RUTGERS

Surface Habitats on the Moon

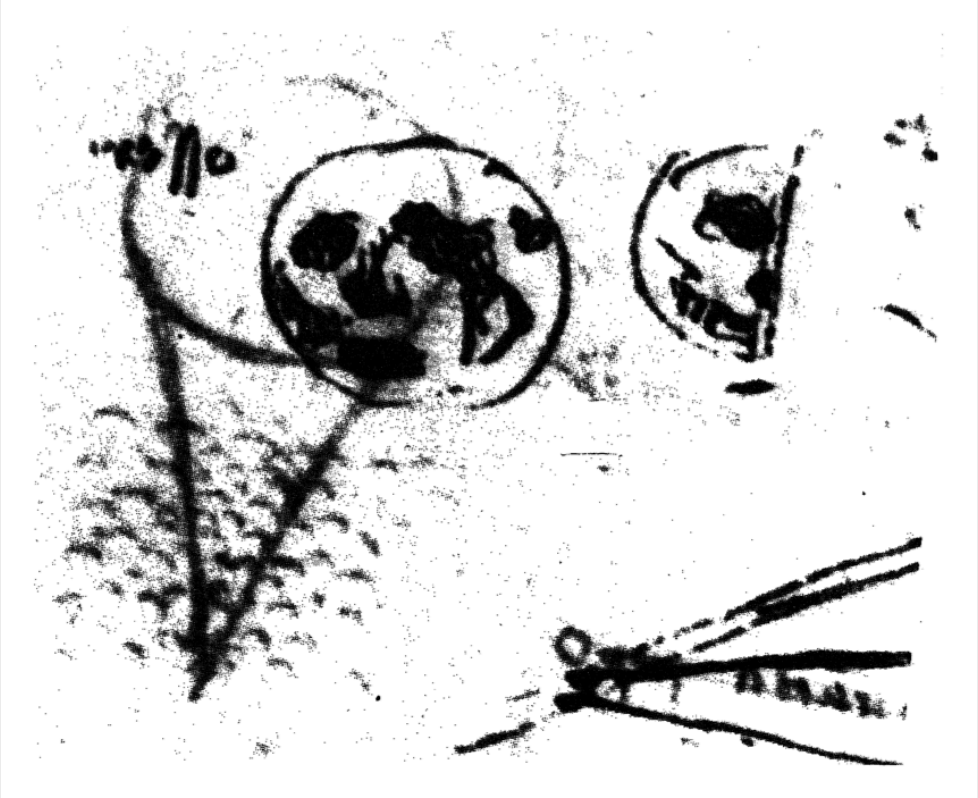
Future City

RUTGERS
School of Engineering

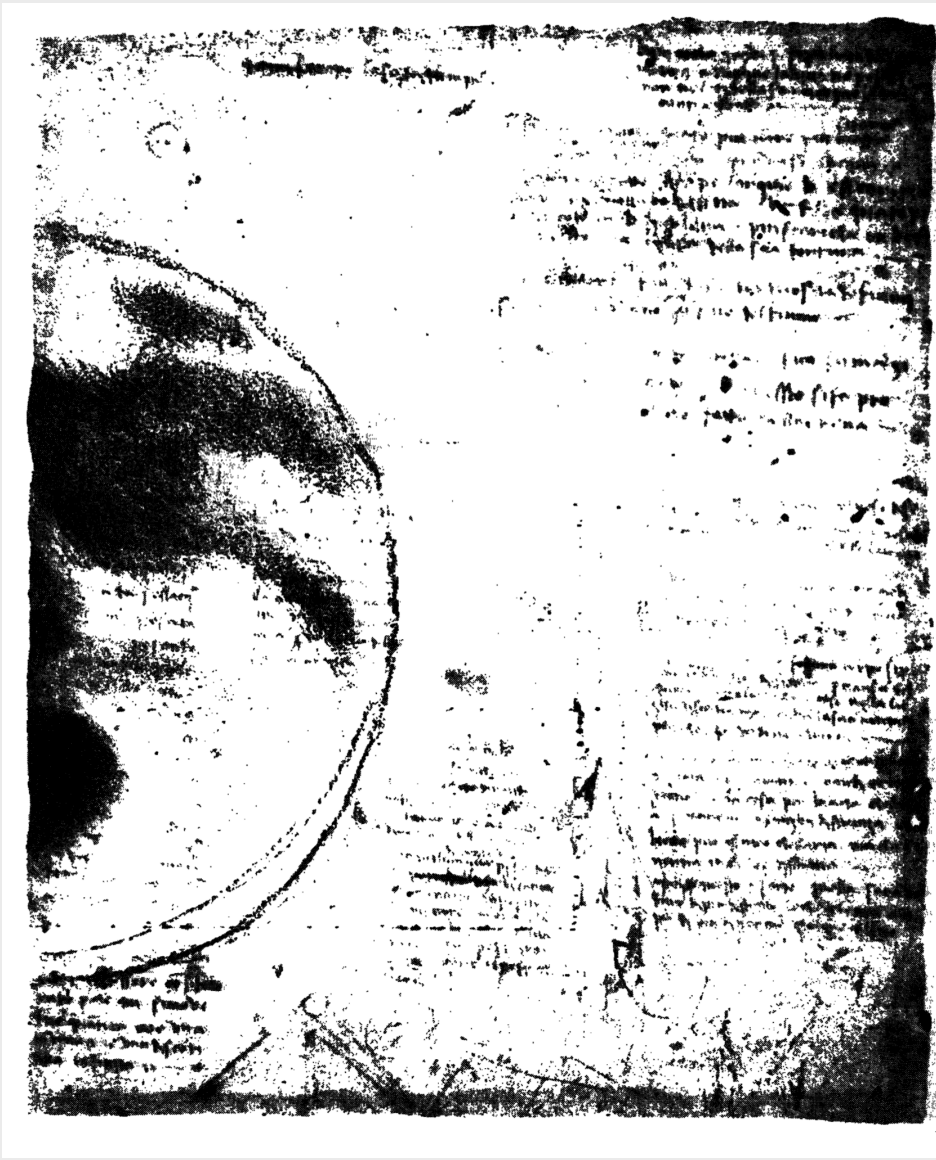
Haym Benaroya
Department of Mechanical
& Aerospace Engineering

28 October 2020

Da Vinci 1505-1508;
¾” (2 cm) across



7” (18cm) diameter



(1882 – 1945)

Robert H. Goddard

in 1926 (first launch of a liquid-fueled rocket)

(1857-1935)

Konstantin Tsiolkovsky

1903 paper on space travel & rocket equation

(1881-1957)

Robert Esnault-Pelterie

1912 independent derivation of rocket equation

(1894-1989)

Hermann Oberth

Research on rocket science 1923-1929

Sports Highlights

The Philadelphia Phillies reinstate star Richie Allen, 1C.

Chicago Cubs increase their National League with two victories over the slumping Phillies, 1C. (Complete Sports, 1-3C)

TODAY

Florida's Space Age Newspaper

Published in Brevard County, Florida

Monday, July 21, 1969

Next Space Shot

Delta rocket will orbit Intelsat communications satellite Tuesday, exact time not announced.

TODAY's Weather

Considerable cloudiness with thundershowers. High 88, low 75. Easterly winds 8 to 15 mph. (Complete weather Page 2A)

10 Cents

MAN ON MOON

NEIL ARMSTRONG, ED ALDRIN ERECT AMERICAN FLAG ON SURFACE OF MOON ON 'LIVE' TELEVISION

Apollo 11 Headlines

Astronauts aboard Lem were calm, but bosses in Houston were biting their nails. (2A)

Neil Armstrong's first step quote goes down in world's history books. (3A)

Last man to check Lem before Apollo flight gives "wow" at landing. (4A)

Astronaut Mike Collins' sister and mother watch from South Merritt Island home. (4A)

The nightclub scene: Confetti splashed and people cried as Armstrong touched the moon. (4A)

Armstrong's parents ask world to pray for astronauts' safe return. (5A)

Spokesman says Aldrin family "thrilled" by lunar landing. (5A)

Landing brought whoops of joy from homes of three astronaut families. (5A)

Veteran broadcaster Walter Cronkite is all "Oh Boy!" for Lem moon landing. (6A)

Astronauts moon walk suits cost NASA $300,0000. (6A)

Seven minutes of engine burn will mean a safe return Tuesday. (7A)

Apollo 12, second U.S. lunar landing mission, will almost double time for surface exploration. (7A)

Director of U.S. space program says successful moon landing opens "a new era." (7A)

Man wouldn't be on moon now if it weren't for NASA engineer who fought for Lem landing concept. (7A)

Dingy Connie Mack Stadium in Philadelphia gives Apollo 11 lusty roar of approval. (1C)

Manufacturers key ad campaigns to products astronauts use. (12C)

Everyday Features

'That's One Small Step for Man; One Giant Leap for Mankind'

TODAY—AP Wirephoto

PRESIDENT SPEAKS TO ASTRONAUTS FROM WHITE HOUSE TELEPHONE
... "This has to be the most historic telephone call ever made"

By SANDERS LaMONT
TODAY Aerospace Writer

HOUSTON — Man landed and walked on the moon for the first time Sunday, July 20, 1969.

Astronaut Neil Armstrong stepped onto the surface at 10:56 p.m. As his left foot touched the surface, he said solemnly:

"That's one small step for man."

As his right foot touched the powdery surface, he added, "One giant leap for mankind."

He was joined on the surface by companion astronaut Buzz Aldrin slightly less than 20 minutes later.

"Beautiful, beautiful, beautiful. A magnificent desolation," Aldrin said.

The pair put on a spectacular live television show for millions for viewers on earth.

Even as Armstrong stepped onto the surface, he described it as "fine and powdery—I can kick it up with my toe. It is like fine charcoal."

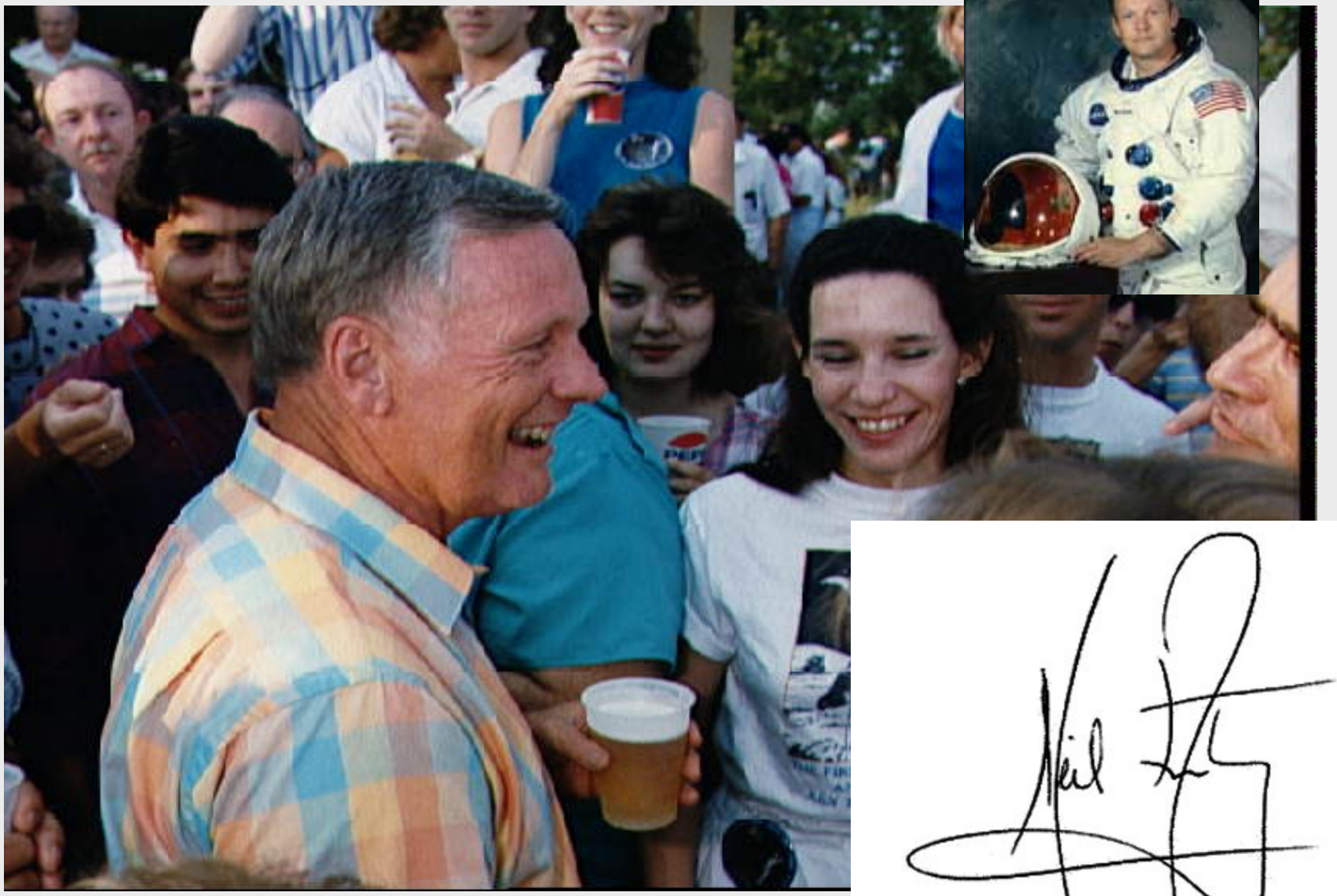
FIRST STEP TO MOON

Before he reached the bottom rung on the ladder from the spaceship he said the surface "looks like very, very fine grains as you get closer to it—almost like a powder."

The two astronauts flawlessly completed their scientific tasks and clambered back into their space ship after two hours and 17 minutes on the lunar surface.

Both had returned to the moonship "Eagle" at 1:13 a.m., more than an hour ahead of the time they were originally to have started it.

Continued Page 2A

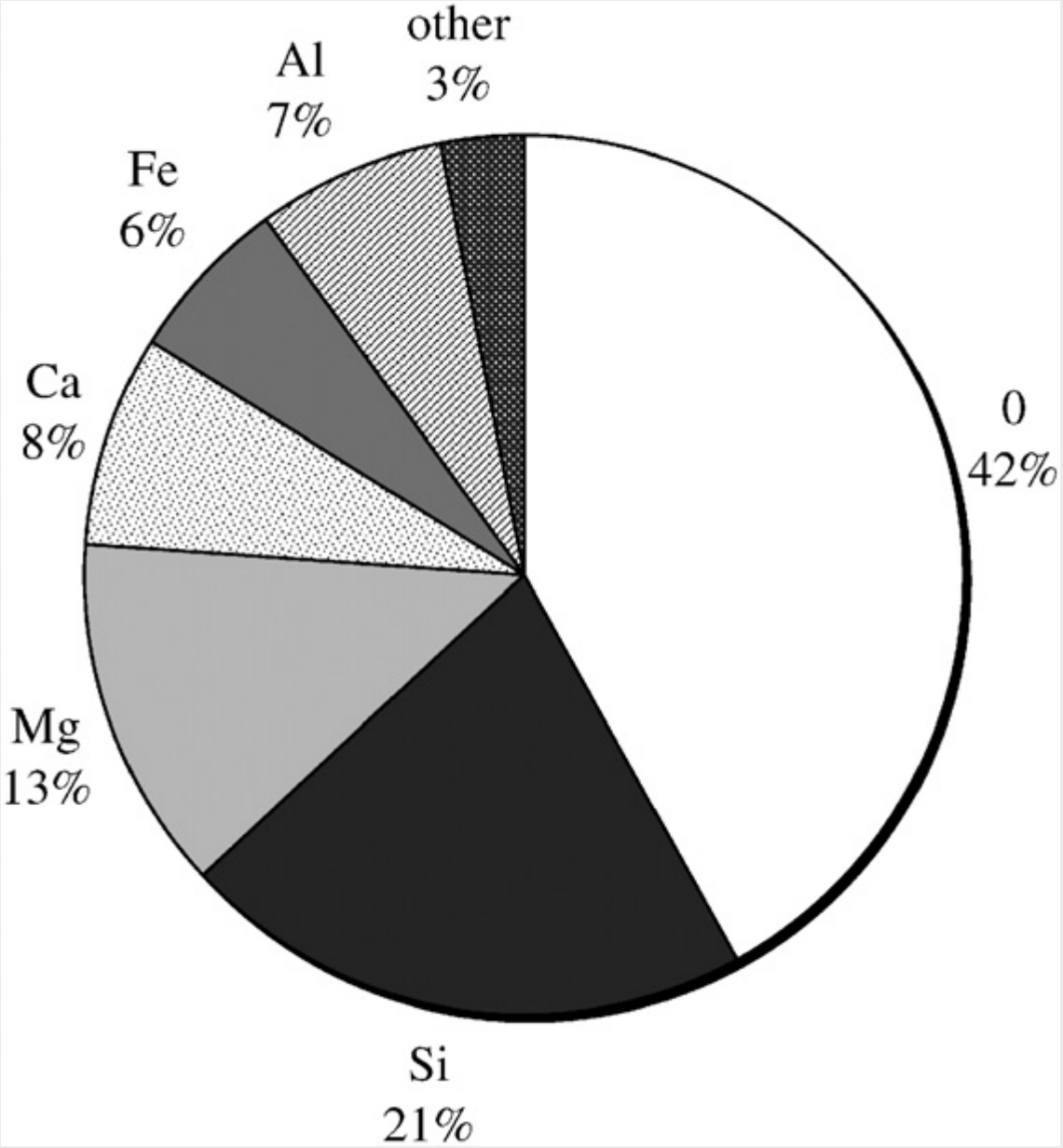


Neil Armstrong (1930-2012)

