Overview of ECLSS for Human Lunar Exploration

Key Non-Polar Destinations Across the Moon to Address Decadal-level Science Objectives with Human Explorers: Panel on Human and Biological Science

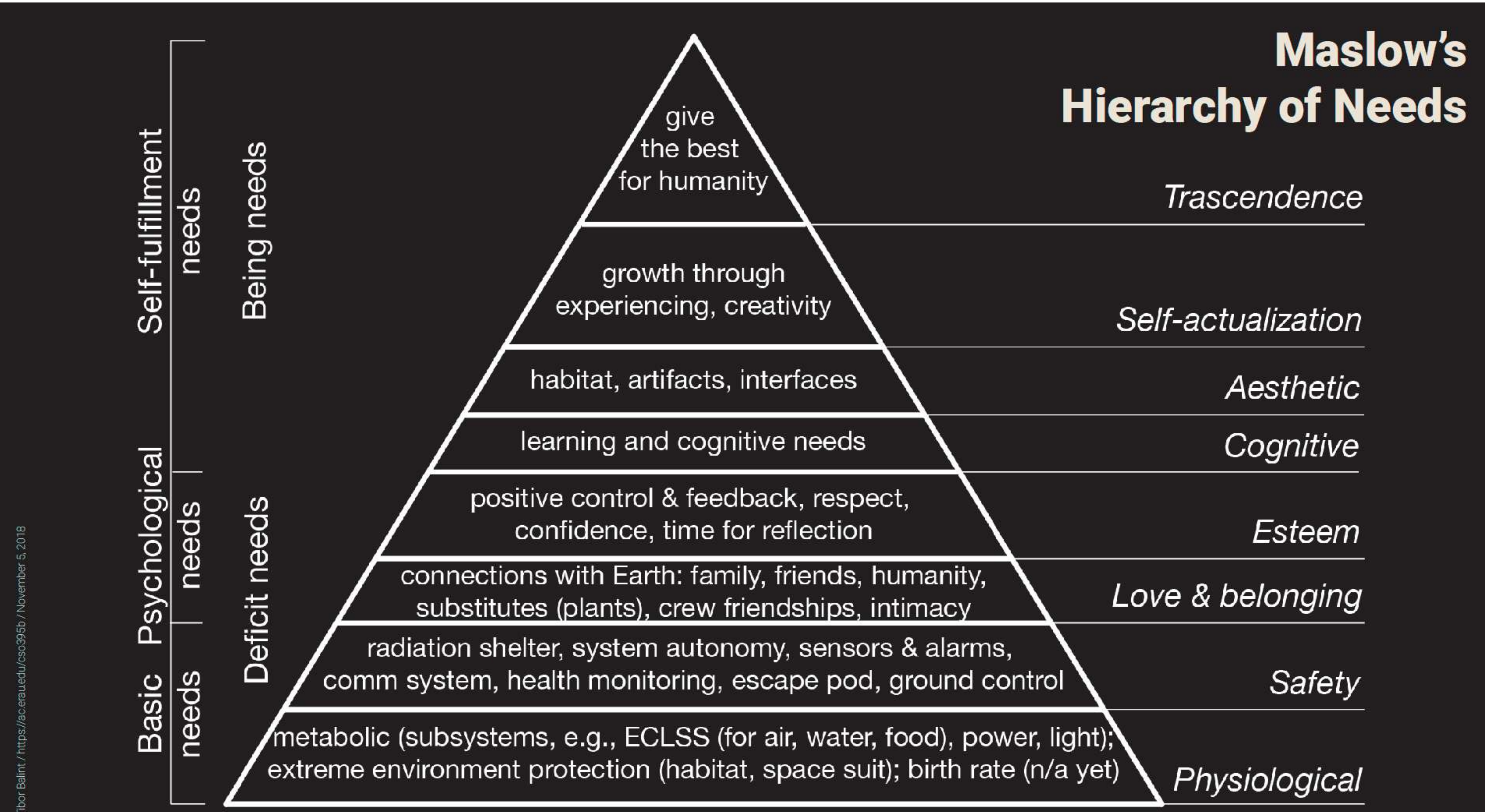
NATIONAL ACADEMIES Sciences Engineering Medicine

