APPETITE AND FOOD INTAKE DURING 11 DAYS OF MILD HYPOBARIC HYPOXIA

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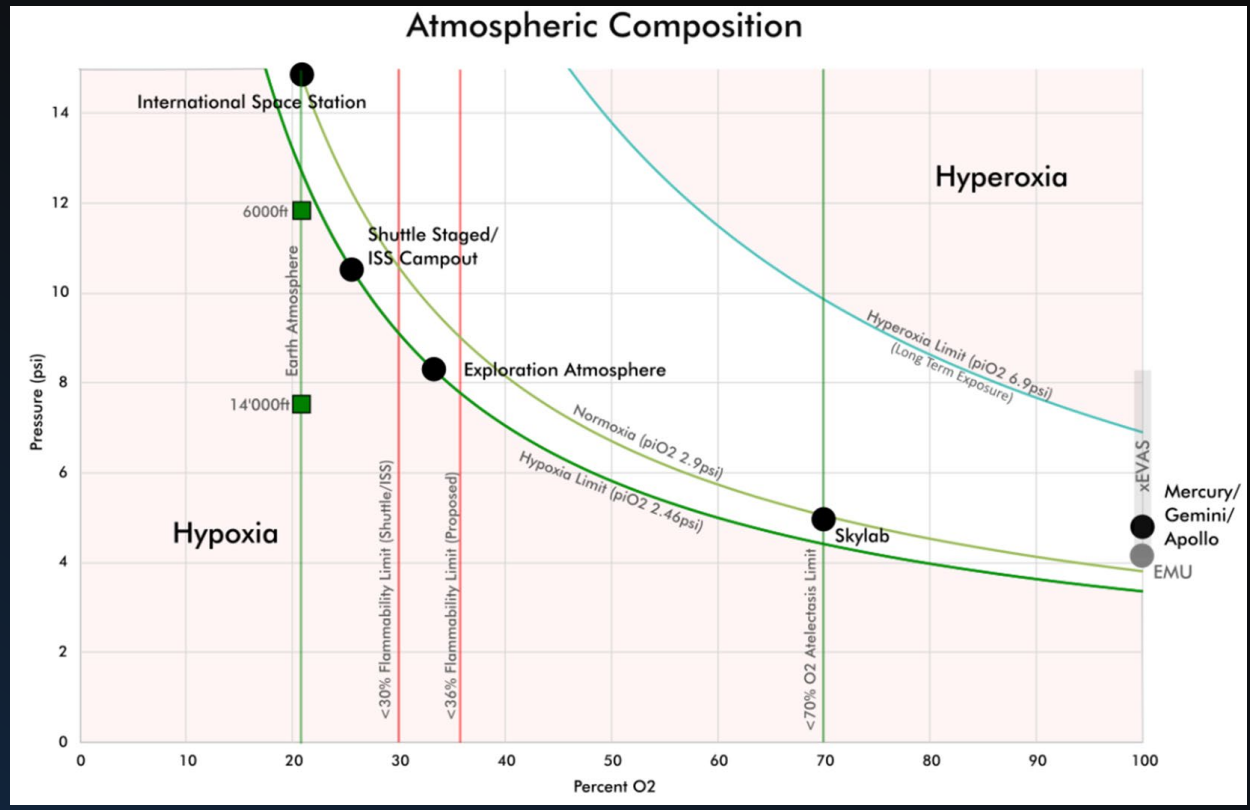
NASA Collaboration

- Human Physiology, Performance, Protection, and Operations
- Space Food Systems Lab
- Nutritional Biochemistry
- Center for Design and Space Architecture
- Bone and Mineral Lab
- Crew and Thermal Systems
- EVA and Human Surface Mobility Program
- Human Research Program

Reminder – Mission Background

- The *Exploration Atmosphere Prebreathe Validation* will validate prebreathe plans for Artemis to reduce decompression sickness (DCS) risk to acceptable levels
  - Lunar EVA (walking) is significantly more provocative for DCS than microgravity EVA (Conkin et al., 2017)
  - Shuttle & ISS protocols are therefore applicable to microgravity only
  - Apollo had 100% O2 cabin and zero EVA prebreathe; unacceptable flammability risk for Artemis
  - Artemis habitat and suit atmospheric parameters have not been finalized



Background

- Hypoxia may be associated with reduced appetite and food intake, as well as increased loss of fat-free body mass (Pasiakos 2017; Wing-Gaia, 2014).
- Acute hypoxic conditions may also alter levels of satiety hormones (e.g. ghrelin) (Bailey et al., 2015; Wasse et al., 2011).
- Reduced food consumption and loss of body/muscle mass have been associated with spaceflight missions (Zwart et al., 2014).
- The acceptability and nutritional content of the food system are central to weight and muscle maintenance strategies (Wing-Gaia, 2014).

