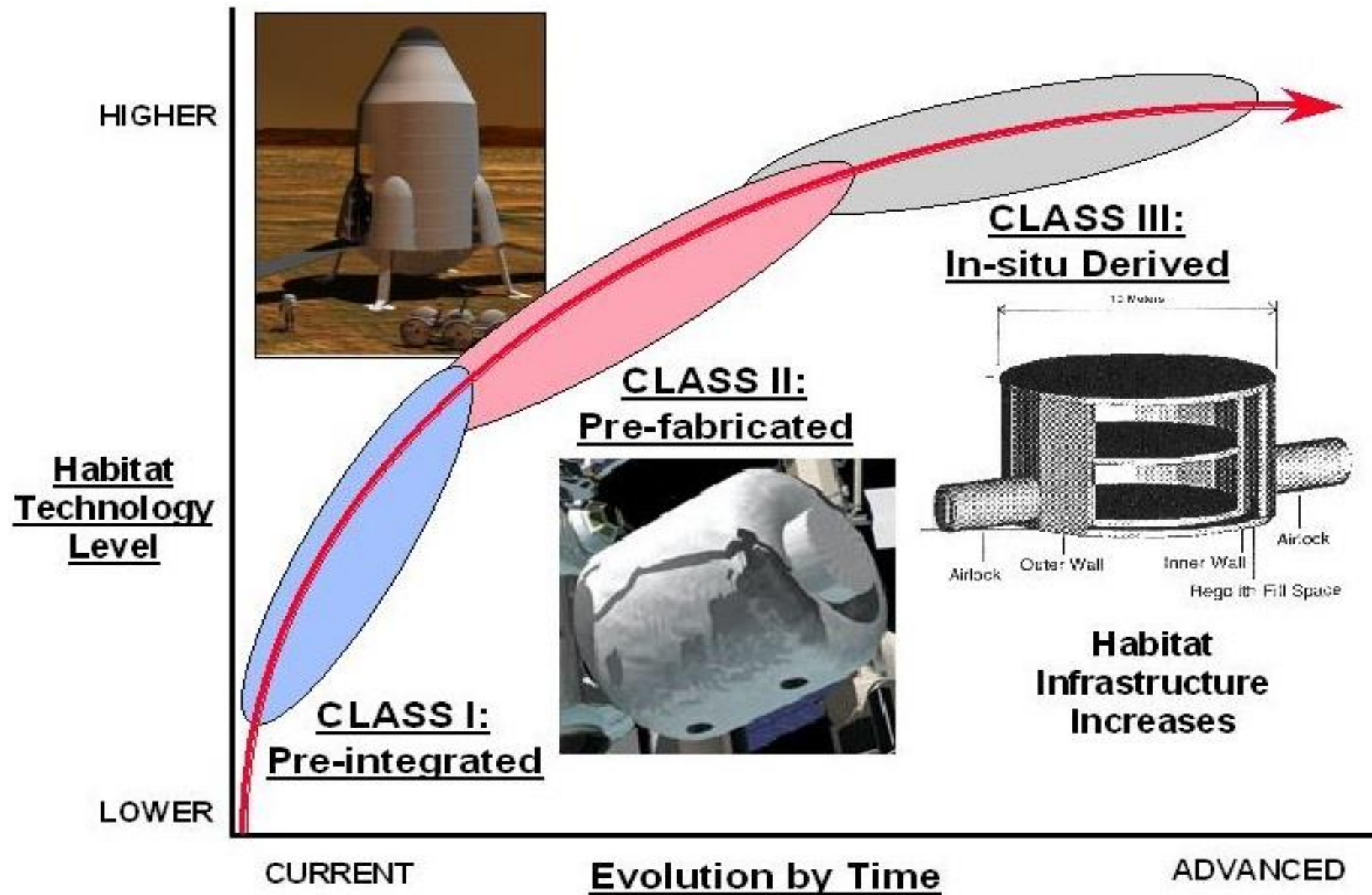
# Surface Outpost Organization and Layout



# Surface Base Concept



# Space Habitat Classifications



# Human Exploration Systems

## Elements

- Crew Return Vehicle
- Deep Space Habitat (DSH)
- Space Exploration Vehicle
- Propulsion Stage
- EVA Capabilities
- Power Generation & Storage
- Deep Space Communications

## Exploration Habitat Systems

- Structure & Environmental Protection
- Environmental Protection
- Life Support
- Power Management & Distribution
- Avionics
- Communications
- Thermal Control
- Crew & Medical Systems
- Laboratory Systems (Science & Research)
- Logistics, Repair & Manufacturing





# Habitation Operations



## Crew Operations - IVA

**Sustain crew on lunar surface for mission.** These functions are necessary to insure the safety of the crew. It also includes providing the functions necessary to sustain the crew from a health and well being perspective.



## Crew Operations – Supporting EVA

**Enable Redundant EVA Function & Enhanced EVA Capability.** These functions are necessary to provide the crew with additional means to conduct routine EVAs. The extent provided is driven by the mission duration and the number of EVAs required to conduct that mission.



## Mission Operations

**Enable Enhanced Mission Operations Capability.** These functions are those that enable the lunar surface crew to conduct surface operations in concert with the Earth based mission control. For longer surface stays it should also establish autonomy from the Earth based "mission control" enabling command and control with other surface assets such as rovers, landers, etc.



## Science Operations

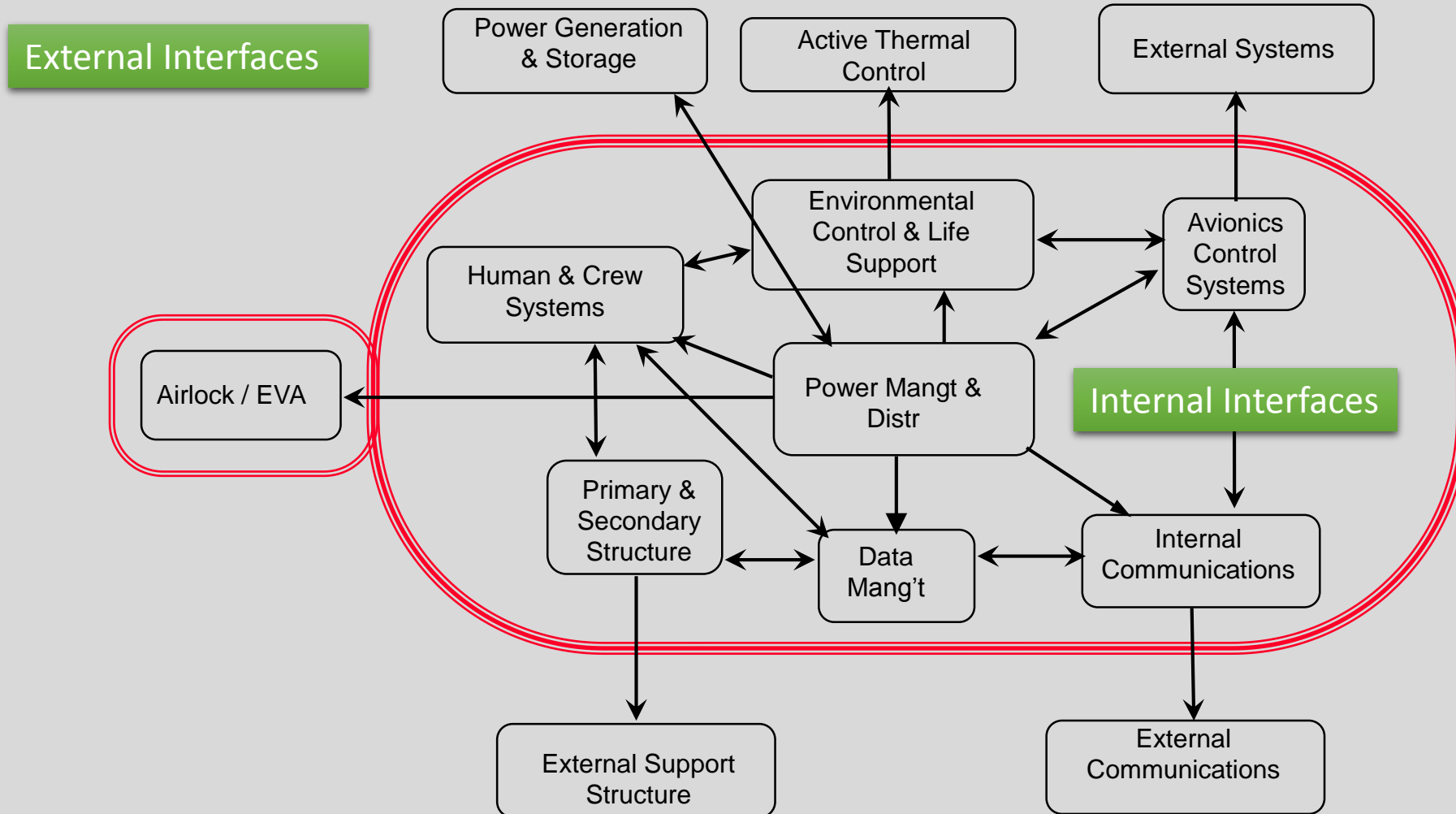
**Enable IVA Bio/Life Science & GeoScience Capability.** These functions are necessary to conduct the science involved with the mission. It can include sample collection, sample analyses, sample prioritization and storage, and any sample return required. It also is meant to include any specific "environmental" requirements specific to Life Science or GeoScience



