Astro-1 Honors 2020
Class 6: Designing a lunar colony

Dr. Jatila van der Veen
Project Scientist, Physics Department, UCSB
Adjunct Professor of Astronomy, SBCC

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TOWARDS THE MOON VILLAGE AND BEYOND

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SCIENCE AND EXPLORATION AT THE MOON AND MARS ENABLED BY SURFACE TELEROBOTICS

Abstract: NASA/ESA are preparing a series of Exploration Missions using Orion and additional infrastructure at a Deep Space Gateway in cis-lunar space. This will provide an opportunity for science and exploration from the lunar farside facilitated by surface telerobotics. We describe several precursor telepresence experiments, using the ISS and a student-built rover, which are laying the groundwork for teleoperation of rovers on Moon and eventually Mars. We describe exciting near-term science that can be conducted from the lunar farside with teleoperated rovers including an astronaut-assisted sample return, a high priority from the U.S. Planetary Sciences Decadal Survey, and the deployment of a low frequency radio telescope array to observe the first stars and galaxies (Cosmic Dawn), as described in NASA's Astrophysics Roadmap.

From the NASA 2018 Strategic Plan:

STRATEGIC GOAL 2: EXTEND HUMAN PRESENCE DEEPER INTO SPACE AND TO THE MOON FOR SUSTAINABLE LONG-TERM EXPLORATION AND UTILIZATION.

NASA will pursue a sustainable cadence of compelling missions in preparation for the first crewed missions to deep space. These include the first test flight of the Space Launch System (SLS) and Orion crew vehicle near the Moon and the first crewed flight of this transportation system, designed for missions beyond low Earth orbit. At the same time, to support a broader strategy to explore and utilize the Moon and its surface, NASA is establishing a Lunar Orbital Platform - Gateway in cis-lunar space, to include a power and propulsion element by 2022, and habitation, airlock, and the required logistics capabilities soon after. In addition, to help pave the way for human exploration, NASA is planning to develop a series of robotic lunar missions to the surface of the Moon.

https://arstechnica.com/science/2019/05/nasas-full-artemis-plan-revealed-37-launches-and-a-lunar-outpost/

Watch NASA's publicity video:
https://www.youtube.com/watch?time_continue=181&v=vl6jn-DdafM&feature=emb_logo

ESA'S MOON VILLAGE: A VISION FOR GLOBA COOPERATION AND SPACE 4.0

Watch two viewpoints:

https://www.youtube.com/watch?v=O7JtOokh4PU

http://blogs.esa.int/janwoerner/2016/11/23/moon-village/

ESA: Space 4.0 represents the evolution of the space sector into a new era, characterized by a new playing field. This era is unfolding through interaction between governments, private sector, society and politics. Space 4.0 is analogous to, and is intertwined with, Industry 4.0, which is considered as the unfolding fourth industrial revolution of manufacturing and services.

http://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0

ESA's director, Jan Worner's vision for an "open station on the Moon, for different member states, for different states around the globe."

https://www.youtube.com/watch?time_continue=37&v=amYK5voqLSk&feature=emb_logo

Summary
A lunar colony must:

Be usable;
Be safe from harsh environment;
Provide sufficient Power for operations, day and night;
Have sufficient Water for drinking, growing food, making rocket fuel;
Be able to produce sufficient food;
Be able to produce sufficient heat during the lunar nights;
Be able to produce and maintain sufficient oxygen.

ESA Vision: Creating a 3-D printed lunar base out of lunar regolith using teleroboticss. This base will be prepared by robots prior to humans arriving.

http://www.esa.int/ESA_Multimedia/Images/2013/01/3D-printed_lunar_base_design

For ESA's 3D-printed lunar base concept, Foster + Partners devised a weight-bearing ‘catenary’ dome design with a cellular structured wall to shield against micrometeoroids and space radiation, incorporating a pressurized inflatable to shelter astronauts.