- Energy intake, weight loss, and ultimately health and performanc, may be further compounded on initial Lunar surface missions by:
  - Operational constraints (vehicle/habitat or schedule)
    - e.g. Potential lack of hot water or food heating capability
  - Energy demanding, high-tempo EVAs

Objectives

- Characterize appetite, food intake, and body composition over the course of an 11-day hypobaric chamber “Exploration Atmosphere” evaluation with 5 simulated EVAs

- Evaluate adequacy and acceptability of the food system in a flight-like, constrained mission environment to inform the Artemis Program

Reminder – Mission Parameters

- 6 Subjects + 2 Doppler Technicians
- Repeated Measures
- 20-Foot Facility in JSC Bldg 7
- Planetary EVA Simulations

Age Group (y)	25-34	≤75%
	35-60	≥25%
	Women	Men
Sex (%)	15-20	80-85
Body Fat (%)	≤ 35 (include)	≤ 30 (include)
VO_2peak (ml/min/kg)	≥ 30 (include)	≥ 35 (include)

Note: Once the subjects enter the study, they will undergo a cycle $VO_{2\ peak}$ test.

Day 1	3hr PB @ 100% O2, 14.7 psia; Depress to 8.2 psia, equilibrate
Day 2	Equilibrate + Hypoxia Characterization
Day 3	Prebreathe; 6hr EVA @ 4.3 psia, 85% O2
Day 4	Hypoxia Characterization
Day 5	Prebreathe; 6hr EVA @ 4.3 psia, 85% O2
Day 6	Hypoxia Characterization
Day 7	Prebreathe; 6hr EVA @ 4.3 psia, 85% O2
Day 8	Hypoxia Characterization
Day 9	Prebreathe; 6hr EVA @ 4.3 psia, 85% O2
Day 10	Hypoxia Characterization
Day 11	Prebreathe; 6hr EVA @ 4.3 psia, 85% O2

Food System

- Similar to early Artemis surface transit vehicles (e.g. HLS) - menus were standard spaceflight food, no preference; no hot water or food warmer was provided*

- Food was packed per subject, by meal, based on resting metabolic rate (RMR), estimated energy requirement(EER), and VO2pk estimates during EVA
  - Experimental meal replacement bars (700-800 kcal) provided for three EVA days
  - Limited condiments and beverage powders were provided
    - Included coffee and tea (i.e. caffeine), NTE 2 of each per day
  - Vitamin D_3 (1000 IU/day) was provided
  - Subjects were allowed to trade and manage their meal plans in-mission; but instructed to record all consumption