## Logistics & Maintenance Operations - IVA & EVA

**Enable Maintenance, Resupply, & Spares Cache.** These functions are those that allows for maintaining the surface assets during recognized maintenance intervals. It also includes those functions necessary to resupply the habitat(s) with consumables (both pressurized and unpressurized) to support the crew for the mission. Lastly, it also includes the functions necessary to deliver and store the necessary spares related to the maintenance as well as unexpected failures.

# Habitation Elements & Interfaces



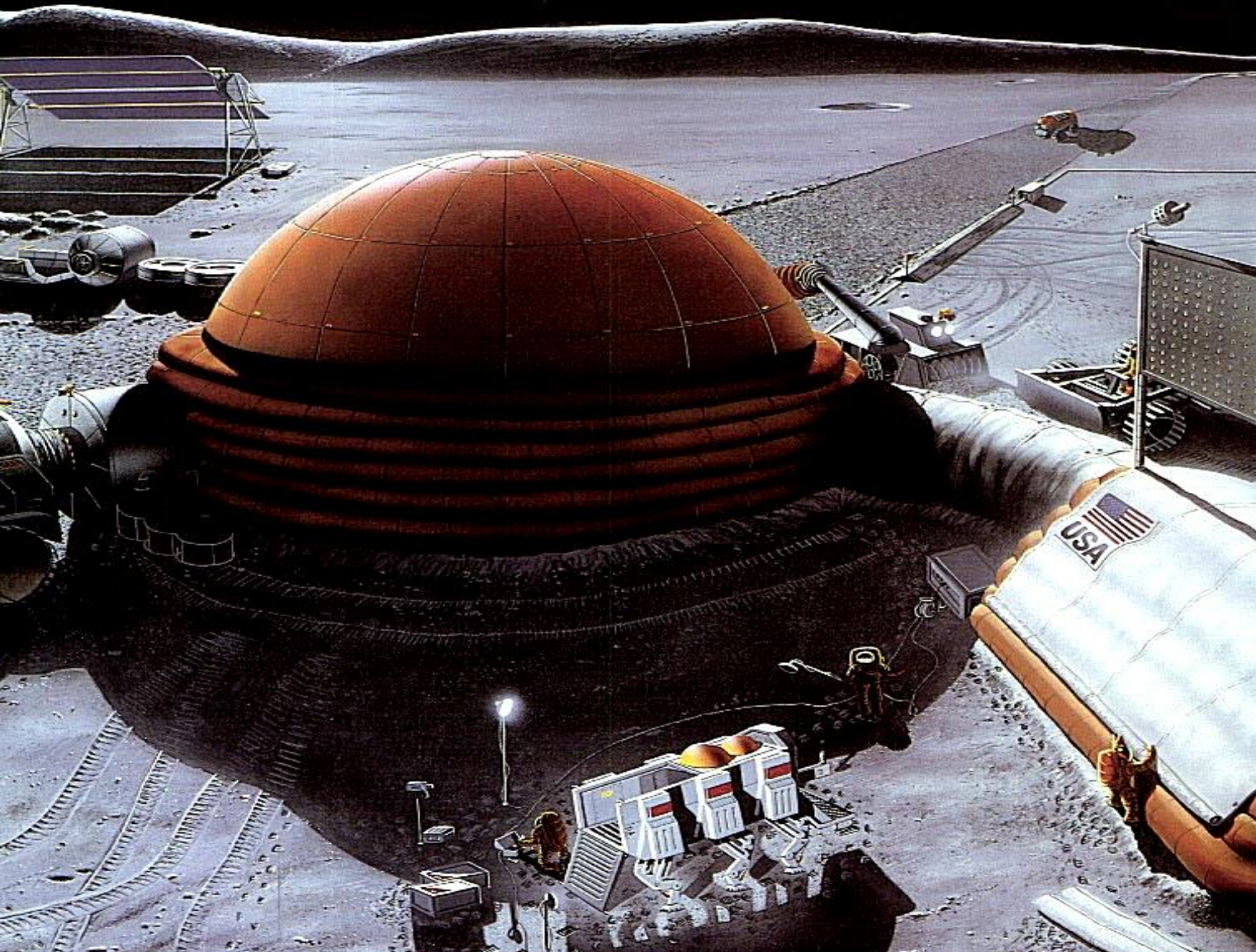
# Example: Exploration Habitat Functionality

| Discipline  | Function Title  | Discipline  | Function Title  | Discipline                                   | Function Title  |
|---|---|---|---|--|---|
| Structures  | Human-Rated Pressurized Volume  | ECLSS (Air)   | Cabin Air Humidity Control  | Avionics/<br>FSW                             | Sensor and Effector Data Collection and Transmittal         |
|   | System Volume   |   | Air Circulation within Modules  |  | Audio System that supports Caution and Warning Annunciation |
|   | Habitable Volume  |   | Air Circulation between Modules   |  | Flight Software Execution and Data Processing               |
|   | Stowage Volume  | ECLSS (Env Monitor)   | Cabin Air Trace Gas Contaminants Control  |  | Ground Commanding and Telemetry                             |
|   | Internal and External Loads   |   | Major Constituent Gases (O <sub>2</sub> , CO <sub>2</sub> , H <sub>2</sub> O, and N <sub>2</sub> or Pressure) Measurement |  | Crew Displays and Controls                                  |
|   | Micrometeoroid Protection   |   | Cabin Air Trace Gases Measurements for Nominal Levels   |  | Data Storage  |
|   | Inter-module Viewing (through hatch)  | Cabin Air Trace Gases Measurements for Non-Fire Contingency Events            | Comm  | Element to Element Communication Hardline    |   |
|   | Extra-Vehicular Activity (EVA) Translation Aids                                       | ECLSS (Waste)   | Trash and Waste Stowage   | GN&C   | Rendezvous and Berthing/Docking Sensors                     |
|   | Grapple Fixtures and Robotic Accommodations   |   | Detect Fires  |  | Rendezvous and Berthing/Docking Targets                     |
|   | Structural Health Monitoring  | Fire Safety   | Suppress Fires  | Imagery                                      | Imagery from Internal Fixed and Hand-Held Cameras           |
| IDSS-compliant Docking and Undocking                  | Measure Trace Gases in Cabin Air from Combustion or Pre-combustion Off-nominal Events |   | Imagery from External Fixed and EVA Helmet Cameras  |  |   |
| Robotic Lander Berthing Capture and Structural Mating | Crew Systems  |   | Vehicle Lighting  | EVA  | EVA to Vehicle Interfaces (EVA wireless comm)               |
| Hatches for Crew and Cargo                            |   | Intra-Vehicular Activity (IVA) Translation Aids                               | EVA Egress or Ingress   |  |   |
| Electrical Bonding                                    |   | In-situ Active Space Radiation Crew Effective Dose and Dose Rate Measurements | Science   | External Science and Research Accommodations |   |
| Transfer of Air, Data, and Power                      | Power   | EVA   | Robotics  | Enabling EVR Maintenance Tasks               |   |
| Power Distribution                                    |   |   |   |  |   |
| Power Storage   |   |   |   |  |   |
| Thermal   | Power Management  |   |   |  |   |
|   | Power Quality Conditioning and Conversion   |   |   |  |   |
|   | Passive Thermal Control   |   |   |  |   |
|   | External Component Thermal Control  |   |   |  |   |
|   | Internal Component Liquid Cooling   |   |   |  |   |
|   | Cabin Air Cooling and Condensation Control  |   |   |  |   |
|   | Avionics Air Heat Rejection   |   |   |  |   |
|   | Heat Rejection  |   |   |  |   |