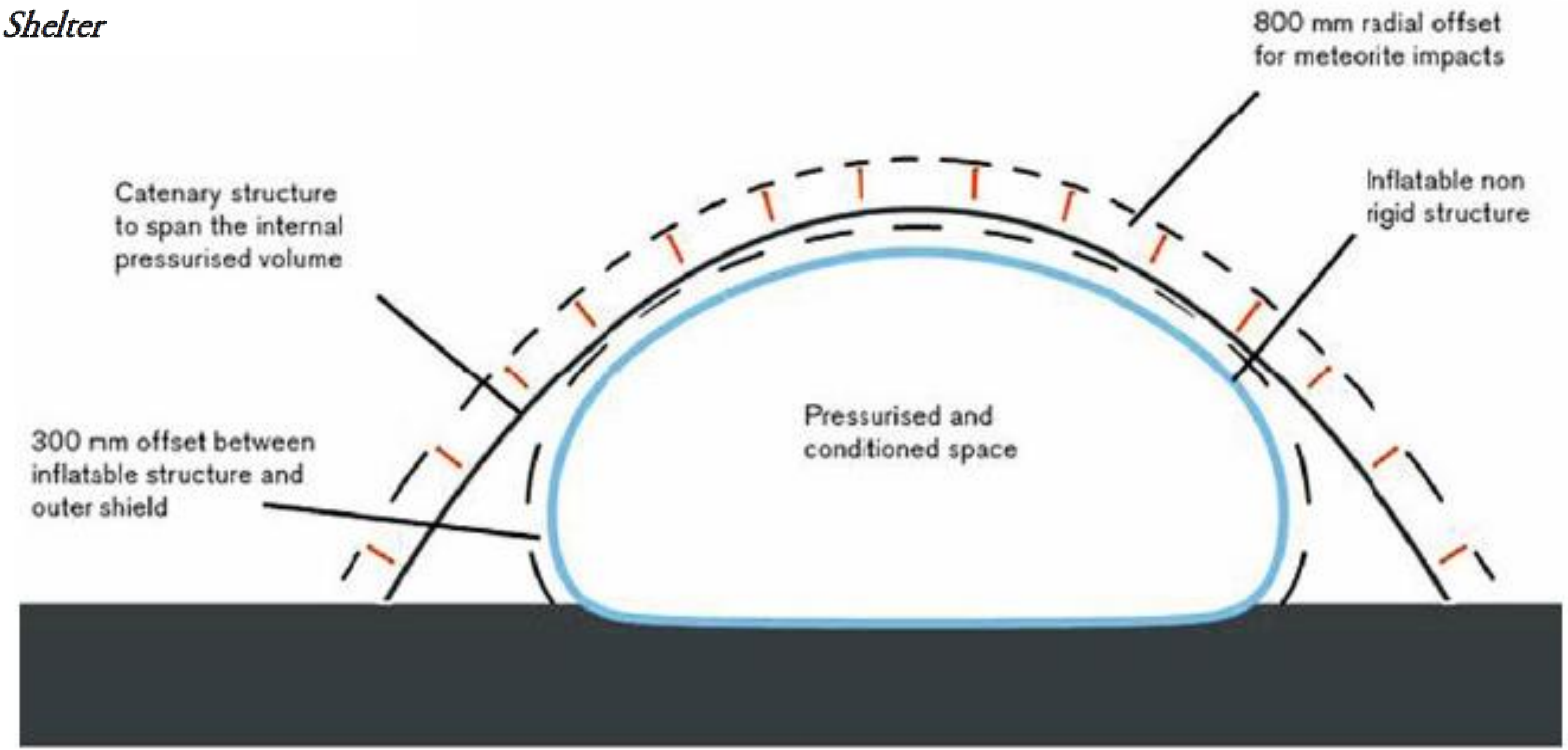


Fig. 12. Radial offset for protection from micrometeorites. Image courtesy of Foster+Partners

Fig. 26. The 3D-printed structure made of simulated regolith on display at the exhibition entitled "Stazione Futuro", Turin, March-November 2011. Photo: authors

A base must have an exploration vehicle that allows crews to live and explore safely for a minimum of a lunar day. NASA's design:

NASA's Space Exploration Vehicle (SEV)

"Suitport" at the front of the vehicle allows rapid

The Space Exploration Vehicle Concept will rely on the incorporation of many advanced technologies. Examples include: **Fuel Cells, Regenerative Brake, Wheels, Light-Weight Structures and Materials, Active Suspension, Avionics and Software, Extravehicular Activity (EVA) Suitport, Thermal Control Systems, Automated Rendezvous and Docking, High Energy Density Batteries and Gaseous Hydrogen/Oxygen RCS system.**

The Space Exploration Vehicle Characteristics (Surface Concept)

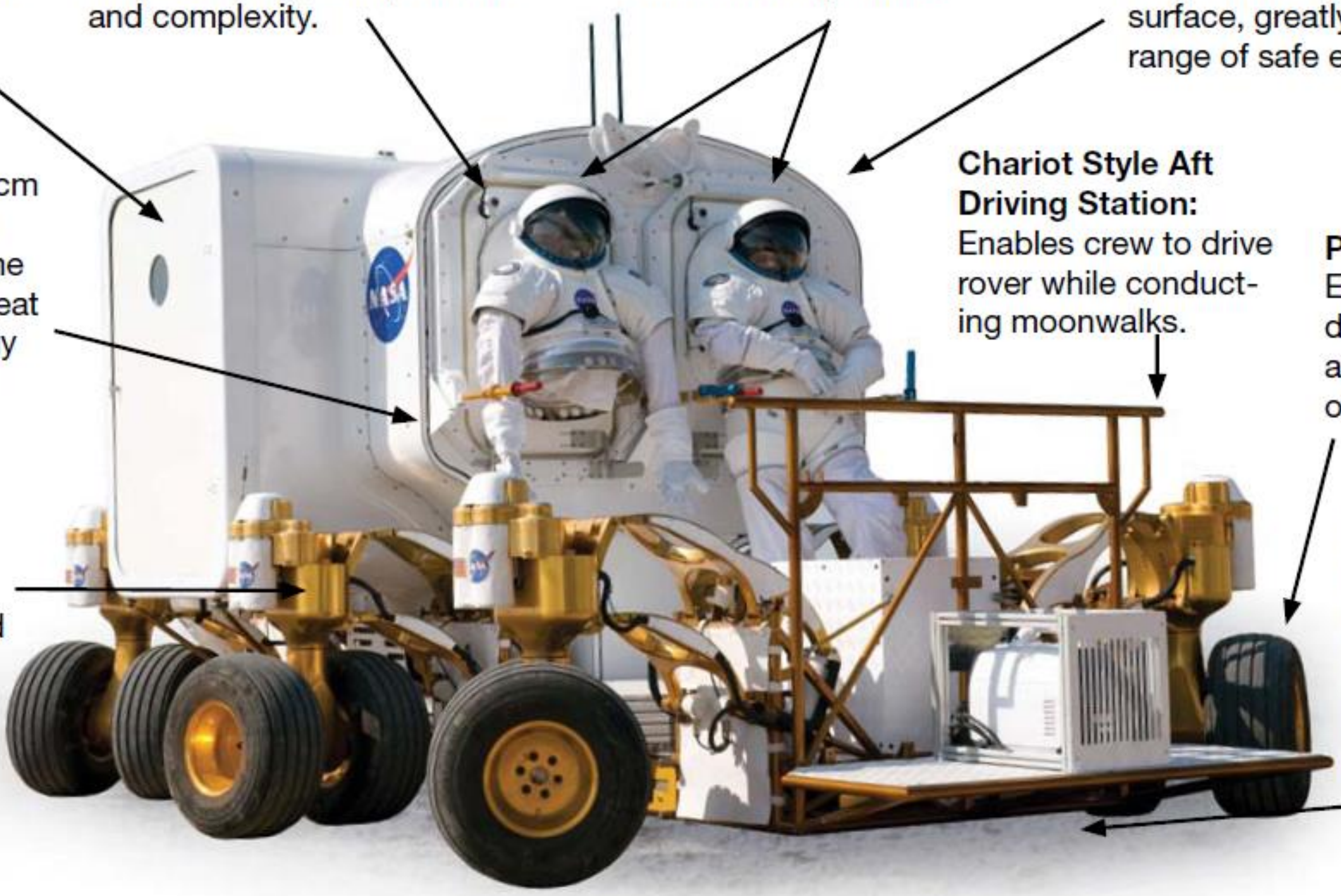
Docking Hatch:
Allows crew members to move from the rover to a habitat, an ascent module or another rover.