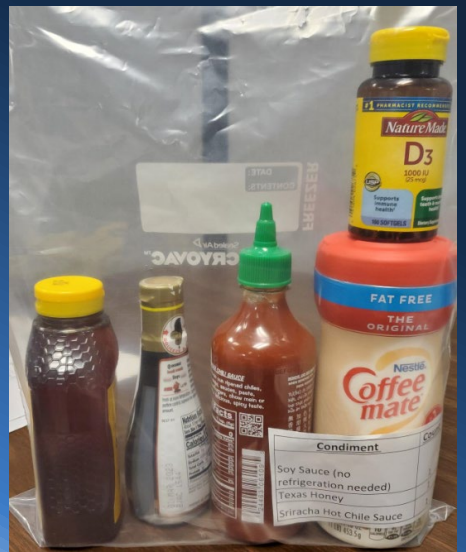
Types of Foods Available

Freeze-dried

Thermostabilized/Irradiated

Spaceflight/commercial packaging

Condiments



Beverages/Caffeine

Meal Replacement Bars

Methods

Pre-/Post-Mission

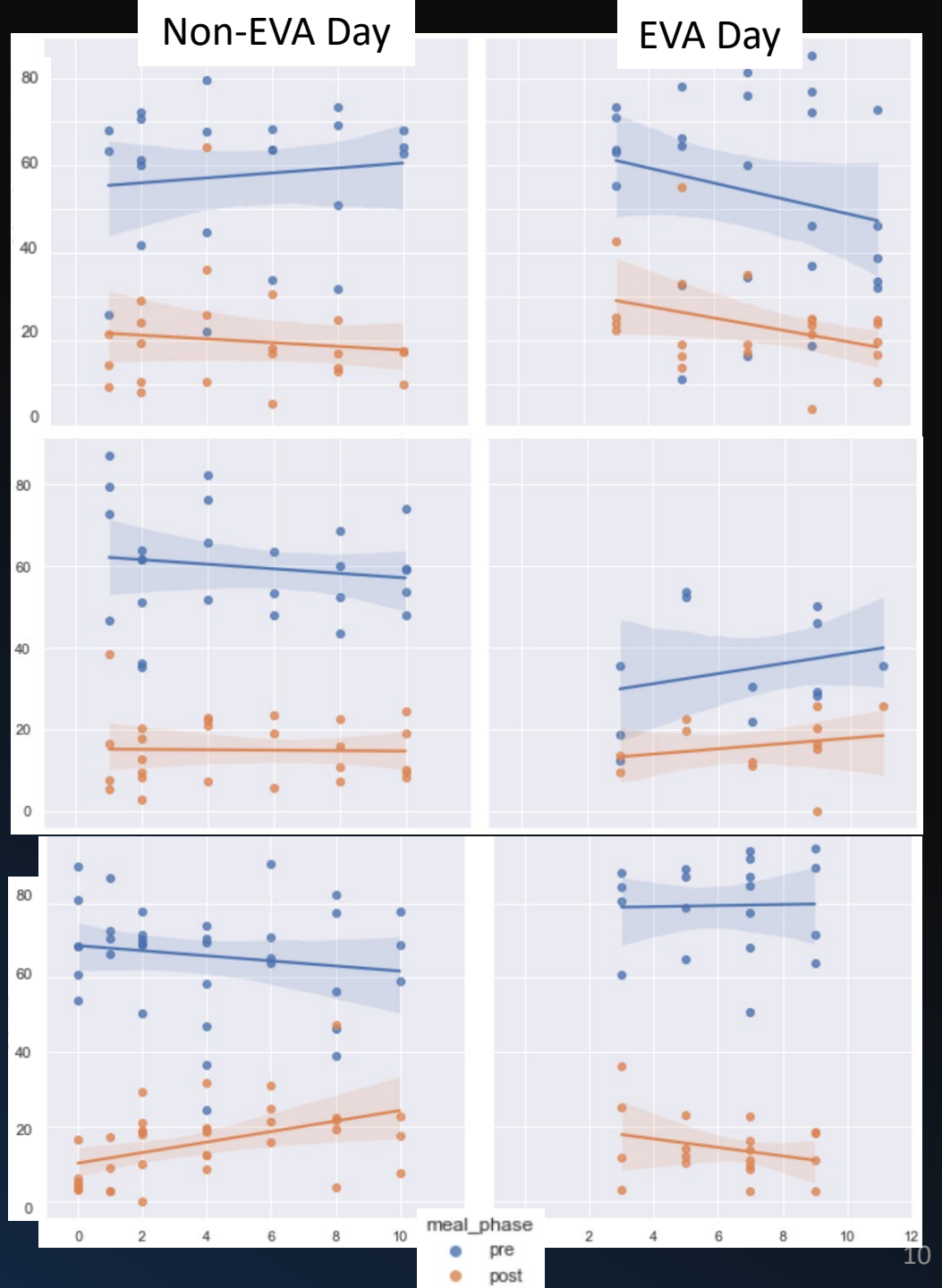
- Subjects completed weighed food record of nominal intake for 6 full days prior to mission.
- Fasted dual-energy X-ray absorptiometry (DXA) bone and body composition scans within 3 days of mission start and end
- RMR (pre-mission only)
- L-1 Fasted body weight
- L-5 Blood sample (ghrelin, leptin)

In-Mission

- Subjects completed weighed food record of all foods/drinks consumed in-mission
- Subjective ratings of appetite and nausea were collected, as well as food acceptability
- Fasted body weight daily during mission
- Blood samples (ghrelin, leptin)
  - Pre/post-EVA on mission days (MD) 3 and 7
  - Morning on MD 10

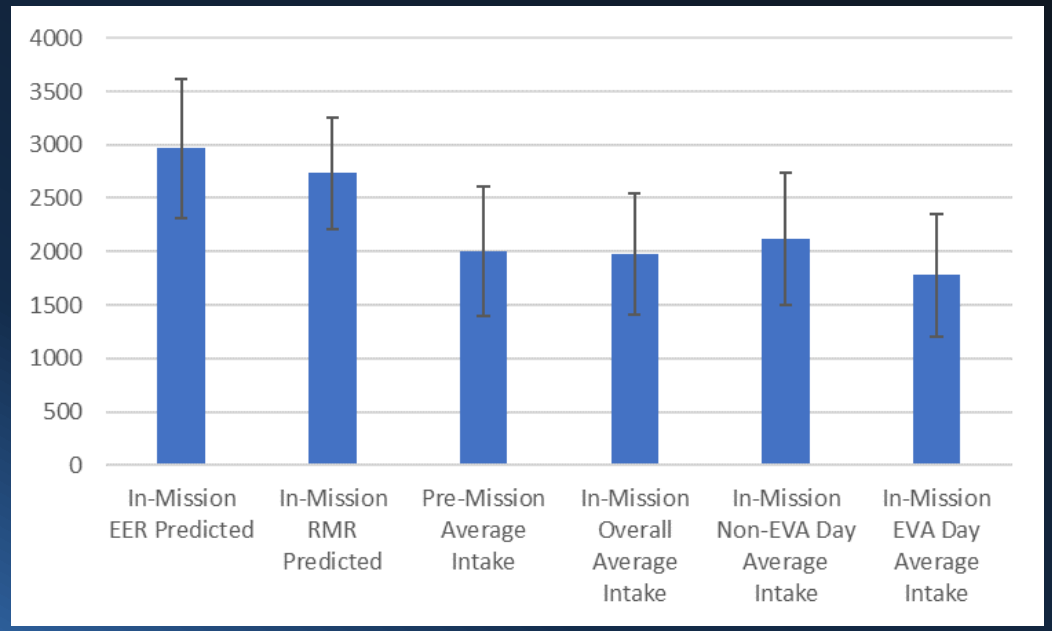
Results – Appetite & Hunger

- Non-EVA Days
  - Hunger was relatively consistent
- EVA Days
  - Decreasing hunger trend at breakfast
  - Low hunger at lunch
    - Lunch timing was ~2hr early on EVA days due to prebreathe ops
- Pre-EVA, subjects tried to avoid foods that may create GI distress.
  - Likely to due different diet and changes in pressure.
  - Nausea was typically rated low, but increased for some individuals at various timepoints.

