Approach to Crew Survivability

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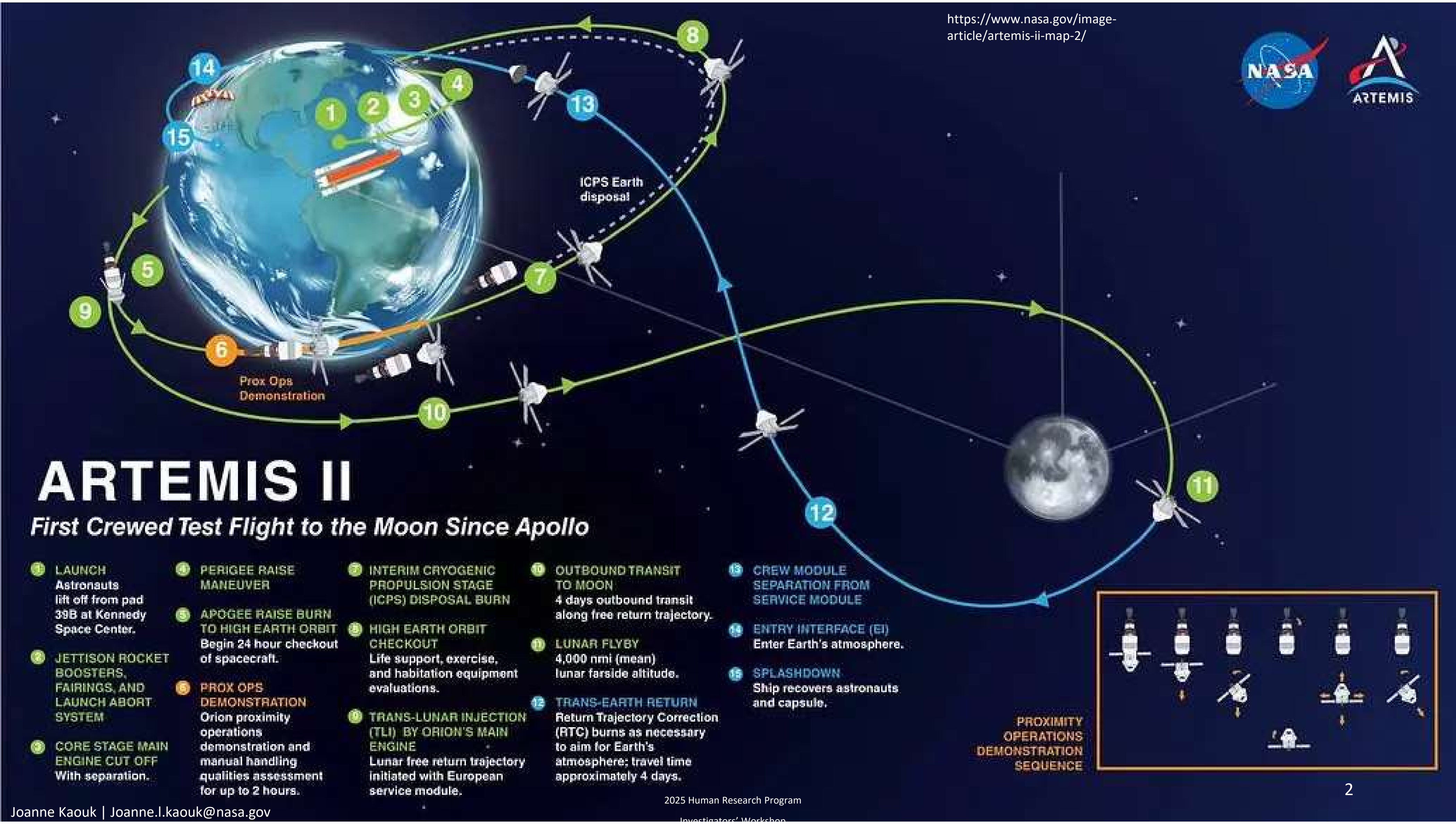
2025 Human Research Program Investigators' Workshop https://www.nasa.gov/image-article/artemis-ii-map-2/



