



In Flight Anthropometry and Health Surveillance for Future Exploration Missions

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Artificial Intelligence (AI) Usage Disclosure

This document was created with assistance from Microsoft CoPilot for image retouching, including object highlighting. The content has been reviewed and edited by K Young.



Why Measure Anthropometry in Spaceflight?

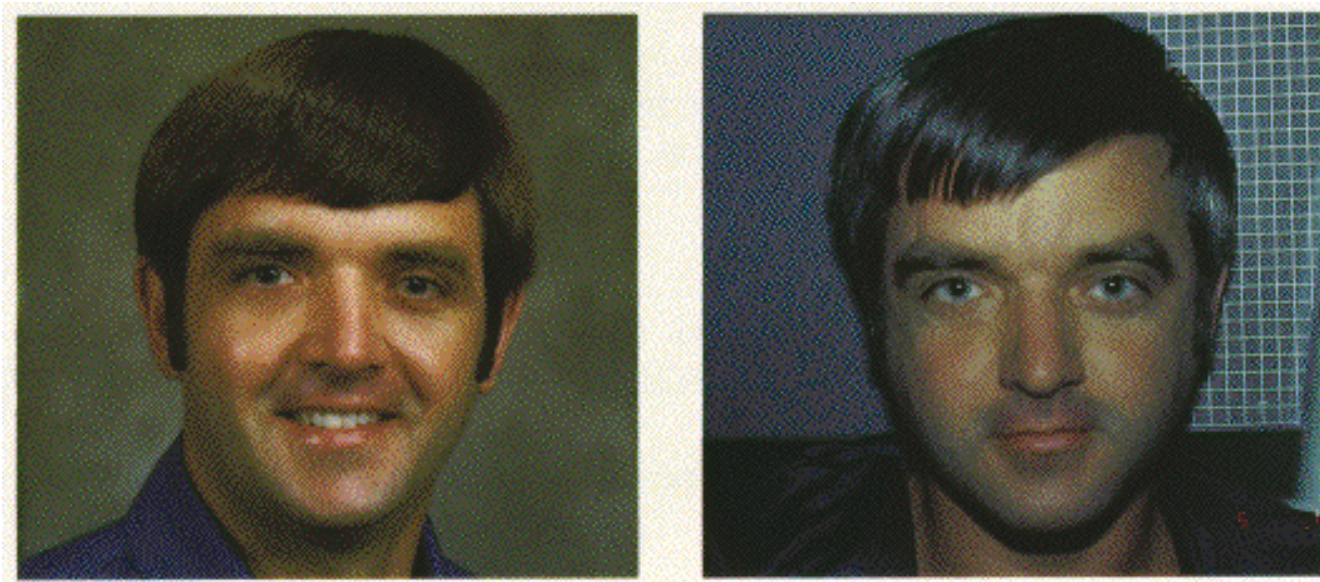
- Body sizes used to be “homogeneous” in early space ages
 - In Apollo, the crew cadre was relatively homogeneous – but even with strict selection parameters and substantially custom-built spacesuits, there were still fit challenges.
- Today, there is a wide variety of crew body sizes
 - Since the shuttle era, astronaut selection has been expanded to allow a variety of astronaut sizes and shapes to fly; this has further increased the sizing challenge.
- Anthropometry is critical for hardware interface design and spacesuit sizing are crucial for crew safety and performance
- Crewmember anthropometric measurements are needed for:
 - Spacesuit sizing
 - Seats and hardware sizing
 - Vehicle and habitat layouts
 - Equipment fit and comfort
 - Contingency planning
 - Vehicle center of mass assessments
 - Astronaut Candidate selection
 - Subject selection for hardware/spacesuit design evaluations
 - Body shape and size changes



