NUTRITION ON THE MOON AND BEYOND
NUTRITION SUR LA LUNE ET AU-DELÀ

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Author's Declaration

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Introduction

During the Apollo Program 12 men spent 3.6 weeks on the moon.

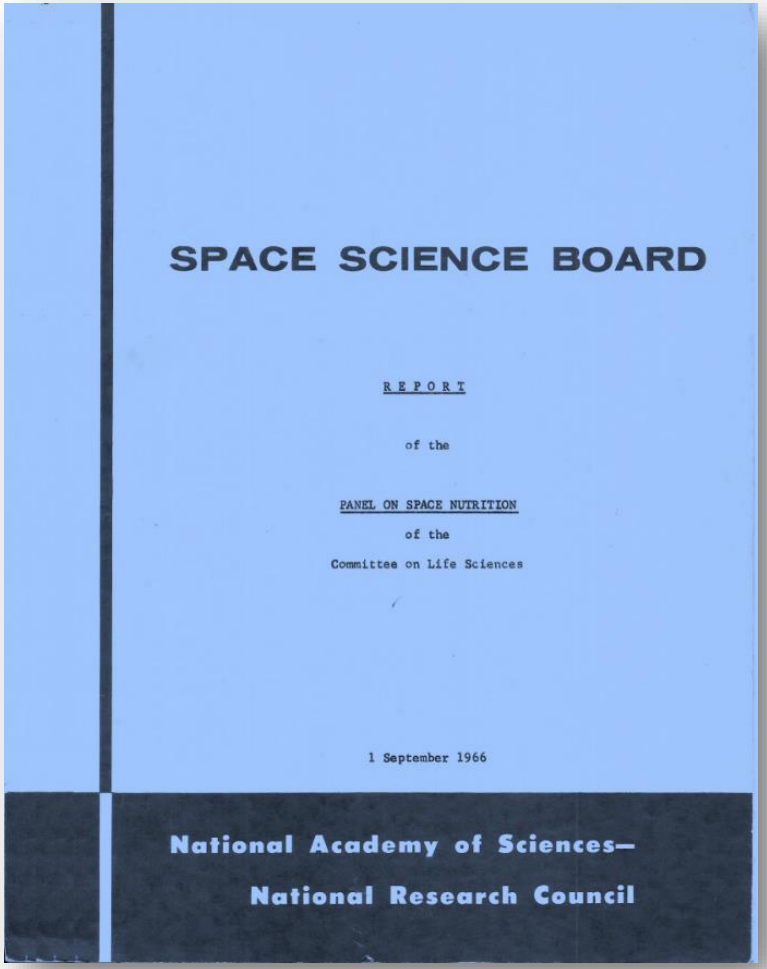
Introduction

- First opportunity to study humans at 1/6 g
- Medical experimentation not a primary objective
- Some metabolic data obtained from life support systems including the food system