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Background- STS-400

- The STS-400 was the rescue contingency plan for the STS-125, the servicing mission of the Hubble Space Telescope.
- The Endeavour sat on launchpad 39B ready to launch in short notice in case the Atlantis suffered major damage during the launch to the telescope
- Prepping for worst case scenario:
  - Determined the CO_2 scrubbing capability of a canister (16-18 hours)
  - <22 days
  - Planned halting of all exercise when emergency was declared
  - Planned to use contingency food bars on board
    - Mixed diet of 40% fat, 20% carbohydrates, RQ= 0.85
    - 141 food bars on board = 8,291 grams

https://www.nasaspaceflight.com/2019/05/sts-400-endeavours-responder-role-atlantis-hubble-mission/

Survival Modes

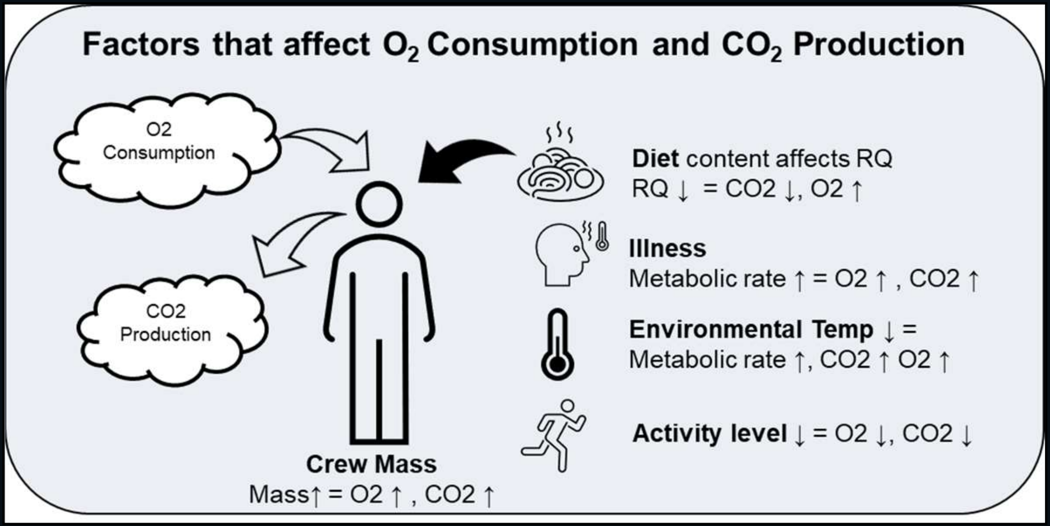
- Baseline
  - Full performance
    - Nominal operations
    - Extra Vehicular Activity (EVA)'s
    - Exercise
  - Full Caloric and water intake
  - Nominal environment control parameters
- Moderate
  - Continuation of most tasks
    - No EVA's or exercise
  - Reduced daily activity by approximately 15%
  - Limit food and water intake to 50% of baseline
  - No long-term impacts
- Severe
  - Strictly limit crew activity by 28% ideally sleeping or idle
    - No EVA's
    - No exercise
  - Significant limit water and food intake by 1/3 of basal metabolic rate needs
    - Modify RQ by altering diet
  - Might result in significant health implications

Limit Consumables

- Oxygen
  - Limited Carbon dioxide scrubbing
- Water
- Food

Factors Considered for Survival Mode

- Activity
- Diet
- Illness
- Environmental Temperature



Activity

- Assumption = 82kg, 45 ml/kg/min VO_2 max

- Sleep: 300 BTU/hr, (76 kcal/hr)
- Nominal ‘awake’ = 474 BTU/hr, (119 kcal/hr)
- Exercise:
  - Aerobic = 3303 BTU/hr
  - Resistive 1184 BTU/hr