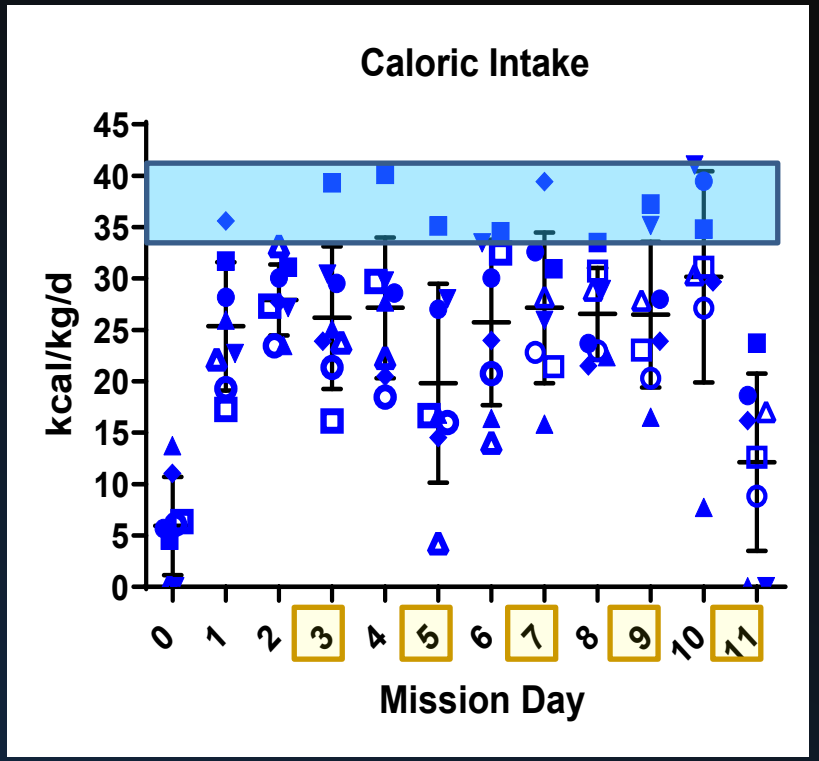


Results: Caloric Intake

- All subjects consumed less in-mission than predicted by EER or RMR



- On average, subjects consumed 341 kcal less on EVA days compared to non-EVA days (p = 0.0511).



Caloric targets varied per subject within shaded region
Day 0 and 11 were partial days

