

Lunar Analog

Session Outline

ISS & Shuttle		6 Crew Capability ▲	▲ Shuttle Retired	▲ End of US Commitment												
Constellation	Program Level	▲ SRR ▲ CDR- Initial Ops		▲ PDR			▲ CDR			▲ Human Lunar Return						
	Orion	▲ PDR ▲ CDR		▲ Full Ops Capability												
	EVA Suit	▲ PDR-suit1 SDR-suit2 ▲		▲ CDRsuit1 ▲ PDR-suit2			▲ CDR-suit2									
	Lander	▲ ATP		▲ SDR			▲ PDR			▲ CDR						
	Mission Operations	PDR-init cap▲		▲ CDR-init cap			▲ SRRPDR▲			▲ CDR						

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)

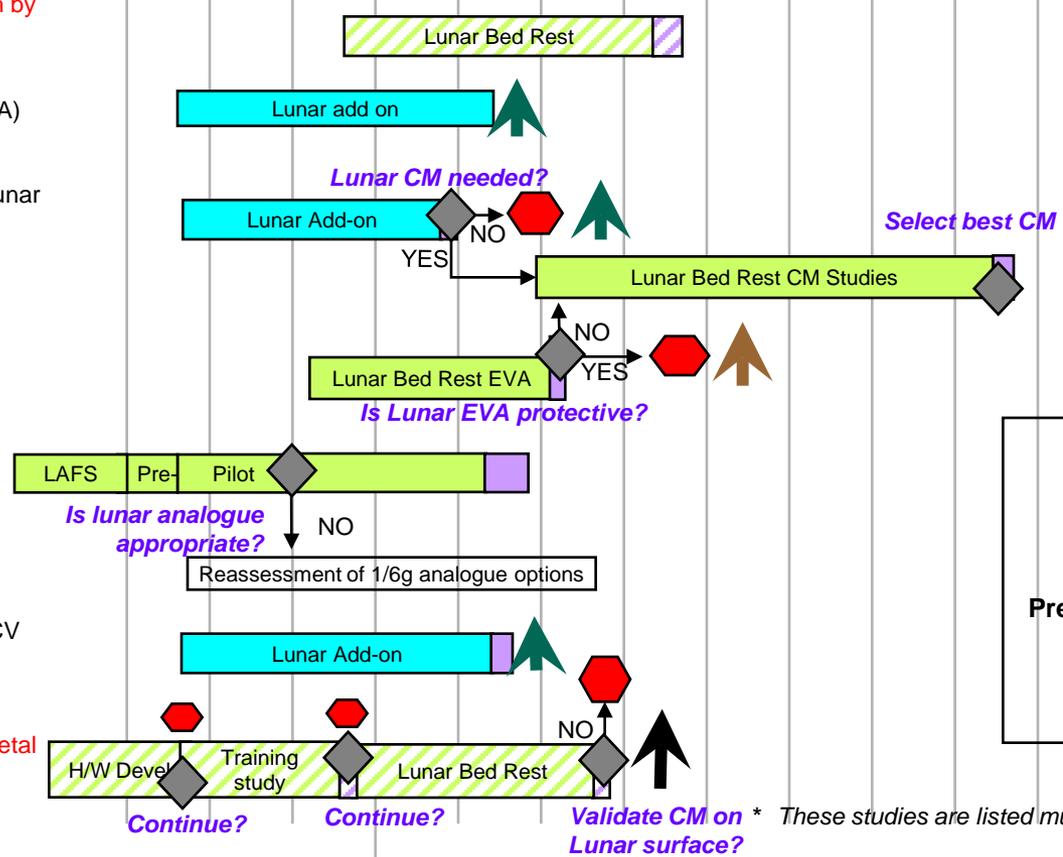
CV Alterations during Lunar Missions* (Platts NRA)

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)



* 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

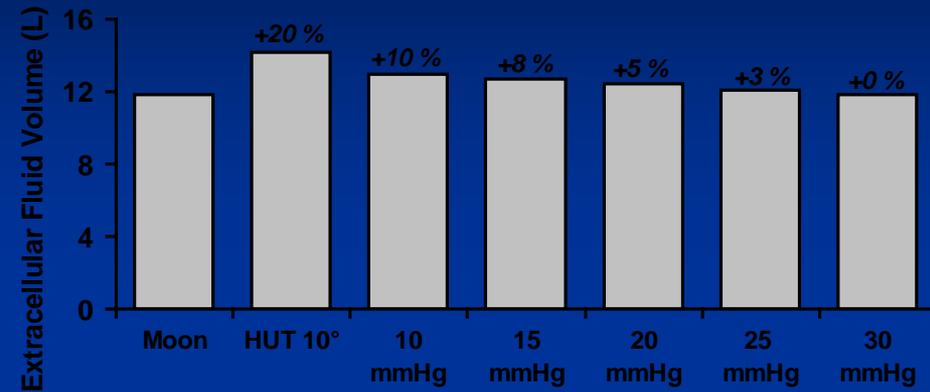
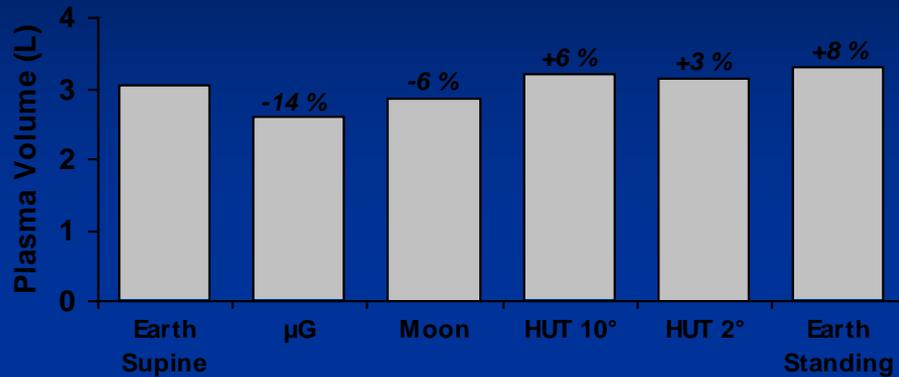
- Knee High Stockings
 - Knee high, custom fit, Elvarex fabric, open toe, 36-46 mmHg (~18 mmHg ave)
- All stocking configurations were evaluated for
 - foot and toe numbness, tingling and pain
 - Knee irritation and pain
- Best combination of characteristics
 - Knee high, custom fit, Elvarex fabric, closed toe, 25-32 mmHg (~12mmHg ave)