Diet

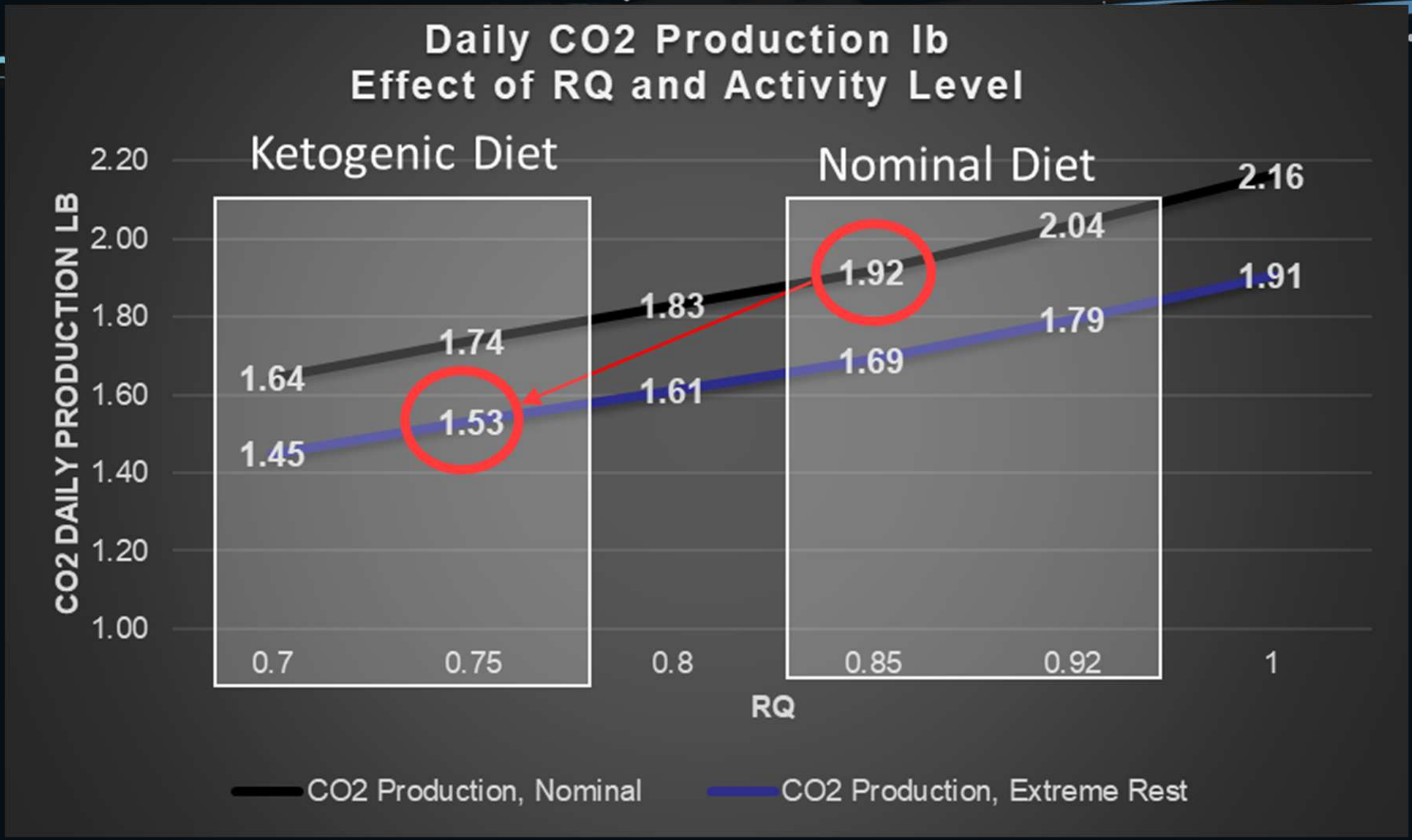
- Different diet compositions will affect the consumption of O_2 and CO_2 output
- Respiratory Quotient (RQ) is a measurement of energy expenditure