# example: Additional Functions

| Discipline             | Function Title   |
|------------------------|--|
| Power                  | Power Distribution   |
| Avionics/<br>FSW       | Crew Displays and Controls                                   |
| ECLSS (Air)            | Cabin Air Particulate Control                                |
|                        | Cabin Carbon Dioxide Removal                                 |
| ECLSS (Env<br>Monitor) | Cabin Air Particulate Measurements                           |
| ECLSS (Water)          | Crew Potable Water Distribution and Dispensing               |
|                        | Maintain Safe, Low Levels of Microbial Life in Potable Water |
|                        | Maintain Safe, Low Levels of Microbial Life in Waste Water   |
|                        | Cold Water Dispensing  |
|                        | Potable Water Storage for Crew Use                           |
|                        | Fluids Transfers between Storage Locations (CWC)             |
| ECLSS (Waste)          | Crew Urine Collection and Addition of Required Pretreat      |
|                        | Crew Feces Collection  |
|                        | Microbial Safety Control                                     |
|                        | Trash and Waste Stowage                                      |
| Crew Systems           | Crew Medical Care  |
|                        | Private Crew Quarters (4)                                    |
|                        | Private Crew Waste Compartment                               |
|                        | Food Preparation   |
|                        | Crew Dining  |
|                        | Private Communications (in sleep quarters)                   |