THE APOLLO FOOD SYSTEM

Development

Early Recommendations

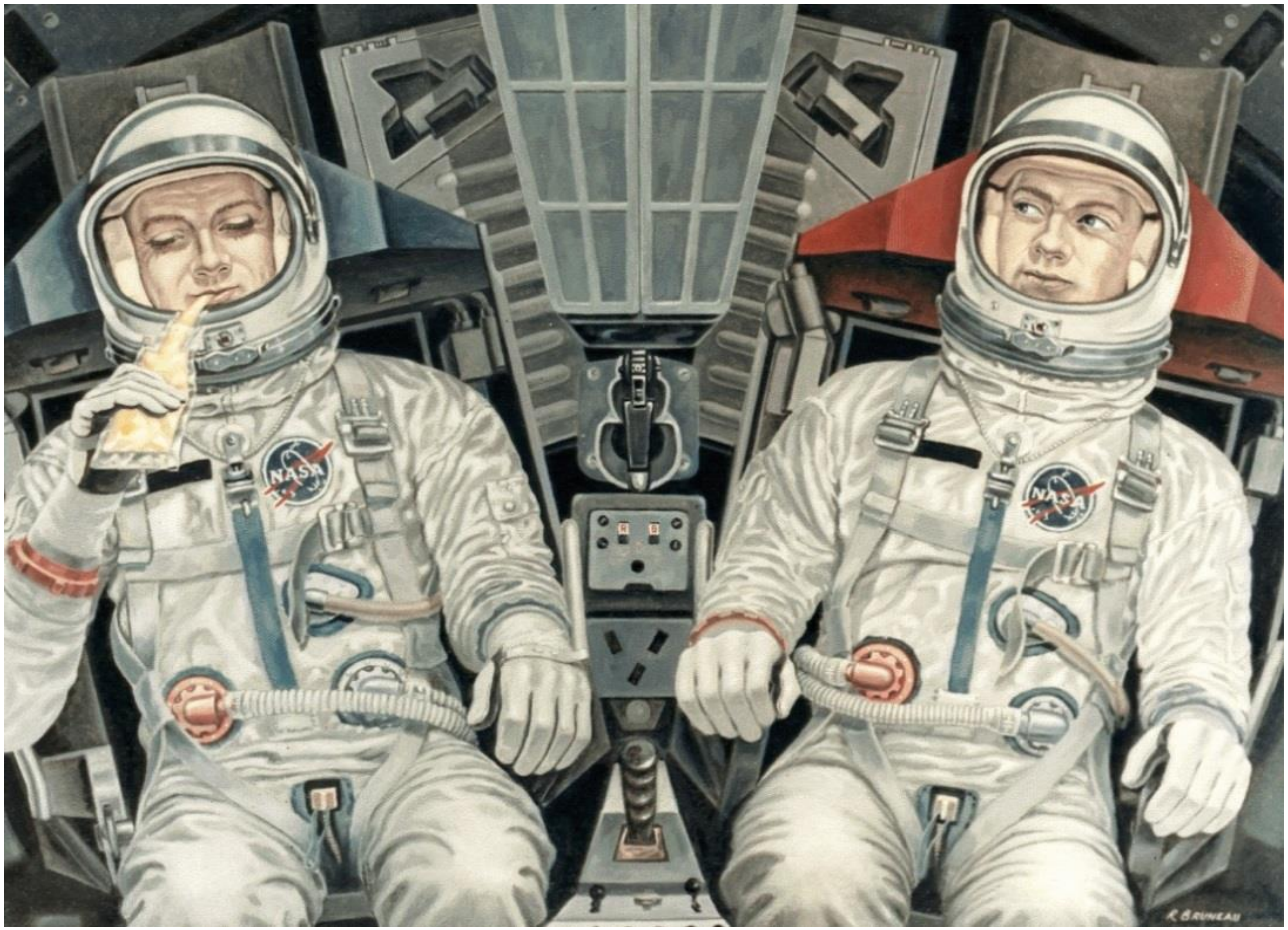


Pre-Apollo study of space nutrition

Early Findings

Primates capable of eating regardless of the direction of the gravity vector.

Early Findings



Normal metabolism for at least 14 days in 0 g.

Food Types

Bite-sized

Intermediate moisture

Irradiated

Rehydratable

In-suit food bar

Testing at 1/6g

Testing at 1g

Lunar Module Menus

Meal A	Meal B	Additional Items
Bacon squares	Beef stew	Extra beverages
Peaches	Cream of chicken soup	Dried fruit
Sugar cookie cubes	Date fruit cake	Candy bar
Coffee	Grape punch	Bread
Pineapple-grapefruit drink	Orange drink	Ham salad spread
		Turkey and gravy

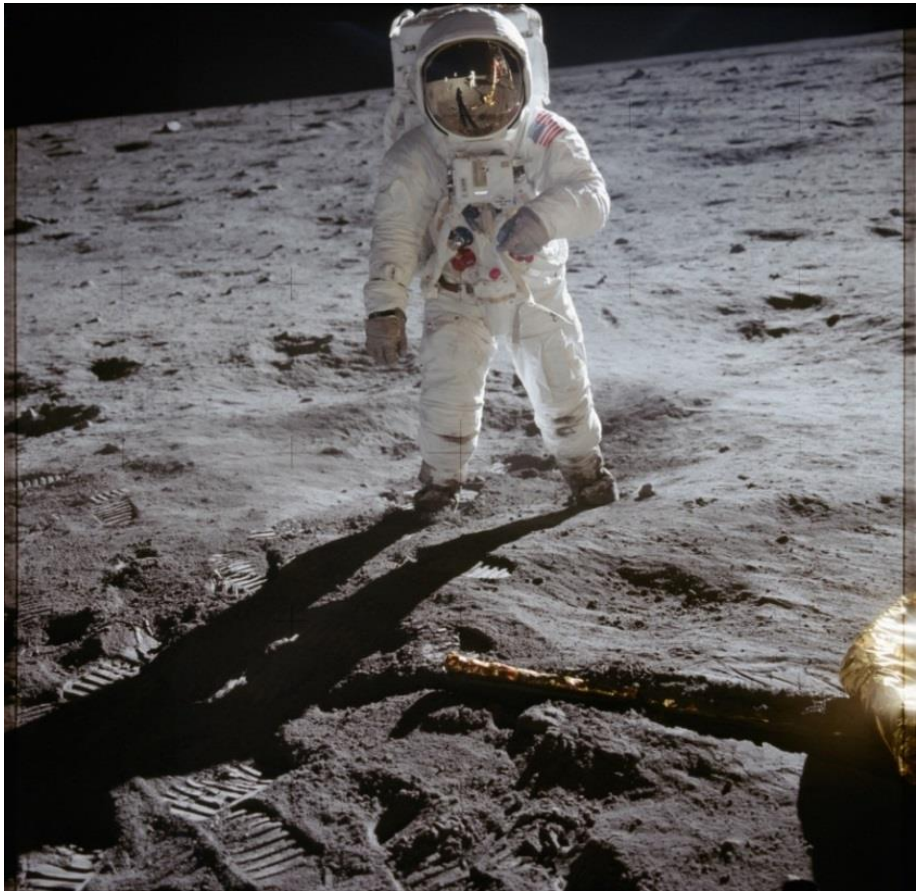
Each menu supplied 3200 kcals.