Suit Portable Life Support System-based Environmental Control Life Support System:
Reduces mass, cost, volume and complexity.

Suitports:
Allow suit donning and vehicle egress in less than 10 minutes with minimal gas loss.

Pressurized Rover:
Low-mass, low-volume design makes it possible to have two vehicles on a planetary lunar surface, greatly extending the range of safe exploration.

Ice-shielded Lock / Fusible Heat Sink:
Lock surrounded by 2.5 cm of frozen water provides radiation protection. Same ice is used as a fusible heat sink, rejecting heat energy by melting ice instead of evaporating water to vacuum.



Chariot Style Aft Driving Station:
Enables crew to drive rover while conducting moonwalks.

Pivoting Wheels:
Enables crab-style driving for docking and maneuvering on steep terrain.

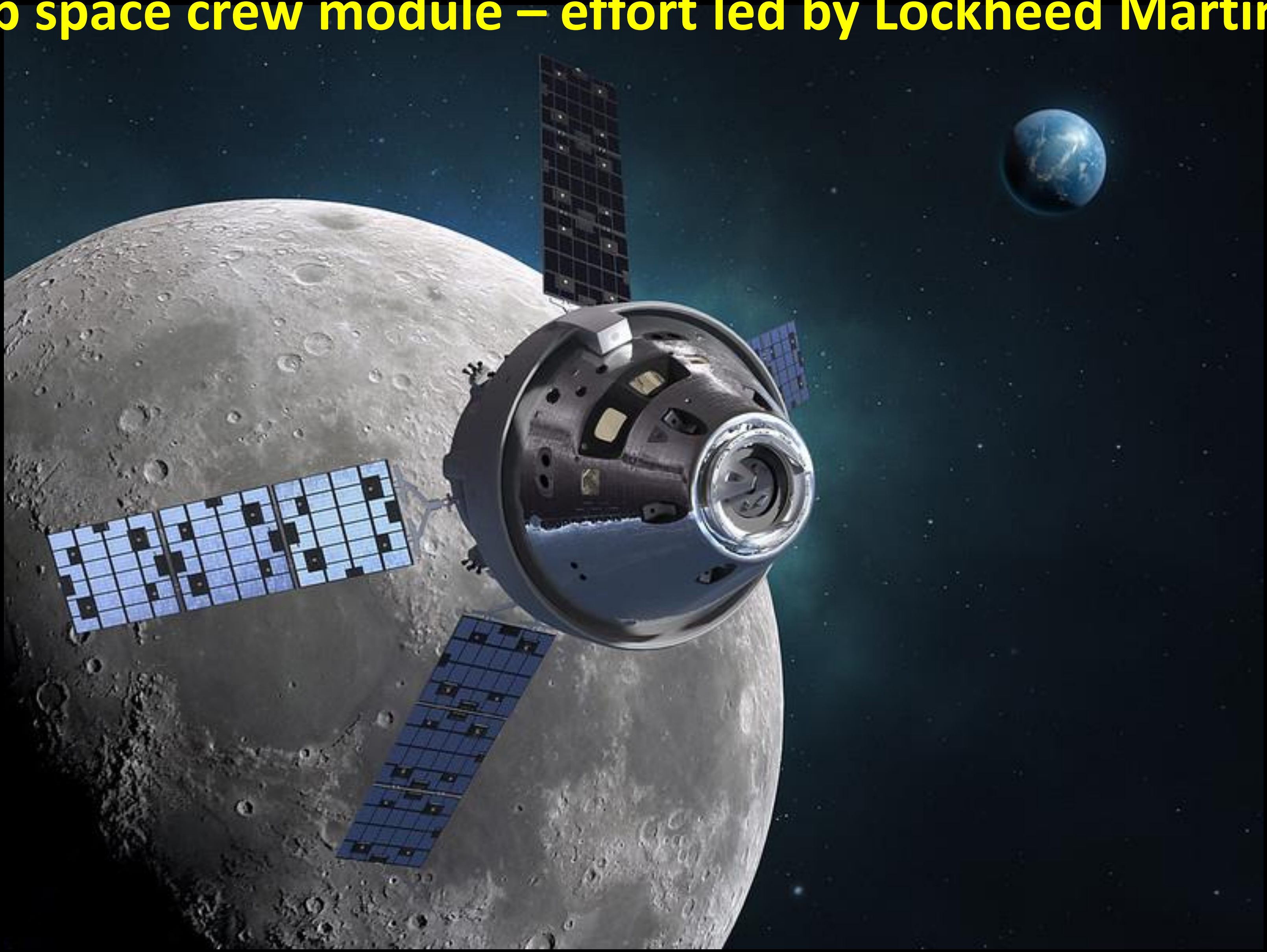
Modular Design:
Pressurized Rover and chassis may be delivered on separate landers or pre-integrated on one lander.