Harrison Schmitt Apollo 17

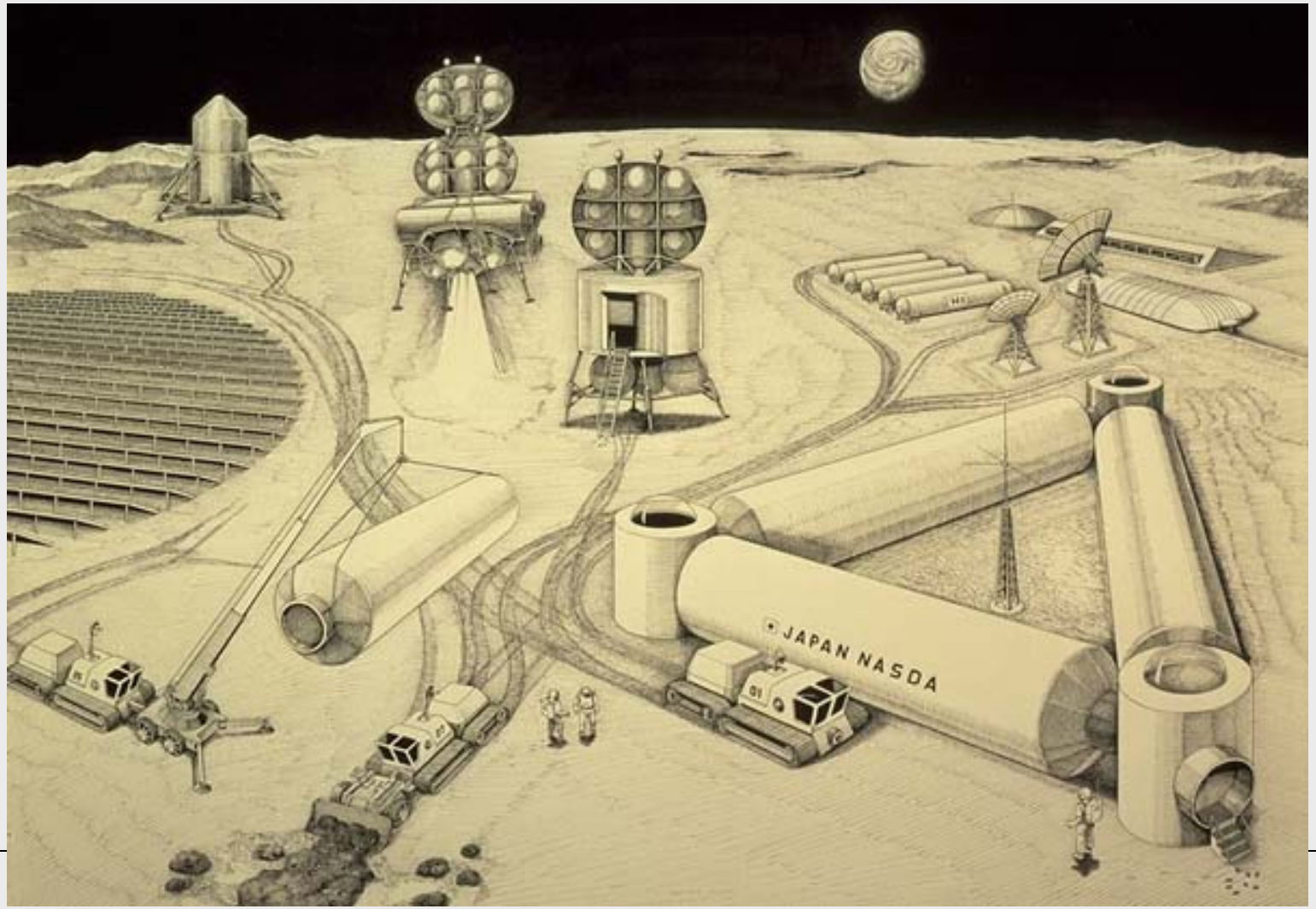
Water Found Recently By NASA's LCROSS* Probe

