Lunar Analog
HHC Infrastructure Gaps

Gaps: Can partial gravity be simulated on Earth? How does 1/6-g or 3/8-g influence CM?

- Monitoring Bone Health by DLS in Lunar Missions (Cavanagh)
- Smart Pill (Putcha NRA)
- CV Alterations during Lunar Missions* (Platts NRA)
- Lunar EVA Study* (Directed Study)
- Lunar Analog development* (Directed Study)
- Thermoregulation and CV Response during Lunar Missions (Keller NRA)
- Integrated Musculoskeletal CM for Lunar Missions (Lang)

**KEY**
- Ground Study
- Flight Study
- Pre-flight Preparation
- Data Analysis
- Add-on

These studies are listed multiple times to answer several gaps.
Concept

- Development of a ground-based lunar analog is necessary as NASA prepares to return to the Moon.

- Relied on Digital Astronaut to:
  - Validate the angle needed for expected changes in bone
    - 9.5° head up tilt
  - Determine what adjustments are required to appropriately model predicted plasma volume changes
    - Compression stockings
Digital Astronaut
Bed Design
Validation of 9.5° Head Up Tilt

- Demonstrate that 9.5° head up tilt provides 1/6 g in the standing position
Lunar Analog Feasibility Study

- Initial study to assess subject comfort and tolerance of the lunar bed and stockings

- Subjects
  - 5 Cleveland Clinic
  - 3 JSC/UTMB

- 11-day study
  - 3 days pre-bed rest with
  - 6 days in bed
  - 2 days post bed rest rehabilitation
Lunar Analog Feasibility Study

- Subjects provided isocaloric diet
- Alternated between periods of sitting and standing
  - 65% sitting
  - 35% standing
- Subjects tolerated the lunar bed well.
Lunar Analog Feasibility Study

- Jobst® Stocking Evaluation – a number of different stocking configurations were tested to determine optimal comfort for subjects.
  - Thigh high, off the shelf, closed toe 30-40 mmHg, (~18 mmHg ave)
  - Thigh high, custom fit, closed toe, 40 mmHg (~18 mmHg ave)
  - Thigh high, custom fit, Elvarex fabric, open toe, 36-46 mmHg (~18 mmHg ave)
Lunar Analog Feasibility Study

- **Knee High Stockings**
  - Knee high, custom fit, Elvarex fabric, open toe, 36-46 mmHg (~18 mmHg ave)

- **All stocking configurations**
  - were evaluated for
    - foot and toe numbness, tingling and pain
    - Knee irritation and pain

- **Best combination of characteristics**
  - Knee high, custom fit, Elvarex fabric, closed toe, 25-32 mmHg (~12 mmHg ave)
Preliminary Data

- Data from 1st 5 subjects at Cleveland Clinic
- Predicted 6% PV loss on moon
- 10° HUT w/o stockings predicts PV **gain** (left)
- 10° HUT w/ stockings predicts PV **loss** (right)
- Actual loss during LAFS **13%**.
- Due to:
  - Lack of Diet Stabilization?
  - Magnitude of Compression?
Change in Segmental Fluid Volume during Short and Long Radius Centrifugation

- Thigh - Short Radius
- Thigh - Long Radius
- Calf - Short Radius
- Calf - Long Radius
Selection of stockings

- Knee high (below the knee) compression stockings are frequently prescribed to prevent DVT. One randomized trial with 223 subjects showed a 10% rate of asymptomatic DVT in control subjects and 0 cases of DVT following long-haul airflights.


- Several meta-analyses have been conducted showing the efficacy of compression stockings for preventing DVT in a number of different clinical scenarios. When knee high were compared to thigh high, a conclusion could not be drawn on which were superior at preventing DVT due to the low numbers, but one review recommends knee high due to the greater comfort.

Pre-Pilot Study

- Validation of Lunar bed rest model for the cardiovascular system
  - Knee high, custom fit, Elvarex fabric, closed toe, 25-32 mmHg (~12 mmHg ave)
  - 8 subjects
  - 14-day pre-bed rest diet stabilization
  - 6 days 9.5° head up tilt bed rest
  - 2 days post bed rest rehabilitation
  - Plasma Volume measures to accurately assess magnitude and direction
Lunar Analog Pilot Study

- Examination of the Lunar bed rest model over long-duration
  - 14 pre-bed rest diet stabilization
  - 60 days 9.5° head up tilt bed rest
  - 14 days post bed rest rehabilitation
  - Standard conditions
  - Standard measures
  - Model verification using Digital Astronaut
Bed Design for Lunar Analog Pilot

Adjustable Foot Support
Slider Plate Assembly

Floor-mounted force plate serves as a seat.

Scissor jack to adjust force plate operated by subject