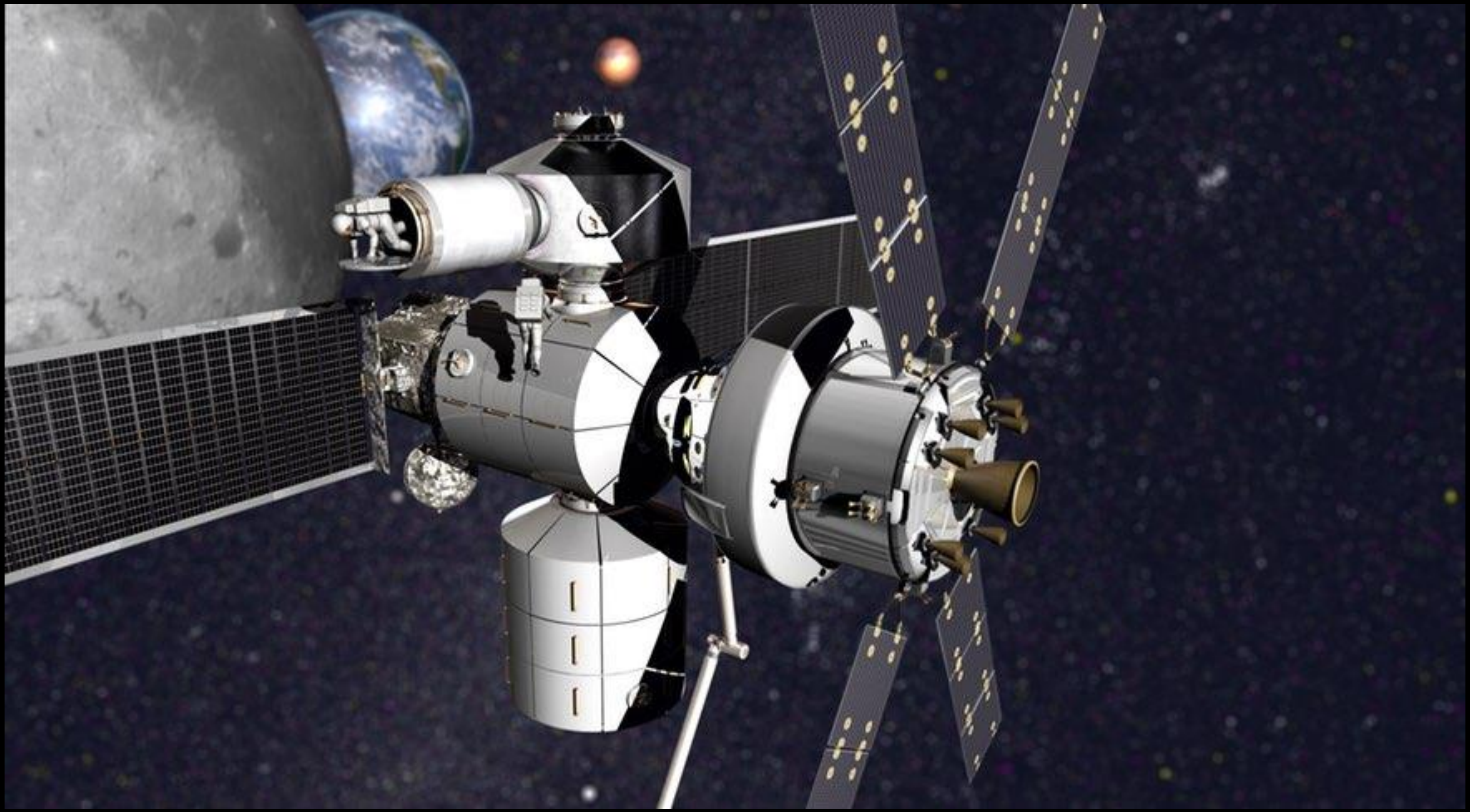
Work Package Interface:
Allows attachment of modular work packages (e.g. winch, cable, backhoe or crane).

https://www.youtube.com/watch?v=j2SRBWpHJA8

Japan’s design:

NASA's vision for Getting to the Moon:
Orion deep space crew module – effort led by Lockheed Martin, USA





Gateway: A Lockheed Martin concept of a cislunar outpost that could support future human missions to the moon or elsewhere. Credit: Lockheed Martin

Protection against harmful radiation – the AstroRad vest

Deep Space is a Harsh Environment:

On Earth and in low Earth orbit, humans are protected by Earth's magnetic field

In deep space, humans and space-craft electronics are exposed to intense radiation environments

Radiation levels on the journey to Mars are similar to cislunar space but crews would be exposed for a much longer period of time

Radiation Standards:

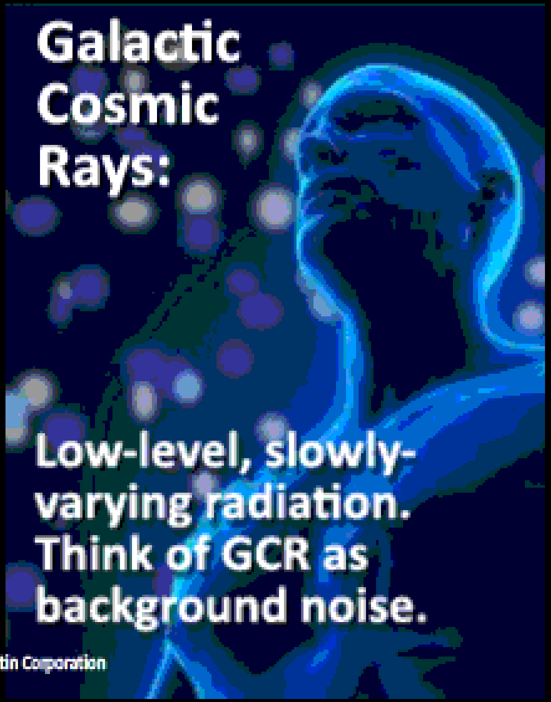
As Low As Reasonably Achiev-able (ALARA)

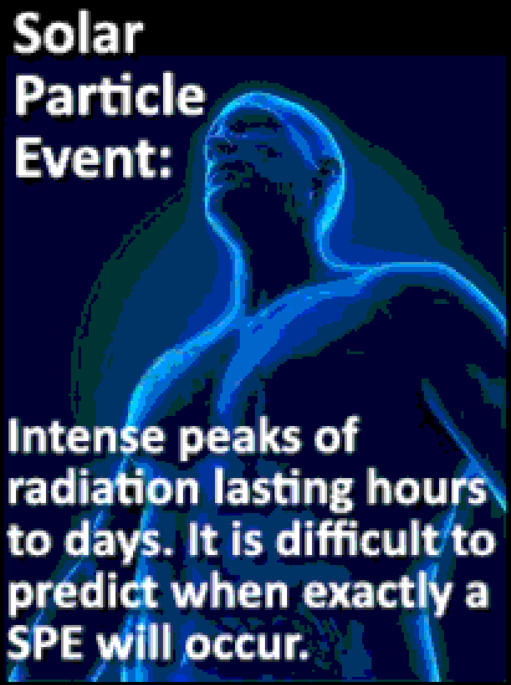
There is currently no level of exposure considered safe