Anthropometry is Integral to Flying Humans Safely in Space

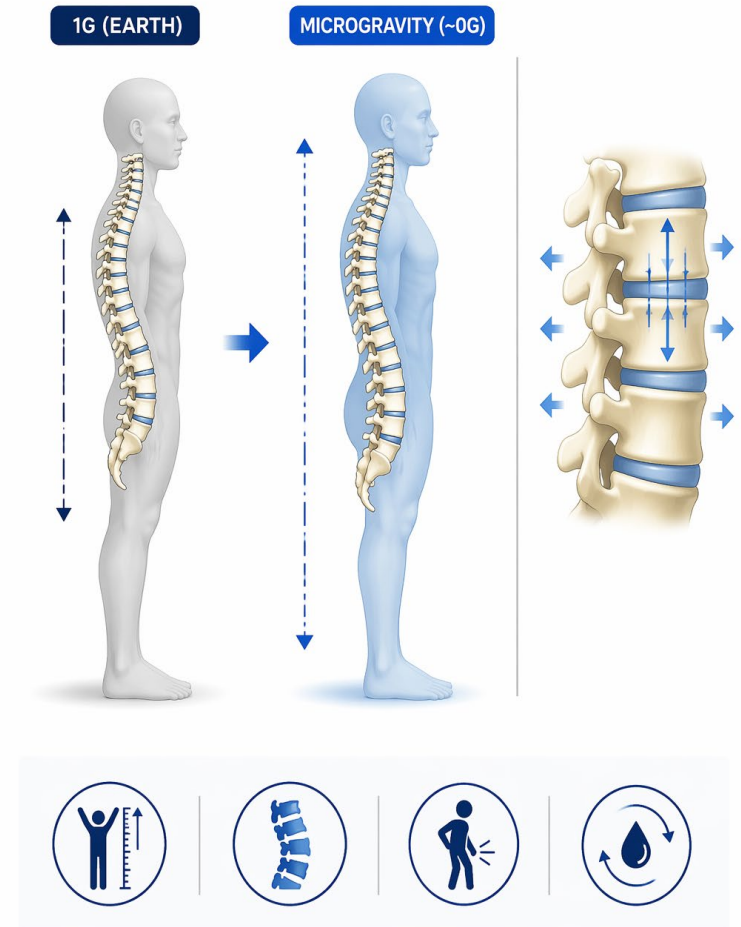
Why Measure Anthropometry in Spaceflight?

- Anthropometry changes in microgravity occur due spinal elongation, fluid shifts, and bone and muscle atrophy
- However, these changes can vary person to person and can affect suit fit, return seat configurations
- Improper suit fit or seat fit can lead to injuries
- Limited research data has been collected to document these changes and applied as requirements
- However, this data has not been collected for population surveillance and overall health



<https://ntrs.nasa.gov/api/citations/20110008309/downloads/20110008309.pdf>

SPINAL ELONGATION (NO COMPRESSION OF SPINE)



AI-generated image

Why Measure Anthropometry in Spaceflight?

Objective:

- Measure body shape changes throughout mission duration for clinical care and occupational surveillance

Rationale:

- 1) Recent ISS events highlight the need for in-flight body shape and anthropometry data, as microgravity-driven changes can affect suit and seat fit
- 2) Future vehicles used for long-duration spaceflight will likely not have body mass measurement capability due to mass/volume/cost constraints which is currently used for crew health