Ryan L. Kobrick, Ph.D.
Space Lab®, Boulder, CO

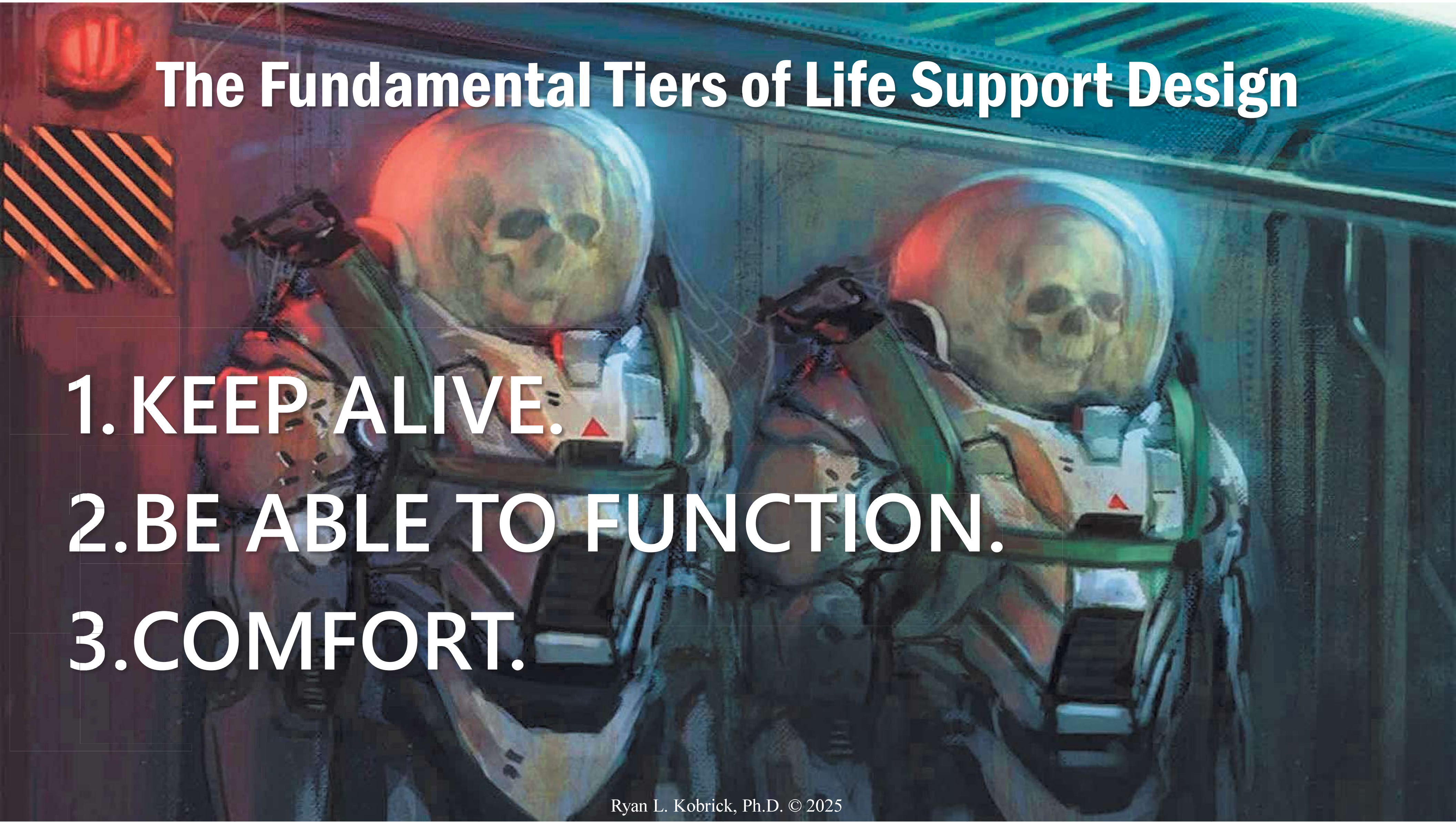
Key Discussion Topics

- Human Centered Design
  - Overview & ECLSS Design Drivers
- ECLSS Portfolio
- Non-Polar Lunar Destination Considerations
- A Few Lunar ECLSS Design Considerations
- Discussion