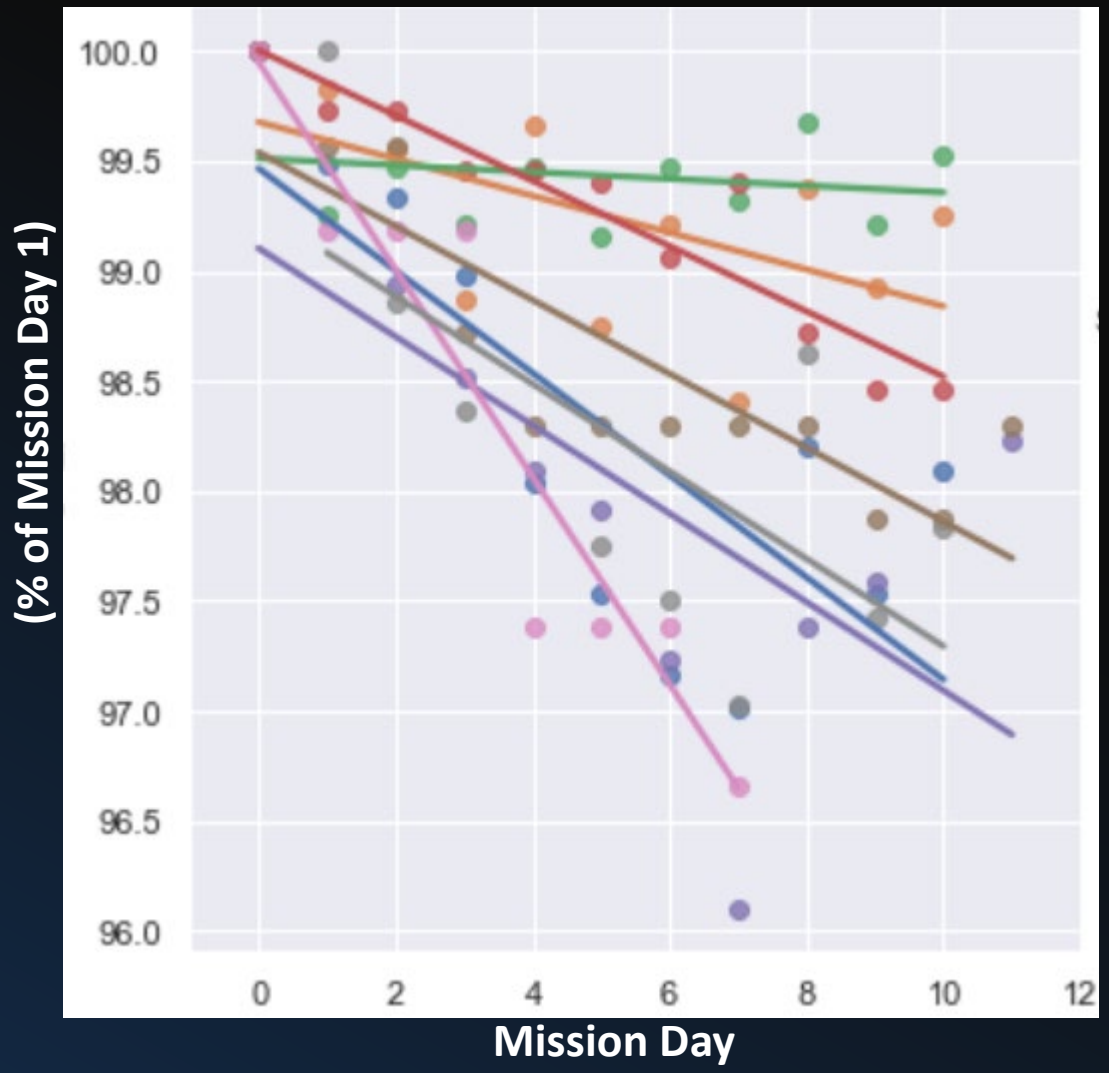
Results – Weight Loss

- Total average weight loss from daily measurements (-1.1 kg, p=0.0028) is consistent with underconsumption and supported by DXA measurements (-1.3 kg total body mass, p=0.0123 and -1.6 kg fat mass, p=0.0016).

- However, despite caloric deficit, the exercise intensity may have supported a gain in a small amount of lean body mass (0.30 kg, p=0.2050) and bone mineral density (0.02kg, p=0.0058).

- Intake of fruits and vegetables decreased from 4.8 servings/day pre-mission to 3.4 servings/day during non-EVA days in-mission (p=0.0872) and 2.3 servings on EVA days (p=0.0020).