The spaceflight industry has the obligation to constantly strive to lower exposure and increase protection

LOCKHEED MARTIN

https://www.lockheedmartin.com/en-us/news/features/2016/stemrad-vest-space.html





Areas of the Body Most at Risk:

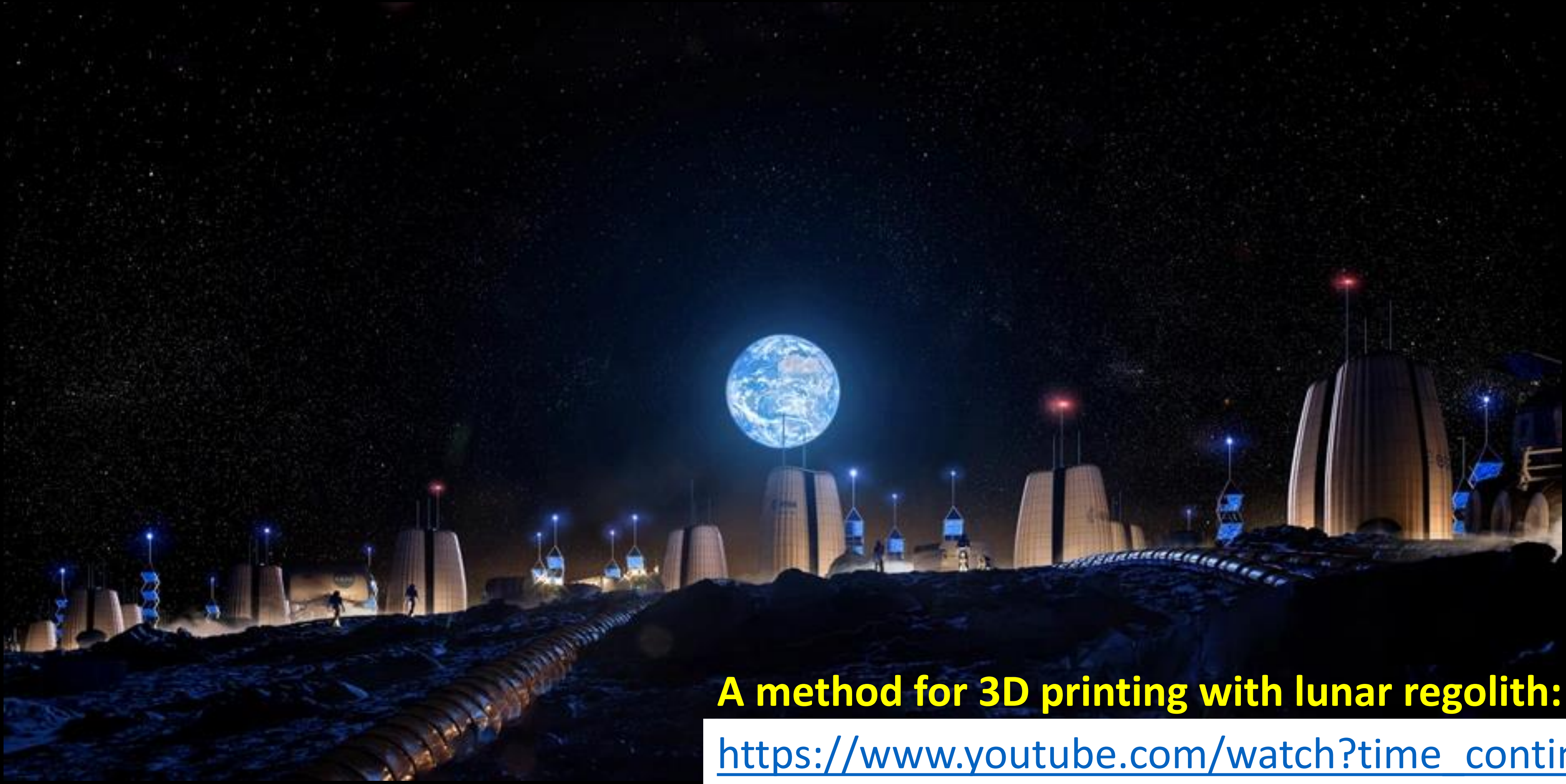
LOCKHEED MARTIN

AstroRad can provide astronauts with protected mobility when traveling between different spacecraft elements of the Gateway (or other future space architecture).

The vest design protects the most susceptible vital organs — like bone marrow, reproductive organs and lungs — from the harmful effects of radiation.

Wearable vests take up minimal space. This is important, since efficient use of mass is critical for long-duration human spaceflight missions.

https://www.citylab.com/design/2019/04/moon-village-som-mit-esa-space-urbanism-planning-habitat/587482/



A method for 3D printing with lunar regolith:

https://www.youtube.com/watch?time_continue=214&v=jVCiPTXYYu8&feature=emb_logo

Beyond the first robotic explorers, science missions, and developers, what will it take to establish permanent human settlements on the Moon?

What do humans need to be happy and healthy, besides the obvious protection against radiation, micrometeorites, regolith inhalation, and the need for oxygen and water?

Healthy and varied food that can be grown on the Moon

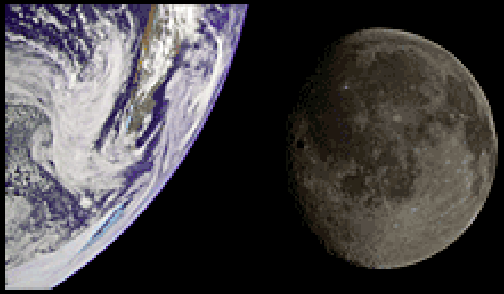
plants? animals?

