MELiSSA
MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE

CREATING
A CIRCULAR
FUTURE

Lunar Nutritional Grower (LuNG)

Assessing the viability of a lunar hydroponic system

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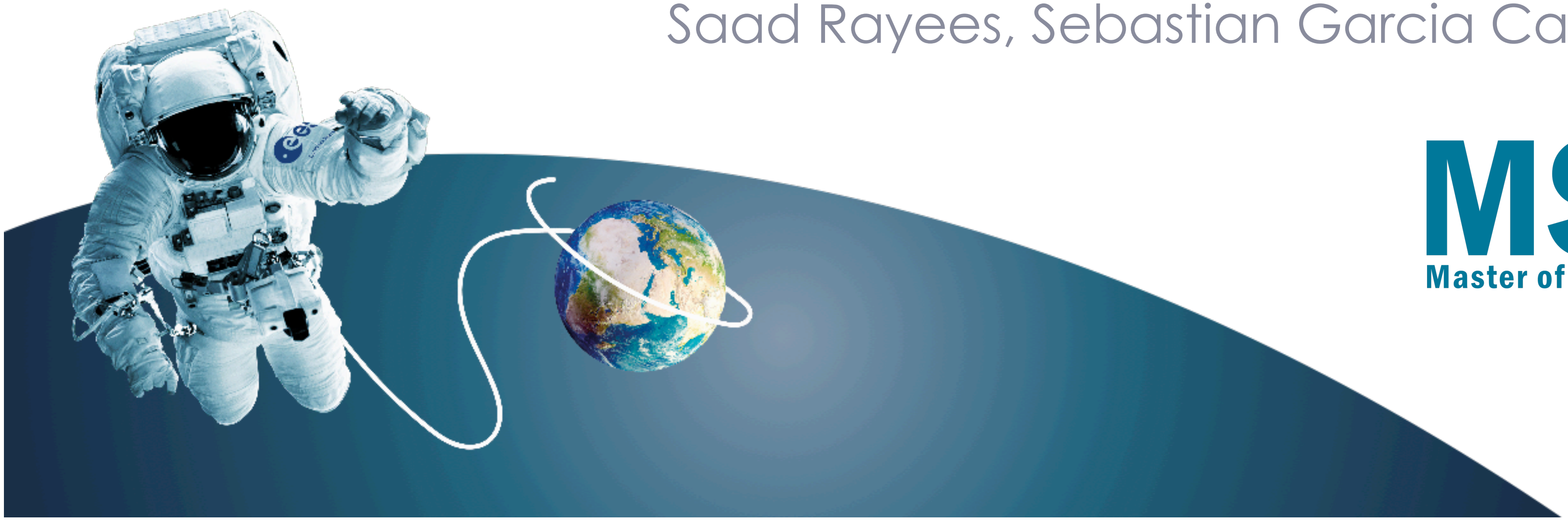