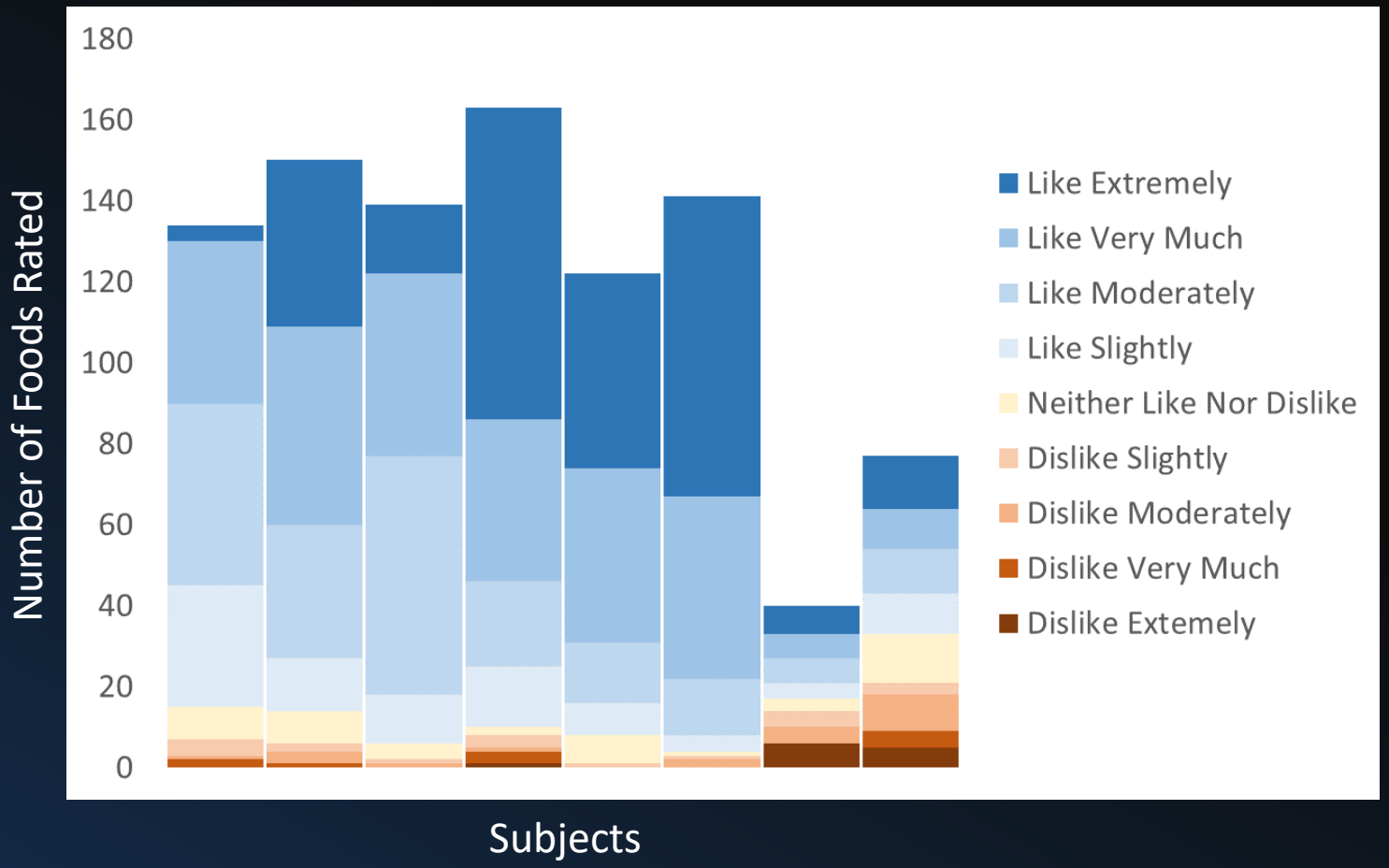
Weight loss trend through mission



Results – Acceptability & Habitability

- Most foods that were consumed were given acceptable scores.
  - Cold/room temp foods were most acceptable.
  - Hot foods eaten cold/room temp were less acceptable (e.g. eggs, pasta)
  - Meal replacement bars were positively reviewed due to convenience.

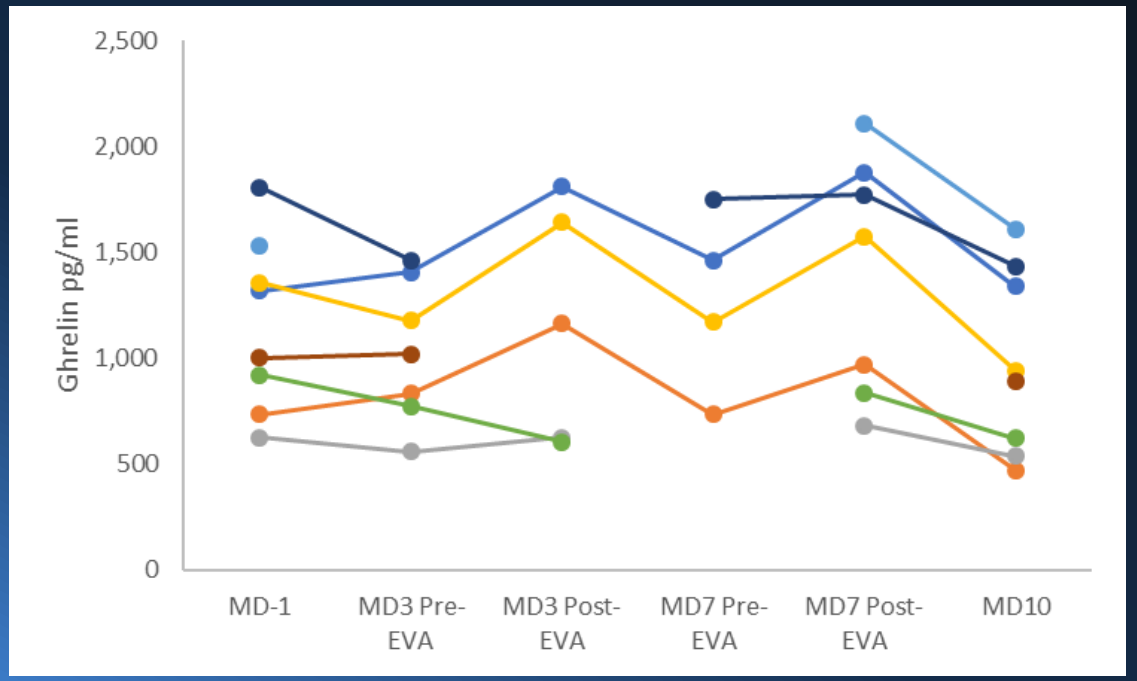
- Comments also indicated that subjects found their favorite foods early in the mission and avoided the foods that they did not like throughout the mission.
  - Lots of trading between subjects!