# Inflatable Lunar Habitat

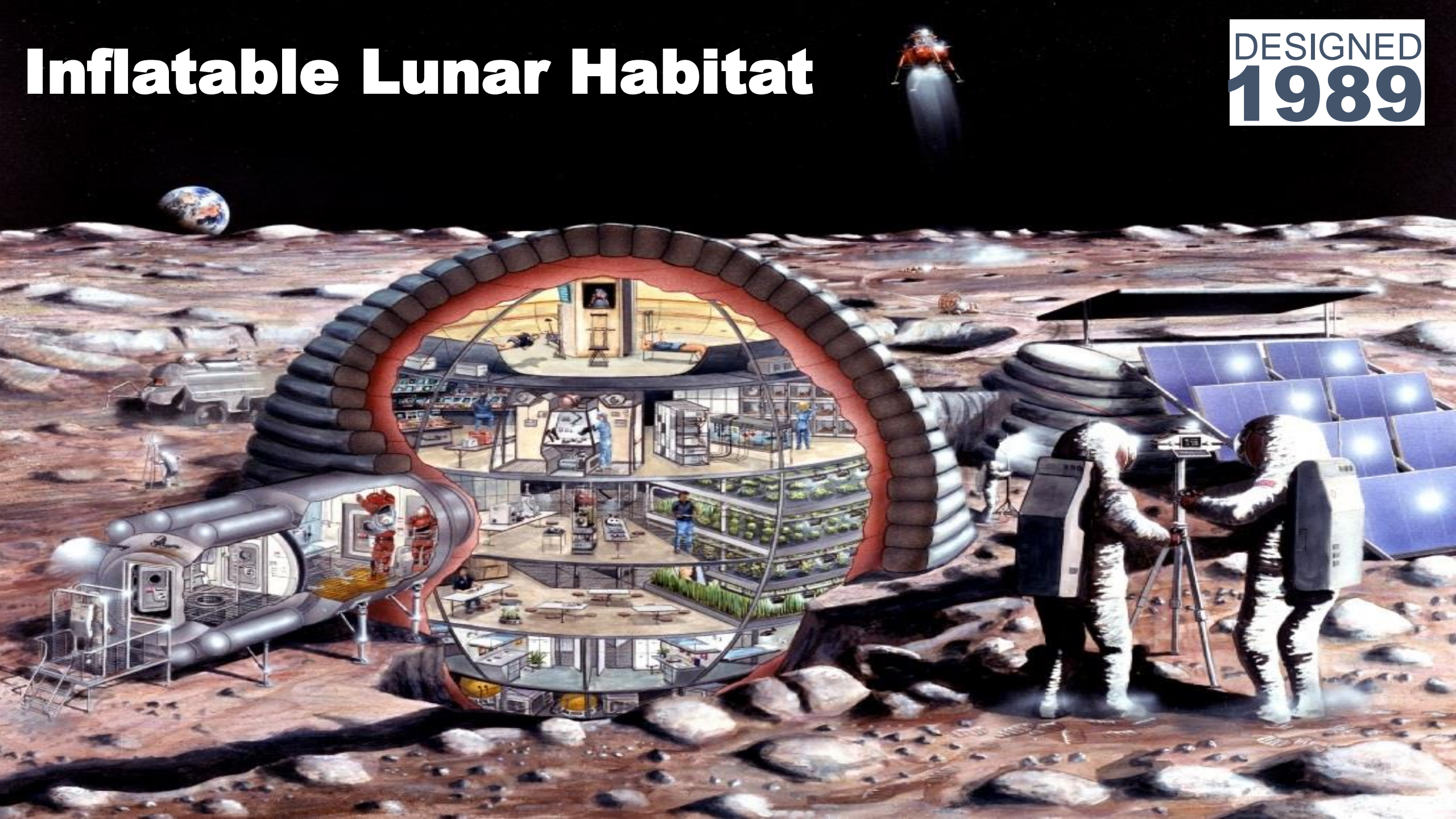


DESIGNED  
**1989**



# Inflatable Lunar Habitat

DESIGNED  
**1989**

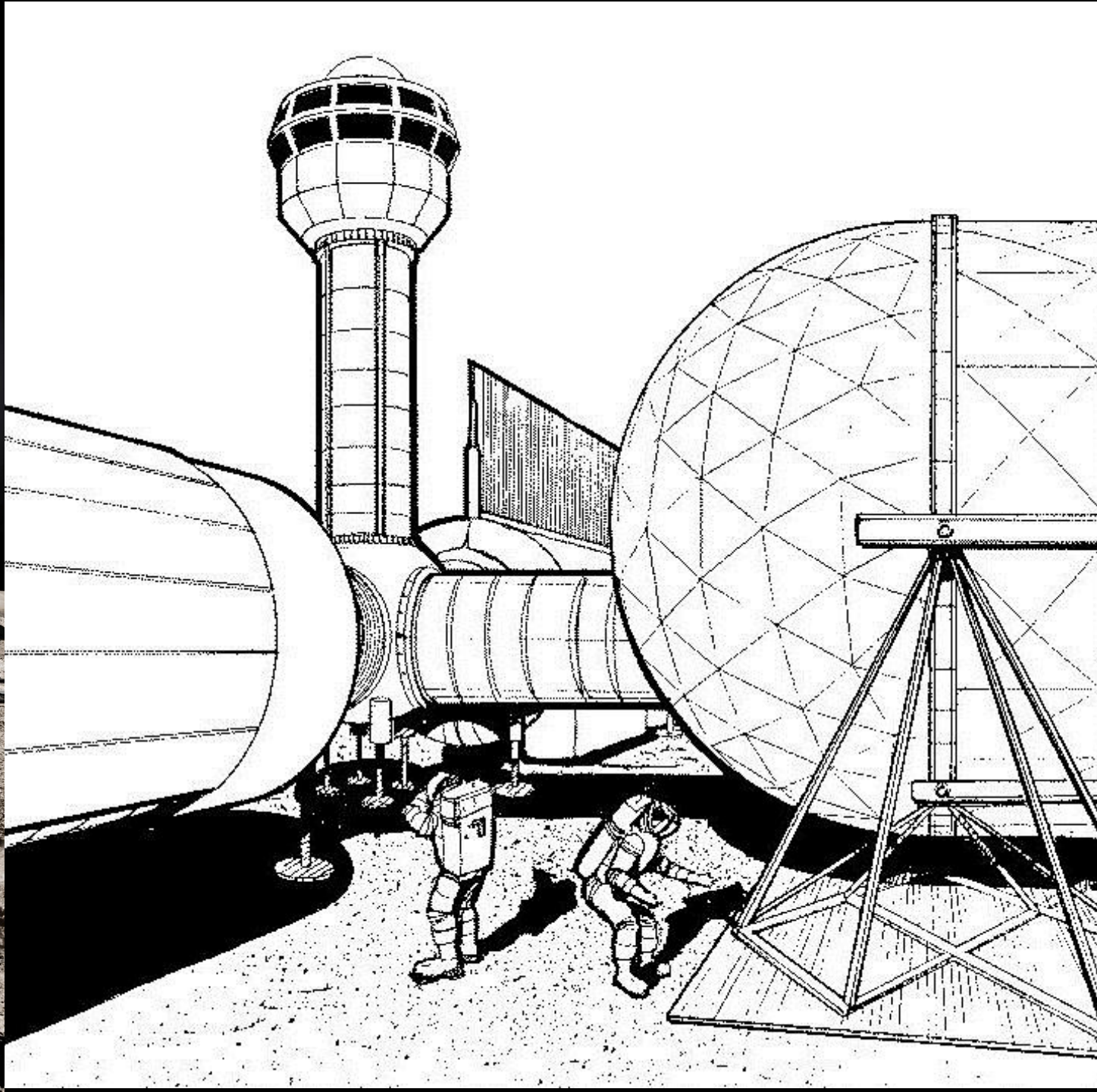
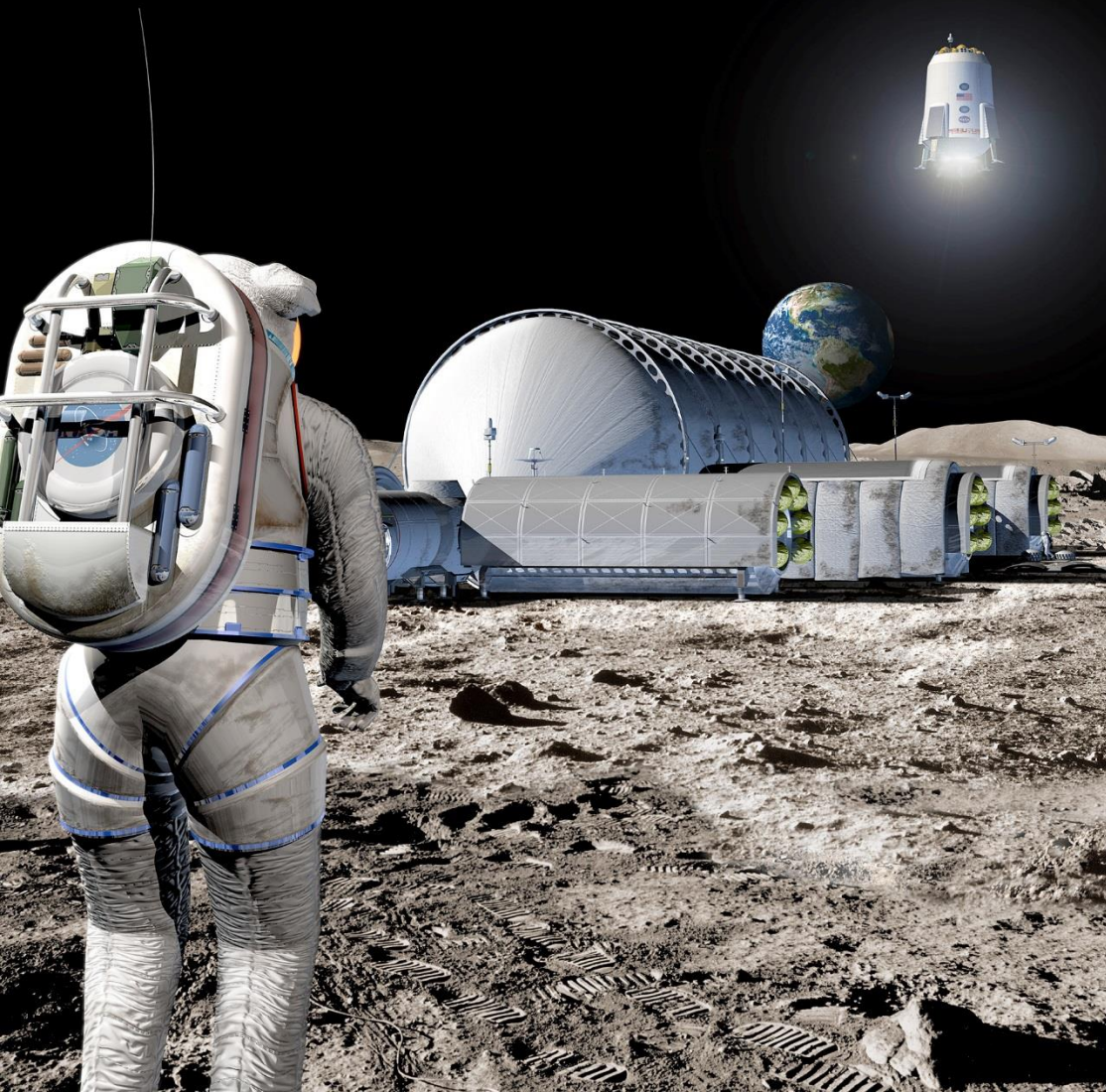