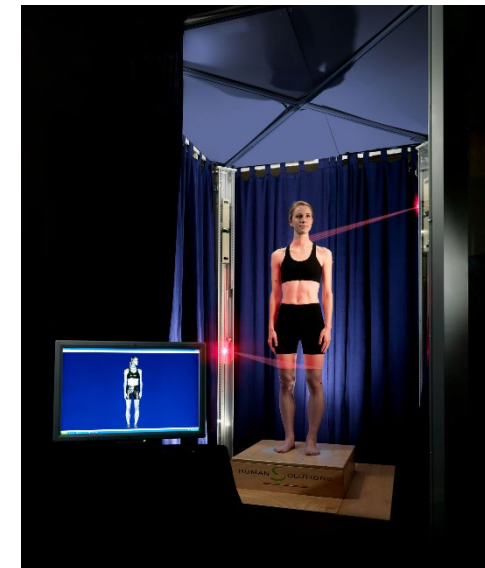
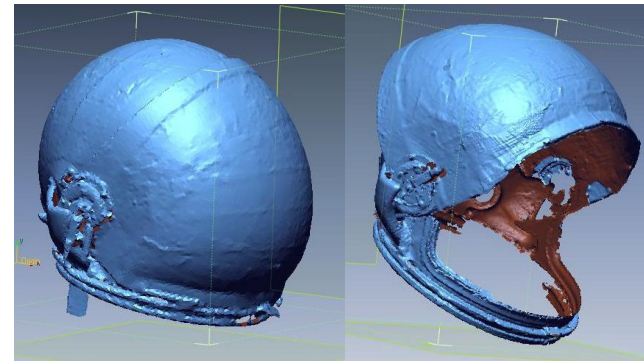
Application:

- Clinical Care:
 - Monitoring body mass and anthropometry changes during long duration missions can be a useful feedback mechanism for a crewmember's dietary and exercise regimens
- Occupational Surveillance:
 - Learn how spaceflight impacts a crewmember's body shape
 - Correlate body shape changes and body mass, which can be directly applicable to future exploration and commercial space missions
- Current Knowledge Gaps:
 - How quickly body shape changes occur and partial gravity impacts



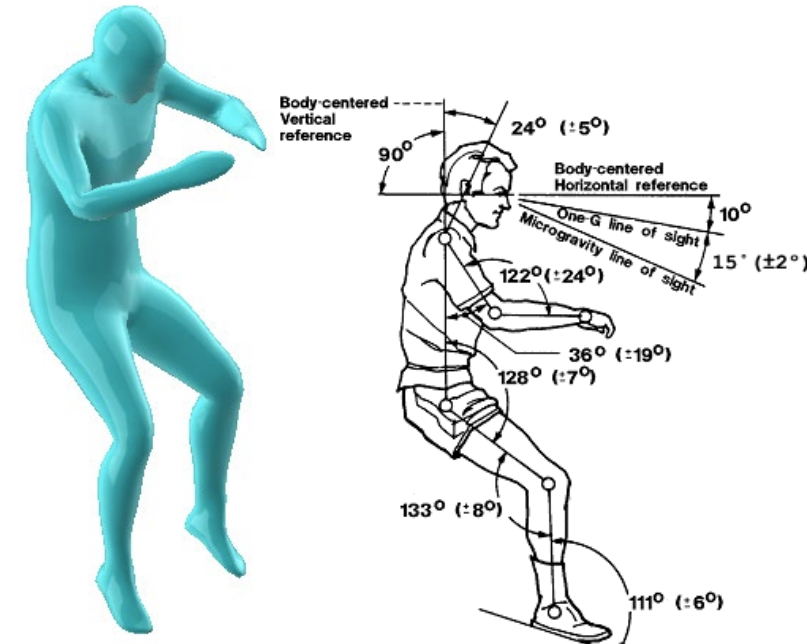
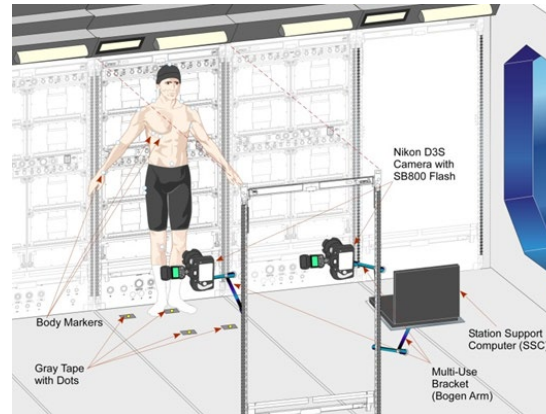
How to Measure Anthropometry in Spaceflight?