Preliminary Data

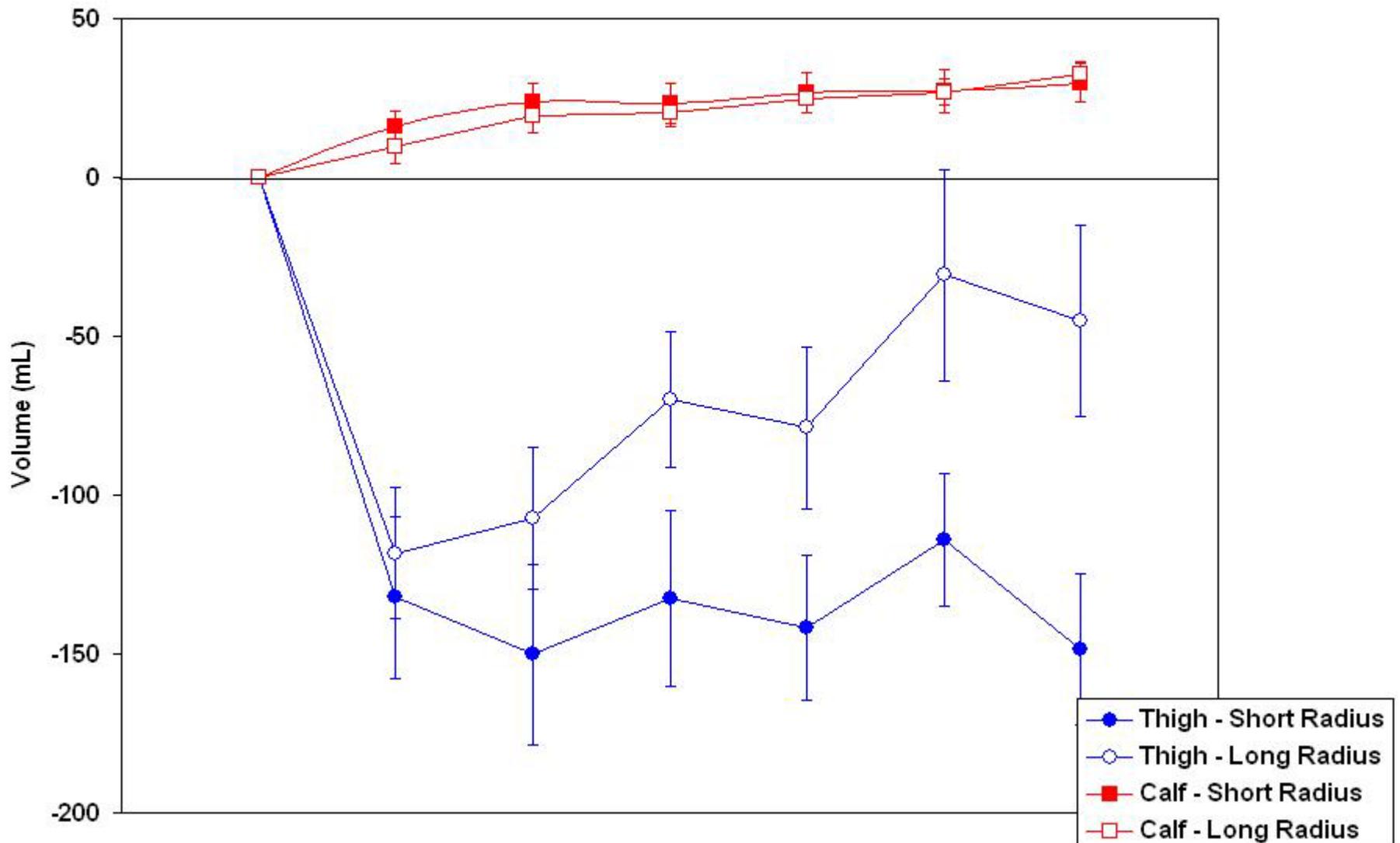
- Data from 1st 5 subjects at Cleveland Clinic

Plasma Volume



- 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



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 flights.

(Frequency and prevention of symptomless deep-vein thrombosis in long-haul flights: a randomised trial. J.Scurr, S.Machin, S.Bailey-King, I.Mackie, S.McDonald, P.Smith *The Lancet*, Volume 357, Issue 9267, Pages 1485-1489)

- 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.

(Roderick P, Ferris G, Wilson K, Halls H, Jackson D, Collins R, et al. Towards evidence-based guidelines for the prevention of venous thromboembolism: systematic reviews of mechanical methods, oral anticoagulation, dextran and regional anaesthesia as thromboprophylaxis. *Health Technology Assessment*. 2005;9. (No 49.))

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