$$RQ = \frac{Volume\ of\ CO_2\ Released}{Volume\ of\ O_2\ Consumed}$$

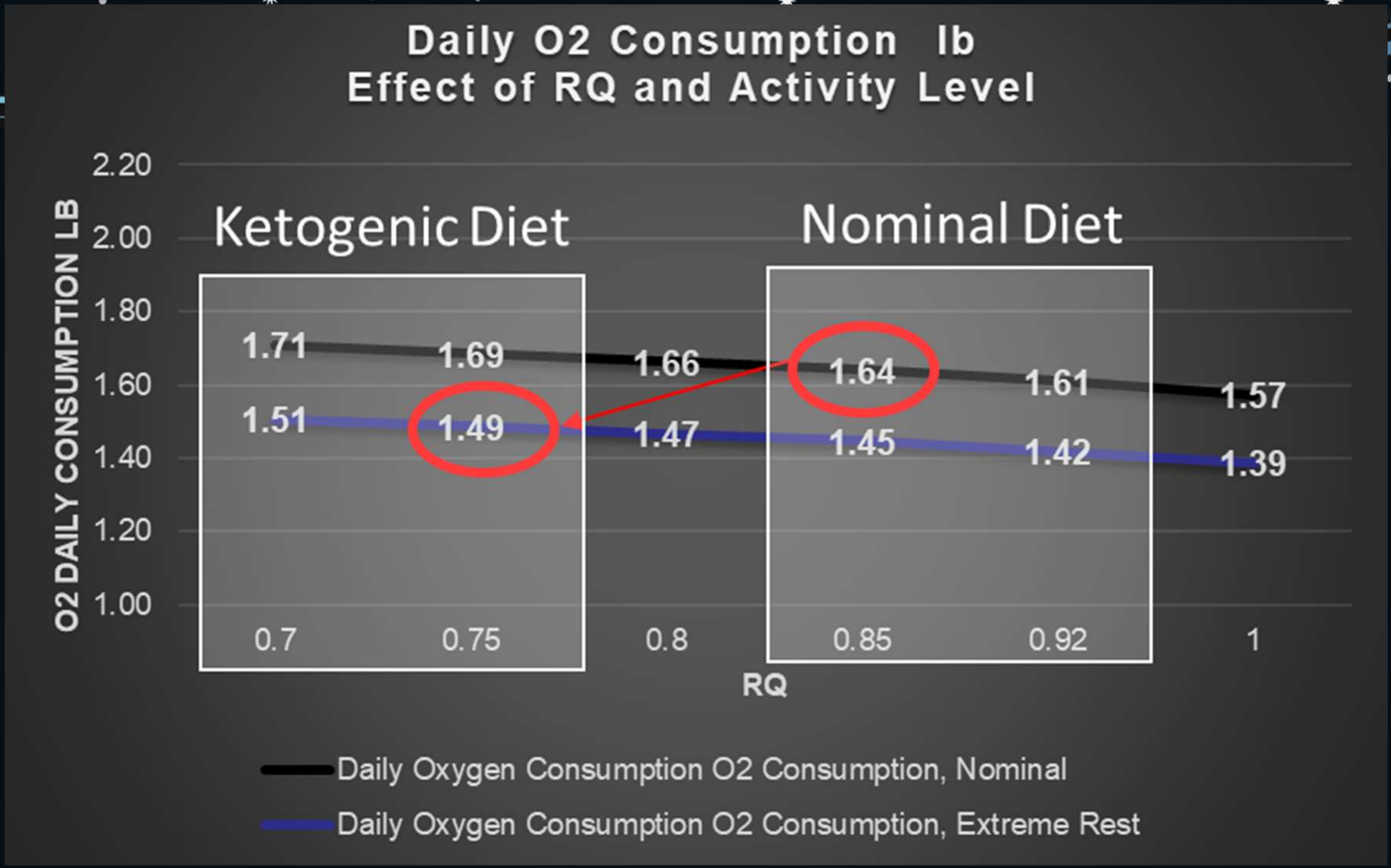
  - RQ= 1 estimates carbohydrate metabolism
  - RQ= 0.7 estimates fat metabolism
  - RQ= 0.8 estimates a mixed diet metabolism
- RQ changes with intensity of activity
  - Low activity = RQ is between 0.8-0.9 (fatty acid is primary fuel)
    - Currently NASA uses 0.85 RQ for missions during sleep and nominal activities
  - High activity = RQ is between 0.9 and 1.0 (carbohydrate is primary fuel)
    - Currently NASA used 0.95 RQ for missions during exercise