*Lunar Crater Observation and Sensing Satellite June-Oct 2009; crash South Pole



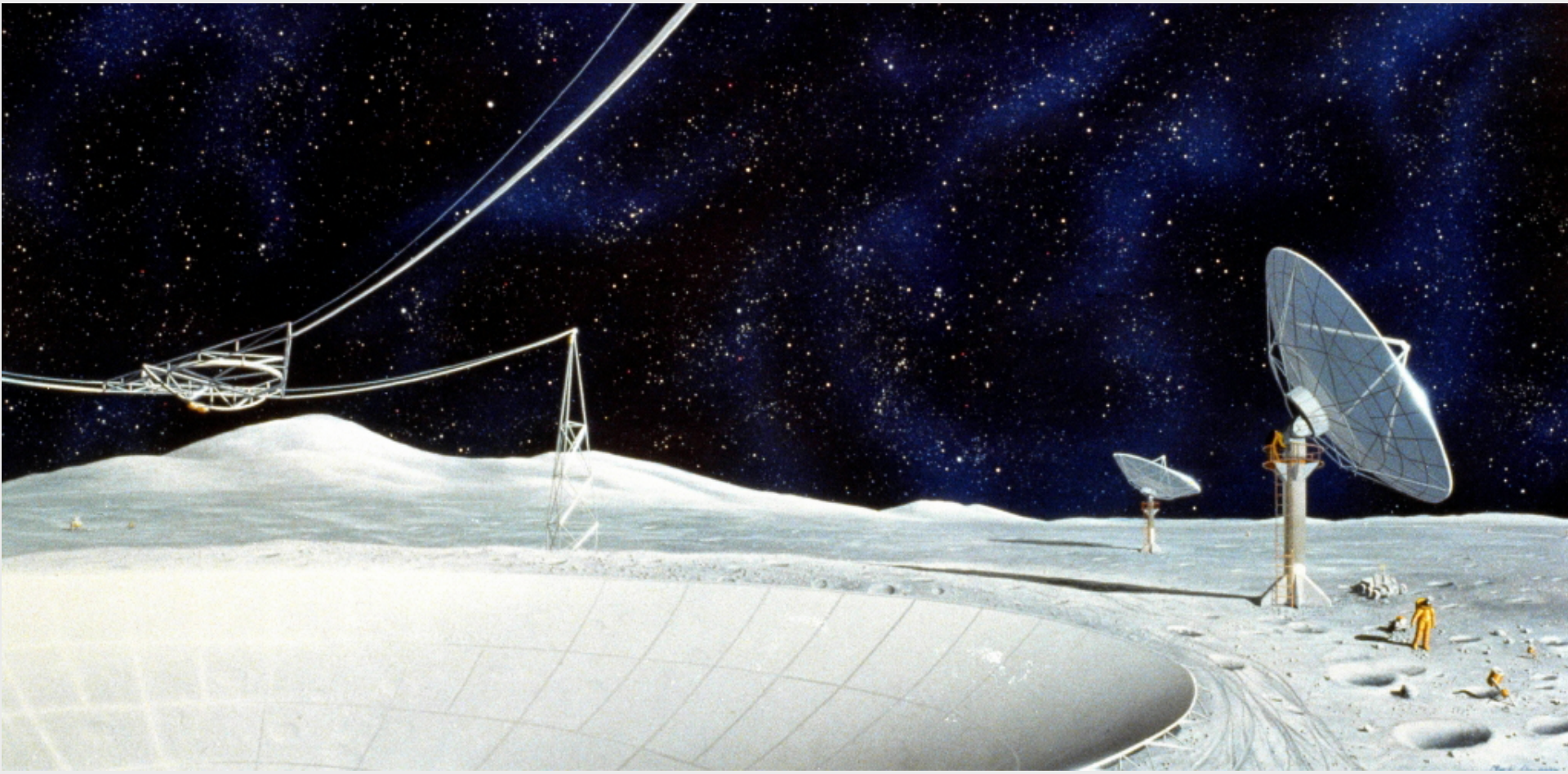
Composition of the lunar regolith

Energy Production

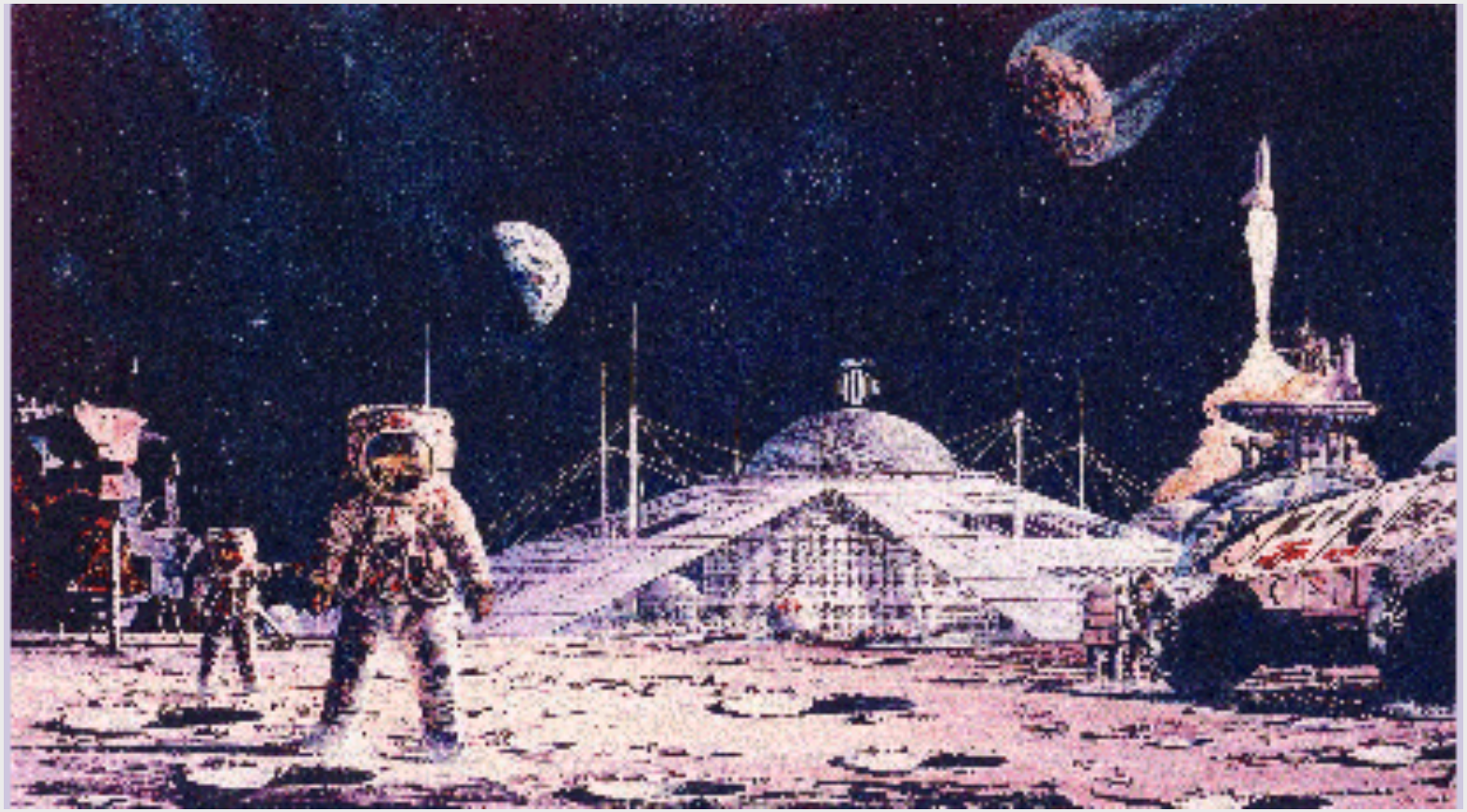


Mining/Platinum

Lunar-Based Astronomy: Lunar Far Side



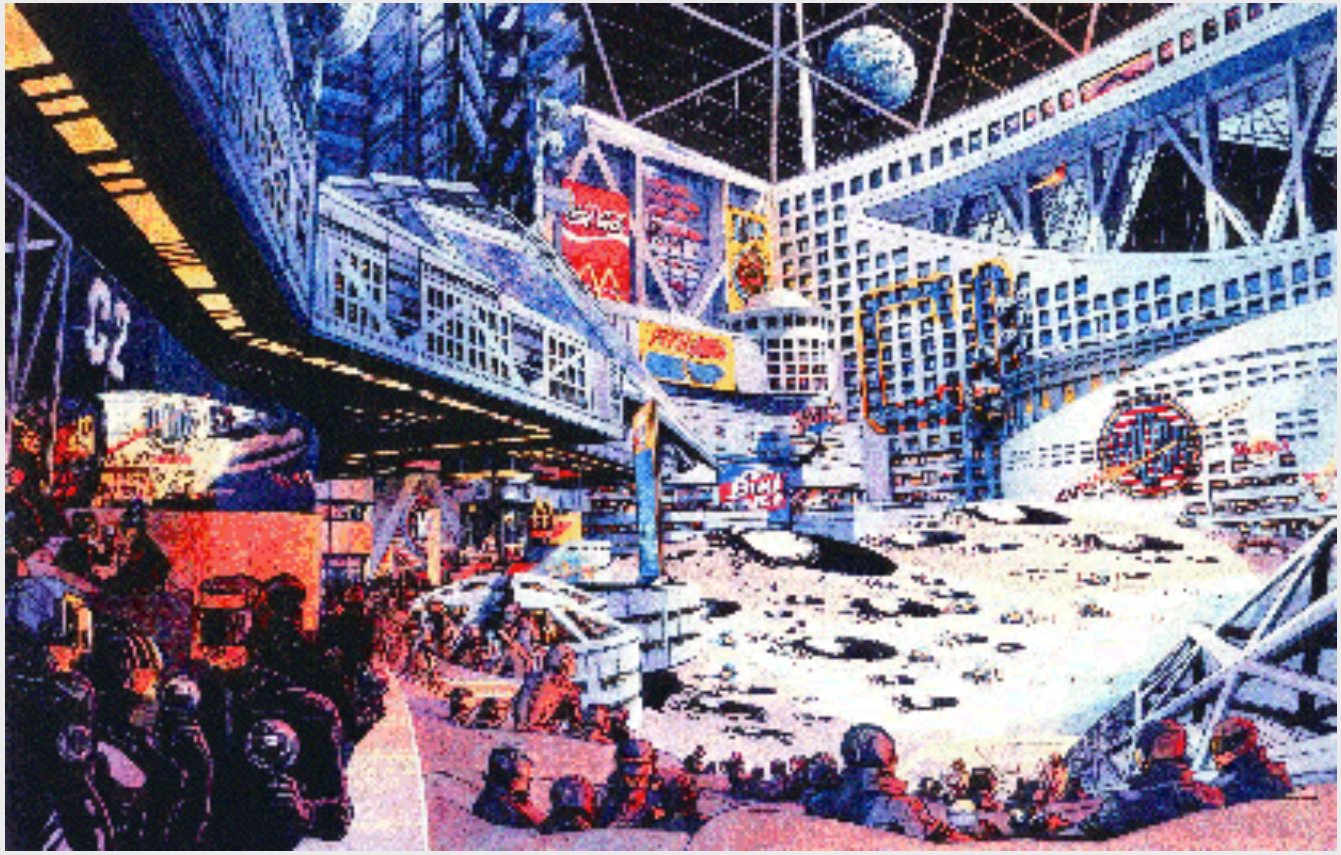
Tourism – Hilton Exterior



Concept and picture courtesy Peter Inston

Barron Hilton 1958

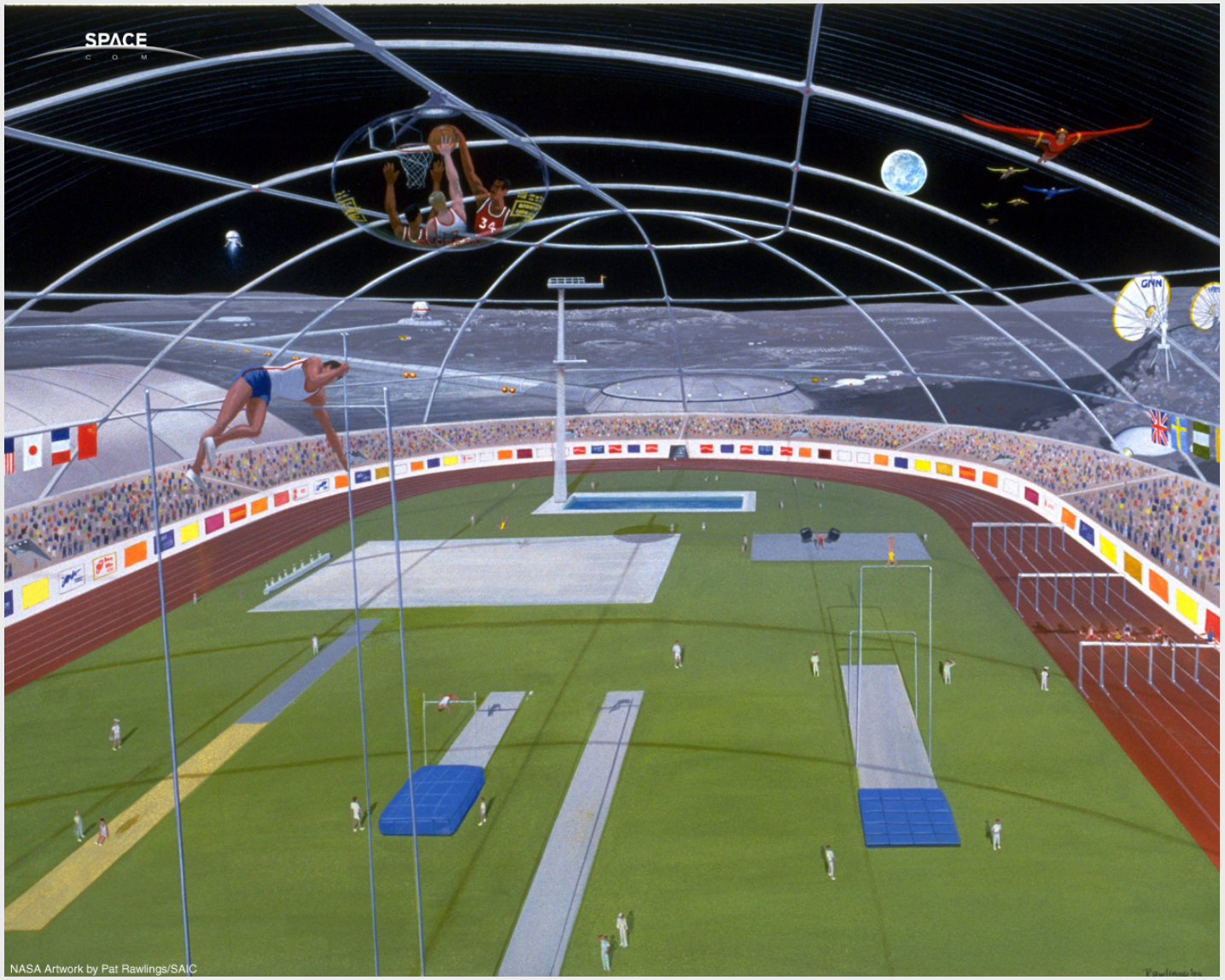
Tourism – Hilton Interior Mall

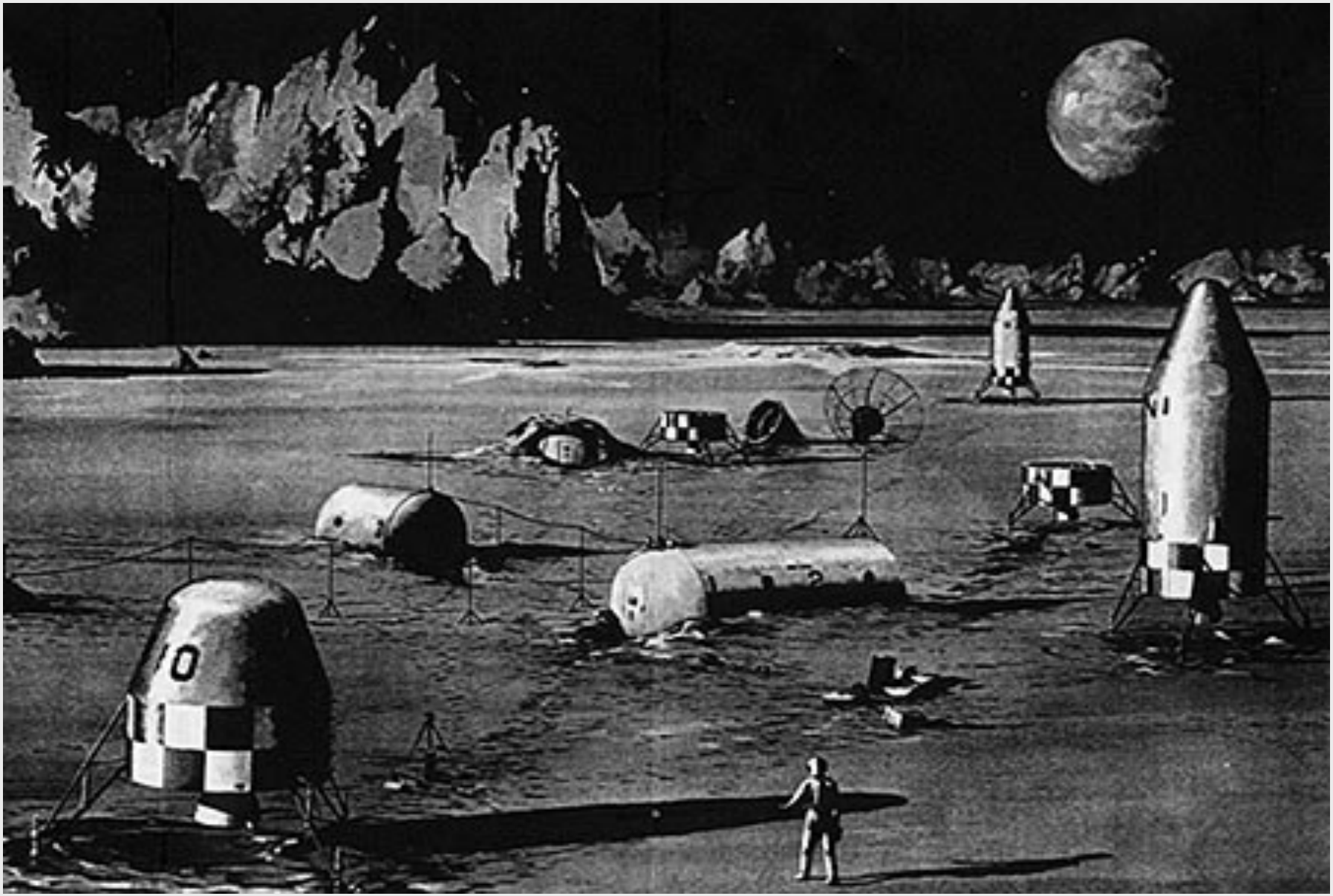


Concept and picture courtesy Peter Inston

Lunar Marriott

3d Football





1962

Lunar Environment

- $\mathbf{g_{Moon}}$ = 1.62 m/s²
- **internal air pressurization** can range from 34.5 kPa (5 psi) to 101.3 kPa (14.7 psi)
- protection from **radiation** and **micrometeoroids**
- insulation (**temperature** differentials of 250°C)
- 2.5 m - 3.0 m of **regolith cover** needed

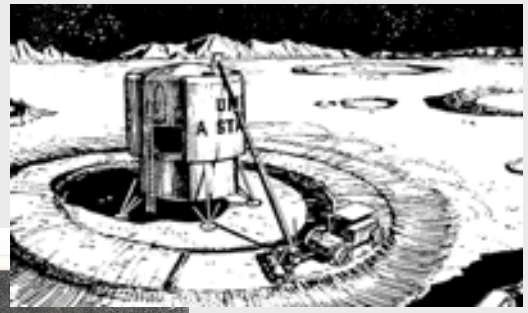
Additionally!!

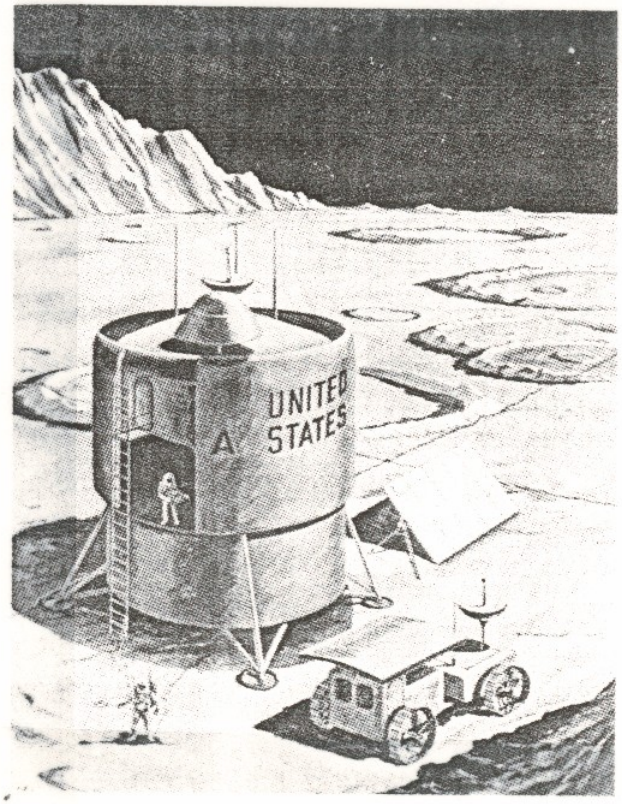
- Human **physiological** unknowns – survival in **low *g*;** **radiation** effects
- Human **psychological** issues
- Medicines don't work – **Pharmacology** only for 1 *g*
- Survival of other living organisms

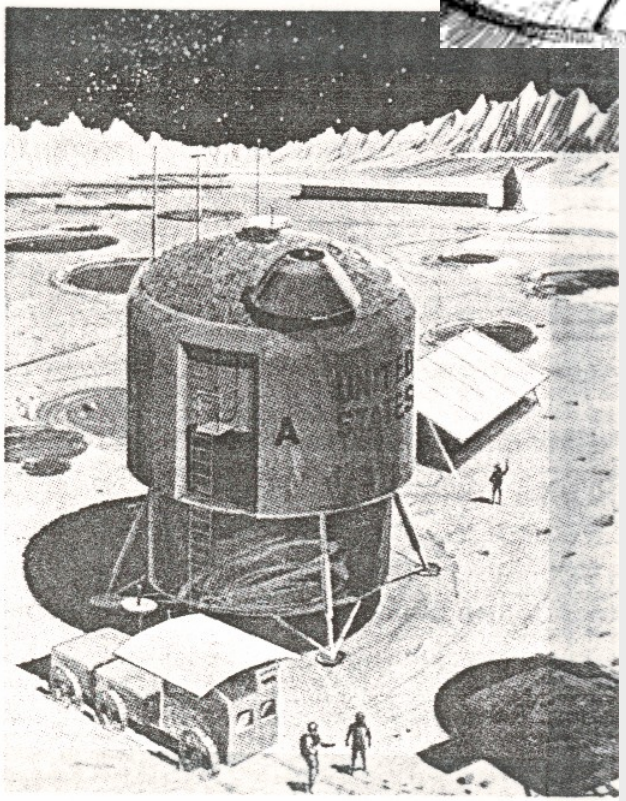
Micro/Low Gravity

- Cardiovascular Deconditioning
- Bodily Fluids Shift to the Upper body
- Distorts Vestibular sense
- Loss of Blood Volume
- Cataracts
- Muscle Atrophies
- Cancer
- Bone Demineralization (1.5%/month)
- Pharmacology issues

Boeing 1963

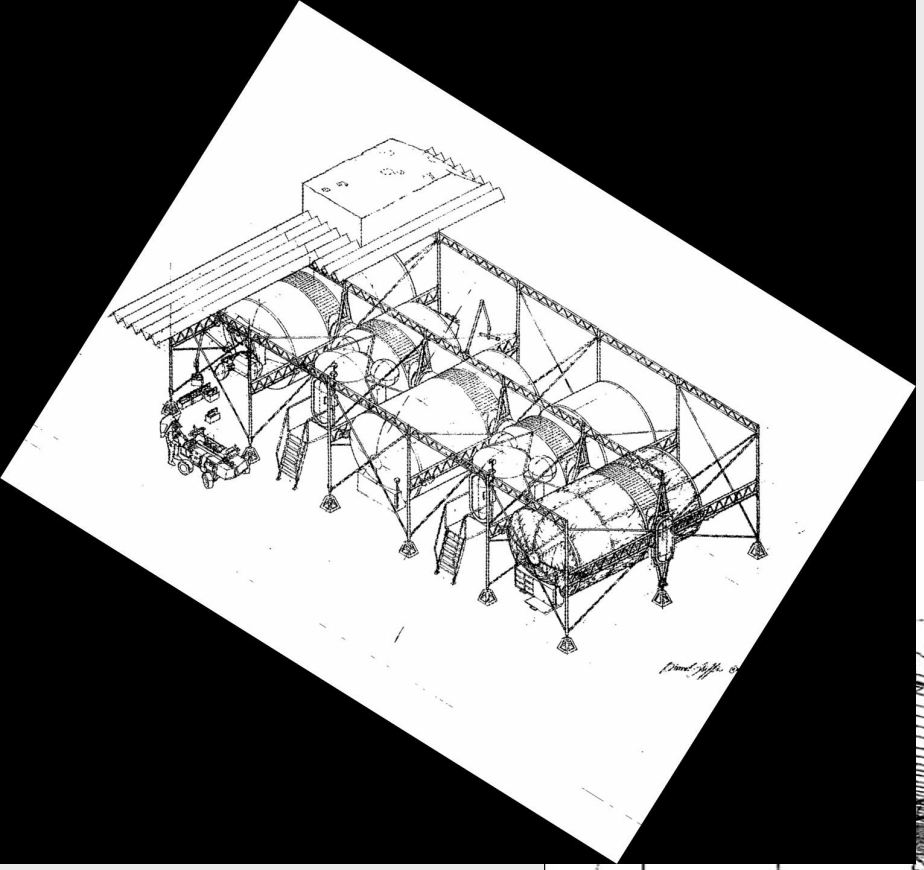


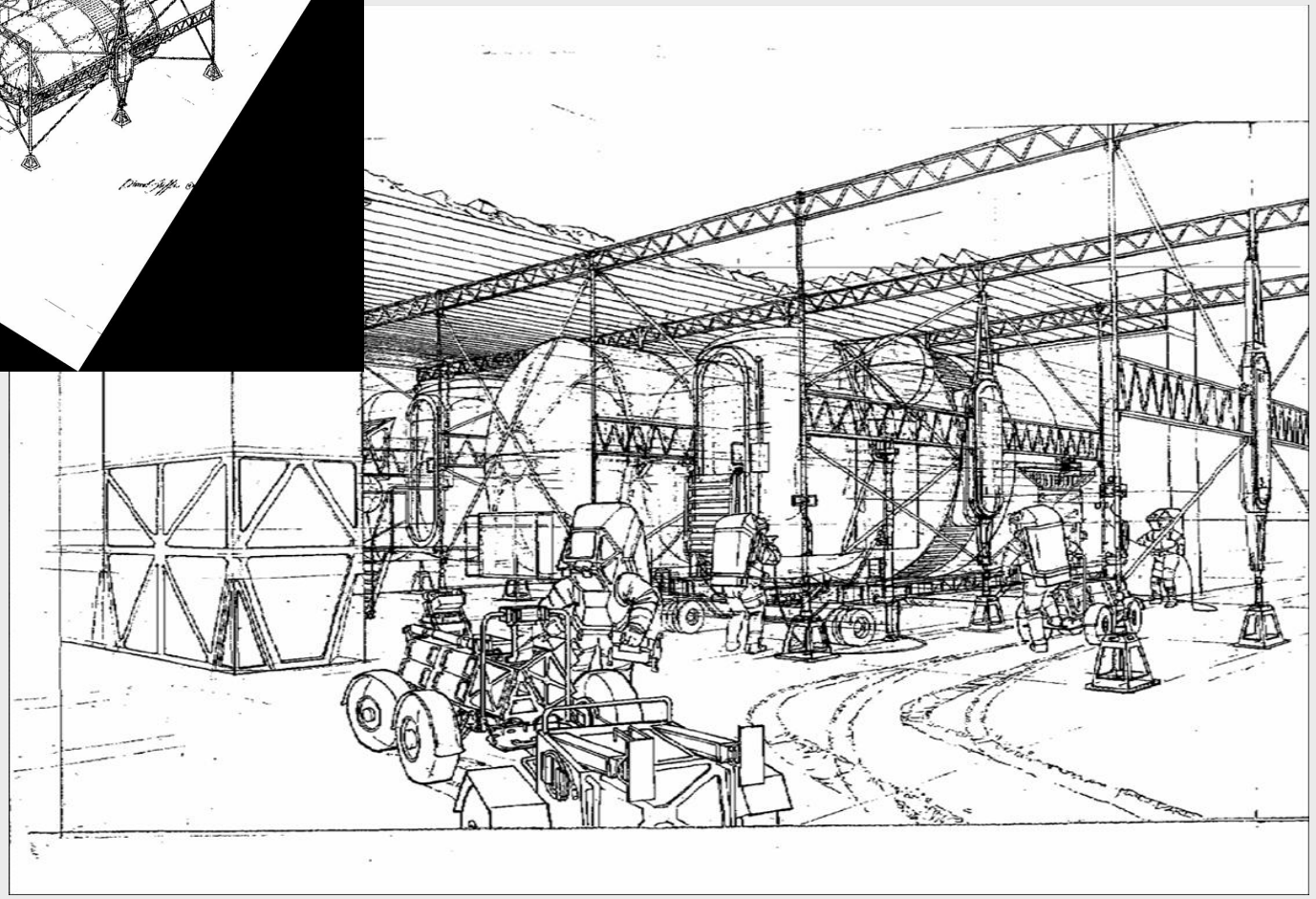




Two versions of LESA modules emplaced on the Moon by Boeing (1963).
[p. 37 Lowman in Mendell, 1985]