Friendly environment with a touch of home (Earth)

Arts and recreation

sports and dance in $1/6^{th}$ g?

TV and radio? News and entertainment programs?



UA CONTROLLED ENVIRONMENT AGRICULTURE CENTER

Prototype Lunar Greenhouse

A NASA STECKLER SPACE GRANT COLLABORATION

See https://www.youtube.com/watch?v=8V54UaUXqXg being developed at ASU

A Japanese design:

LunaRevolution-Role of the Moon in the Future of Human Space Activity

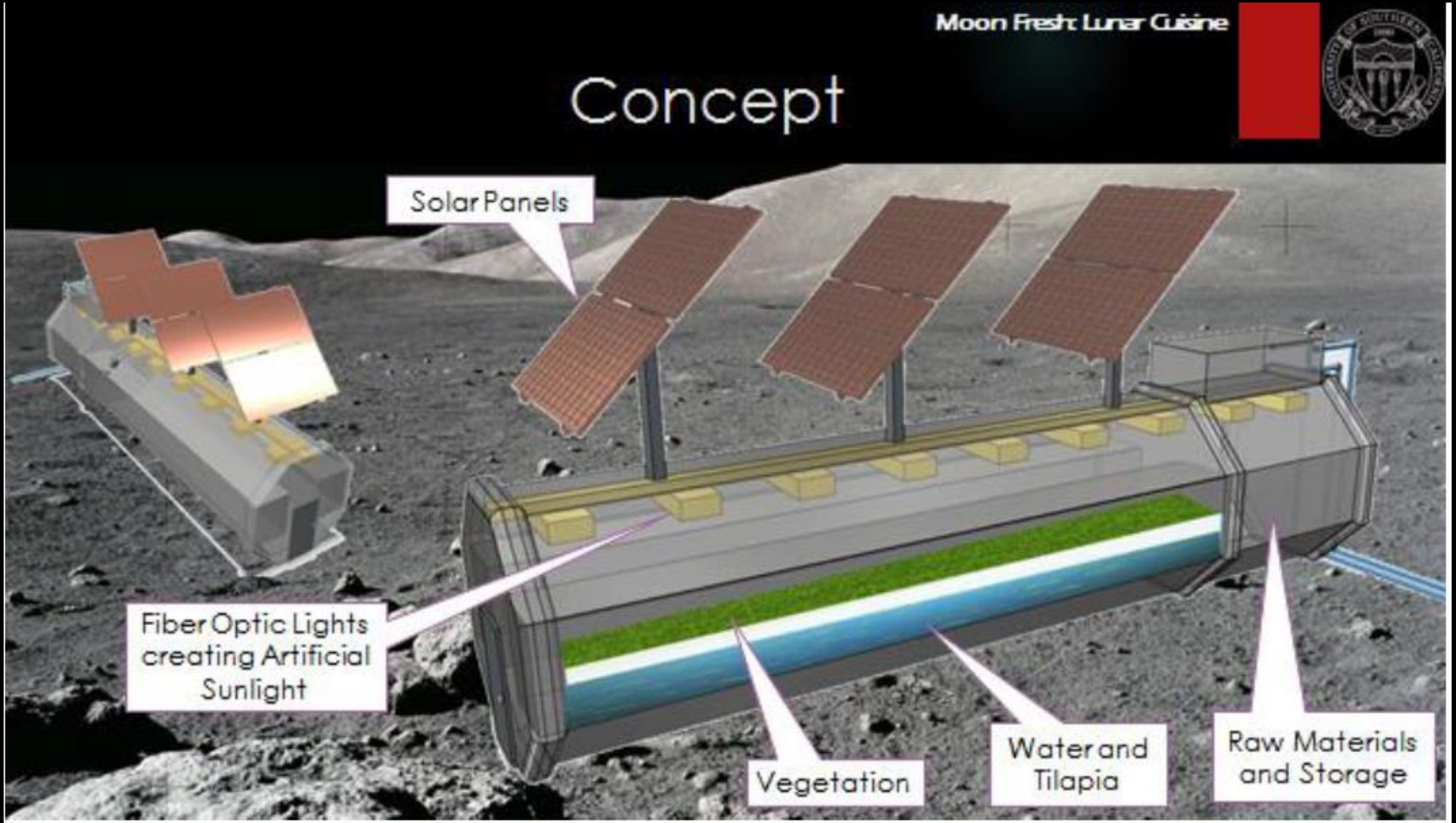


Figure 10. Salient features of the MoonFresh™ bioregenerative lunar greenhouse and aquaponics chamber that is powered by photovoltaic arrays in the continuously available sunlight available in the lunar polar regions.

Aghdasi, F & Caillouet, T & Chao, Andrew & Ives, B & Lali, Mehdi & Perakalpudi, N & Rajguru, A & Shields, A & Vasmate, Vishal & Thangavelu, Madhu & J.D.Burke,. (2016). LunaRevolution-Role of the Moon in the Future of Human Space Activity.