- Current ground-based JSC anthropometry protocols use measurements extracted from 3D body scans
 - Commercial 3D body scanners provide accurate data but are not suitable for in-flight use
 - A customized prototype 3D body scanning system is being developed specifically for in-flight crew measurement
-
- Scanning & Anthro Analysis Capabilities (1g)
 - 3D whole body laser scanners
 - Hand/feet laser scanner
 - Portable handheld scanners
 - Large environmental scanners for entire rooms/mockups
 - Capabilities in Microgravity
 - Photogrammetry
 - Traditional hardware: Anthropometer and Tape Measure
 - Mobile device based scanner
 - Goal is to collect anthropometric and volumetric data consistently, repeatably, and reliably in space and lunar environments



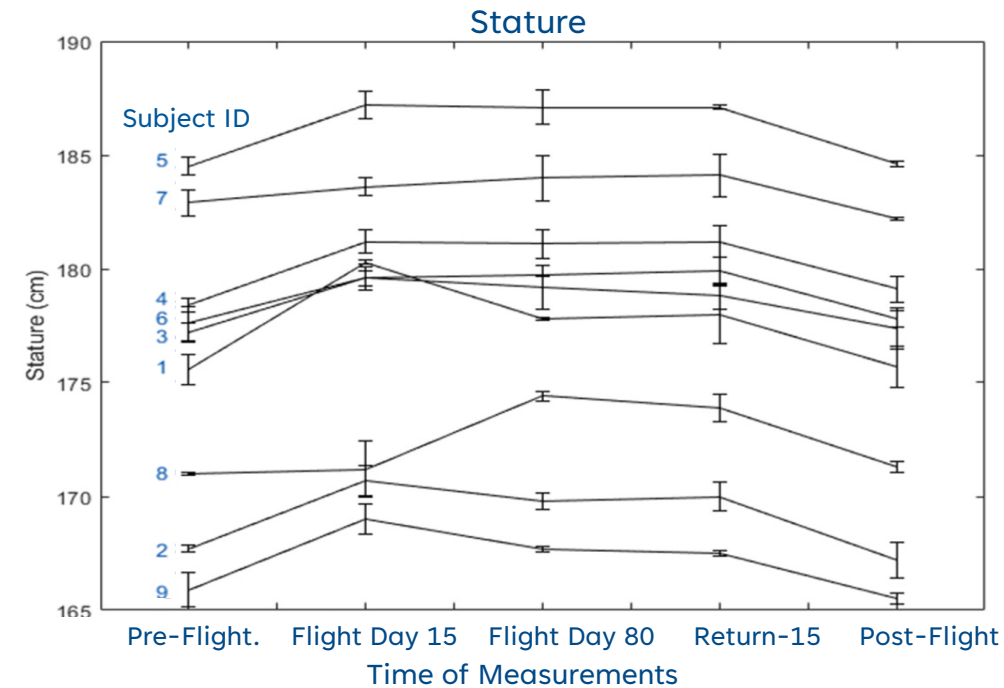
Previous Spaceflight Anthropometry Studies

- Previous studies during SkyLab, Shuttle, and ISS have measured stature, seated height, and circumference
- Measurements taken with 'traditional' methods and photogrammetry
- Measurements demonstrated spinal elongation in microgravity (+3% stature and +6% seated height), which was incorporated in NASA standards, suit and hardware design
- The unique body posture in microgravity ("neutral body posture") was also estimated and compared to the NASA-3001 standard



Previous Spaceflight Anthropometry Studies

- Previous studies identified the general trend of anthropometric changes
 - Skylab (Skylab 4 (S4) and Apollo-Soyuz Test Project (ASTP)) (n=3) (1973-1975)
 - Measured stature once (S4) and throughout mission (ASTP)
 - 3% stature change
 - Shuttle Spinal Elongation (n=29) (2009-2011)
 - Measured seated height and stature once per mission
 - 3% stature change and 6% seated height change
 - ISS Body Measures (n=9) (2013-2017)
 - Measured heights, breadths, circumference throughout mission
- Currently, minimal anthropometric data is collected on ISS
 - Medical requirement (MedB) collects body mass, monthly
 - Orthostatic Intolerance Garment: collects leg circumferences garment fit
- Knowledge gaps
 - How quickly do body changes occur and how quickly do they recover postflight
 - How much variability between crewmembers
 - For future exploration, where body mass may not be measured, how do we track changes for health monitoring?
 - How do we collect reliable, repeatable in-flight body shape data for occupational surveillance and suit/seat fit?