# Inflatable Lunar Habitat

DESIGNED  
**1992**



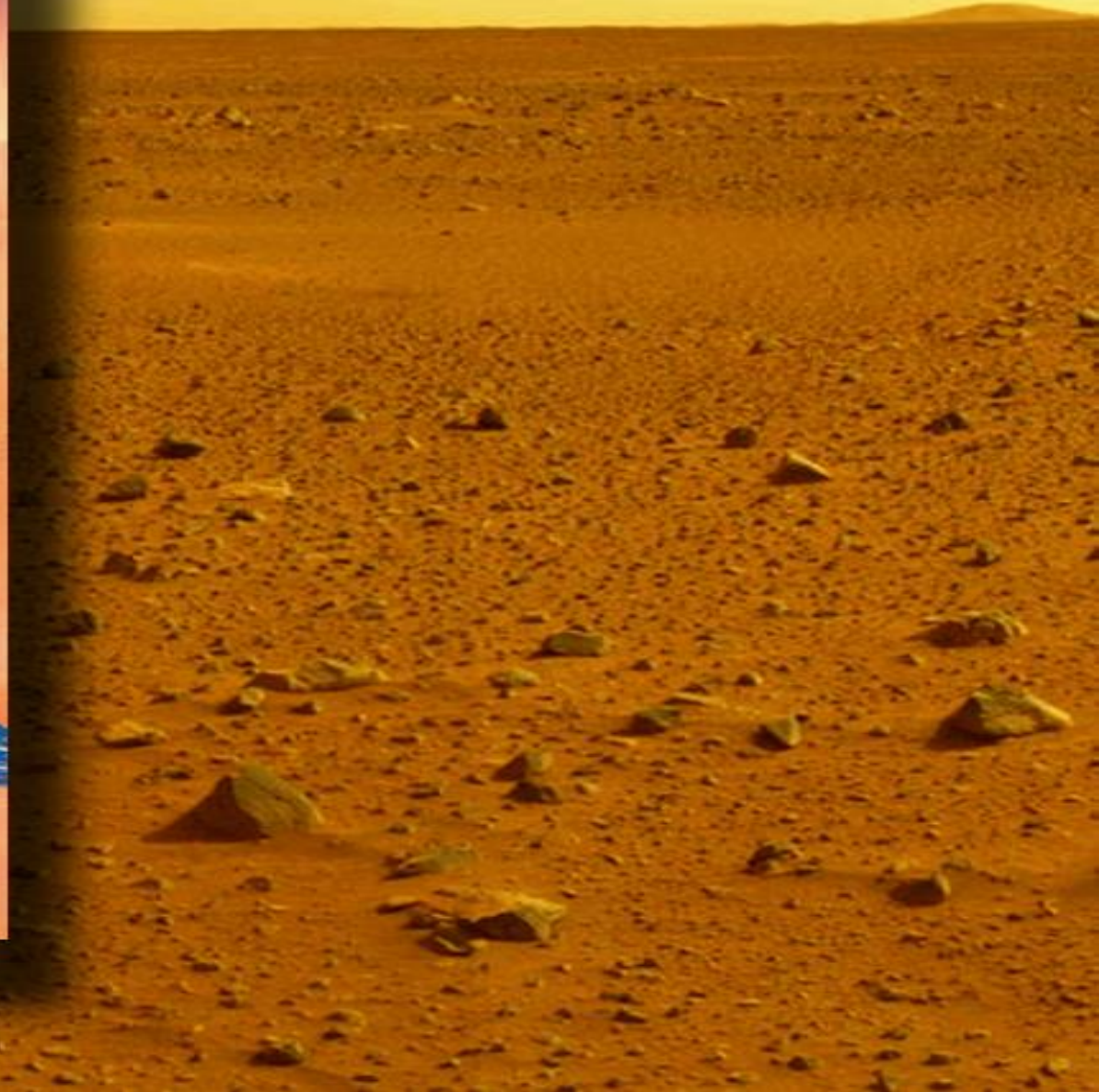
# Inflatable Lunar Habitat





# Mars Robotics Sample Return

DESIGNED  
**1994**



# Lunar Excursion Vehicle

DESIGNED  
**1995**



# Mars Base & Mission Planning 1996



# TransHab

## Inflatable Space Habitat

DESIGNED  
**1997**  
U.S. Patent



# *ISS TransHab*



# ***ISS TransHab*** Full Scale Shell Development Unit (SDU-3)



**First Inflation:** November 17, 1998

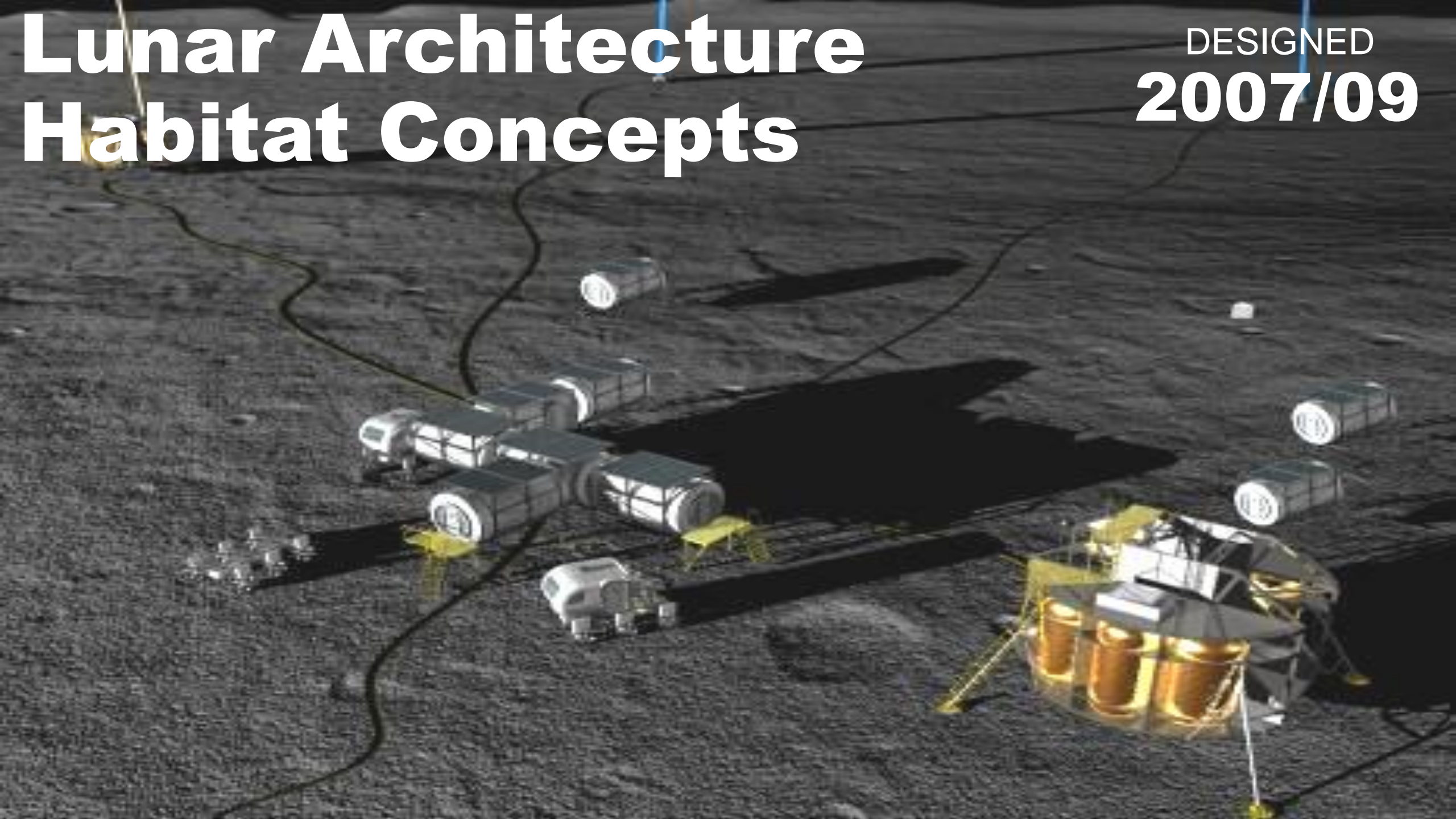