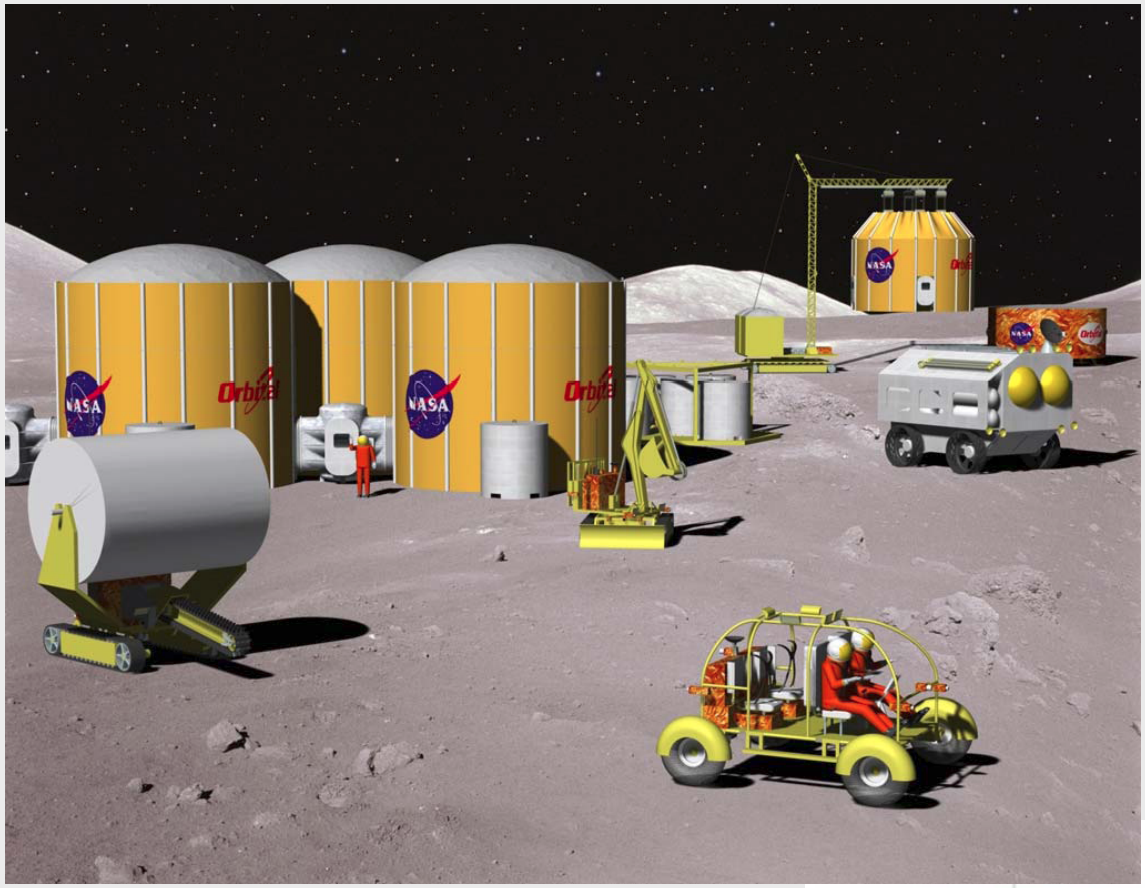
Cylinder Modules

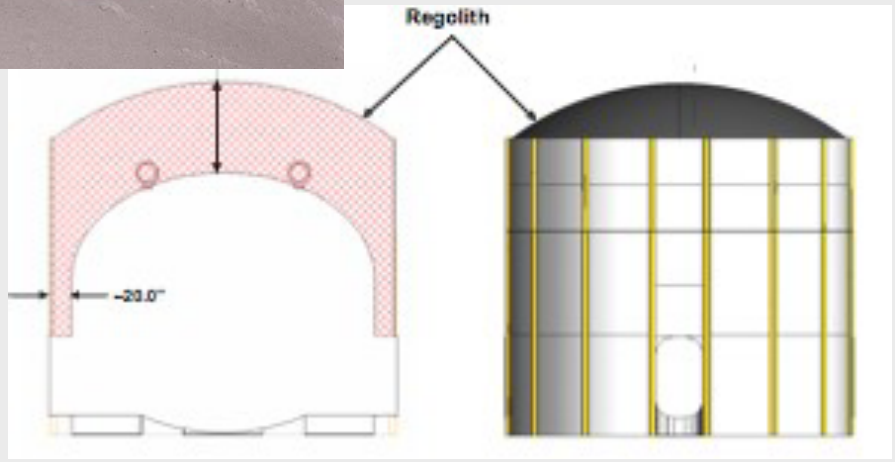




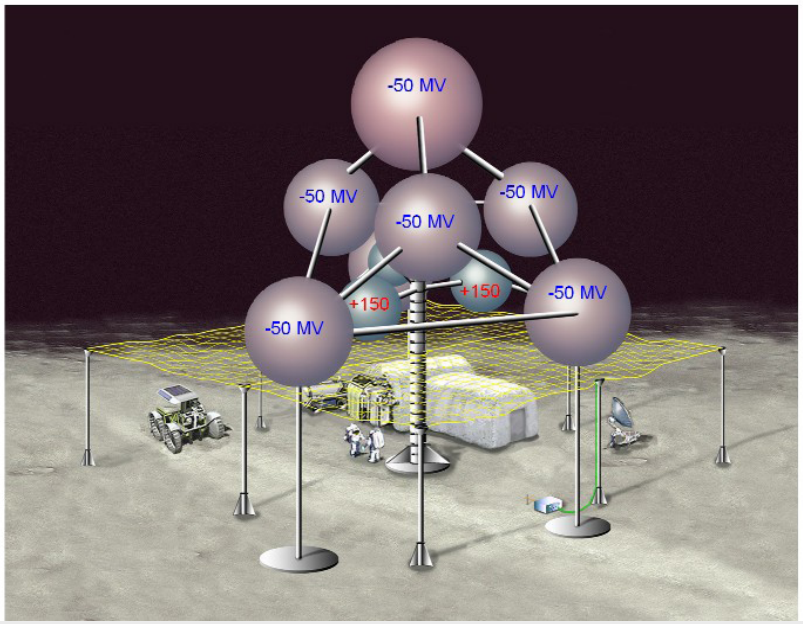
Brand Griffin

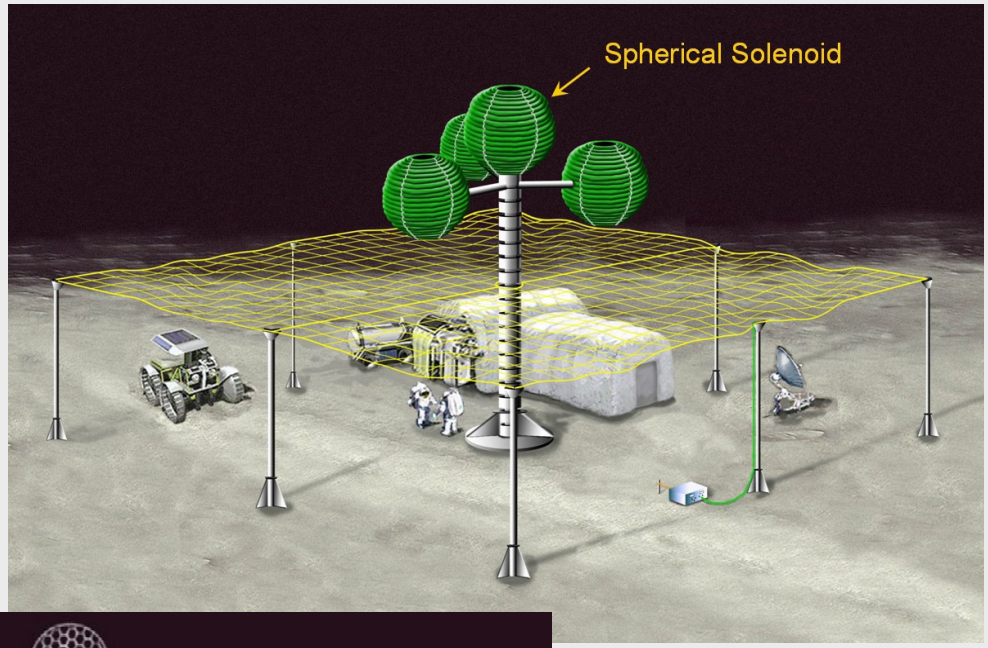

Mars
3

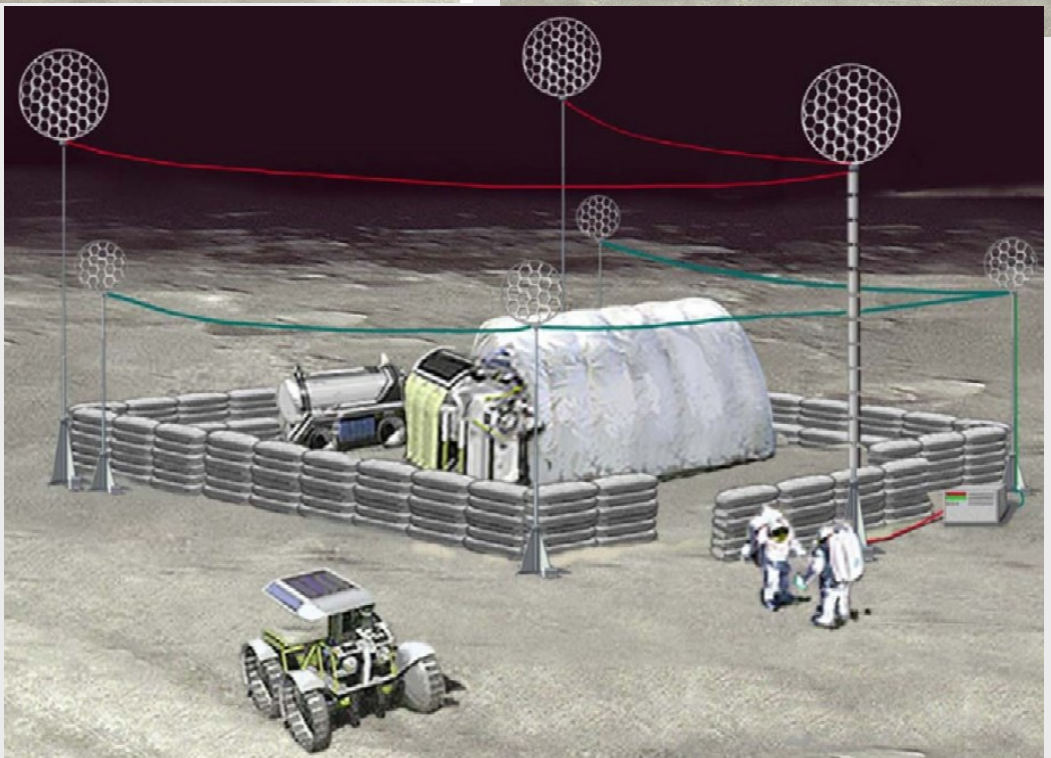




Courtesy **Orbital Sciences**



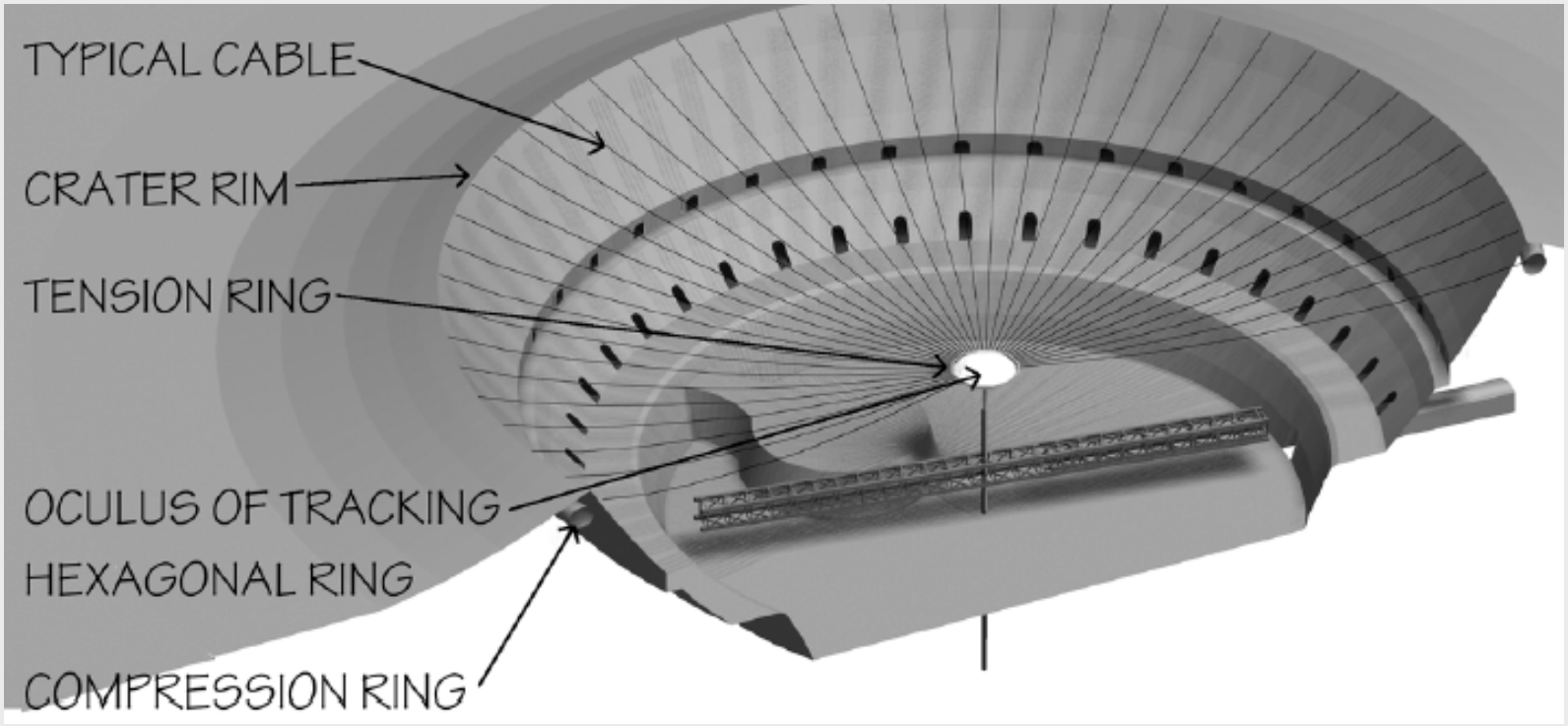




NASA

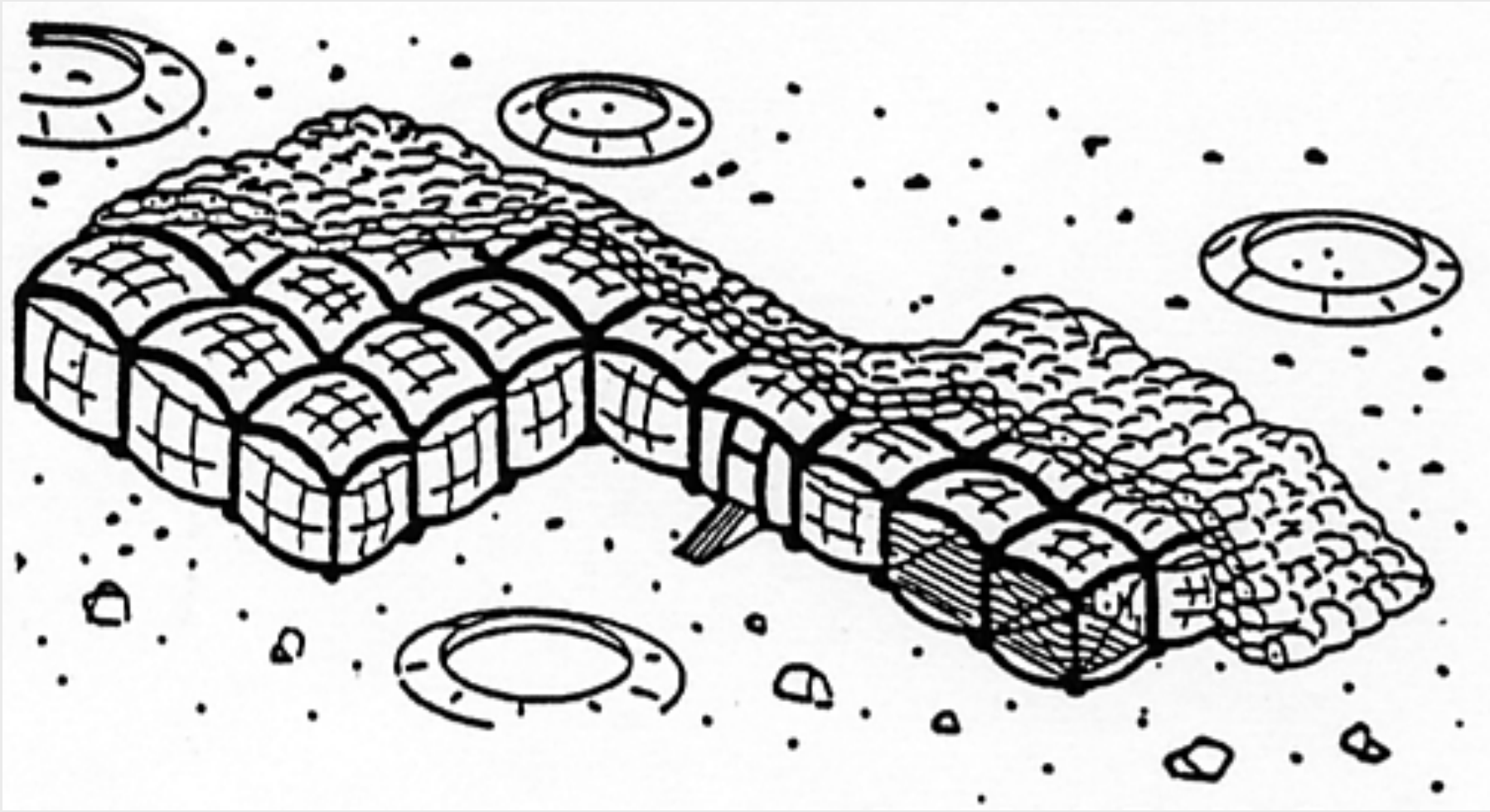

NASA
"MOON EVA"

A Lunar Crater Base



Concept and picture courtesy to A. Eichold (NASA)