Need for Spaceflight Anthropometric Data

- Since 2017, no inflight body measurements have been measured
- However, this data is critically needed for human-to-hardware interactions, designs, and health surveillance
- Without this data, misfit injury risk may not be effectively identified or mitigated
 - Injury during suit donning prior to undock
 - Several crew having difficulty fitting into their seat until reentry G
 - Vehicle seat fit can be very sensitive to spinal elongation (not currently measured)
- NASA has recently updated a medical requirement to include anthropometric measurements to understand how the body changes inflight (spinal elongation, fluid shifts, etc.)
 - This will apply to all ISS and Artemis missions going forward
 - Body mass will be collected on ISS but not likely during Artemis missions
 - Anthropometric measurements will be collected during:
 - pre-, in-, and post-flight for ISS missions
 - pre-, lunar surface, and post-flight for Artemis missions

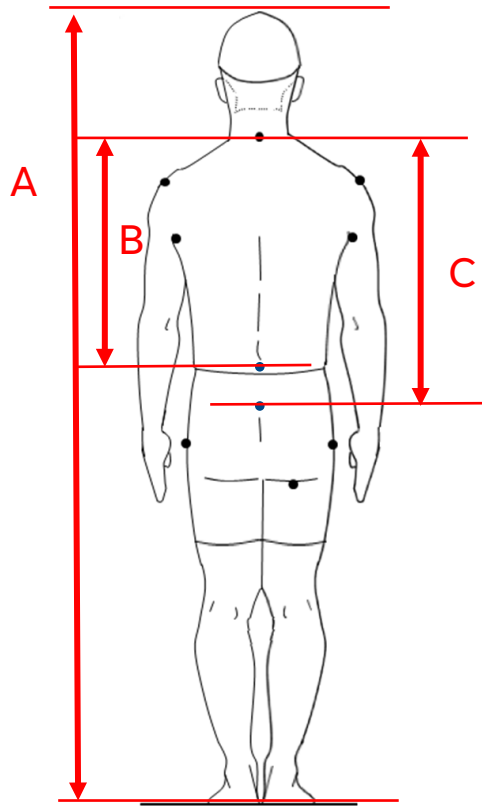
What Measurements are Required?

- Identify measurements based on application:
 - Measurements needed for clinical, operational, population surveillance
 - Spinal elongation, including stature and torso length
- Measurement methods in microgravity vs ground laboratory
 - Measurement devices
 - Posture
 - Trained vs untrained
 - Crew time
- Performed ground-based study for measurement down selection
 - 6 pilot subjects
 - 2 sessions ~ 1 week apart
 - Repeated measurements (3x)
 - Two operator groups:
 - Trained: Previously trained and completed a 1-hour training
 - Untrained: no measurement training
 - Collected measurements:
 - Part A: Heights, lengths; anthropometer and tape measure
 - Part B: Heights, lengths, and circumferences; Tape measure only