Apollo 11 – First Meal on the Moon

- Sugar cookies
- Coffee
- Bacon squares
- Peaches
- Grapefruit juice

Apollo 11 Metabolic Data

- Oxygen bottle pressure
- Coolant-water temps
- Suit-gas temps
- Sublimator water usage
- Heart rates



Apollo 11 Metabolic Data

		CDR	LMP	CMP
Caloric Intake	kcals/day	2,040	1,640	2,280
Metabolic Rate during EVA at 1/6 g	kcals/hour	227	302	

High energy expenditures during EVA

Apollo 15 – Irregular heart beats

- Bigeminies, premature auricular & ventricular contractions
- Potassium loss & hypokalemia
- Potassium gluconate fortification

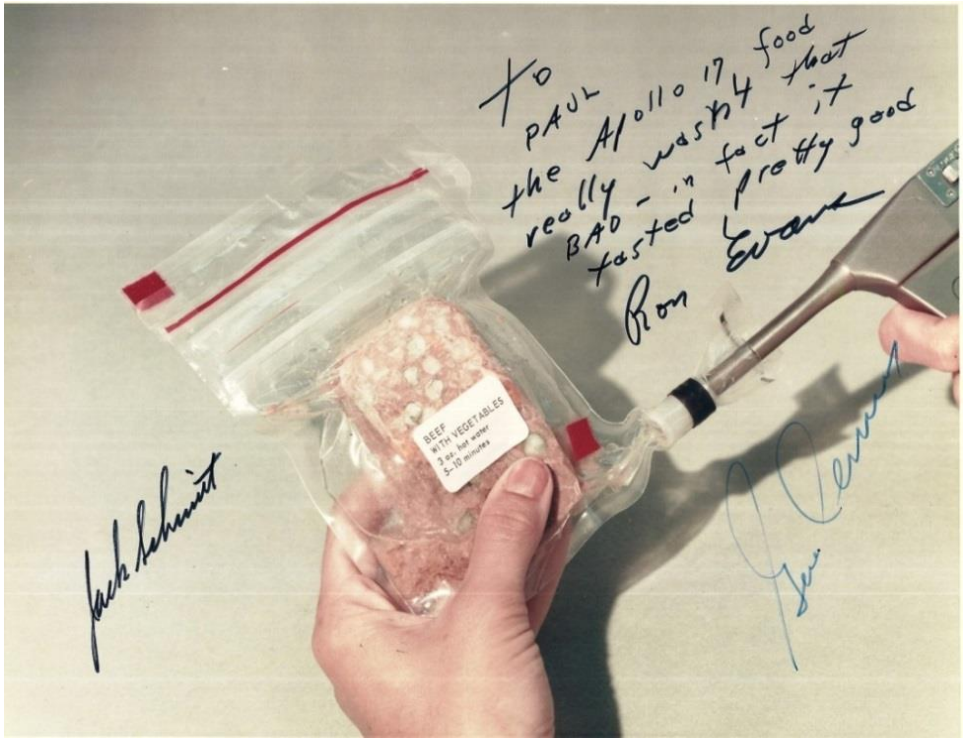
Apollo 15 Metabolic Data

		CDR	LMP	CMP
Caloric Intake	kcals/day	2,903	2,492	2,572
Metabolic Rate during EVA at 1 g	kcals/hour	379	379	
Metabolic Rate during EVA at 1/6 g	kcals/hour	263	218	
Metabolic Rate during EVA at 0 g	kcals/hour		115	235