A Box Shaped Inflatable

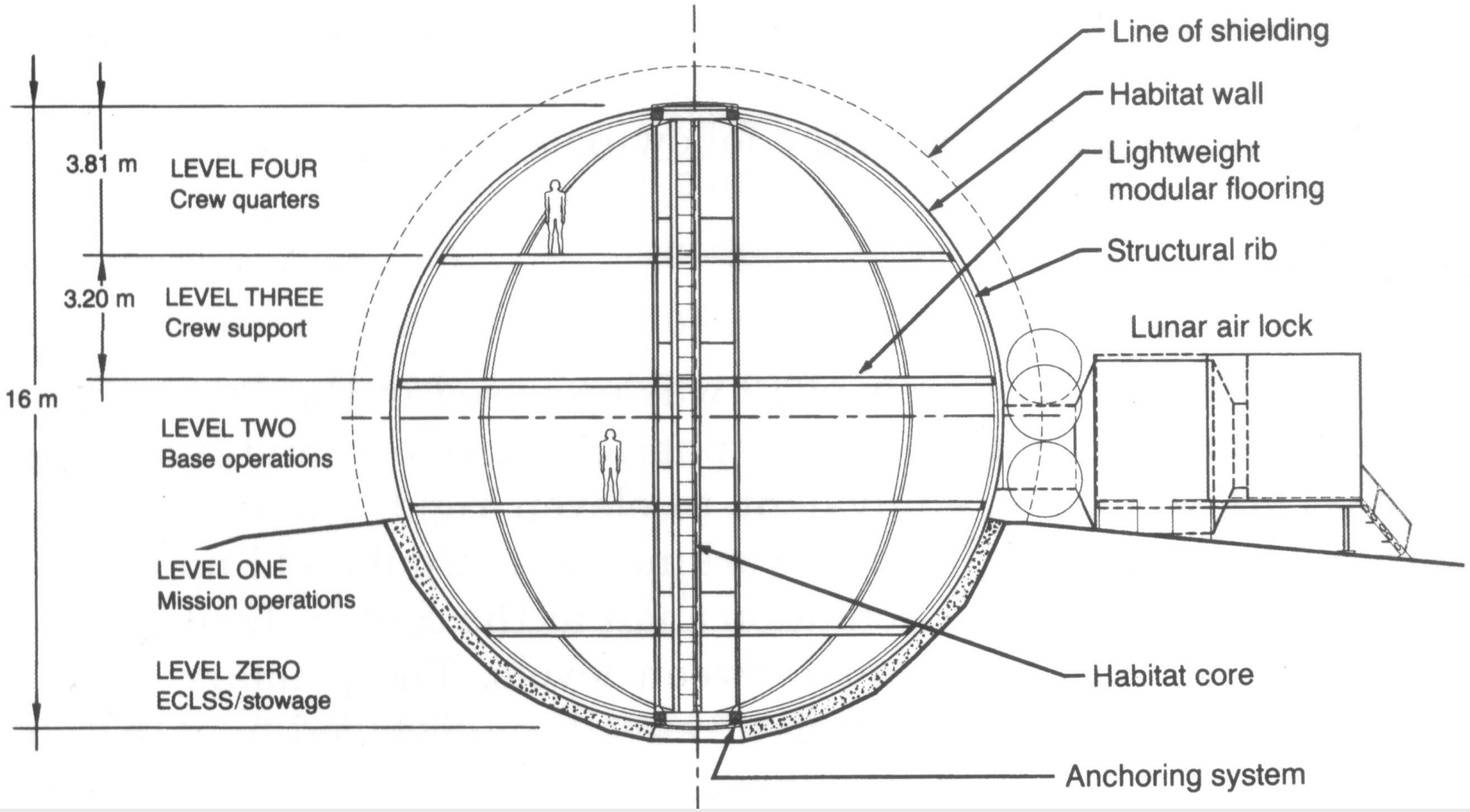


Concept and picture courtesy to P. Nowak

A Spherical Inflatable

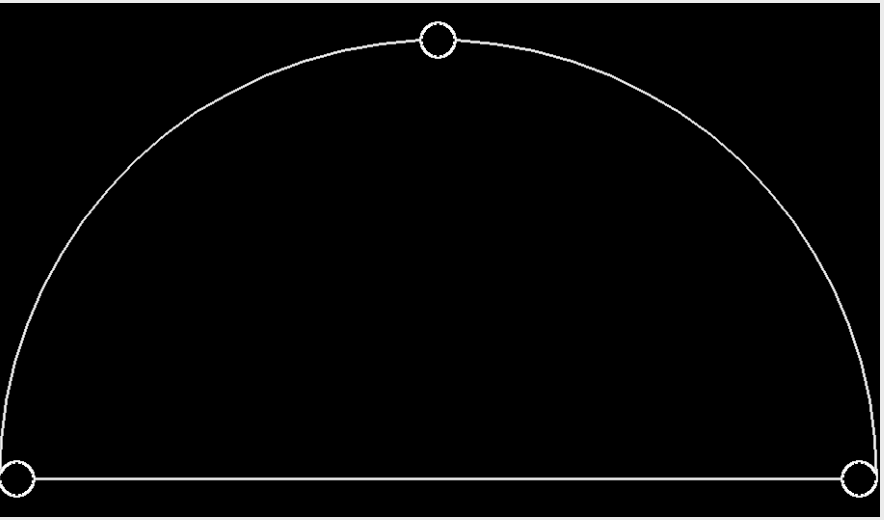
Gary Kitmacher

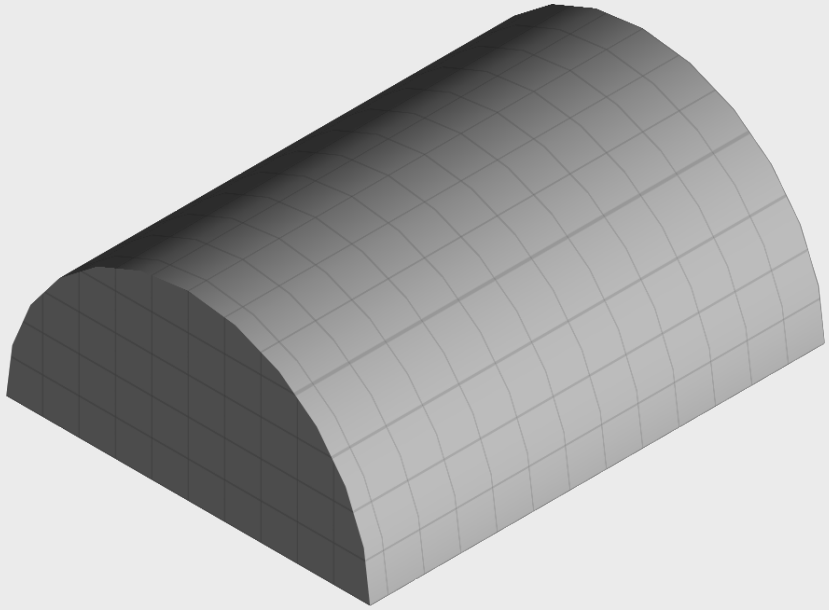
A Spherical Inflatable



Concept and picture courtesy M. Roberts (NASA)

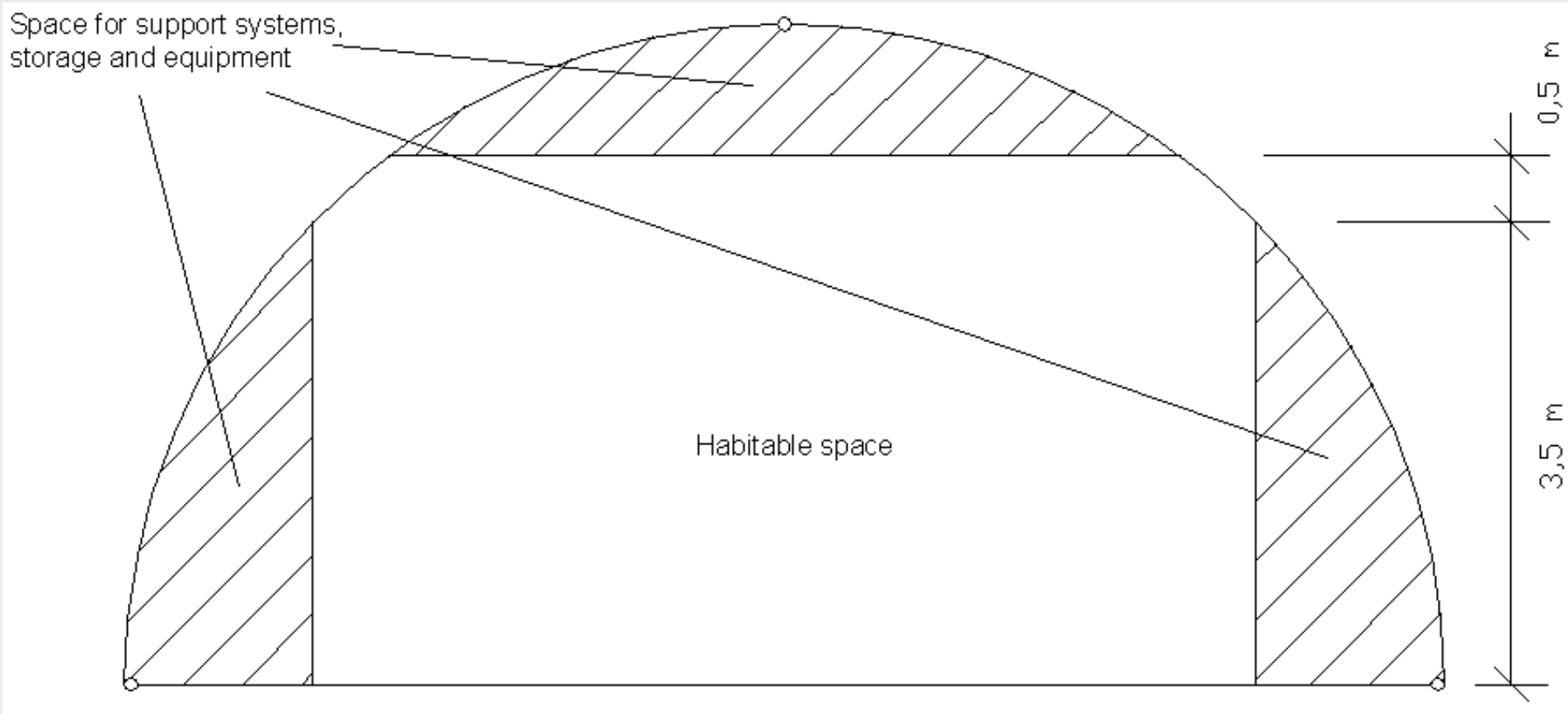
Proposed Design:
A Tied-Arch Shell Structure