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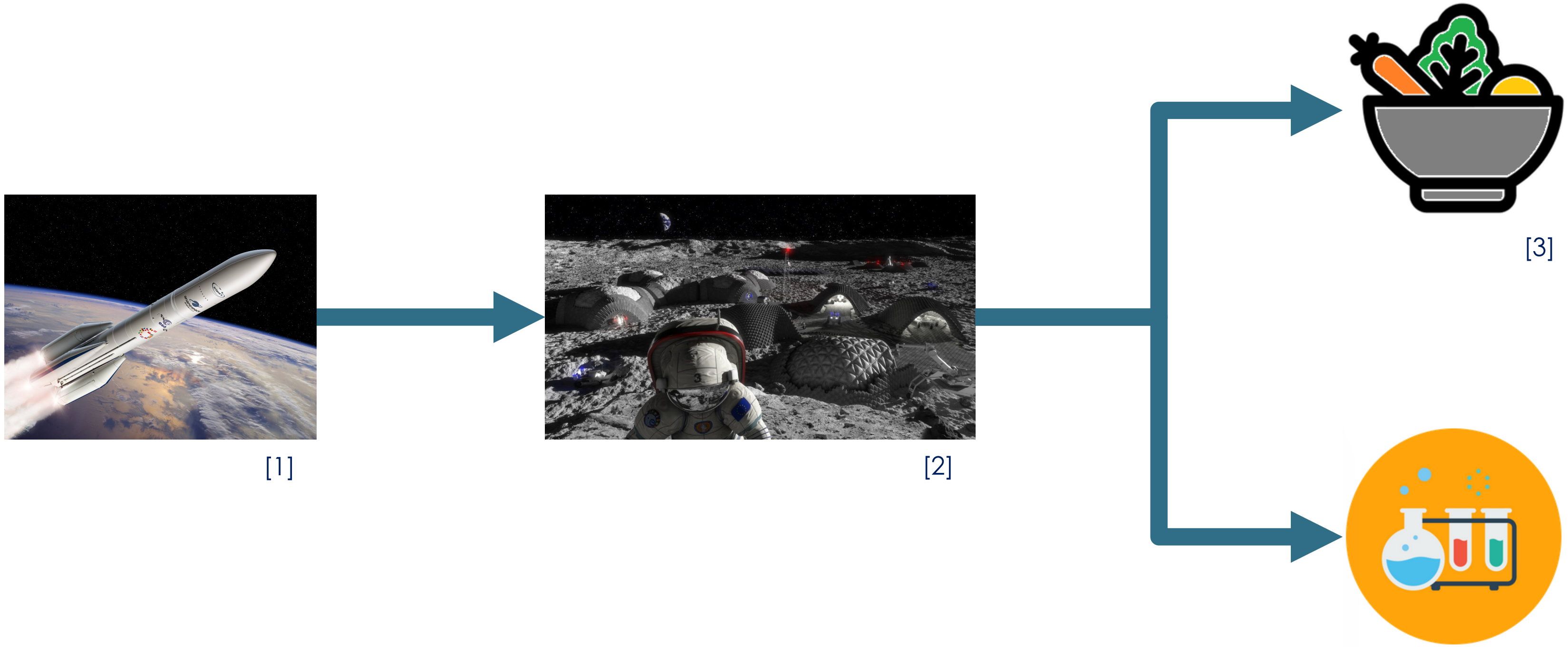
Mission Statement



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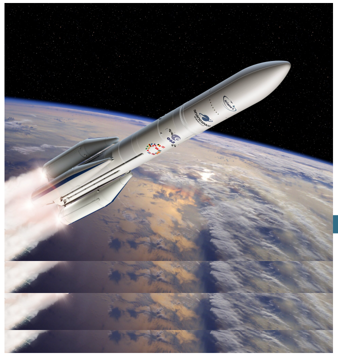
Mission Statement



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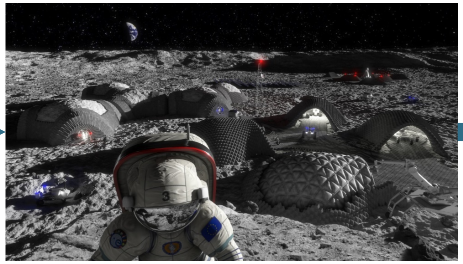

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Risk levels

Mission Costs

Mission Statement

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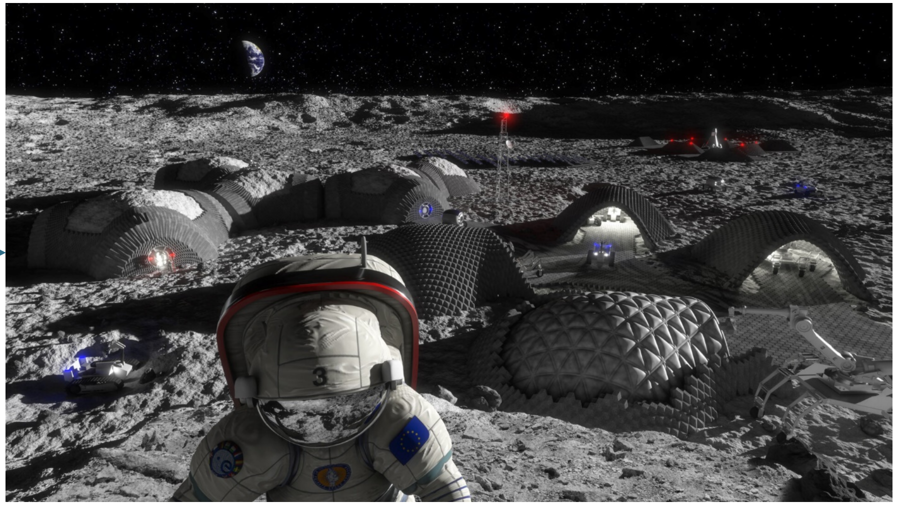

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Mission Statement

LuNG seeks to act as a top-level design study that will:

- ✓ Establish a suitable hydroponic system architecture for a permanently crewed Lunar base.
- ✓ Identify key aspects, budgets and interfaces for LuNG.
- ✓ Critically assess performance and viability for LuNG.