Metabolic rates highest on Earth and lowest in space

Apollo 17 – Metabolic Balance

- Complete metabolic balance study
- Negative H_2O, N, Ca, P, Na, K.
- Enabled accurate estimates of caloric requirements



Apollo 17 Metabolic Data

		CDR	LMP	CMP
Caloric Intake	kcals/day	1,805	2,284	2,007
Metabolic Rate during EVA at 1/6 g	kcals/hour	302	285	
Metabolic Rate during EVA at 0 g	kcals/hour		145	300

Metabolism of lost fat and protein contributed another 925 kcals/day

Energy Intakes (kcals/kg/day)

Apollo Missions	CDR	LMP	CMP
11	26.77	21.72	30.94
12	26.22	25.19	24.01
14	30.24	21.49	34.72
15	36.49	34.61	37.41
16	31.13	21.81	31.63
17	23.08	30.93	28.92
Average	28.99	25.96	31.27
SD	4.28	5.09	4.25

Same low energy intakes whether at 1/6 g or 0 g

Weight Losses (Percent)

Apollo Missions	CDR	LMP	CMP
11	4.72	0.53	4.34
12	2.85	8.45	4.80
14	(0.52)	(0.62)	7.49
15	1.63	3.33	1.92
16	4.40	3.48	5.00
17	5.37	2.57	1.46
Average	3.08	2.96	4.17
SD	2.03	2.87	2.02