# Mars Surface Hab/ Combo Lander

DESIGNED  
2000



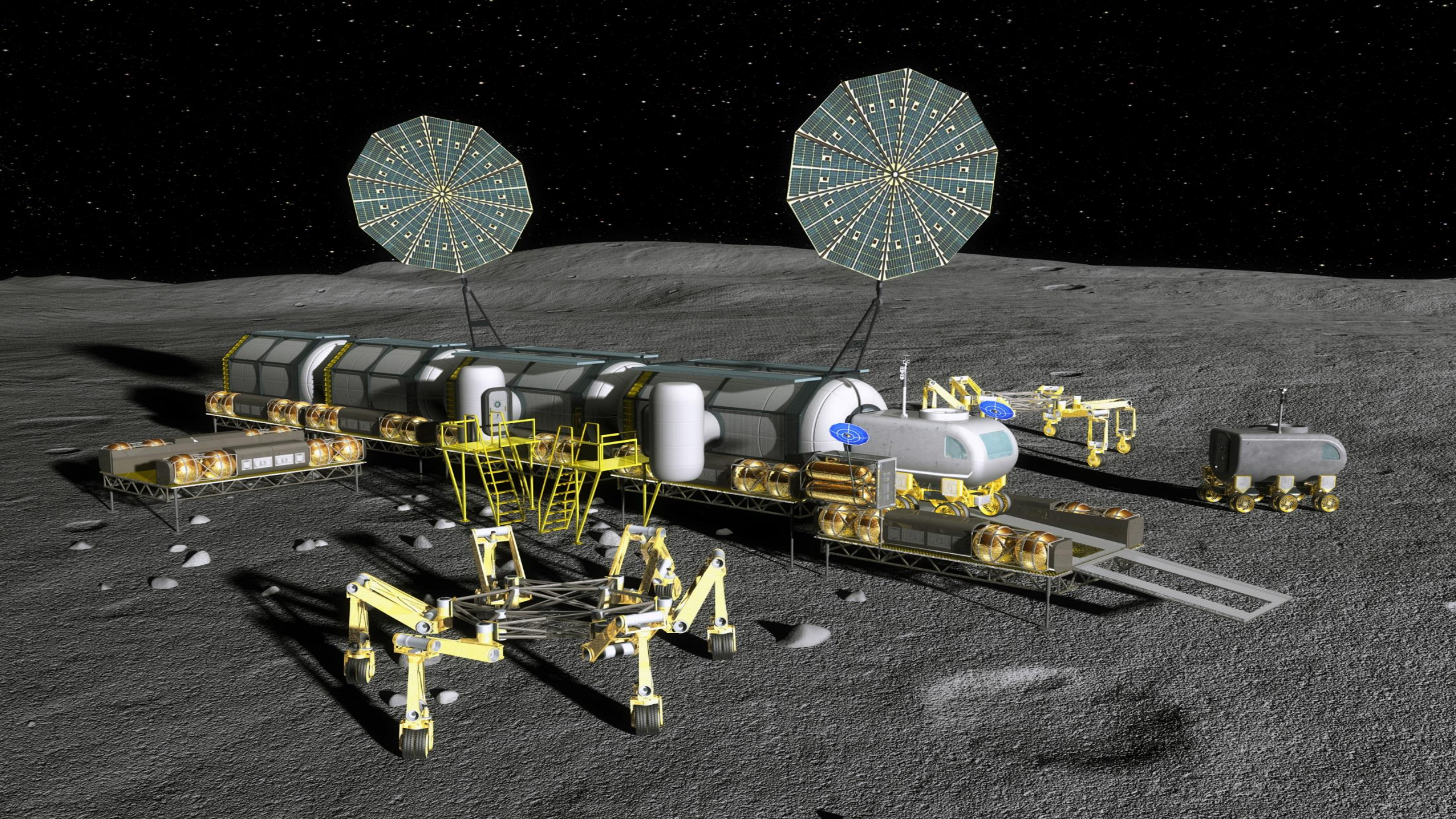
# Lunar Architecture Habitat Concepts

DESIGNED  
**2007/09**



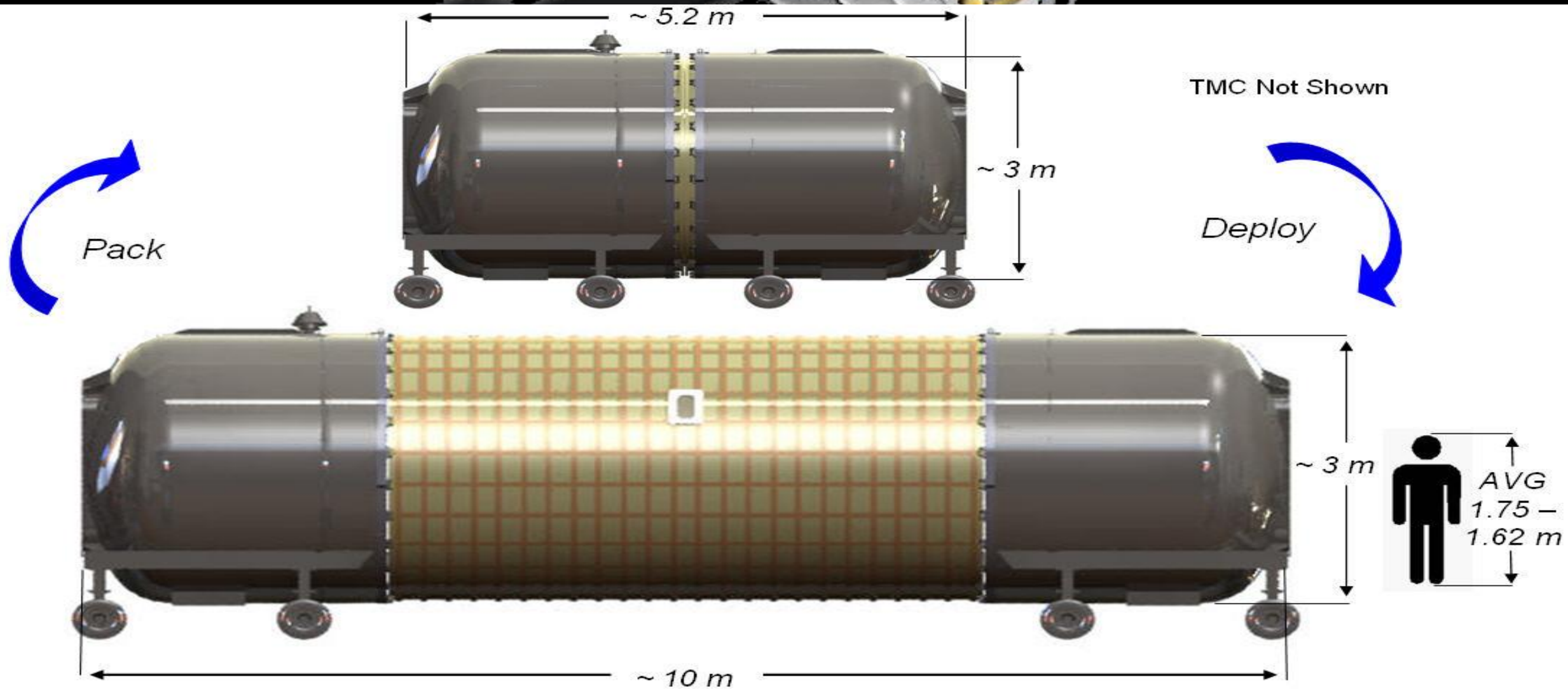






# Mid-Expandable Habitat

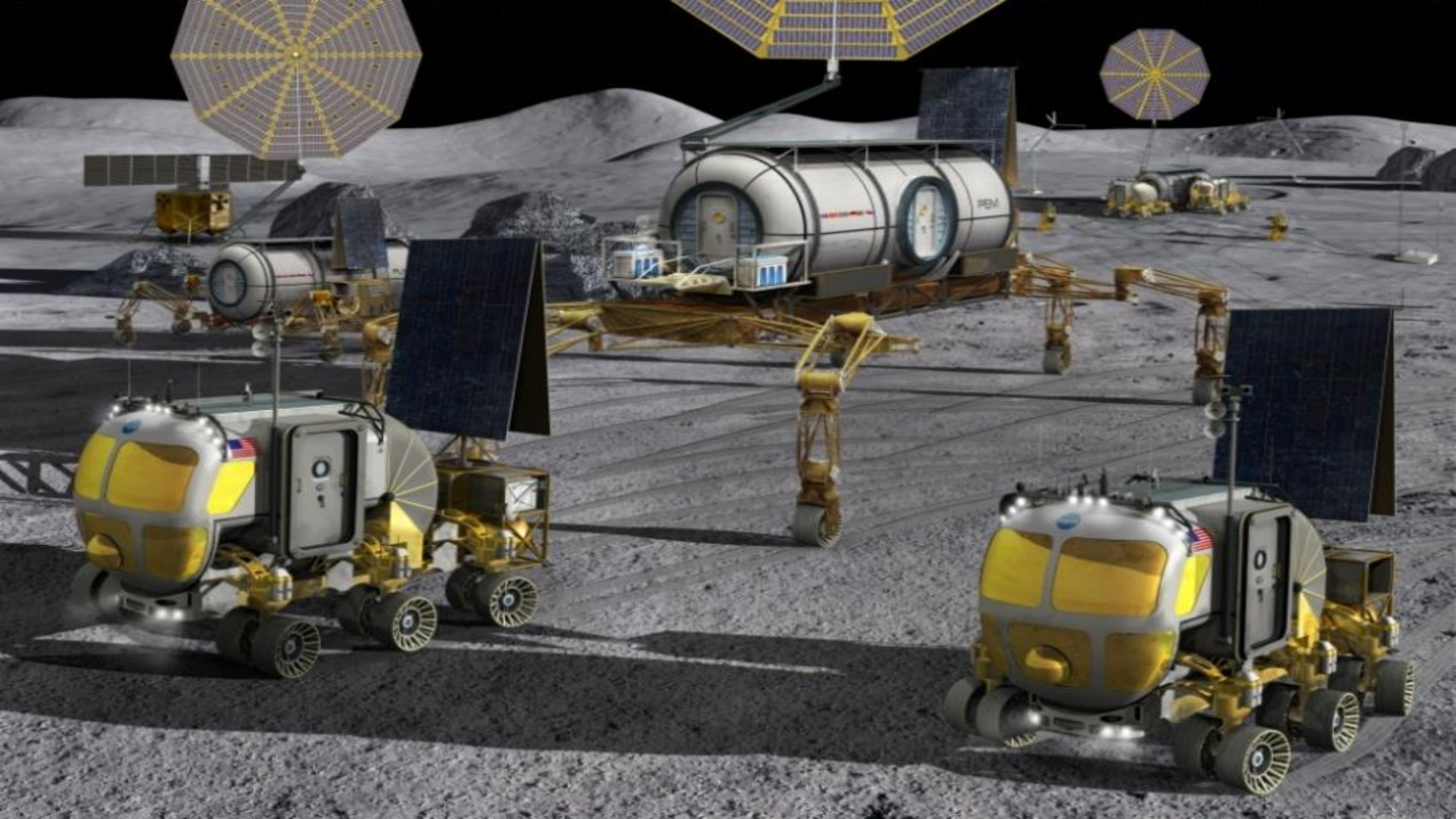
DESIGNED  
**2008**



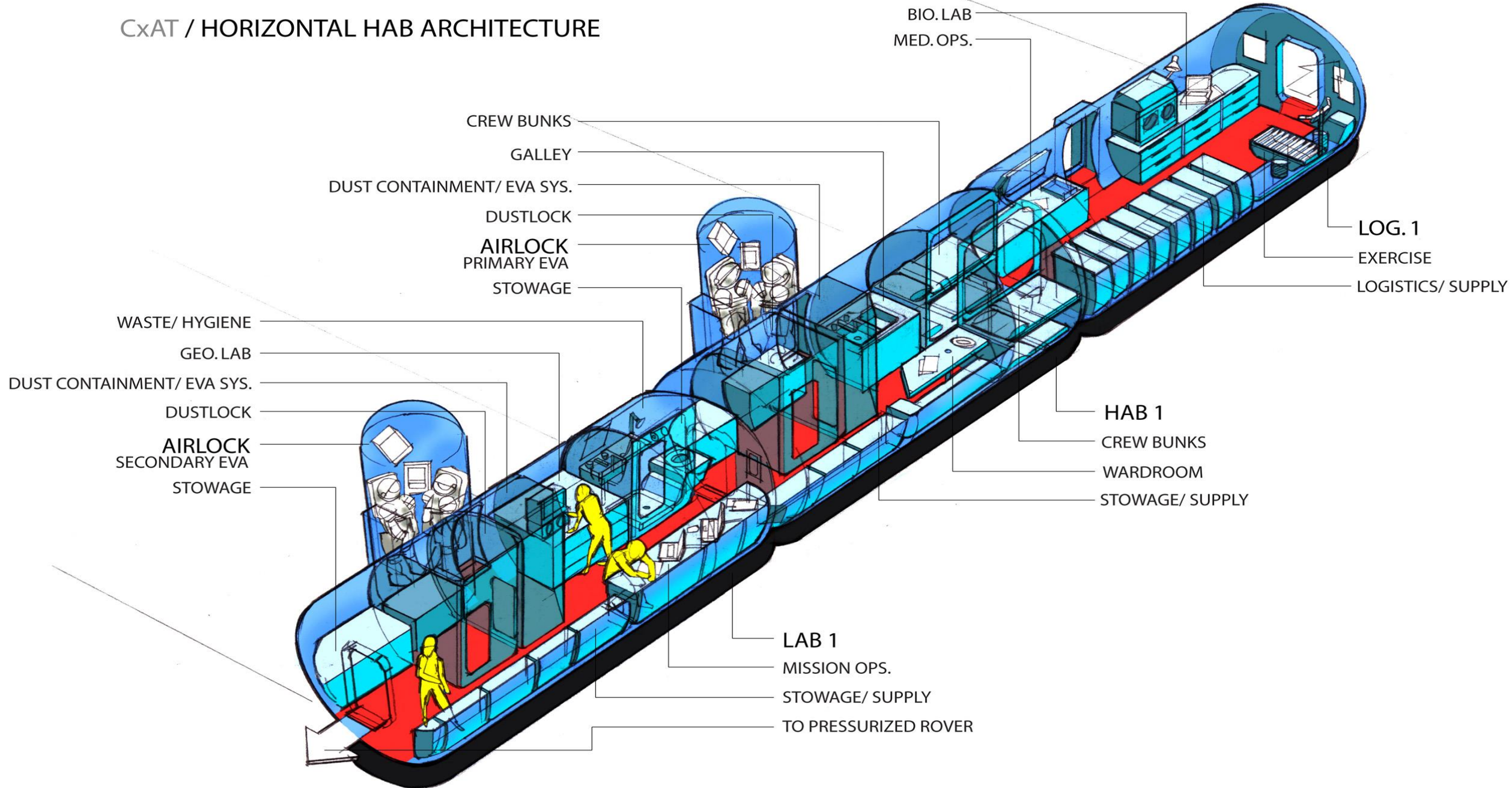
# Pressurized Excursion Module

DESIGNED  
**2009**



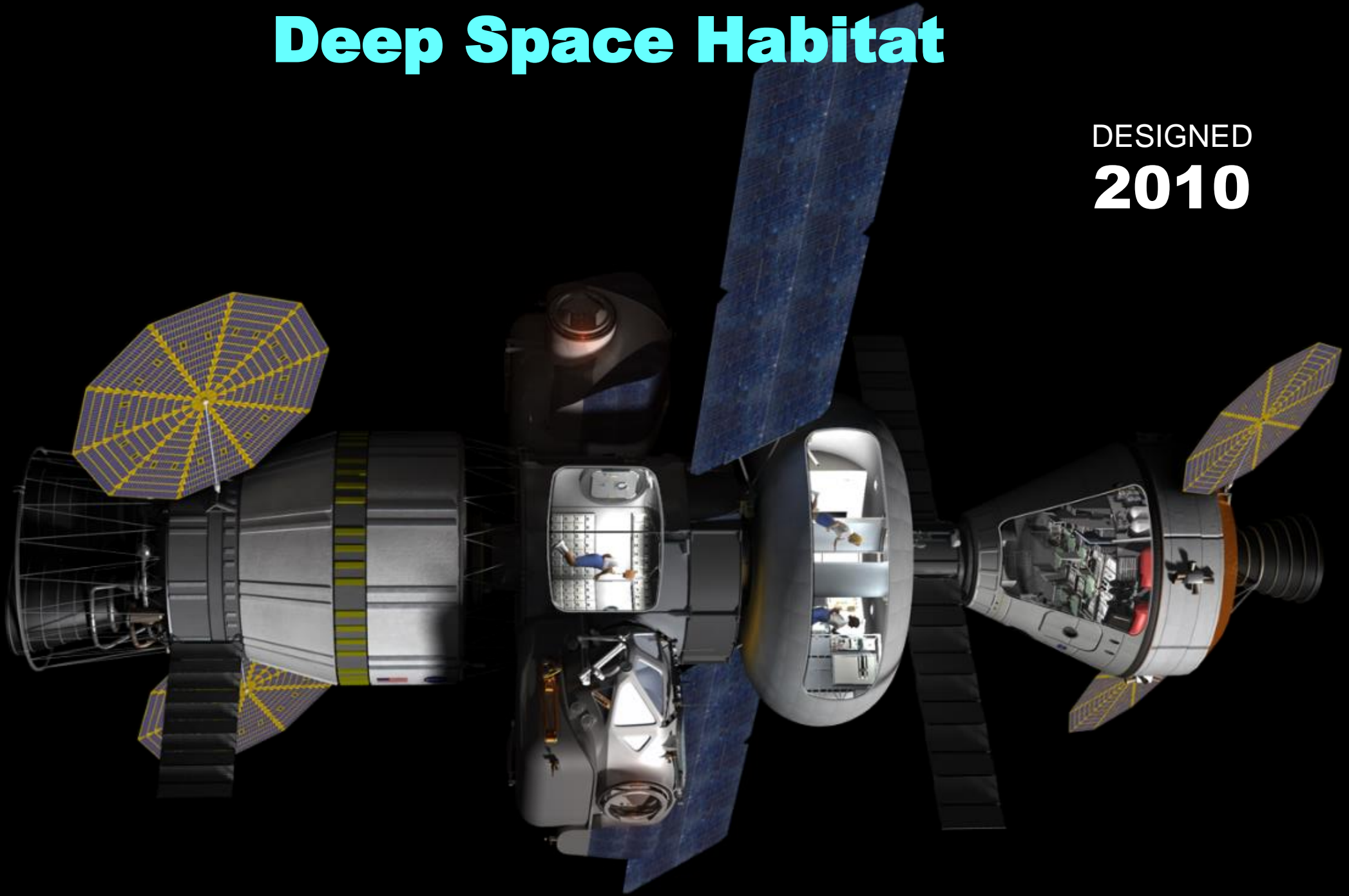