Ketosis

- A high fat and low carbohydrate diet to force metabolism of fat for energy
- Starvation State
- Why not feed a solely fat diet?
  - Ketoacidosis
    - Too low of carbohydrates can lead to overproduction of ketone bodies resulting in a very acidic blood pH
    - Symptoms: nausea, vomiting, fast heartbeat, fruity breath, headache, confusion
    - Long term effects: cognitive decline, brain damage, heart and kidney failure



Calculations based on NASA 41-Node Metabolic Man Model



Calculations based on NASA 41-Node Metabolic Man Model

Food/Nutrition

- Studies have been conducted on soldiers that limited their caloric intake to half = 1800 kcal/day for 24 weeks
  - Resting expenditure decreased by 40%
  - Body weight loss of about 10% = 10-15% decline in VO_2 max
    - Studies found that body mass loss of about 10% has no impairment on physical performance
- Survival Modes: *Body weight assumption of 82 kg
  - Moderate= 1,800 calories/day
  - Severe= 600 calories/day = 10% loss of body weight in 52 days

Water

- General water recommendations are 1 to 1.5 ml/kcal expended per day
- Higher water turnover at higher altitudes
  - 1000m increase = approximately 500 ml increase in water turnover

Executive Summary

Nutrition has been critical in every phase of exploration on Earth, from the time when scurvy plagued seafarers to the last century when polar explorers died from malnutrition or, in some cases, nutrient toxicities.

The space food system must provide food that is safe, nutritious, and acceptable to the crew to maintain crew health and performance during space flight. Nutritional standards in NASA-STD-3001 are based on National Institutes of Health (NIH) standards dietary recommended intake (DRI). Achieving and maintaining food system acceptability, nutrition, and safety for space flight is complex and influenced by factors such as availability of mass, volume, power, crew time, food preparation capability, preference foods, resupply, variety, mission duration, and required shelf life.

NASA astronaut Kjell Lindgren (left) and Japan Aerospace Exploration Agency (JAXA) astronaut Kimiya Yui, participate in a food tasting session.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C
[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 3016] Post-Mission Health Care
[V1 3018] Post-Mission Long-Term Monitoring
[V1 4019] Pre-Mission Nutritional Status
[V1 4020] In-Mission Nutrient Intake
[V1 4022] Post-Mission Nutritional Assessment and Treatment

NASA-STD-3001 Volume 2, Rev D
[V2 3006] Human-Centered Task Analysis[1]
[V2 6026] Water Quality
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 7001] Food Quality
[V2 7002] Food Acceptability
[V2 7003] Food Caloric Content
[V2 7004] EVA Food Caloric Content
[V2 7007] Food Microorganism Levels
[V2 7008] Food Preparation
[V2 7009] Food Preparation and Cleanup
[V2 7010] Food Contamination Control

(continued on next page)

1. OCHMO-TB-018 Human-in-the-Loop (HITL) Technical Brief

Executive Summary

Water is necessary for our bodies' proper hydration, our health, and a full active life. In spaceflight, water (including quantity and quality) is a critical resource that needs to be carefully managed for crew health and safety. In the context of human spaceflight, water has a variety of uses to support crew health including hydration, food rehydration, and personal hygiene. Being well hydrated during operations is absolutely critical as dehydration can result in decrements in decision-making, concentration, and physiology of the crew. This Technical Brief focuses on the water required for human consumption during spaceflight missions.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C
[V1 3003] In-Mission Preventive Health Care