Nutritional Requirements

- The proposed system would need to meet the nutritional needs of three crew members.

- For the purpose of the study, macro-nutritional needs for an all-male crew undertaking vigorous physical activity were taken into account.

Table 1. Macronutrients required for one person base [6]

Intake Level	Carbohydrates		Fats		Proteins		Fiber		Total	
	kcal	g	kcal	g	kcal	g	kcal	g	kcal	g
Low	1485	432	810	94.5	405	67.5	-	40.5	2700	634.5
Medium	1650	480	900	105	450	75	-	45	3000	705
High	2035	592	1110	129.5	555	92.5	-	55.5	3700	869.5

Table 2. Macronutrients required for three person base [6]

Carbohydrates		Fats		Proteins		Fiber		Total	
kcal	g	kcal	g	kcal	g	kcal	g	kcal	g
6105	1776	3330	388.5	1665	277.5	-	166.5	11100	2609

Crop Identification

- Similar studies that focused on biomass growth were identified and reviewed :

Table 3. Selection of CLSS studies that involved biomass production

Institution	Mission
ESA - Roscosmos	Mars500
SSP	Bios
JAXA	Closed Ecology Experiment Facilities (CEEF)
NASA	Vegetable Production System (Veggie)
CNSA	Lunar Palace

- Additional crops were selected to be evaluated. Their viability for hydroponic farming was the key criteria:
    - Potato, Tomato, Barley Wheat, Dwarf Spring Wheat, Pinto Beans, Soy Beans.

Crop Selection

The nutritional breakdown of the various crop types were considered, and various crop mixes that met the nutritional requirements of the system were identified.

It became clear that it would be very difficult to meet the system requirements in a nutritionally efficient manner, so a viability threshold was used as can be seen in Table 3.

Table 4. Nutritional thresholds requirements for LuNG objective [6]

Thresholds					
LuNG Criteria	**Percentage**	**Carbohydrates [g]**	**Fats [g]**	**Protein [g]**	**Fibers [g]**
Viability Threshold	90 %	1598	350	250	150
Full Requirement	100 %	1776	389	278	167

Crop Selection

Table 5. Nutritional results of crop mix A for a 3 person's crew [7,8,9]

Crop Mix A					
Crops	Mass [g]	Carbohydrates [g]	Fats [g]	Protein [g]	Fibers [g]
Potato	1000	155	1	21	20
Tomato	1000	26	2	9	13
Barley Wheat	1000	562	23	125	173
Dwarf Spring Wheat	1000	706	20	179	95
Pinto Beans	1000	471	12	214	155
Soy Beans	1000	69	68	130	42
Percentage fulfilled		**112%**	**32%**	**243%**	**298%**

🟩	Requirements Fulfilled
🟨	Above Threshold
🟧	Under Threshold

Crop Selection

Table 6. Nutritional results of crop mix B for a 3 person's crew [7,8,9]

Crop Mix B					
Crops	**Mass [g]**	**Carbohydrates [g]**	**Fats [g]**	**Protein [g]**	**Fibers [g]**
Dwarf Spring Wheat	2000	1412	40	358	189
Soy Beans	5000	343	340	648	210
TOTAL		**99%**	**98%**	**362%**	**240%**

Table 7. Nutritional results of crop mix C for a 3 person's crew [7,8,9]

Crop Mix C					
Crops	**Mass [g]**	**Carbohydrates [g]**	**Fats [g]**	**Protein [g]**	**Fibers [g]**
Dwarf Spring Wheat	2500	1765	50	448	237
TOTAL		**99%**	**13%**	**161%**	**142%**

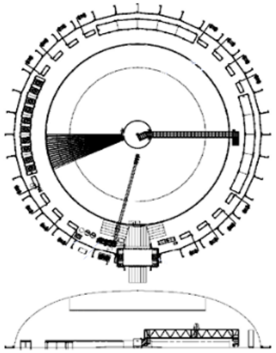
🟩	Requirements Fulfilled
🟨	Above Threshold
🟫	Under Threshold

System Design

A simple circular growing table hydroponic architecture was chosen as:

- ✓ Scalable
- ✓ Integrates automation
- ✓ Effective use of space
- ✓ Simple commercially available technology

Inspired by the Japanese GSE Domes, currently used to harvest lettuce and other crops.