# CxAT / HORIZONTAL HAB ARCHITECTURE



# Deep Space Habitat

DESIGNED  
**2010**



# Earth Analog Testing





# Habitat Demonstration Unit



**Rapid Prototyping**



# Habitat Demonstration Unit 2010 Interface Test w/ Rover







**HABITAT  
DEMONSTRATION  
UNIT**

**segment H**





BXL

DEEP SPACE HABITAT

HYGIENE MODULE

Segment C

Segment B

Segment A

HPL DSH

SECURITY

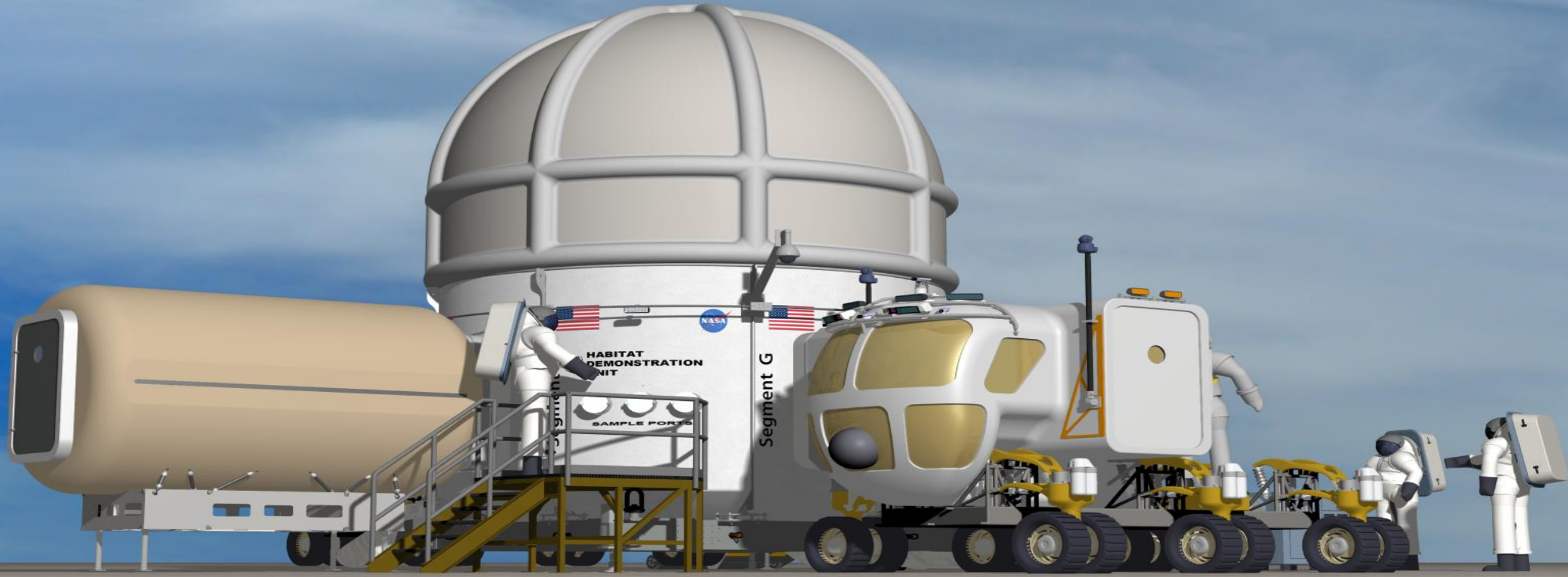
# Exploration Habitat Academic Innovation Challenge