Concept and picture by F. Ruess and H. Benaroya

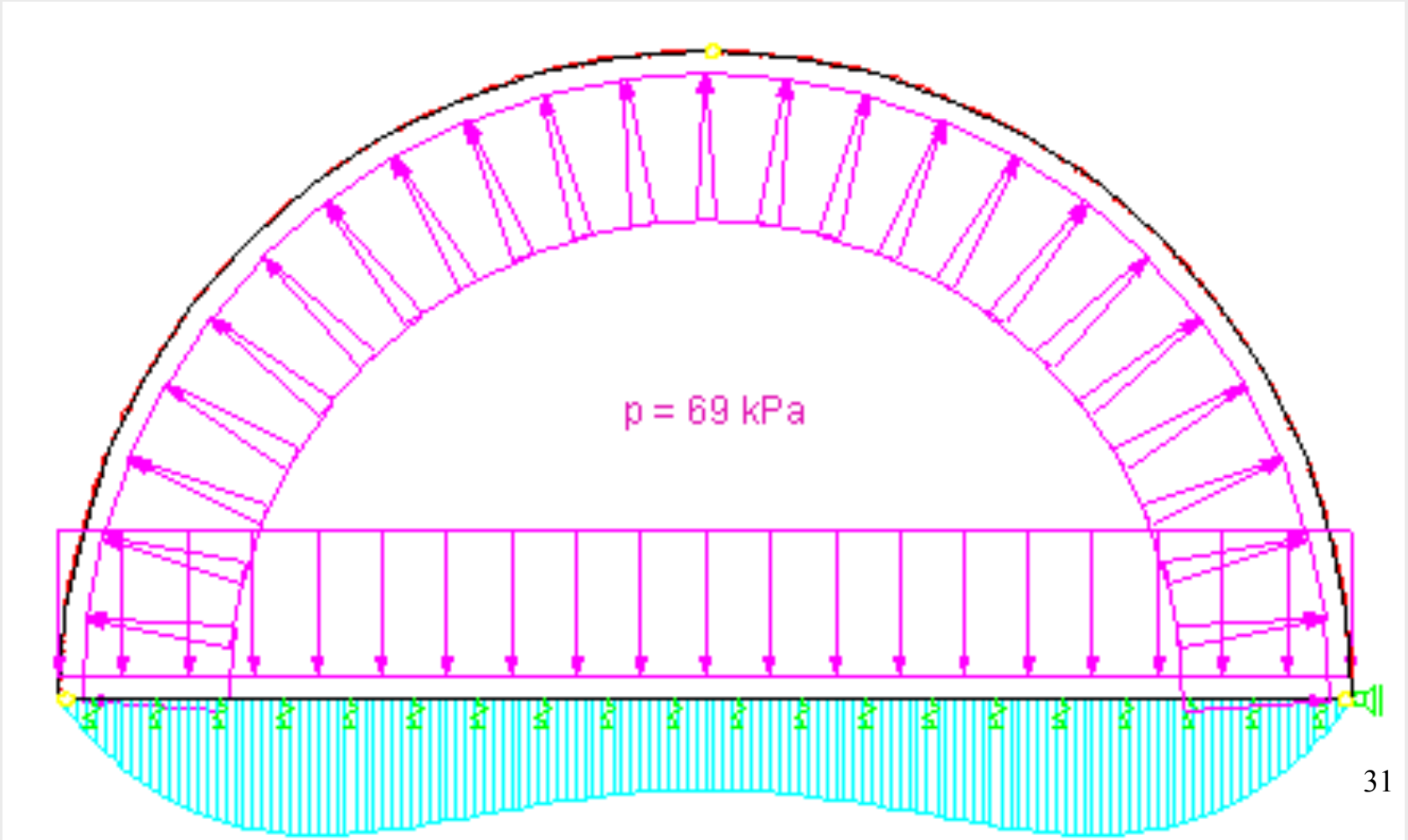
Structural Analysis



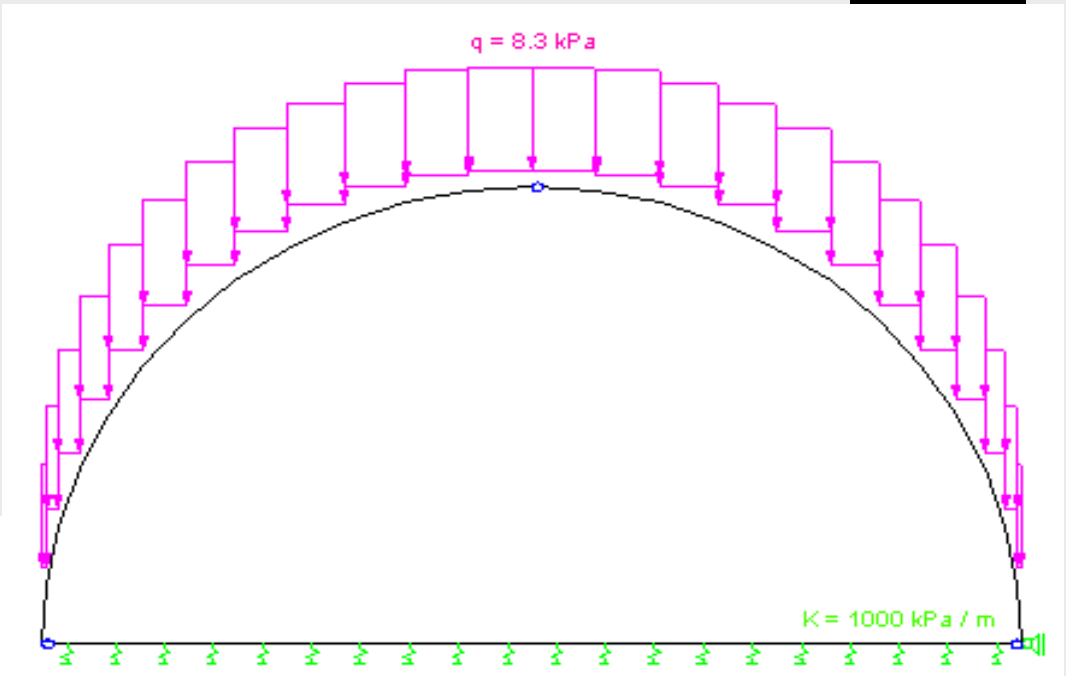
global safety factor applied: 5

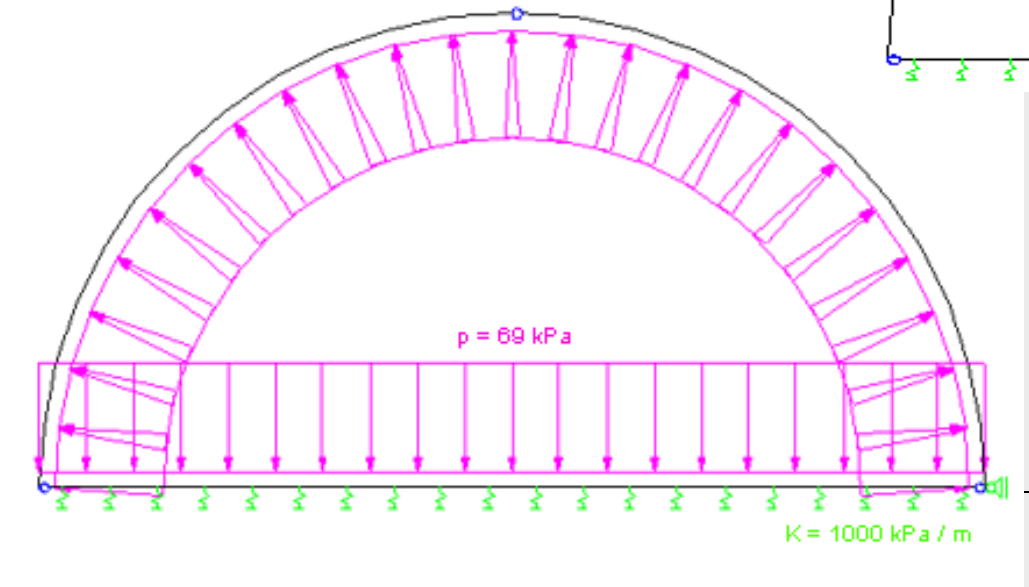
Bending Moment: Circular Arch

Internal Pressure Dominated

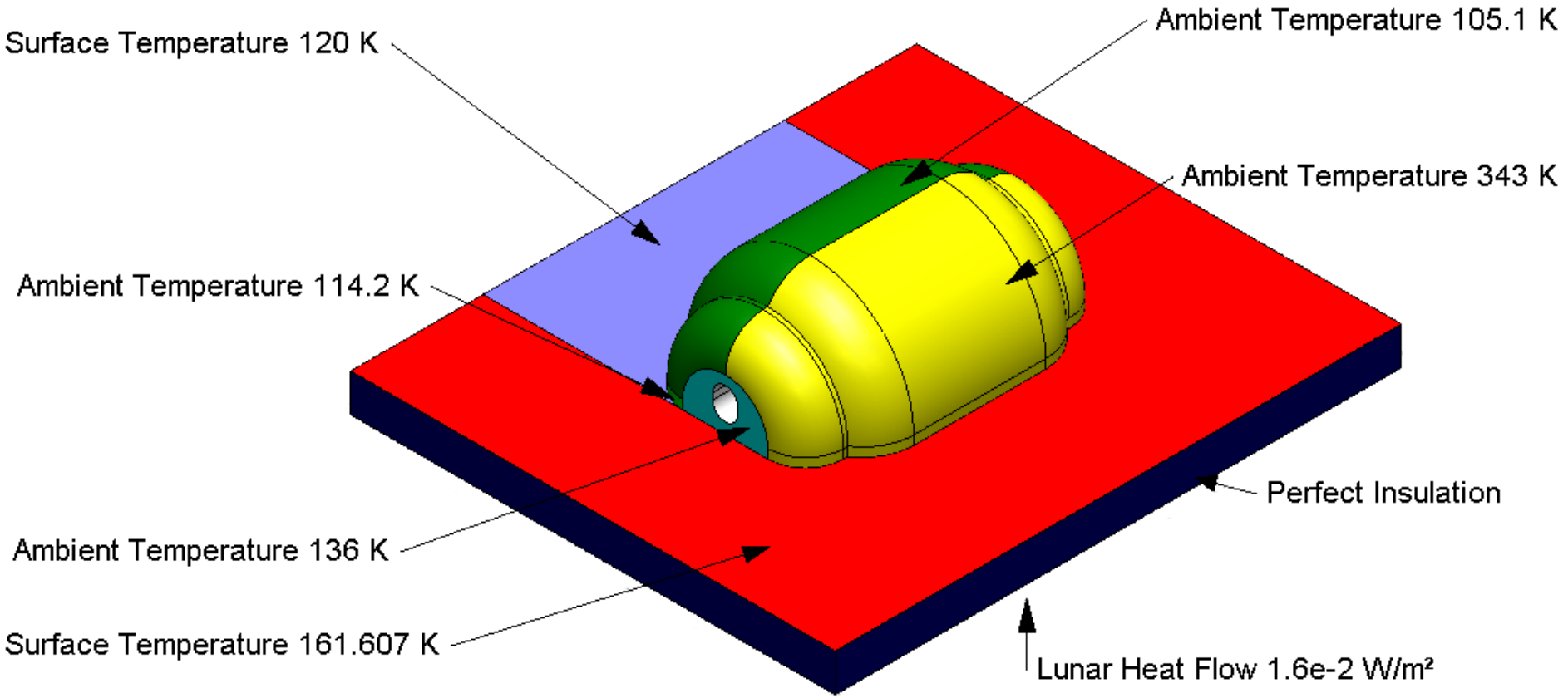


Loads



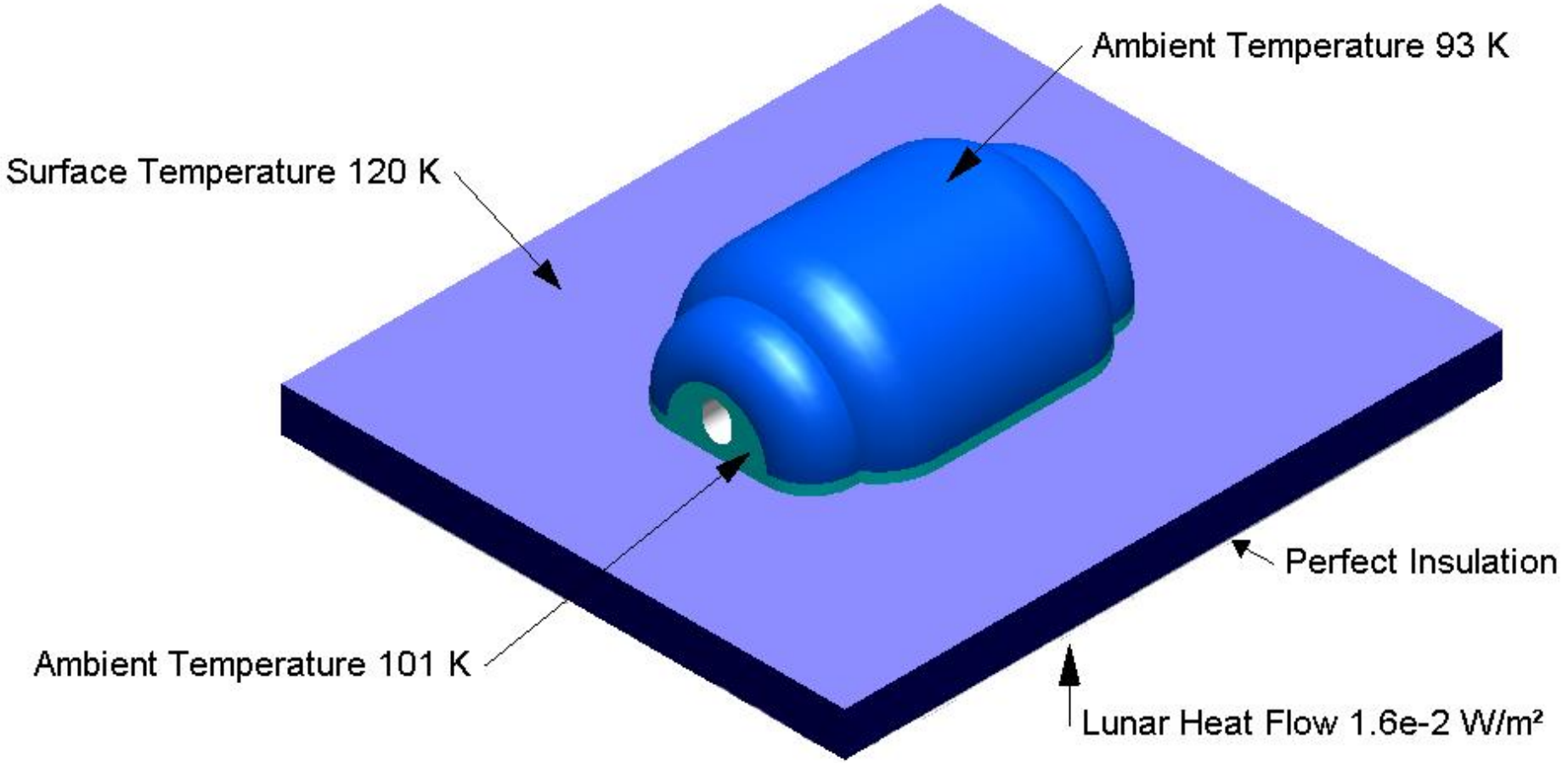


Thermal Loads and Parameters



(120 K ~ -153 ºC ~ -244 ºF) (a) (343 K ~ 70 ºC ~ 158 ºF)

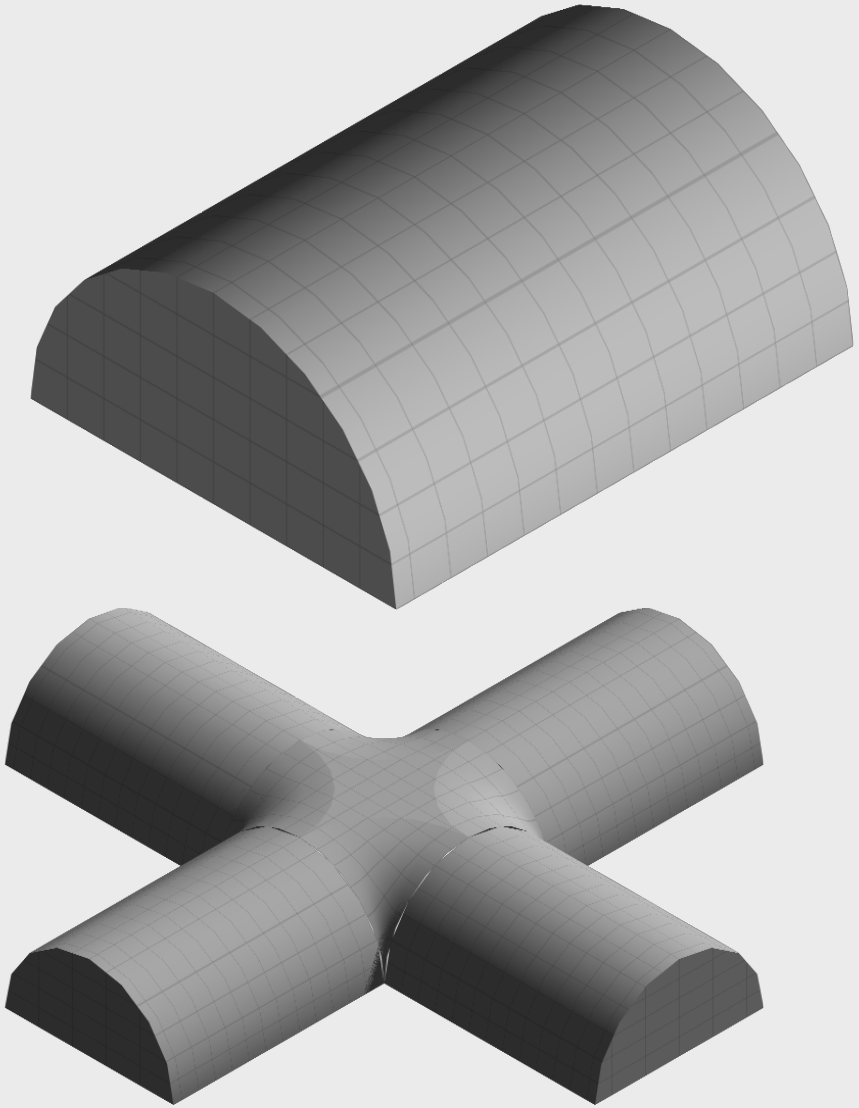
Thermal Loads and Parameters

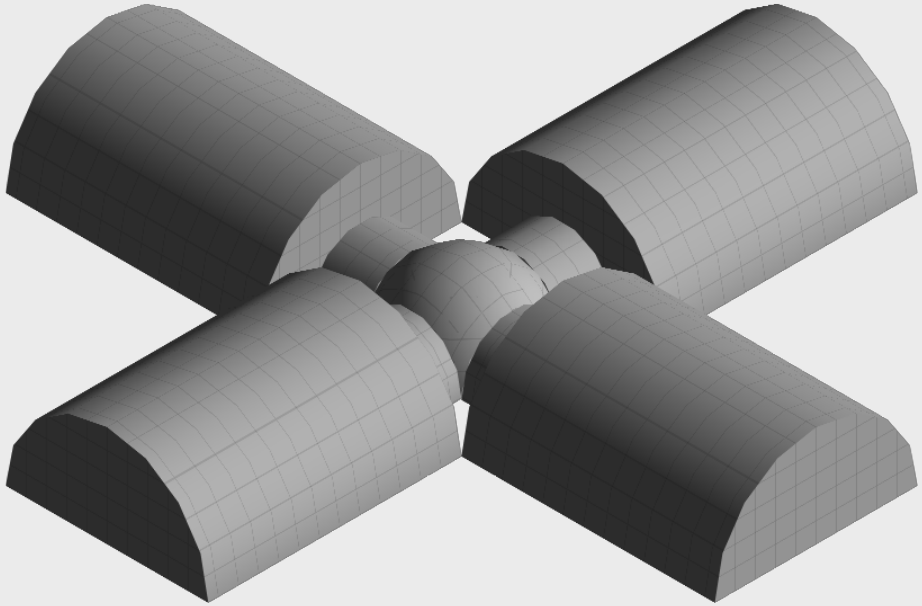


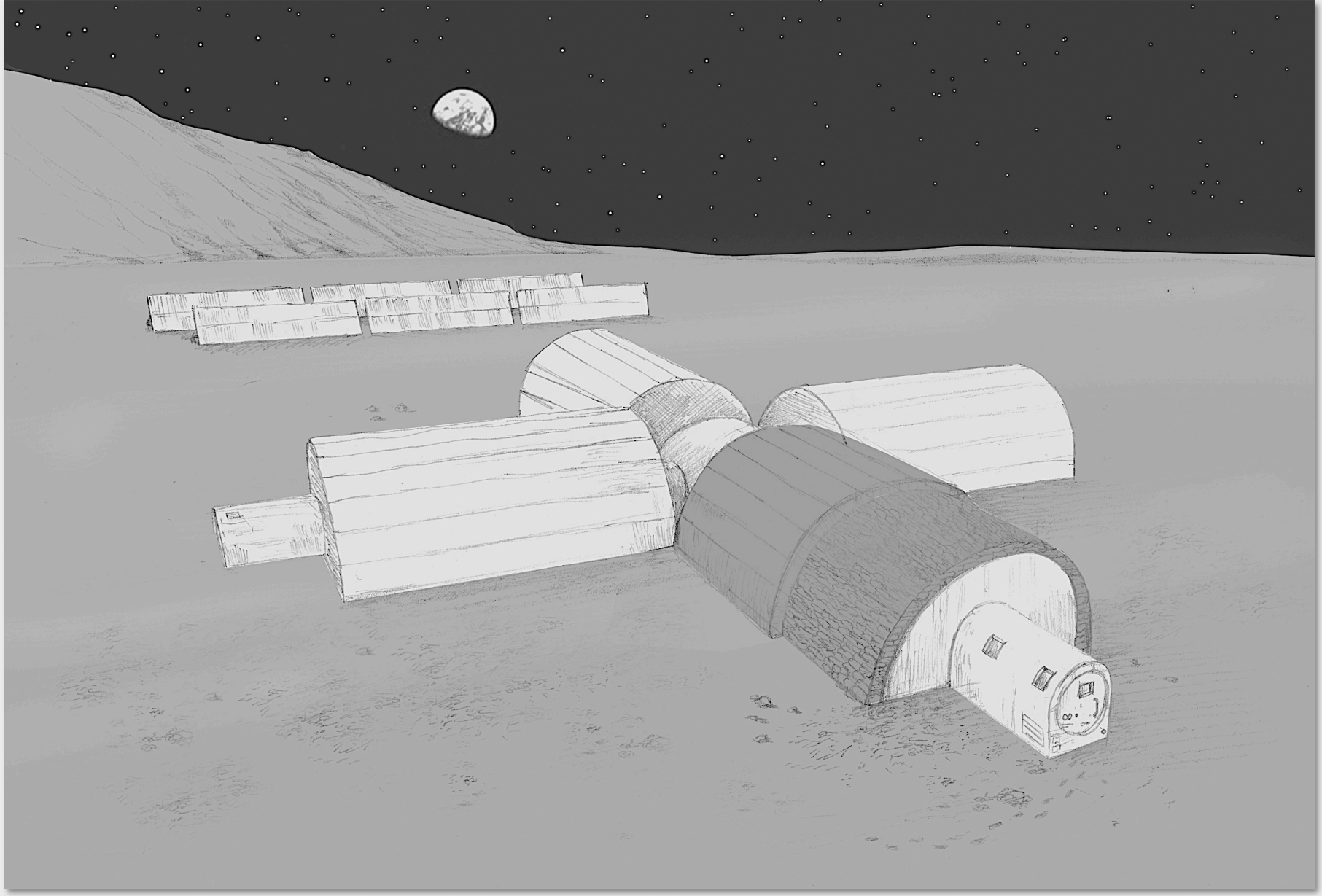
(120 K ~ -153 ºC ~ -244 ºF)

(b)