NASA-STD-3001 Volume 2, Rev D
[V2 3006] Human-Centered Task Analysis
[V2 6026] Potable Water Quality
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6046] Water Quality Monitoring
[V2 6051] Water Contamination Control
[V2 7052] Stowage Location
[V2 8001] Volume Allocation
[V2 11029] LEA Suited Hydration
[V2 11030] EVA Suited Hydration

From: NASA image and Video Library

Environmental Parameters

- Studies have found that temperatures at approximately 65°F and below result in an increase in energy expenditure
  - Shivering
  - Increased blood flow

CO2 Consideration

- Hypercapnia
  - described by the increase of CO_2 partial pressure to above 45 mmHg
  - characterized by a variety of symptoms such as headache, fatigue, dyspnea, and space fog, a term coined to describe poor concentration and delayed mental abilities during spaceflight
  - In severe cases can even lead to death by metabolic acidosis where significant CO_2 buildup leading to very acidic blood resulting in kidney disease or failure

Consideration of Illness

- Guidelines are based on the assumption that crewmembers are healthy
- State of health
  - Impacts O_2 consumption and CO_2 production
    - Food and nutritional needs
  - Alter temperature/humidity needs
    - Fever
- Physiological changes as the body fights off an infection
  - Increased body temperature
    - Increases metabolic rate by 10-12% for every 1 °C over 37 °C
      - O_2 consumption rates of 1.86 lbs/day for a mild illness
      - O_2 consumption rates of 2.86 lbs/day for a severe illness
  - Elevated heart rate
    - 1°C increase in body temperature = heart rate increases by 7bpm
  - Inflammation

NASA-STD-3001 Technical Brief

Crew Survivability

OCHMO-TB-047

Executive Summary

As future spaceflight missions become increasingly complex, longer in duration, and a further distance from Earth, readily available rescue and evacuation options must be evaluated to protect crewmembers during off-nominal survival scenarios. This technical brief explores options to support rescue scenarios by reducing the human usage of consumables (i.e., oxygen, food, water, power) to extend the mission to enable rescue. By considering these potential survival scenarios during the planning and design phase, providers can make informed decisions on vehicle capabilities, mission supplies, crew make-up and rescue options.

Artemis I SLS waiting on the launchpad

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C
[V1 3004] In-Mission Medical Care

NASA-STD-3001 Volume 2, Rev D
[V2 4015] Aerobic Capacity
[V2 6001] Trend Analysis of Environmental and Suit Data
[V2 6003] O2 Partial Pressure Range for Crew Exposure
[V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels
[V2 6012] Crew Health Environmental Limits
[V2 6014] Crewmember Heat Storage
[V2 6017] Atmospheric Control
[V2 6109] Water Quantity
[V2 7003] Food Caloric Content
[V2 7100] Food Nutrient Composition

NOTE: The parameters discussed in this technical brief are for illustration purposes only. The details for a mission extension scenario must consider exact circumstances and crew complement.

Technical Requirements

NASA-STD-3001 Volume 1 Revision C

- [V1 3004] In-Mission Medical Care

NASA-STD-3001 Volume 2 Revision D

- [V2 4015] Aerobic Capacity
- [V2 6001] Trend Analysis of Environmental and Suit Data
- [V2 6003] O2 Partial Pressure Range for Crew Exposure Levels
- [V2 6012] Crew Health Environmental Limits
- [V2 6014] Crewmember Heat Storage
- [V2 6017] Atmospheric Control
- [V2 6109] Water Quantity should be t
- [V2 7003] Food Caloric Content
- [V2 7100] Food Nutrient Composition

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Thank you!

Questions?

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