Results – Blood Biomarkers

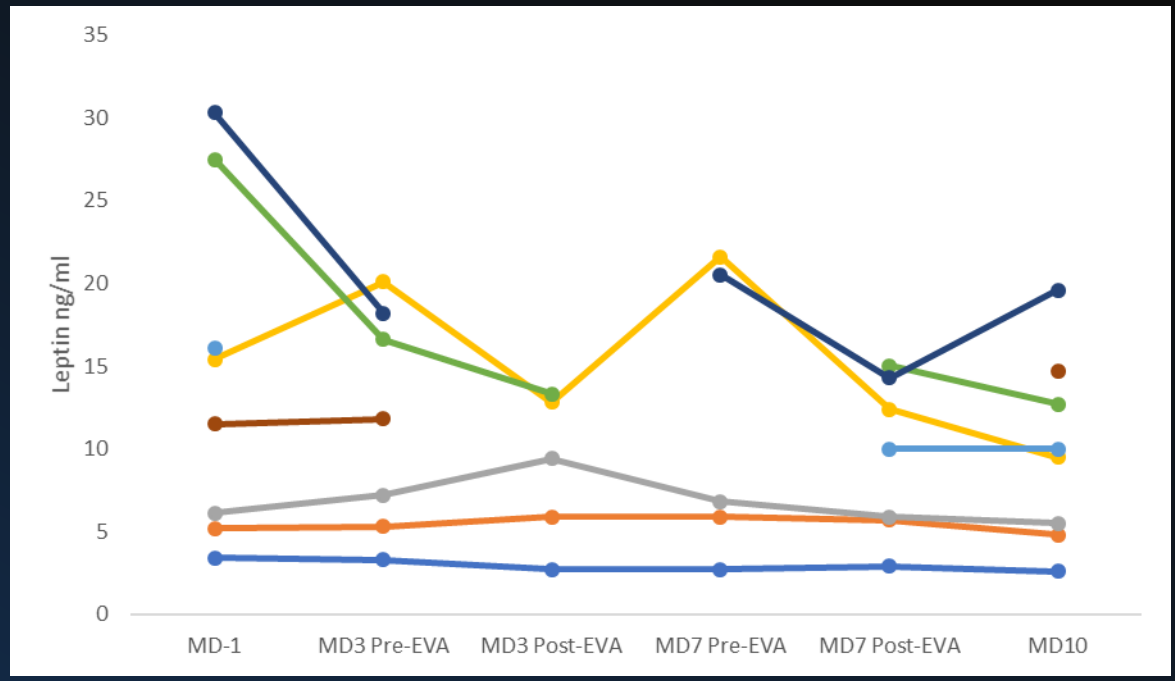
Ghrelin

- Hunger-inducing hormone
- Decreased pre-EVA and on non-EVA days, when compared to pre-mission and post-EVA ($p = 0.0136$).
  - Due to normoxic exposure during EVA



Leptin

- Hunger-suppressing hormone
- Fasting levels of leptin did not change throughout the mission.



*Non-fasted samples were not included.

Discussion

- Food intake declined in mission, similar to previous spaceflight missions.
  - Resulted in weight loss of 0.5 – 3.0% over the course of 11-days.
  - Subjectively due to limitations with food choice, preparation capabilities (or lack thereof), time, and physiological challenges with pressure transitions
  - Mission operations should likely allow recovery days between EVA days
- Ghrelin appeared to be affected by hypoxic conditions; but not leptin.
- Acceptability varied widely, but some aspects of the food system were considered borderline or unacceptable for an 11-day simulated spaceflight mission in the Exploration Atmosphere.
- Limitations:
  - Loss of data pre-mission in some cases; 24% of in-mission data points were incomplete or unusable.
  - Food system is relatively restricted (e.g. lack of heating)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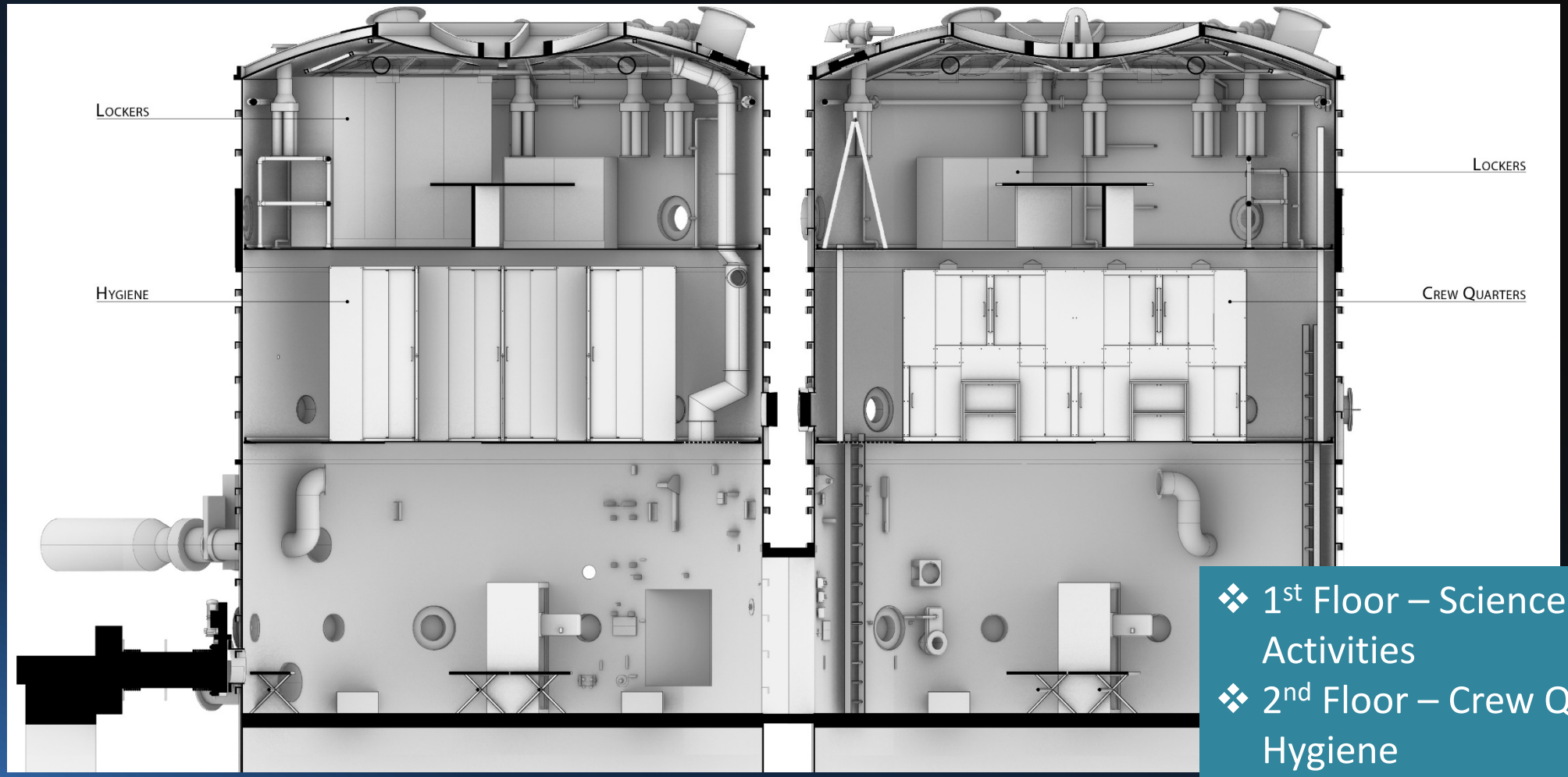
Thank you!