HUMAN CENTERED DESIGN



Courtesy of Tibor Balint

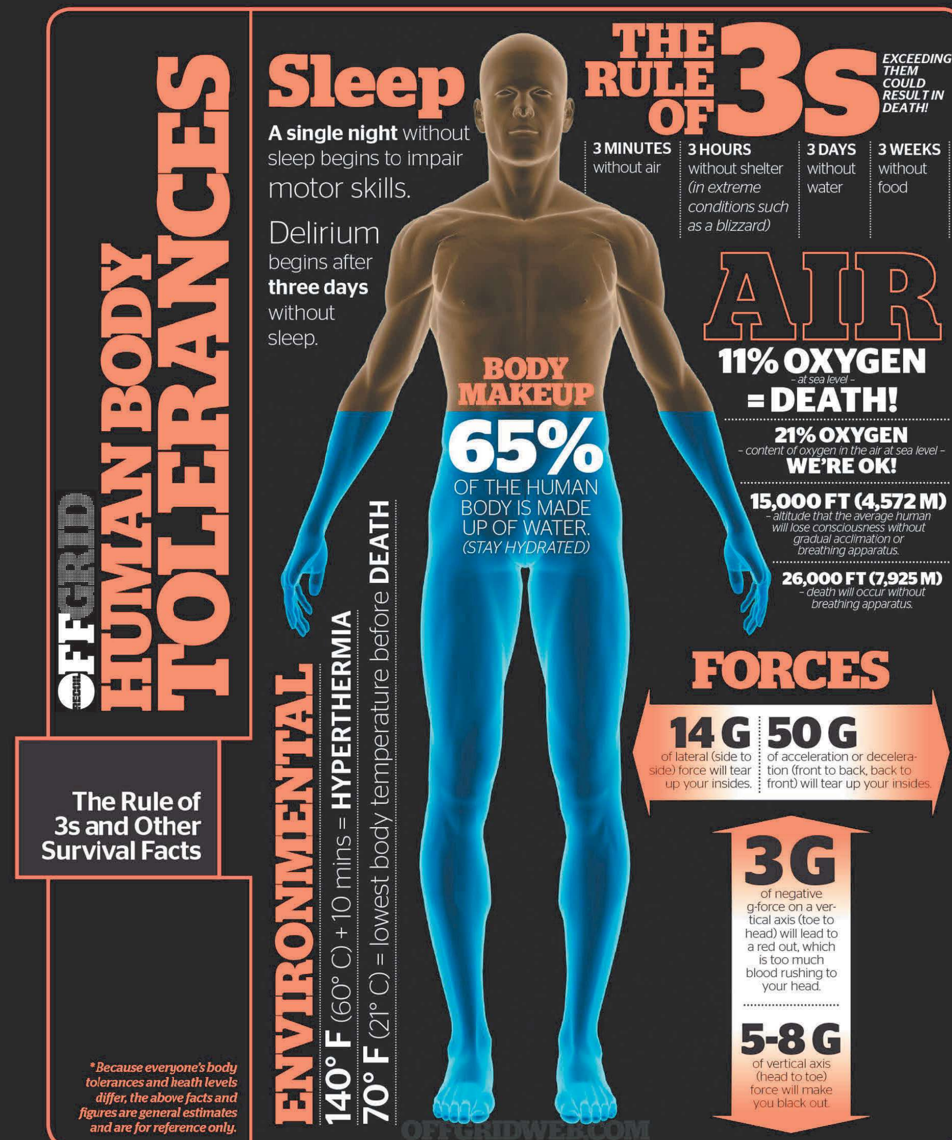


The Fundamental Tiers of Life Support Design

1. KEEP ALIVE.
2. BE ABLE TO FUNCTION.
3. COMFORT.

The Rule of 3's

- Missing from infographic: PRESSURE → 3 seconds!
- https://www.offgridweb.com/survival/infographic-the-survival-rule-of-3s/
- https://www.youtube.com/watch?v=nag-z7WwFdY