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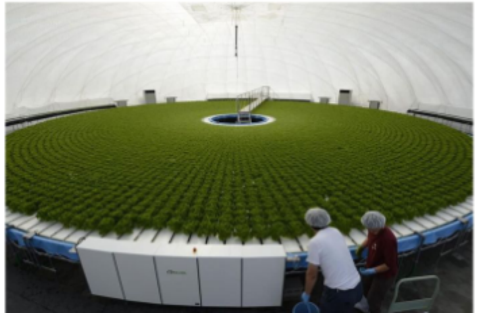

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System Design

- Circular growing table with a water tank embedded.
- Planter system plants seeds at inner (**blue**) ring.
- Plants grow on **radial channels** and are pushed outwards as they mature.
- Harvester system reaps mature crop at outer (**red**) ring.
- LED strips are used to light the crop on a 24h basis.

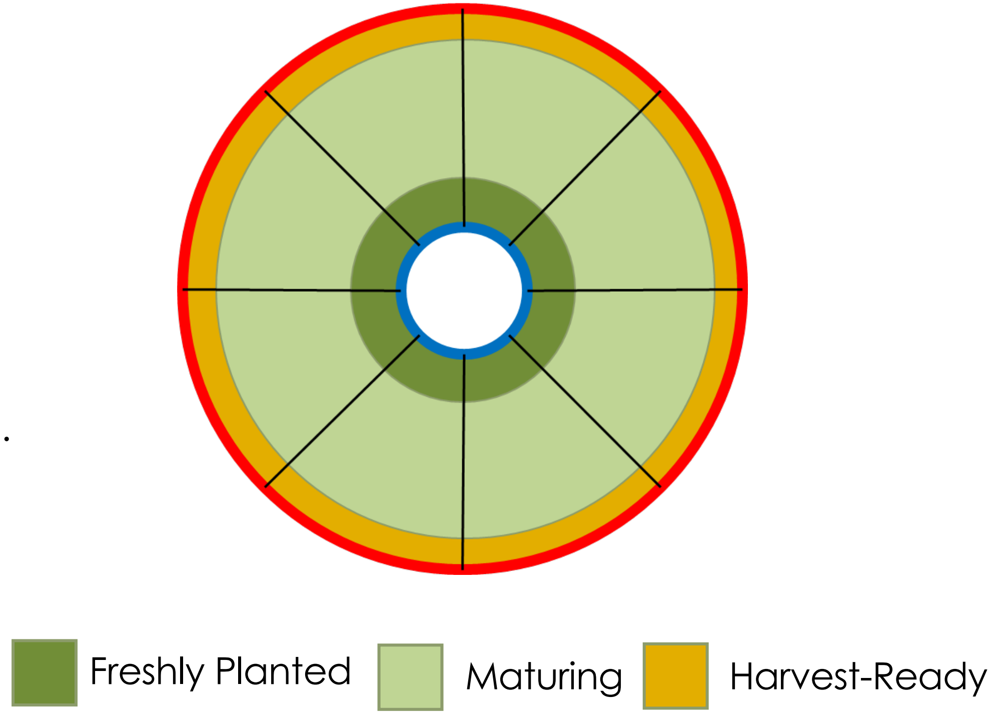

Figure 1. Top View schematics for proposed design

System Dimensioning

Estimated biomass requirements

The chosen Dwarf Spring wheat has a harvest cycle of 70 days, and a daily required yield of 2.5 kg

$$\underbrace{2.5 \text{ kg/day}}_{\text{Daily biomass}} \text{ x } \underbrace{70 \text{ days}}_{\text{Harvest cycle}} = \underbrace{175 \text{ kg}}_{\text{Total yield}}$$

Lunar Palace 1 experiments showed that a 1 kg/m^2 yield rate can be achieved with Dwarf Spring Wheat.