Concept

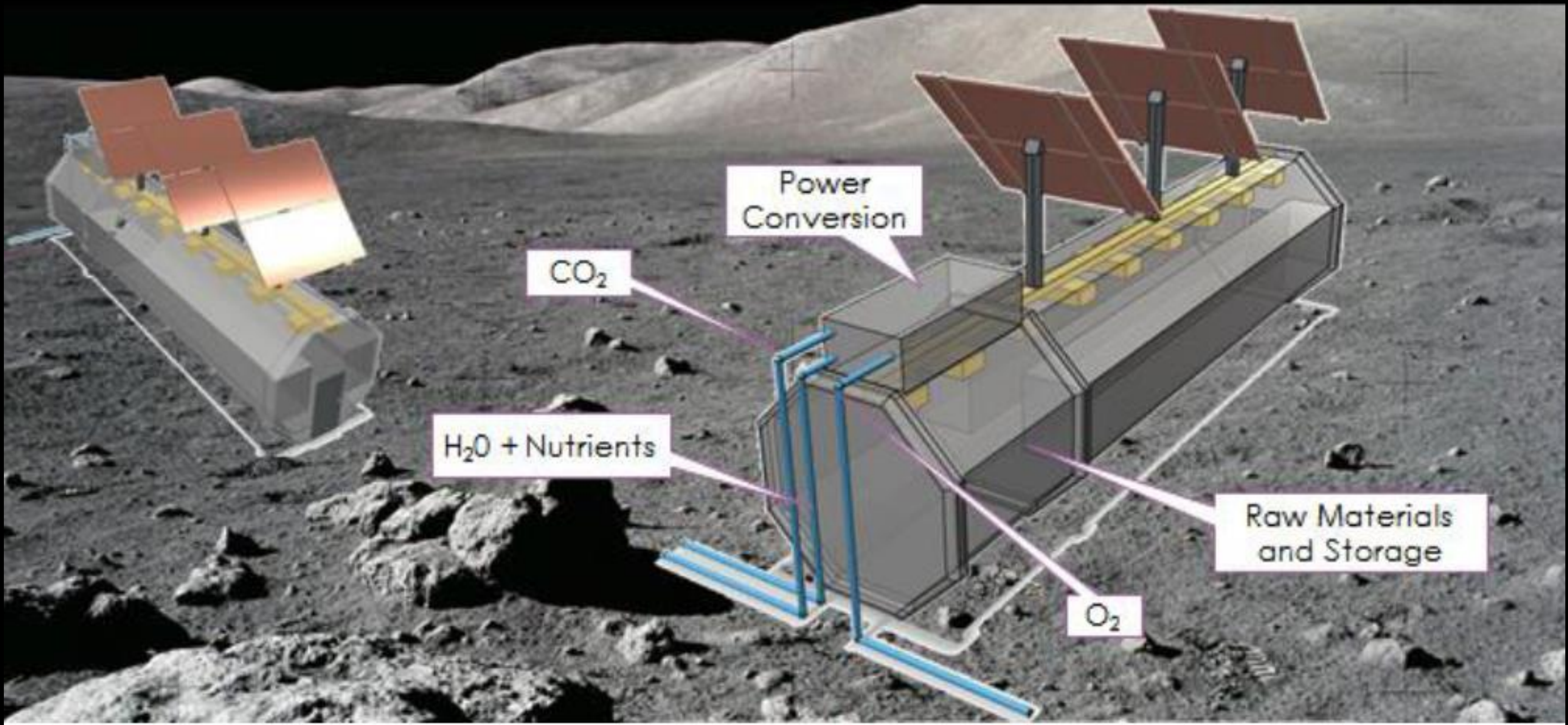
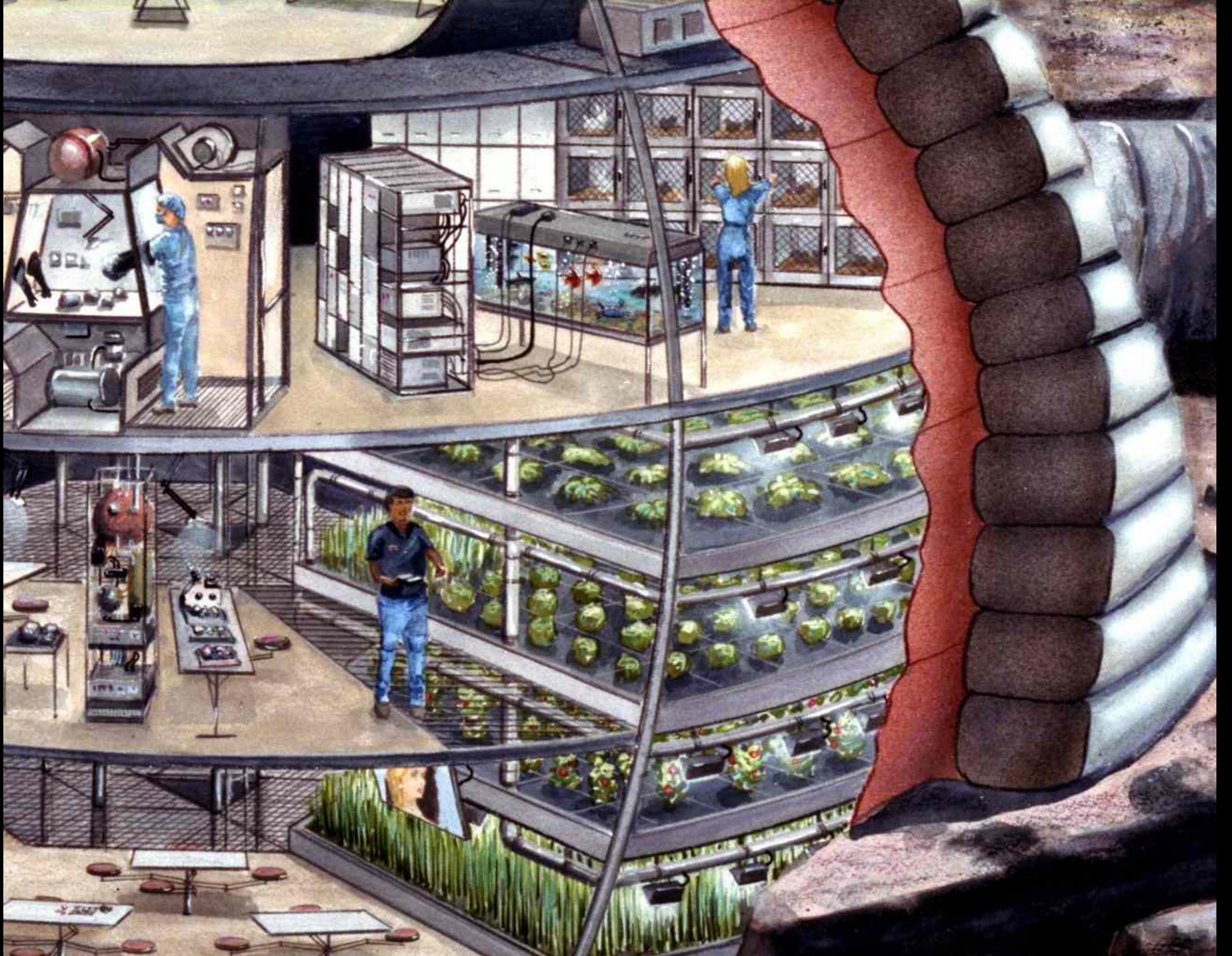


Figure 11. Schematic of the MoonFresh™ lunar greenhouse, PV energy conversion system and products

Moon farming
of the future?