Human Physiological Needs → Consumables
Human Metabolic Inputs & Outputs

Human Needs = ECLSS Design Drivers

ECLSS = Environmental Control & Life Support Systems

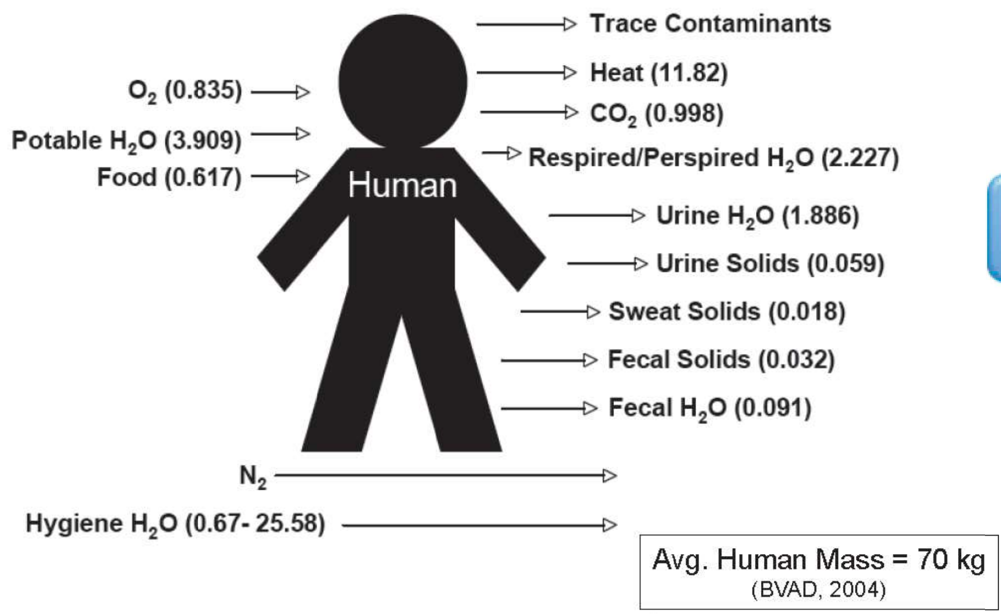
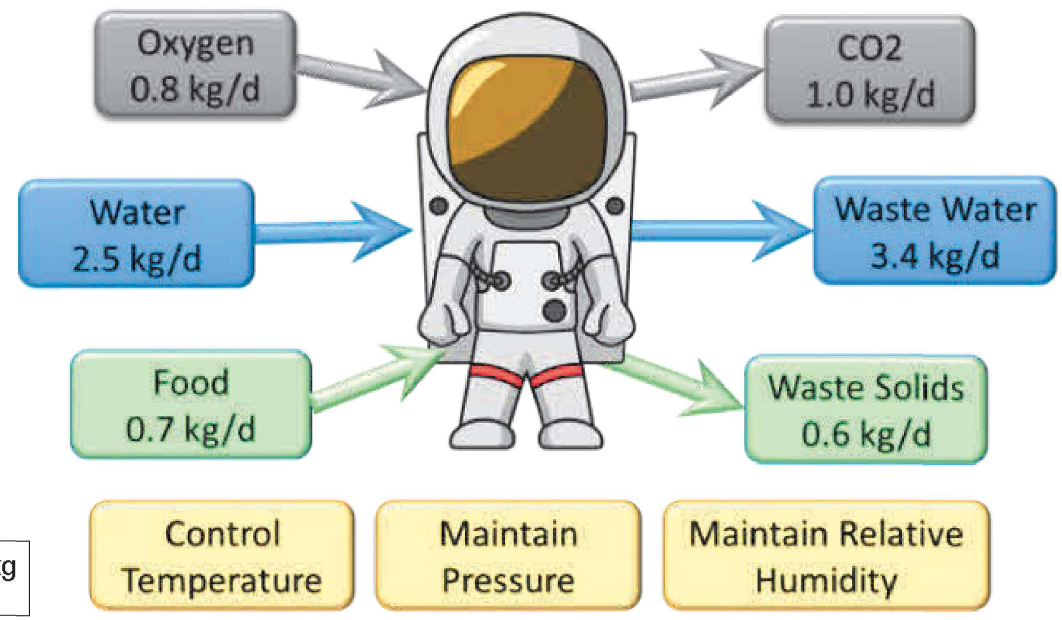
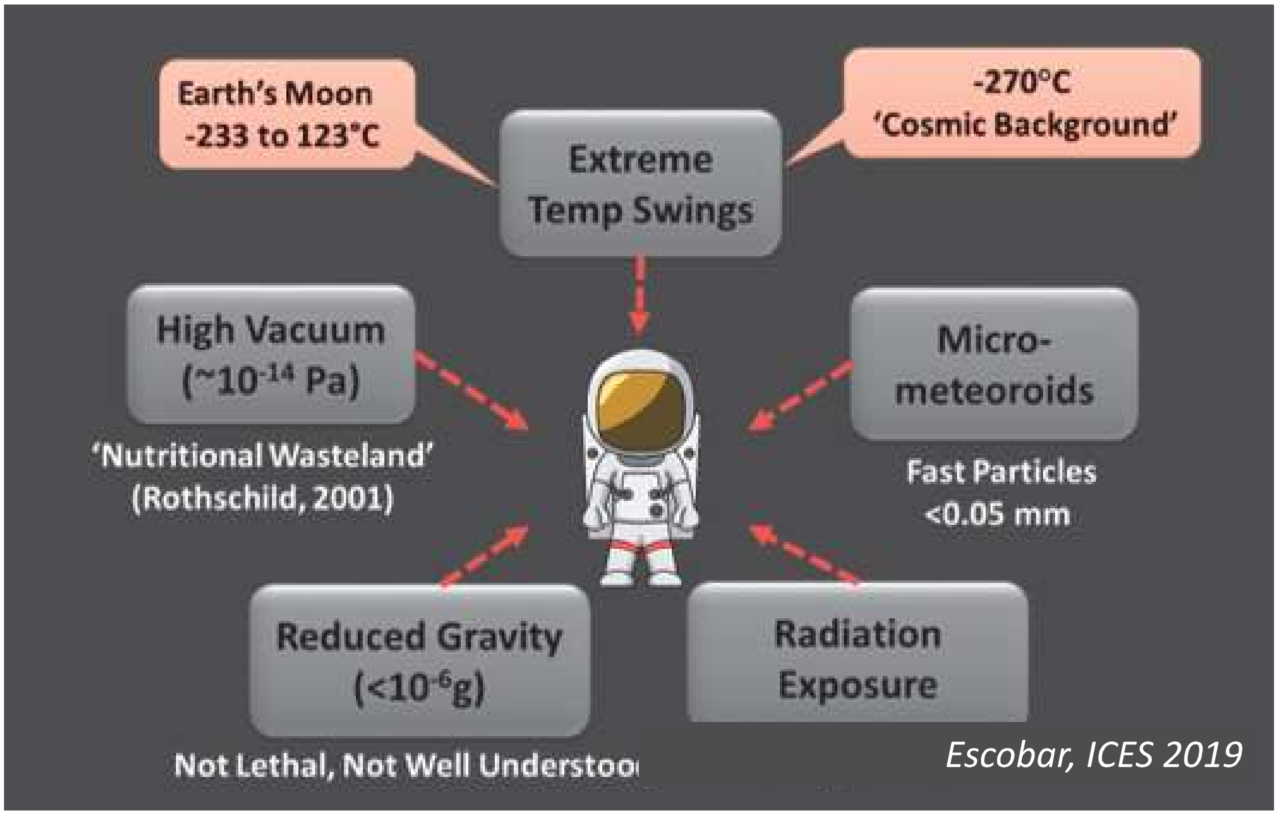