Base Layout

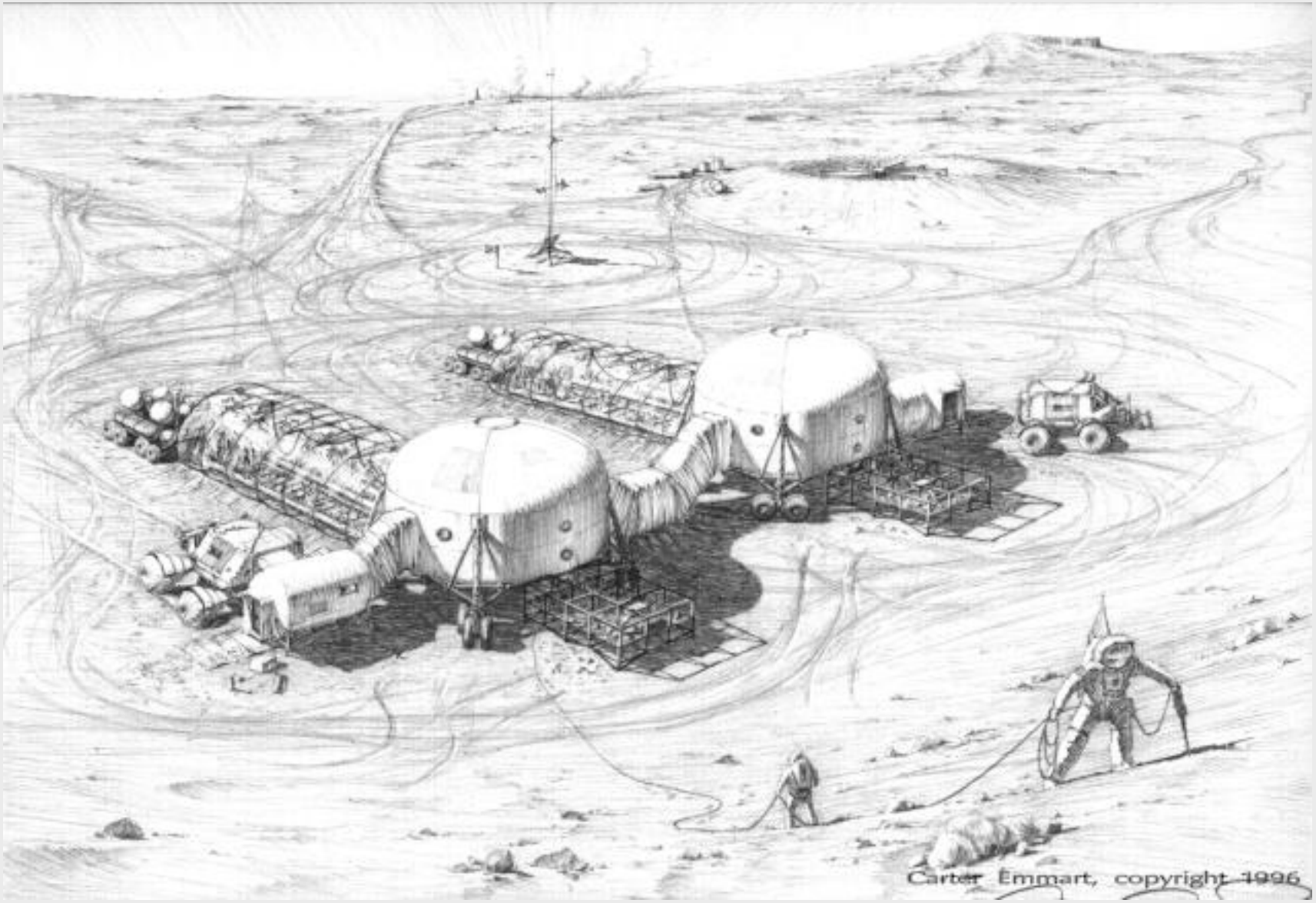






Rutgers Concept

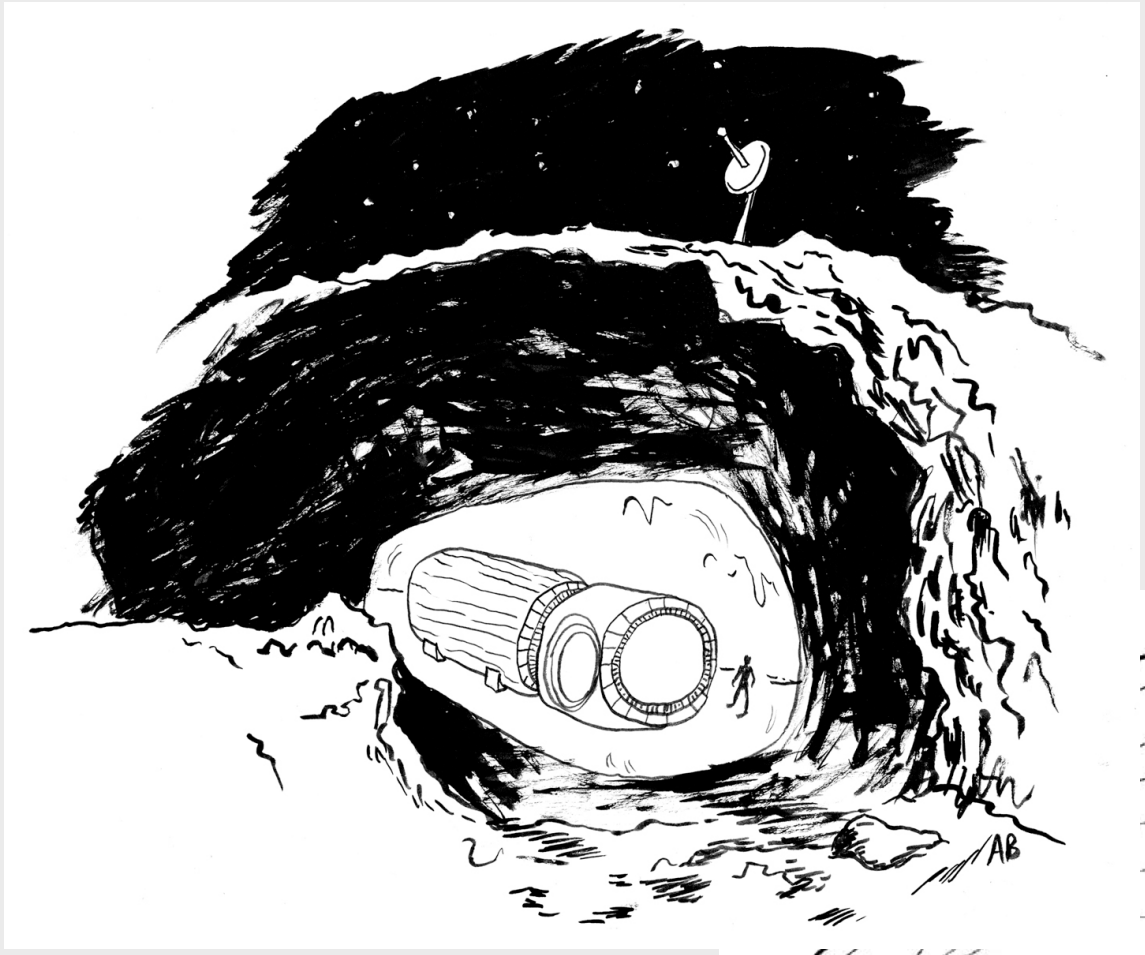
Drawing: **Andre Malok**, Newark Star Ledger



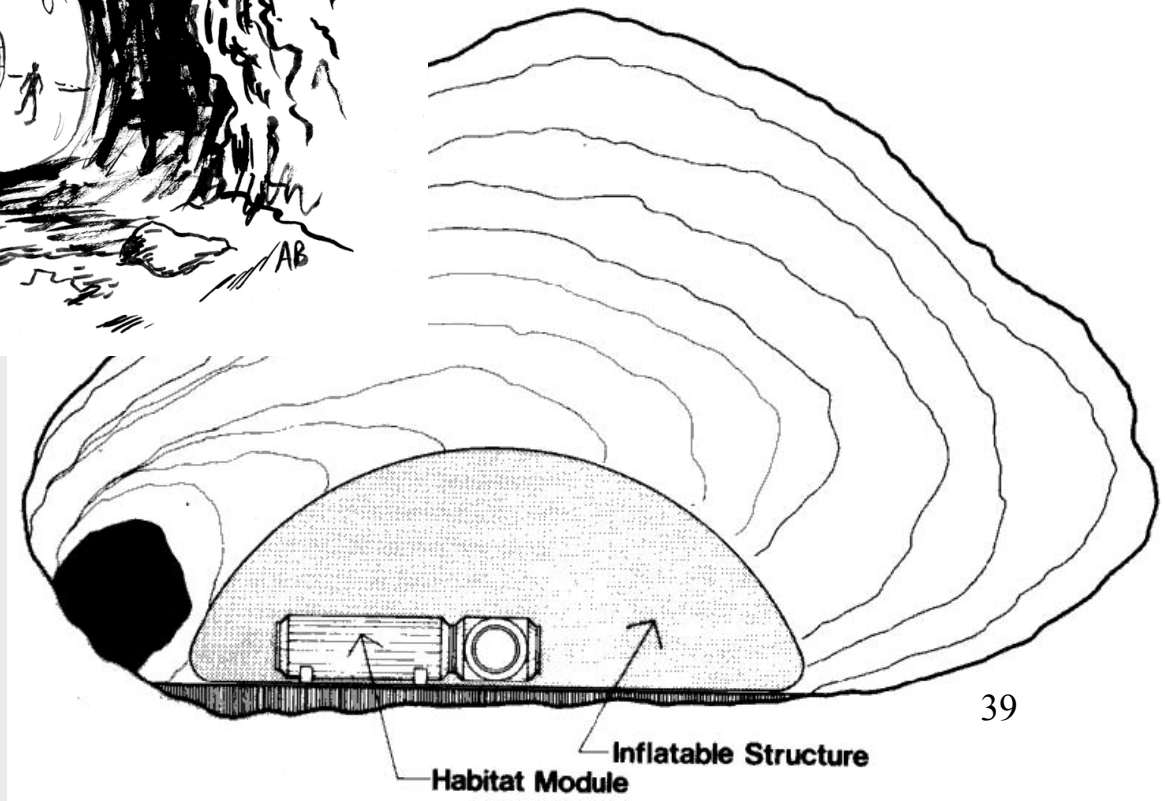
Carter Emmart

Carter Emmart

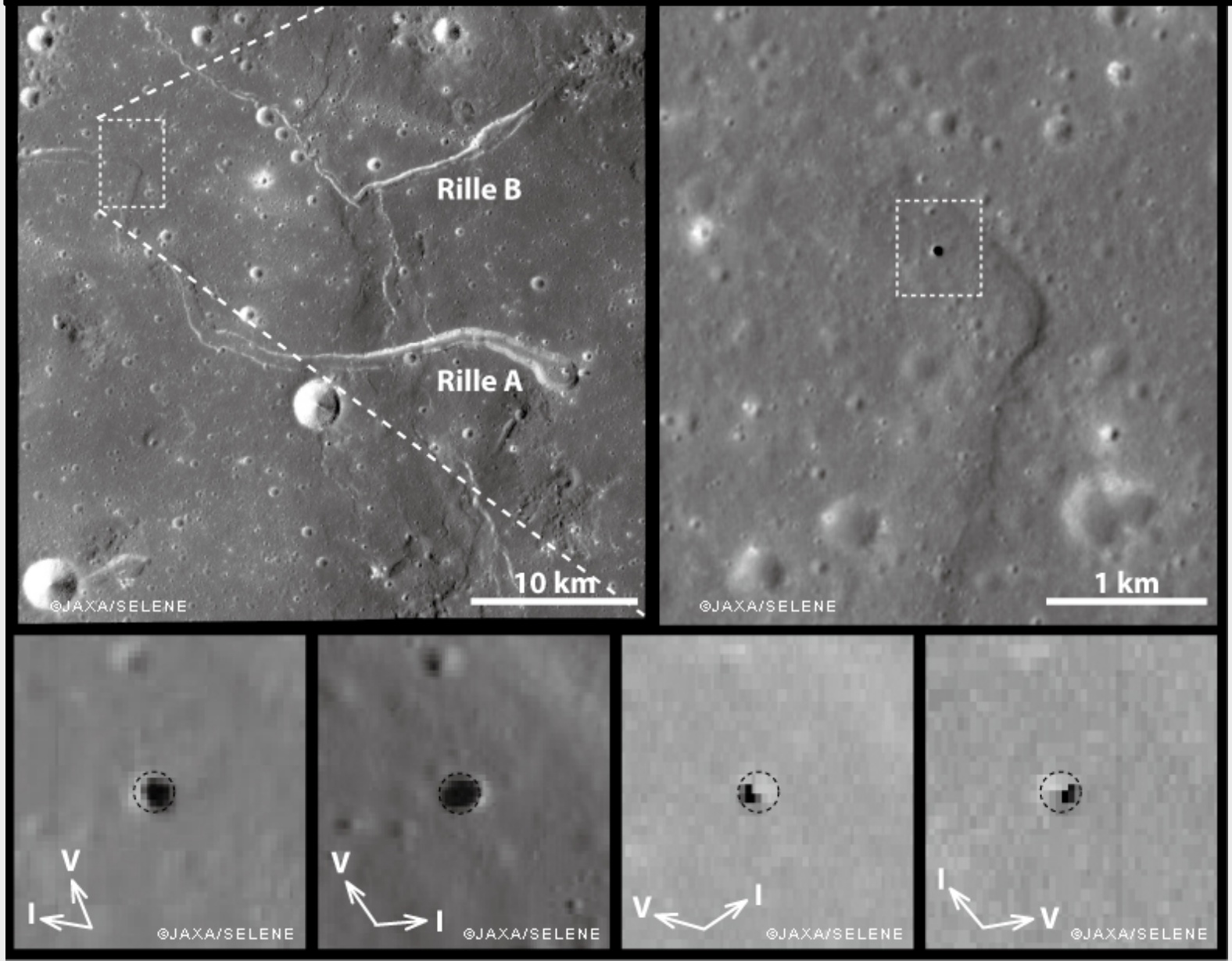
Lava Tube



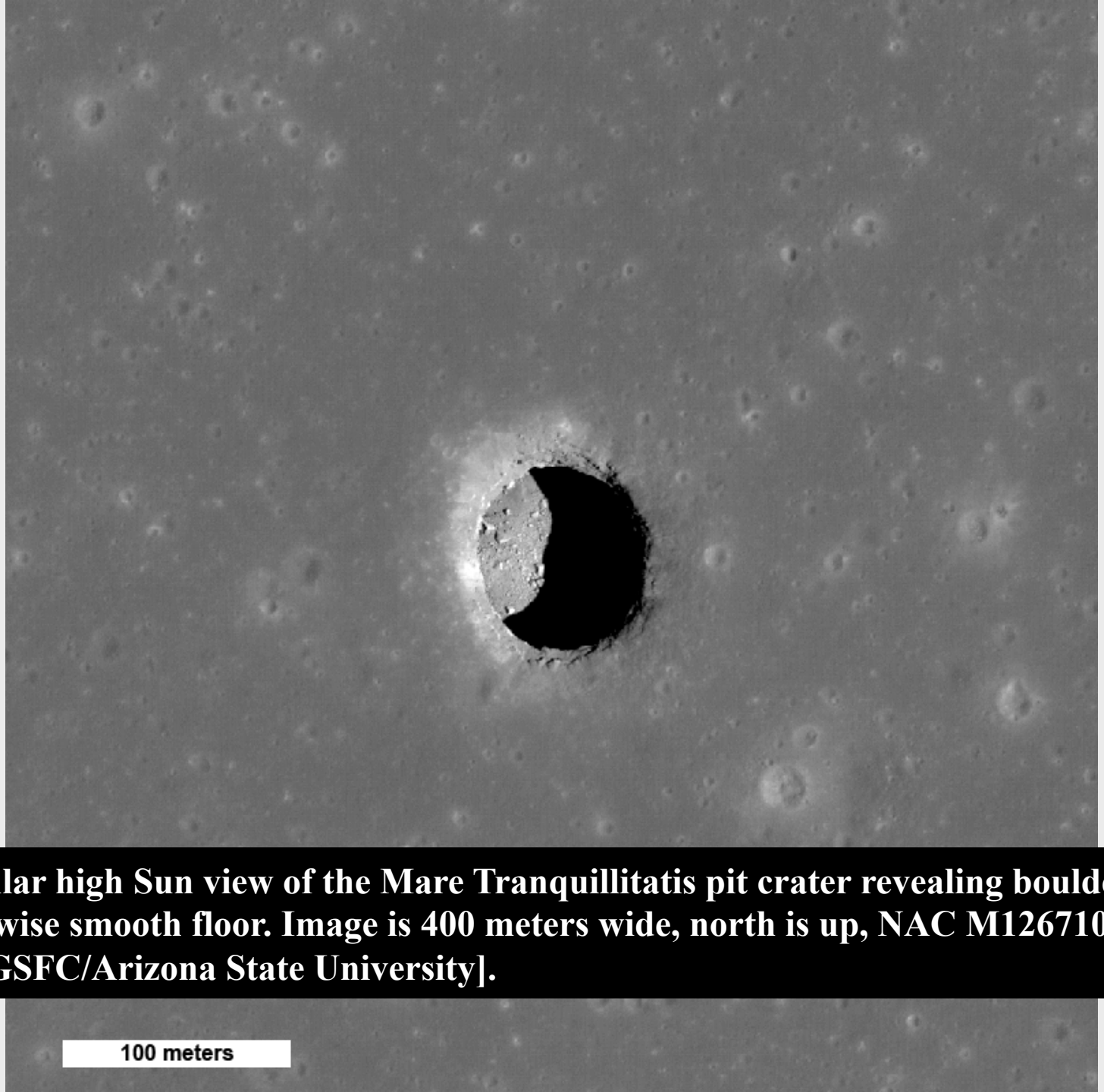
Picture courtesy **A. Benaroya**



Images of the Marius Hills pit as observed under different solar illumination conditions by the SELENE/Kaguya Terrain Camera and Multiband Imager [JAXA/SELENE].