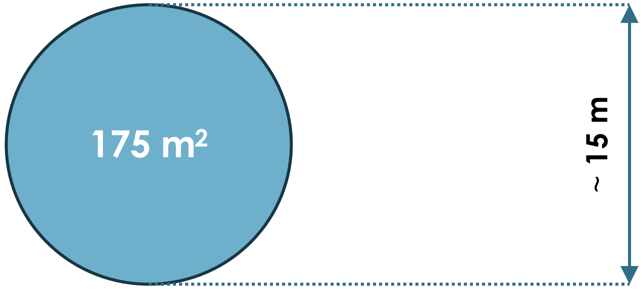

Figure 2. Area required for the proposed design

System Dimensioning

Estimated water requirements

The planting area is used to calculate the required tank capacity to irrigate the system:

$$\underbrace{175\ m^2}_{\text{Total growing area}} \times \underbrace{40\ liters/m^2}_{\text{Hoagland solution needed}} = \underbrace{7000\ liters}_{\text{Tank capacity needed}}$$

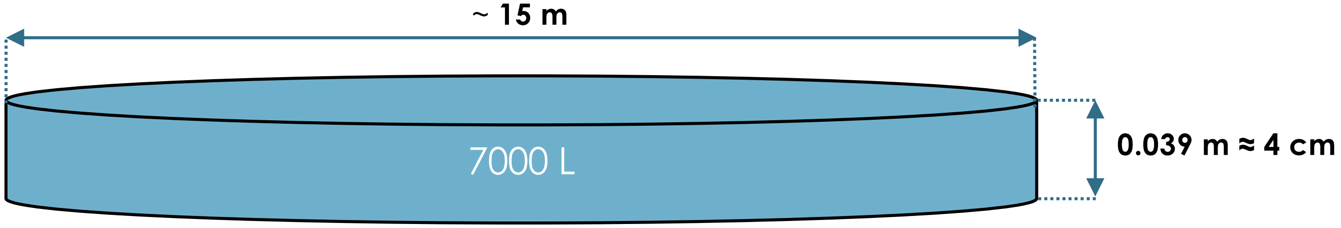

Figure 3. Tank capacity required for proposed design

System Dimensioning

Estimated power requirements

Table 8. Initial estimated power requirements for LuNG [12,13,14]

Components	Units	Unit Power [kW/unit]	Total Power [kW]
Air Conditioning	4	6	24
Air Ventilation	4	0.75	3
Water Recirculation	1	0.4	0.4
Water Treatment	3	0.5	1.5
LED Lighting	2	0.4	0.8
Planter / Harvester / Control System	1	5	5
Subtotal			34.7
Total (including 15% safety factor)			39.91