Started  
**2010**



**H A B**

**ACADEMIC INNOVATION  
CHALLENGE**





DEEP  
SPACE  
HABITAT



Segment B

Segment A

HYGIENE MODULE



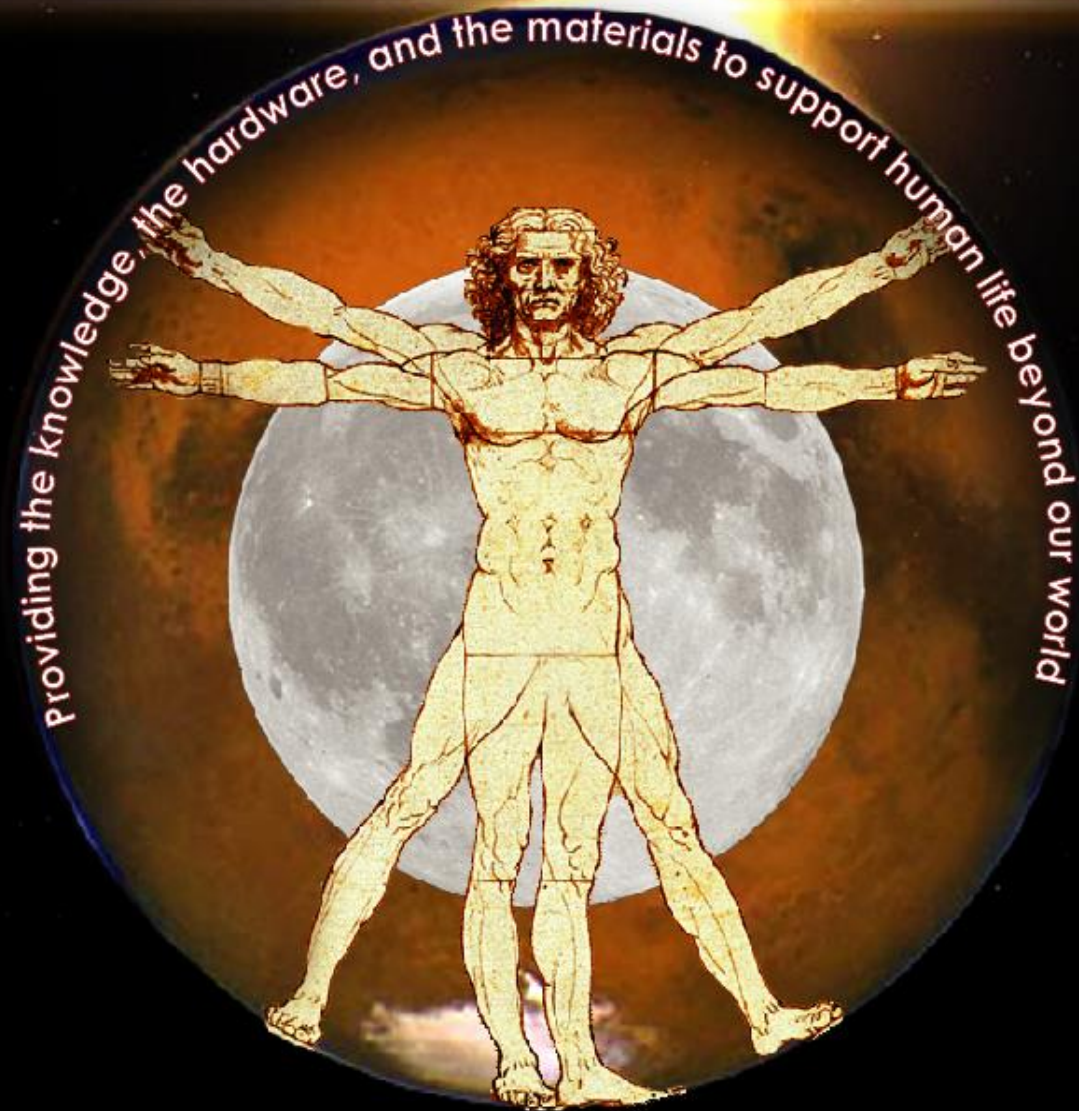


# Moon, Mars, Beyond...

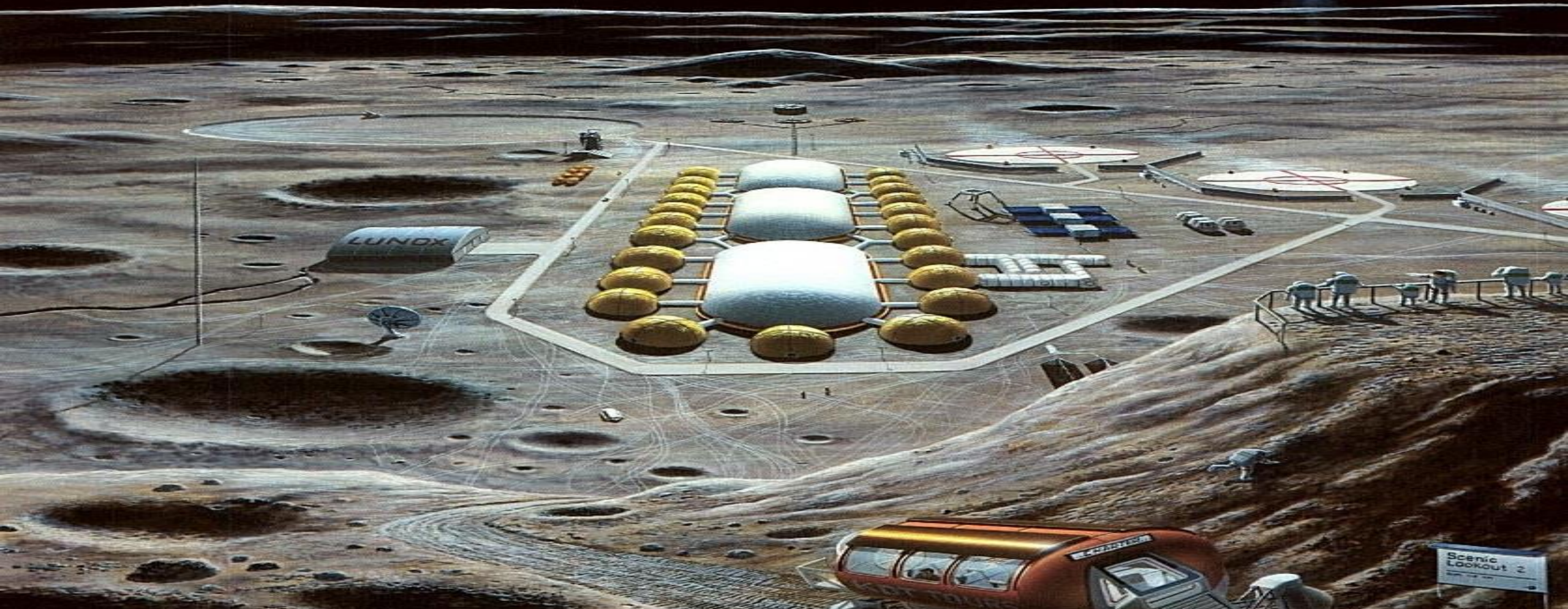


# ***Colonization***





# ***Space Architecture...***



***...architecting the future***

[www.spaceflight.nasa.gov](http://www.spaceflight.nasa.gov)

[www.nasa.gov](http://www.nasa.gov)