20FT Chamber Overview



- 1st Floor – Science & EVA Activities
- 2nd Floor – Crew Quarters & Hygiene
- 3rd Floor – Stowage & Media Center

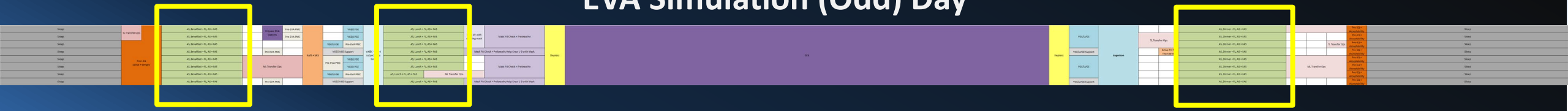
Current Configuration: 3rd Floor Visual Imagery

Daily Schedule - Examples

Hypoxia Characterization (Even) Day

- Wake – 0715
- Breakfast – 0745 to 0845
- Lunch – 1145 to 1245
- Dinner – 1945 to 2045

EVA Simulation (Odd) Day



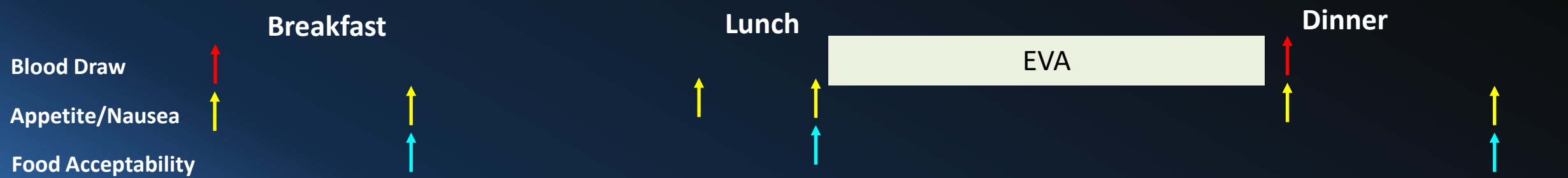
- Wake – 0630
- Breakfast – 0700 to 0800
- Lunch – 0945 to 1045
- Dinner – 1930 to 2045

Pre-Mission						
L-7	L-6	L-5	L-4	L-3	L-2	L-1
Daily Weighed Food Record, Daily Fasted Weight						
				RMR, DXA,		
		Ratings		Ratings		Ratings

In-Mission										
1	2	3	4	5	6	7	8	9	10	11
Daily Food Record, Daily Fasted Weight										
		EVA		EVA		EVA		EVA		EVA
Ratings	Ratings	Ratings	Ratings	Ratings	Ratings	Ratings	Ratings	Ratings	Ratings	Ratings

Post-Mission		
R+1	R+2	R+3
DXA		

Example: Mission Day 3



- RMR = Resting metabolic rate; DXA = dual-energy X-ray absorptiometry.
- Blood is collected once on Days L-5 and Day 10 and twice on Days 3 and 7.
- Subjective ratings of appetite and nausea will be collected up to 6x and food acceptability will be collected up to 3x on selected days. Orange boxes signify blood draw days, when ghrelin will also be measured.