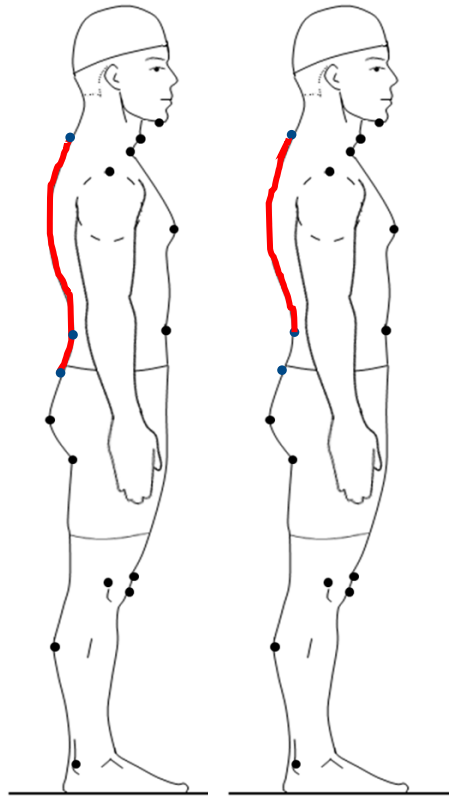
Ground-based Study Postures

What Measurements are Required? Part A



Anthropometer

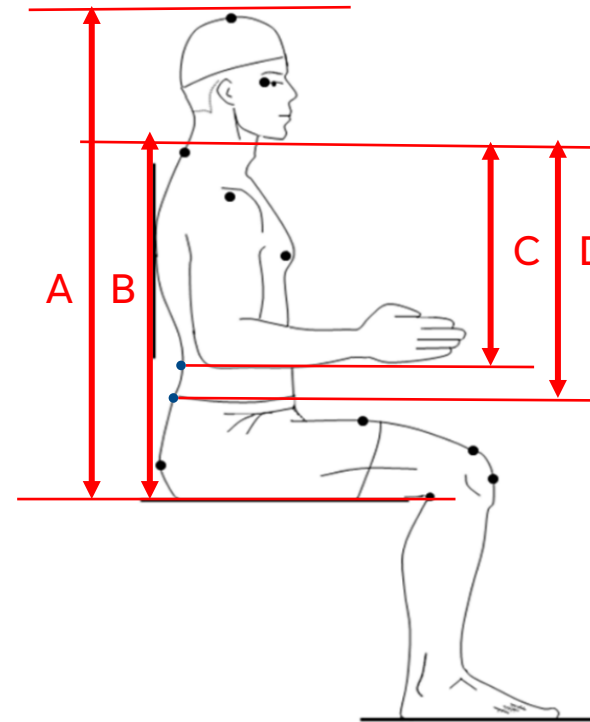
A: Stature
B: C7-to-L5
C: C7-to-S1



Tape Measure

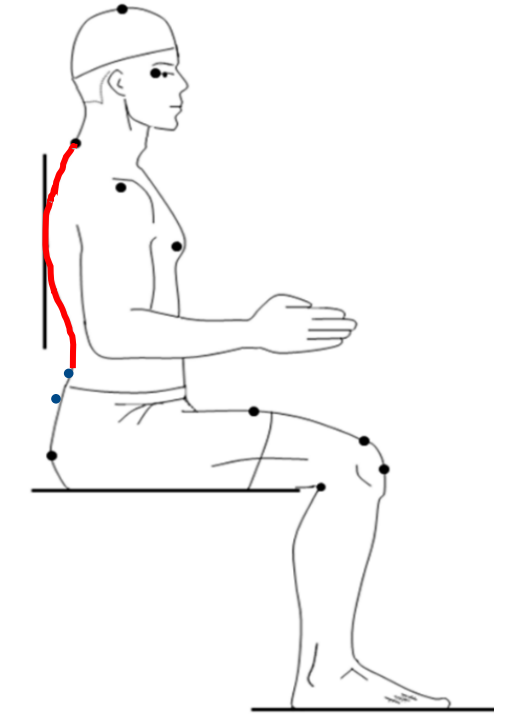
C7-to-S1
C7-to-L5

“Scan chair” and “stool” pose



Anthropometer

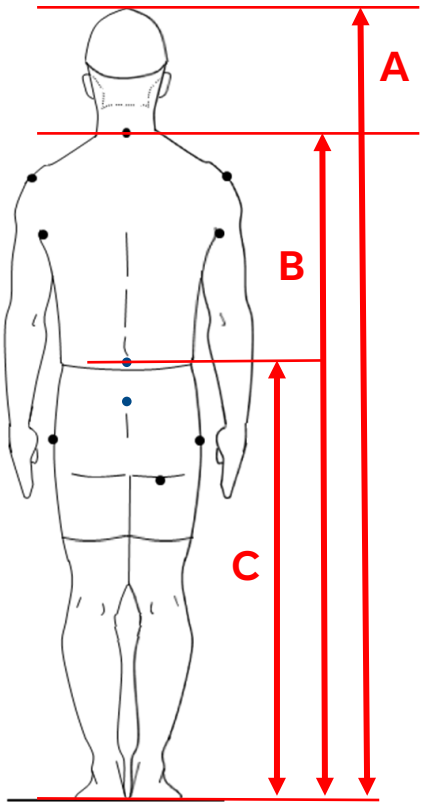