Figure 1. Human Consumable and Throughput Values in kg (or MJ)/crewmember/day (Klaus et al., 2005)



BVAD 2015 (pp 50, 53, 64, & 106)
Escobar, ICES 2019

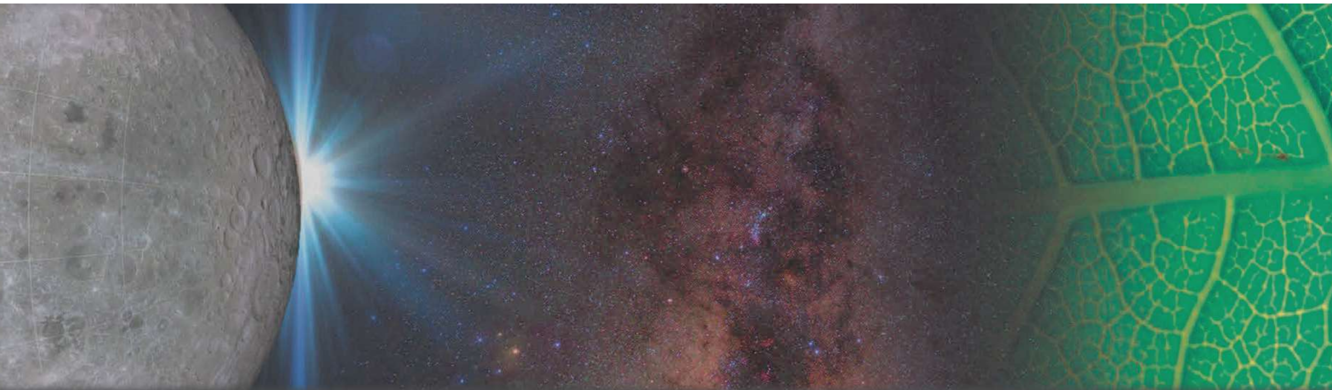
ECLSS Design Drivers
Interplanetary Environment



ECLSS PORTFOLIO

ECLSS Portfolio on the Lunar Surface

- Static: Landers, Habitats
- Mobile: Spacesuits, Pressurized Rovers
- Payloads: Life Science, ISRU reactors
  - Ex. LEAF
    - Human-tended payload with an ECLSS by a suited astronaut that has their own ECLSS after leaving the ECLSS of their lunar lander.



LEAF

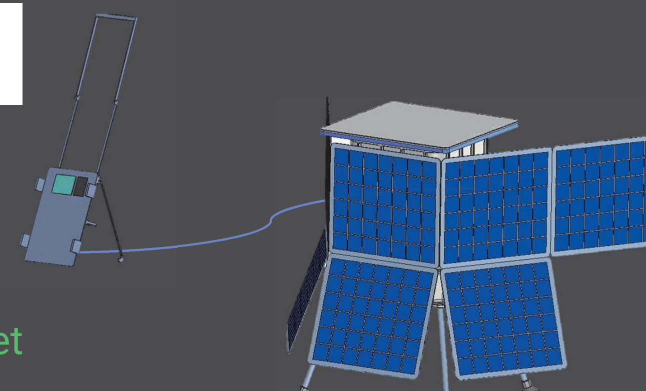
Lunar Effects on Agricultural Flora

The future of sustainability includes plants in space…

- ECLSS:
  - Air & Water Revitalization
  - Waste Management
  - Nutrious Food
- Bioproducts:
  - Medicine, Biofuel, Fibers, Polymers

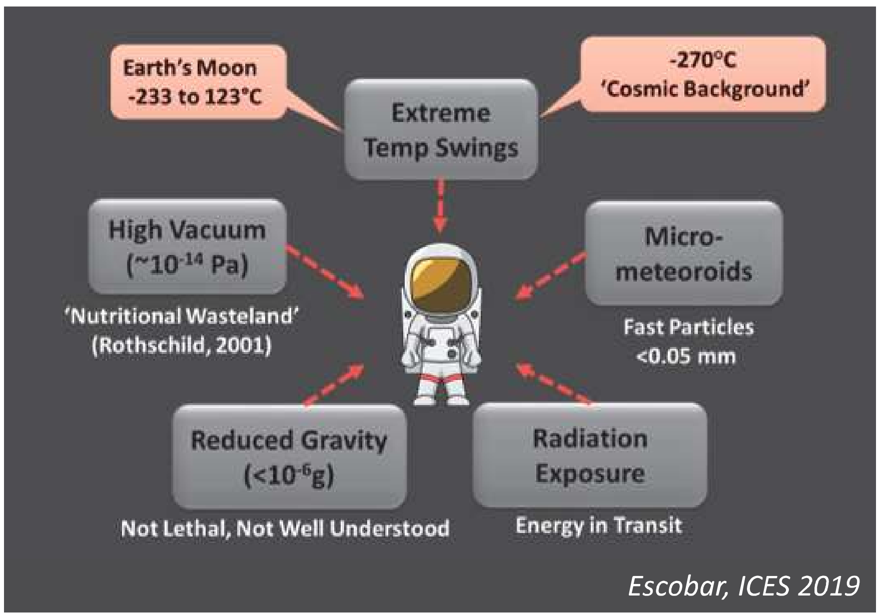
Lunar Effects on Agricultural Flora (LEAF β) will provide the first, comprehensive assessment of organism-wide effects of the Lunar environment on model space-crops, reducing risks for sustainable off-planet food production and life support.