System Dimensioning

System Interfaces

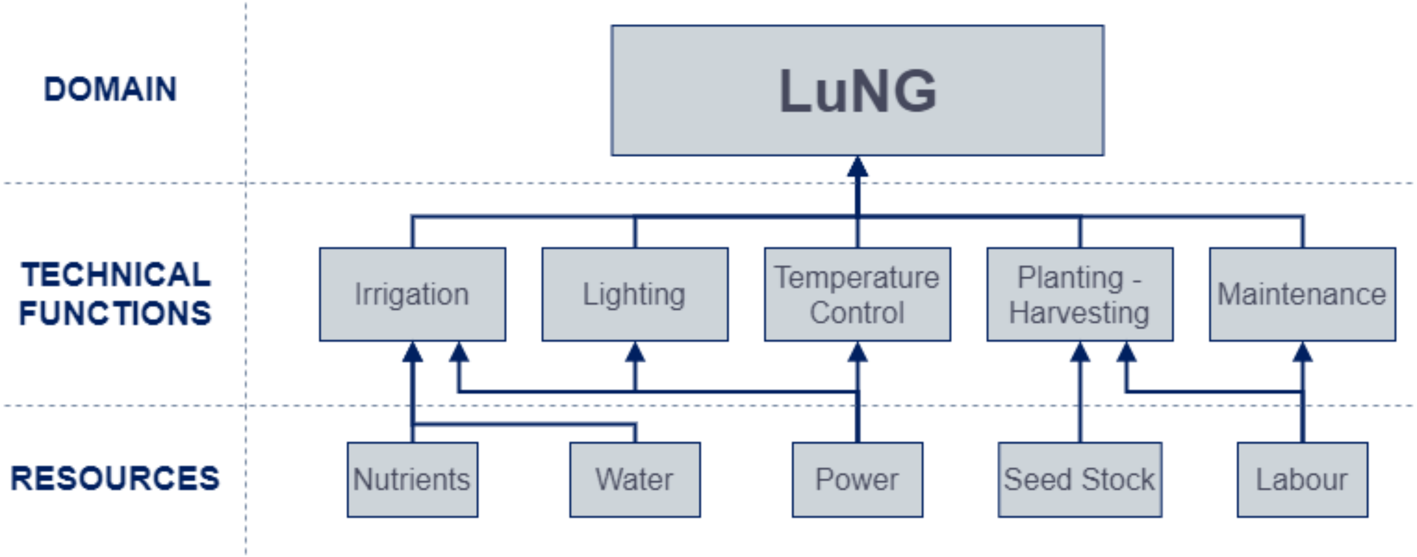

Figure 4. LuNG system abstraction hierarchy

Key Findings

- LuNG verified that a hydroponics system could fulfill nutritional requirements for a three-person crew.
- LuNG achieves high nutritional efficiency, meeting requirements with just 2.5 kg of biomass a day.
- It achieved this with low labor intensity, allowing the crew to focus on other aspects of exploration.
- Using conservative estimates, the system required a growing area of 175 m^2, 7000 L of water, and a power demand of approximately 40 kW.
- The system will be able to continuously and sustainably produce fresh crop after initial harvest, while allowing staggering of harvests to adjust to the needs (and number) of crewmembers.

Key Findings

- Although this study proposes a monoculture, system can be adapted to include additional crop species and increase the crews diet variety.
- Fat deficiencies can be addressed using other sources like insect farms, aquacultures, or small livestock.
- Byproducts can be feed for livestock, or towards In-Situ Resource Utilization (ISRU).
- A permanently-lit chamber with fresh vegetation can act as a morale booster.

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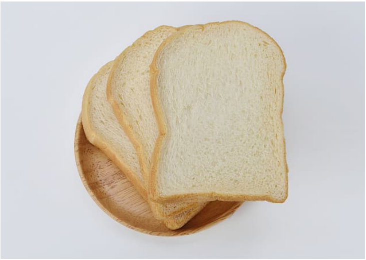

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Next Steps…

- Feedback from subject experts to drive development to the next stages…
- Cooperation from industry to further strengthen concept…
- Developing a proof of concept in a terrestrial setting…

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THANK YOU.

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REFERENCES

References

- [1] https://www.esa.int/Enabling_Support/Space_Transportation/Launch_vehicles/Ariane_6
- [2] https://www.esa.int/ESA_Multimedia/Images/2018/11/Future_Moon_base
- [3] https://thenounproject.com/term/light-food/1695234/
- [4] https://iconscout.com/icon/science-research-testtube-experiment-bubble-study-project-1
- [5] https://commons.wikimedia.org/wiki/File:CDC_South_Aquaponics_Raft_Tank_1_2010-07-17.jpg
- [6] I. of Medicine, Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). National Academies Press, 10 2005.
- [7] U. SR28, "National nutrient database for standard reference, release 28," US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. http://www.ars.usda.gov/ba/bhnrc/ndl. Accessed, vol. 26, 2016.
- [8] C. Dong, L. Shao, Y. Fu, M. Wang, B. Xie, J. Yu, and H. Liu, "Evaluation of wheat growth, morphological characteristics, biomass yield and quality in lunar palace-1, plant factory, green house and field systems," Acta Astronautica, vol. 111, pp. 102–109, 06 2015.

References

- [9] Mass Flows, Flow Control, and Tradeoffs for a Spectrum of Multistage Evolving Space Farms, 2017.
- [10] L. G. Philippsen, "From tank to table: Granpa dome revolutionizes the factory farm", Modern Agriculture Magazine, 02 2016.
- [11] Vertical farm, "Hydroponic farm japan granpa dome", 12 2014.
- [12] G. S. Engineering, "GSE dome with hydroponics", 2017.
- [13] P. Aqua, "Commercial reverse osmosis RO systems ro-200."
- [14] A. Lighting, "How to determine how many LED lumens you'll need to properly light your space", 12 2018.
- [15] https://www.pikrepo.com/ffnzs/yellow-pasta-lot
- [16] https://www.pikrepo.com/fisow/three-sliced-breads-on-round-beige-plate
- [17] https://commons.wikimedia.org/wiki/File:Fresh_ramen_noodle_001.jpg

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