Weight loss may have been greater at 0 g than at *1/6 g*

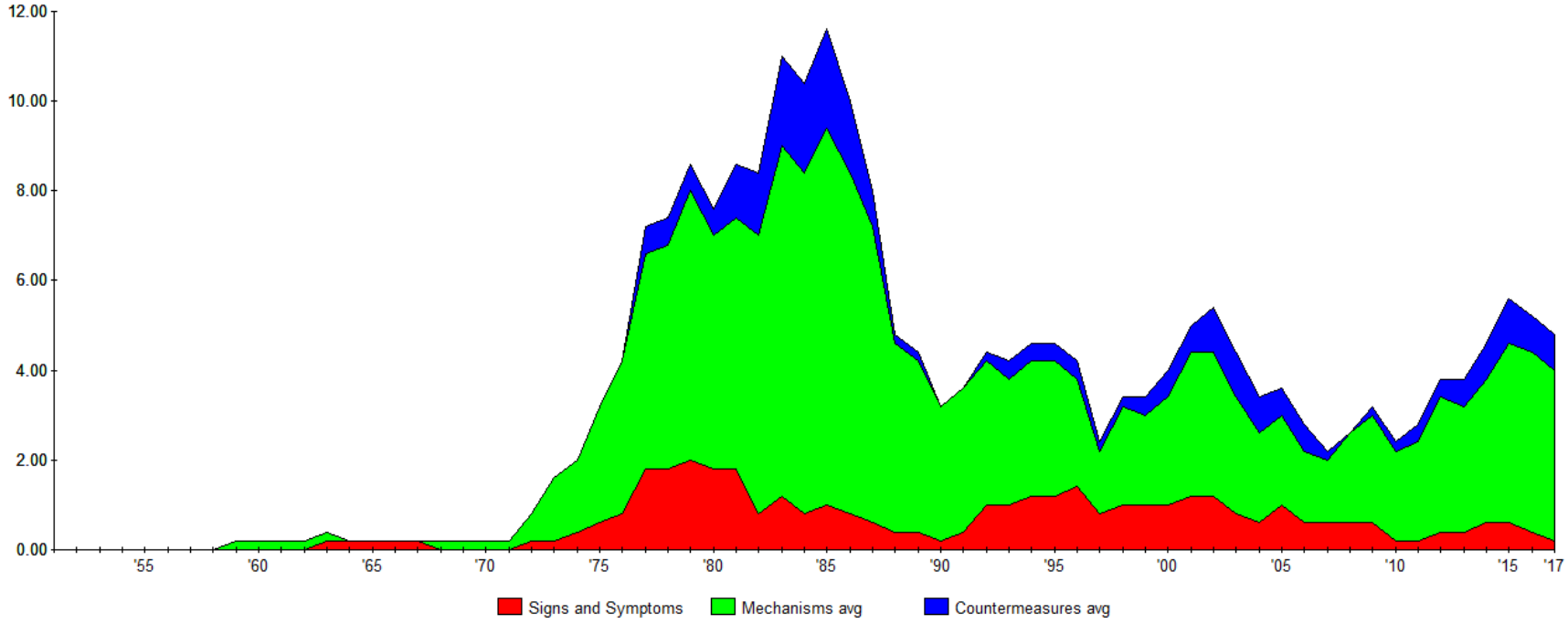
Metabolic Rates at 1/6 g

Apollo Mission	Crewman	LRV activities kcal/hr	All activities kcal/hr
15	CDR	146	263
	LMP	103	218
16	CDR	136	207
	LMP	122	224
17	CDR	121	239
	LMP	113	239
Mean		124	235

Lowest rates while riding LRV

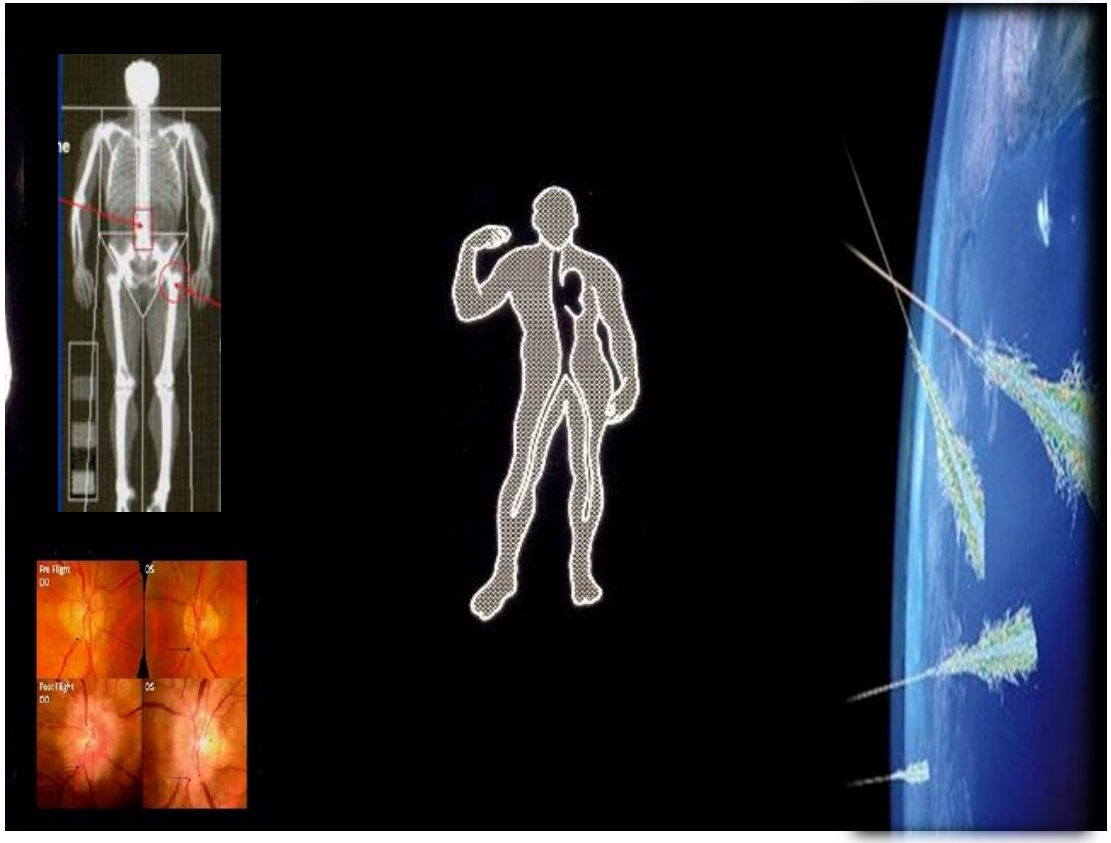
Space Nutrition Research

- 239 publications
- 6% of all publications
- 15% on countermeasures



Nutritional Countermeasures

- Muscle Loss
- Bone Loss
- Weight Loss
- Renal Stones
- Visual Disturbances
- Ionizing Radiation