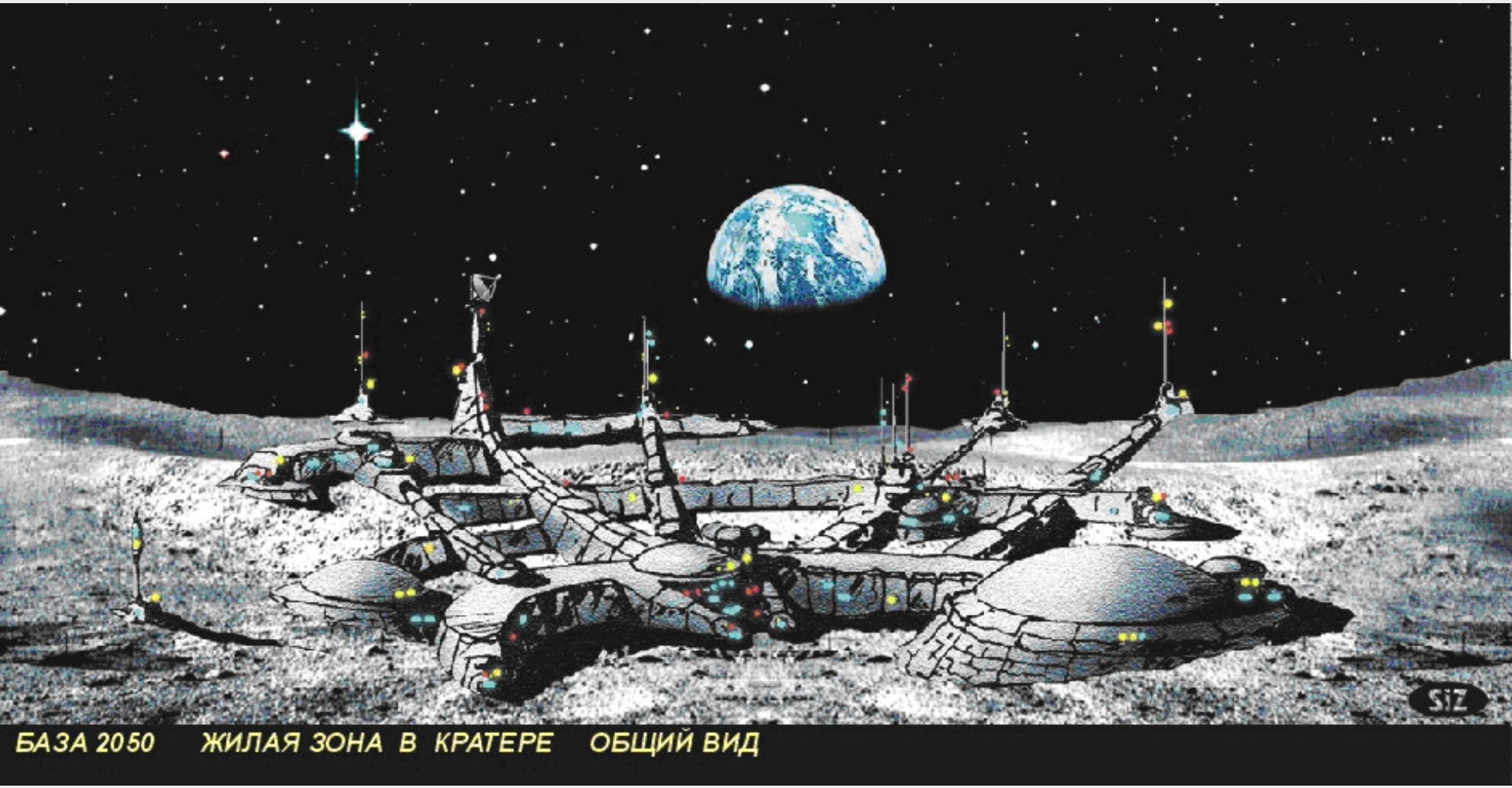


2007-2009



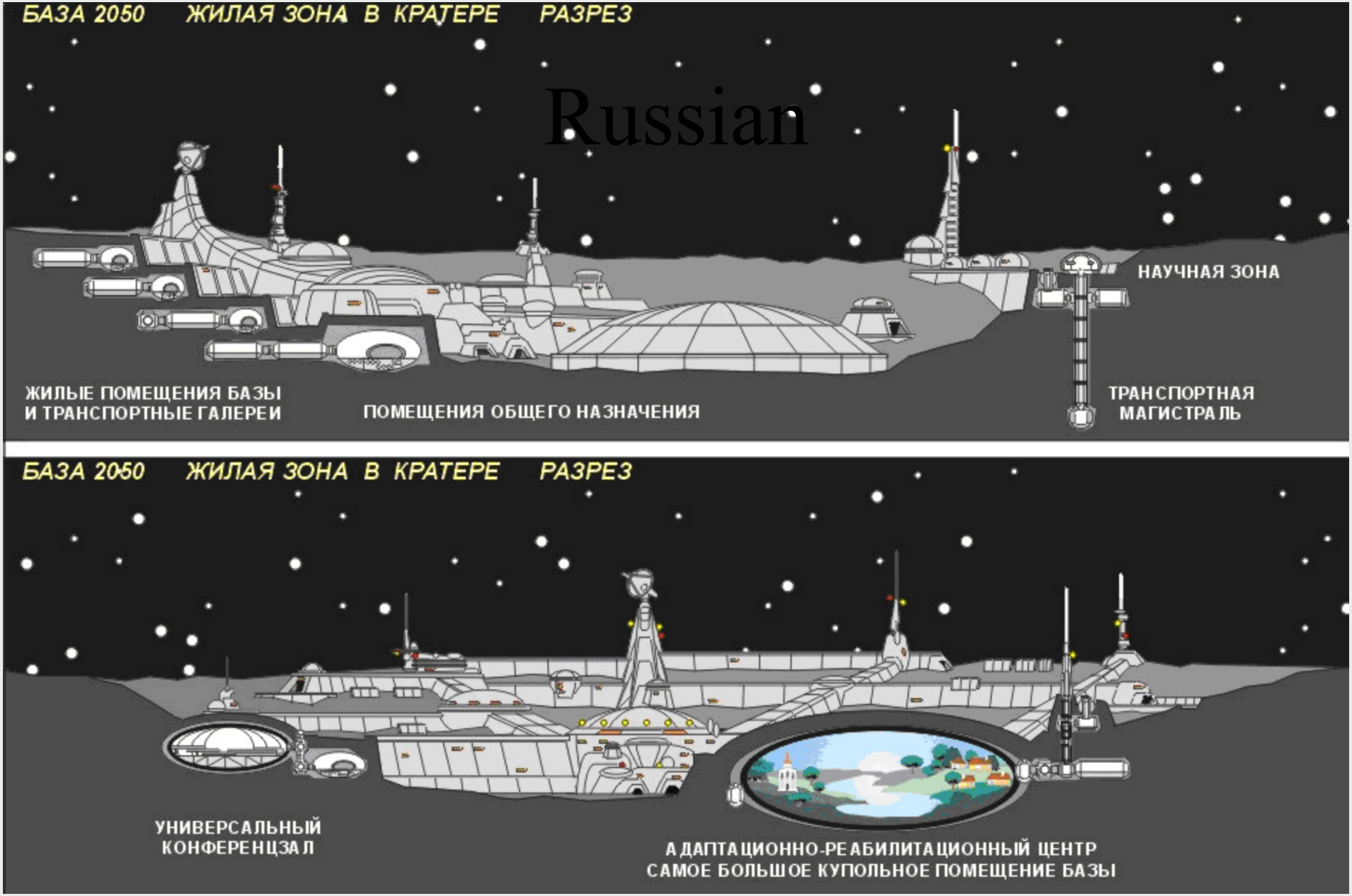
Spectacular high Sun view of the Mare Tranquillitatis pit crater revealing boulders on an otherwise smooth floor. Image is 400 meters wide, north is up, NAC M126710873R [NASA/GSFC/Arizona State University].

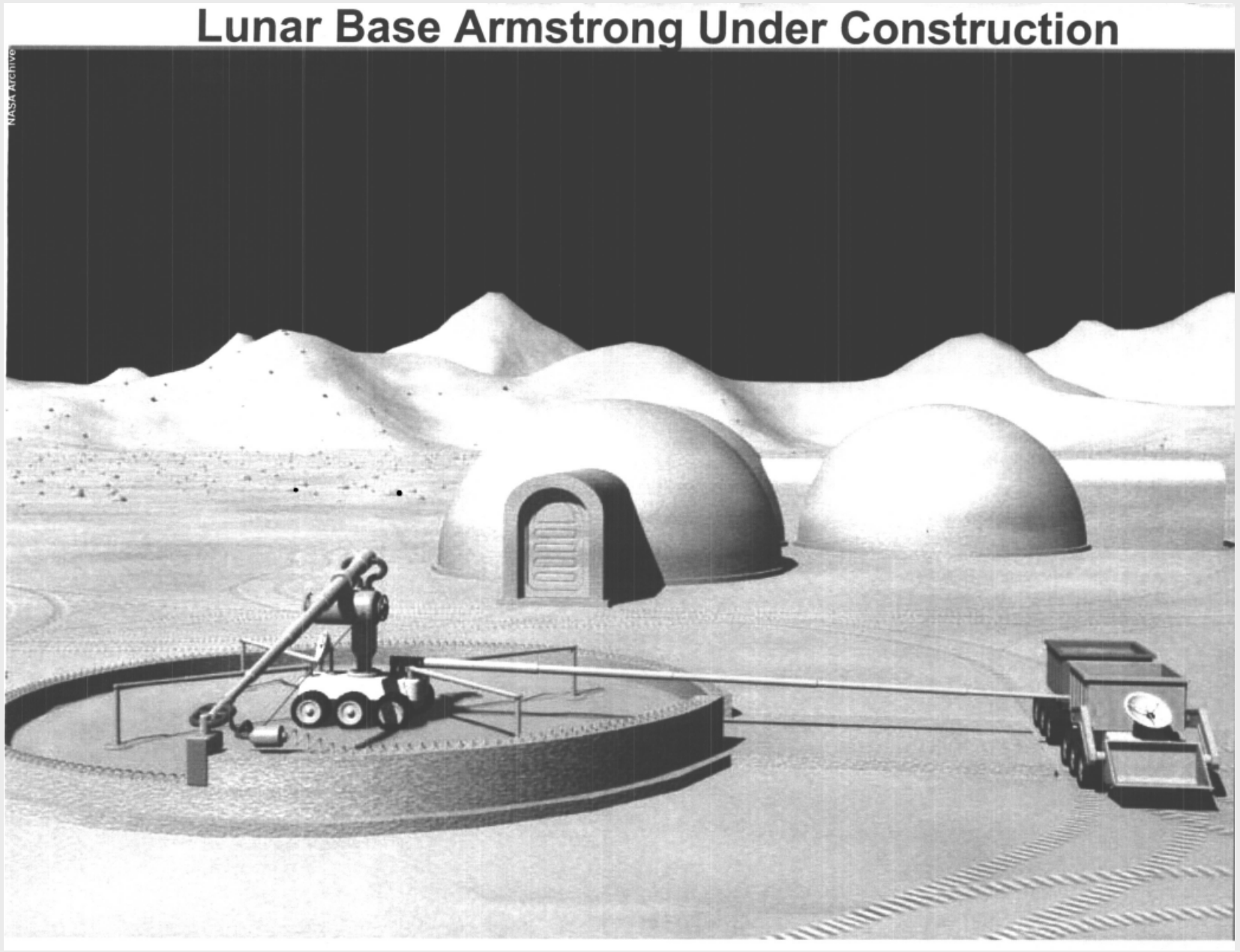
LUNAR MANNED LUNAR BASE - 2050
ENERGIA-STERNBERG PROJECT



BASE 2050: Residential Zone in Crater, General View

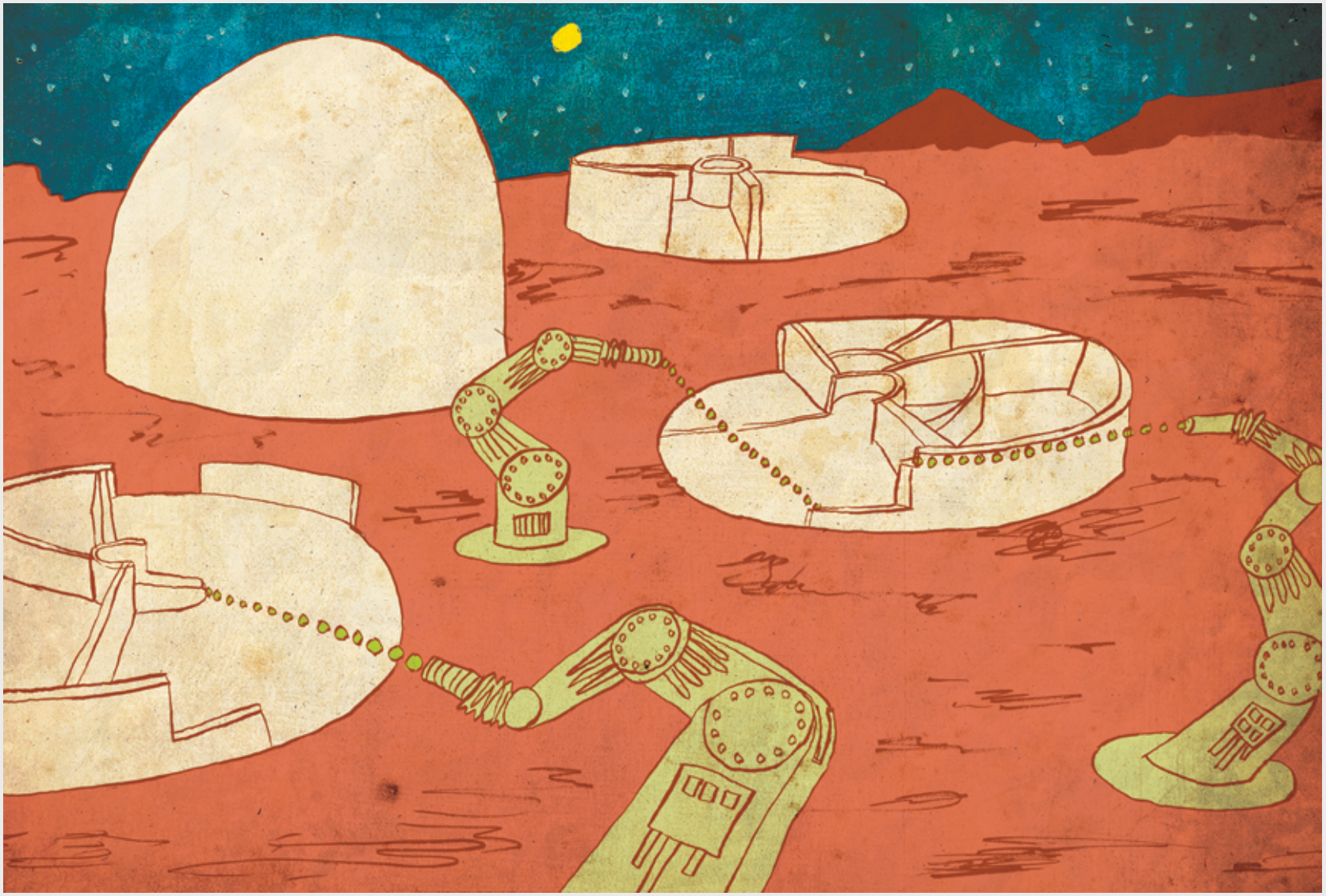
Cross-section View



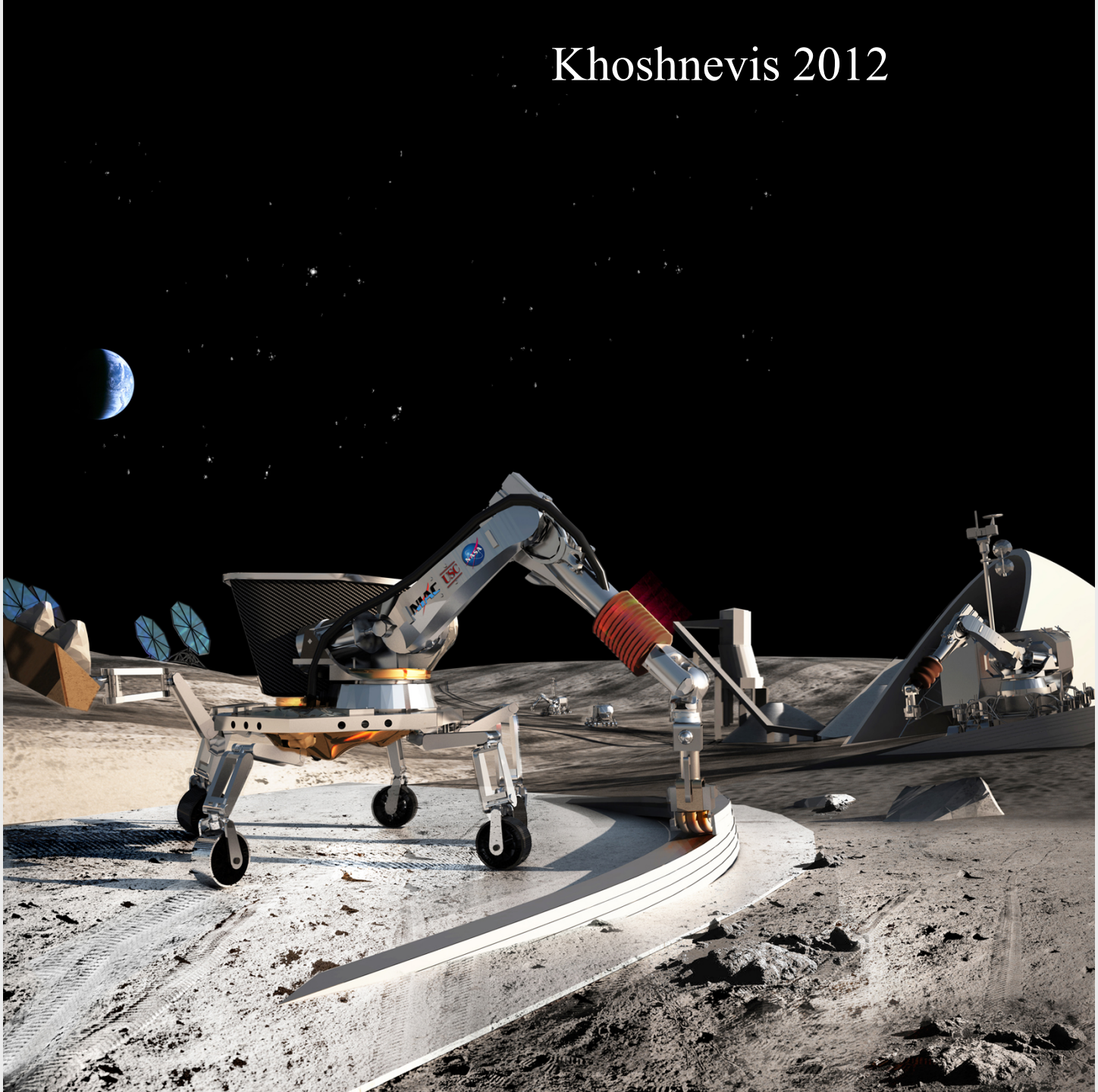


3D-Printing using Regolith

ISRU Mars Construction



Courtesy A. Benaroya


Khoshnevis 2012

Thank You!