Artemis III Deployed Instruments (A3DI)



NON-POLAR LUNAR DESTINATION CONSIDERATIONS

What does this mean for “Non-Polar” Lunar?



- Assume uniform: Vacuum, g, dust
- Protected by Layers: Micrometeoroids, Cosmic Radiation
  – Structures, suit layers, regolith, natural terrain features
- **Location Driven: Thermal (Solar Radiation and Temperatures)**
  – **Structures, suit layers, regolith, natural terrain features (esp. shadows)**
  – **Time/exposure up to 2 weeks**

Lunar Considerations for Non-Polar ECLSS

Operational & Resource Advantages

- **Continuous Solar Power (14 Days)**
  - Provides long periods of stable energy for ECLSS operation and potential bioregenerative systems (plants).
  - Predictable for thermal management (and energy).
- **Local Oxygen Source (ISRU)**
  - Oxygen is universally abundant in non-polar silicate regolith (SiO_2) for in-situ O_2 production.
- **Stable Communications**
  - Equatorial location provides predictable, direct line-of-sight with Earth for mission support.

Lunar Considerations for Non-Polar ECLSS

Key ECLSS Design Challenge (Disadvantages)

- **Massive Diurnal Temperature Swings**
  - **Lunar Day (+120∘C):** Requires massive **Heat Rejection** radiator surface area for habitat cooling.
  - **Lunar Night (–170∘C):** Requires robust **Insulation and Active Heating** to prevent ECLSS fluid lines and components from freezing. Passive options, but are high mass and complicated.
- **14-Day Power Loss**
  - Requires a high-mass **Energy Storage** solution (e.g., Regenerative Fuel Cells) to maintain critical ECLSS functions through the night.
- **Water Scarcity**
  - No concentrated water ice; forces extremely high ECLSS **Water Recycling** closure rates (>95%).

Lunar Considerations for Non-Polar ECLSS

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A FEW LUNAR ECLSS DESIGN CONSIDERATIONS

A few final lunar thoughts…

- Test-as-We-Build.
  - habitation infrastructure is established in functional increments
    - analogous to living in a home while it is being built
  - AIAA Lunar Surface Exploration and Development Task Force
  - Chartered to “identify and document critical initial steps for lunar surface exploration that will promote sustainable lunar and space exploration, international cooperation and coordination, and economic development.”
- The best R&D for the Moon, is on the Moon.
- Artemis, Get Dirty.


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Dirty as Schmitt.


Images.NASA.gov
Not so clean Gene.

DISCUSSION

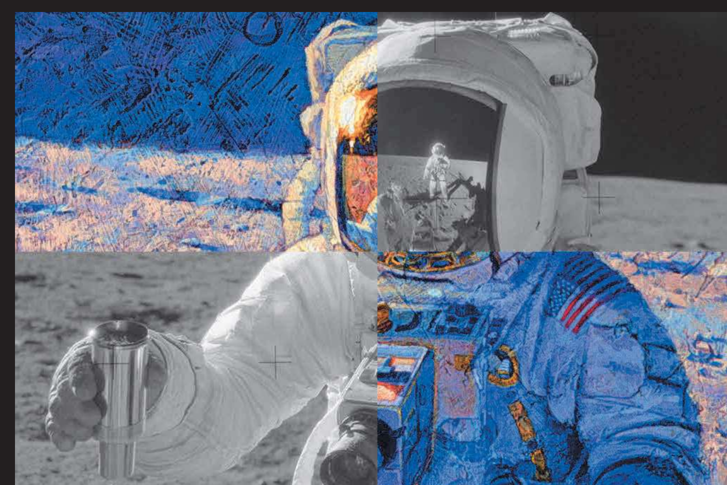

Image credit: NASA/Alan Bean via collectSPACE.com

Ryan L. Kobrick, Ph.D.
Space Lab®, Boulder, CO

Email: ryan@spacelabtech.com
Social: @RyInSpace