Moon Villa: Spherical Lunar Home for Low-Gravity Living

A touch of home?

split-level, stair-less configuration of the space – a nod to the lower-than-Earth gravity conditions that would allow residents to leap and bound from one floor to the next.

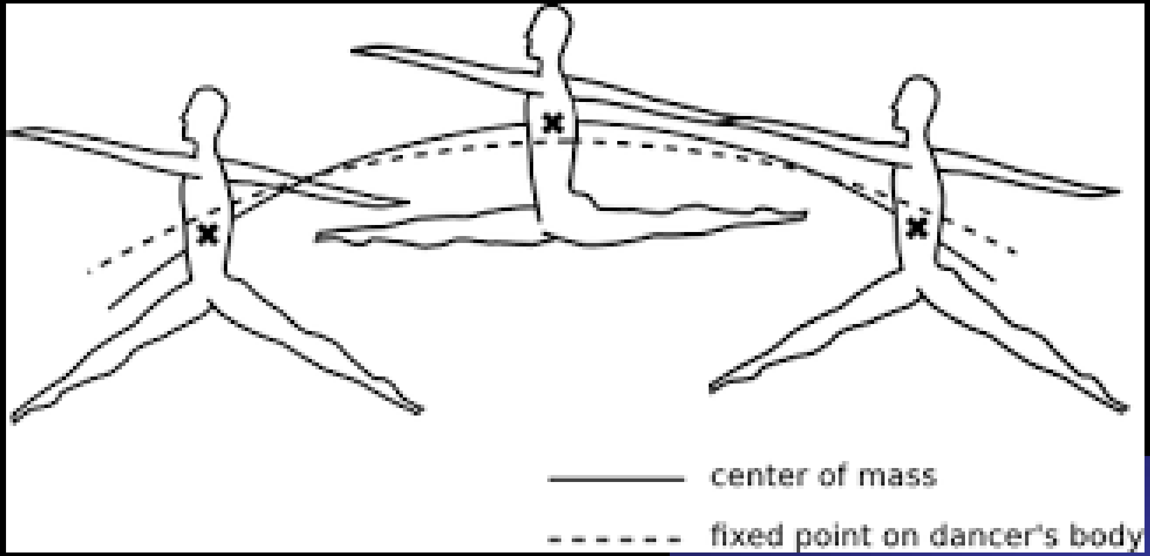
https://dornob.com/moon-villa-spherical-lunar-home-for-low-gravity-living/

A series of rotating shades help regulate light and heat, reducing temperature extremes while gathering the sun’s energy. For more serious solar storms, an underground bunker provides safer emergency shelter.

How would you like to live in this lunar condo?

What sports can be played in a 1/6th g environment?

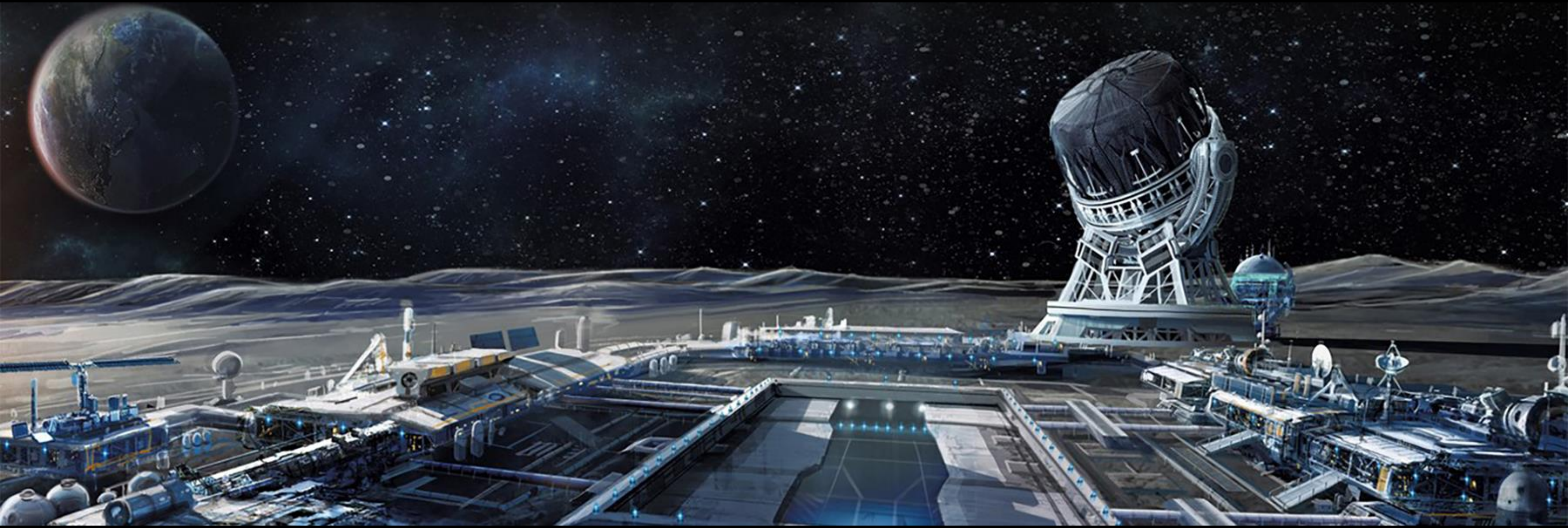
How about dance in 1/6th g?



http://web.hep.uiuc.edu/home/g-gollin/dance/dance_physics.html#9

How would the physics of dance be different on the Moon, where g = 1.6 m/sec^2?

Moon Village Association https://moonvillageassociation.org/



Preserving human values of decency on the Moon