Nutritional Countermeasures

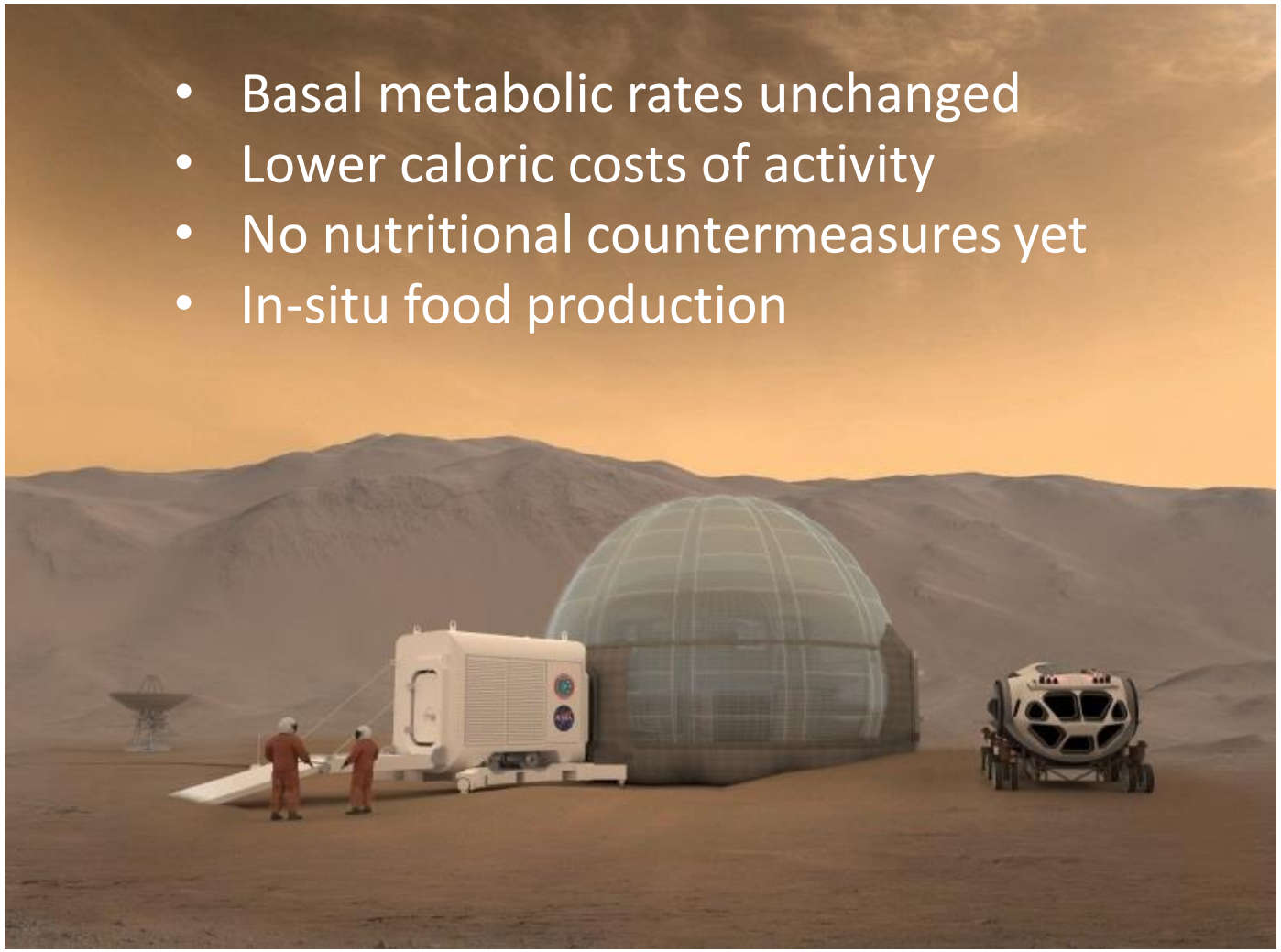
- Energy, protein and B substrate metabolism in simulated microgravity (Acheson et al., 1995).
- Vitamin K status in spaceflight and ground-based models of spaceflight (Zwart et al., 2011).
- Bone loss ameliorated with adequate intakes of energy and vitamin D. (Lane et al., 2013).
- Magnesium and Space Flight (Smith, 2015).
- Spaceflight-related ocular changes: potential role of genetics, and the potential of B vitamins as a countermeasure (Smith and Zwart, 2018).

Space Food Research

Recycling:

- Water & Oxygen
- Plants
- Synthetic biology
- Synthetic carbohydrates

Conclusions



Thank You