A: Seated Height
B: Seated C7 Height
C: C7-to-L5
D: C7-to-S1



Tape Measure

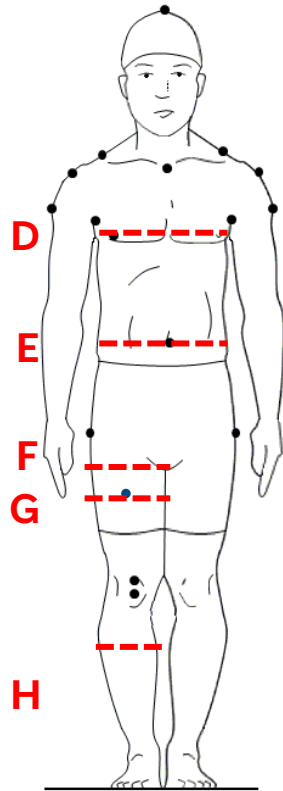
C7-to-S1
C7-to-L5

What Measurements are Required? Part B



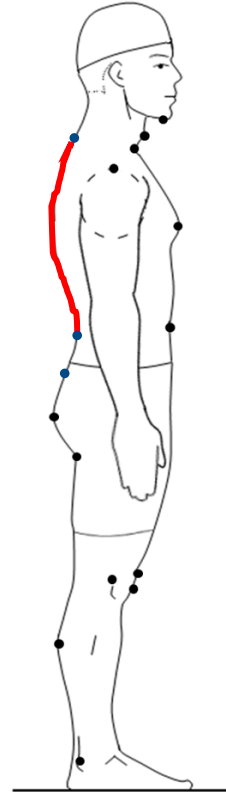
Anthropometer

A: Stature
B: C7 Height
C: L5 Height

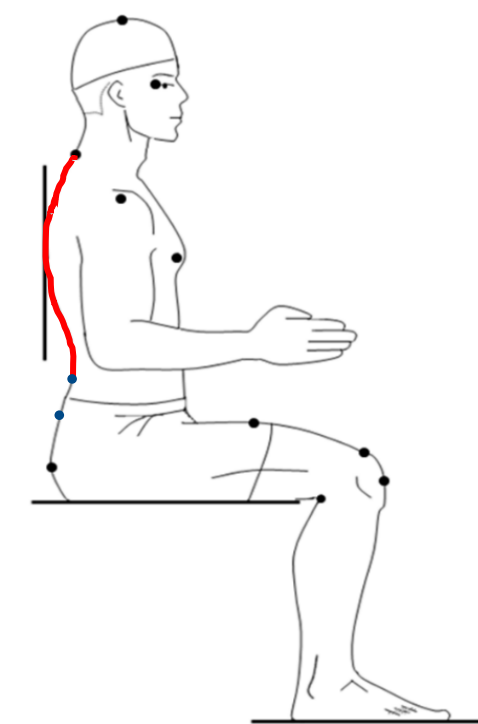


Tape Measure

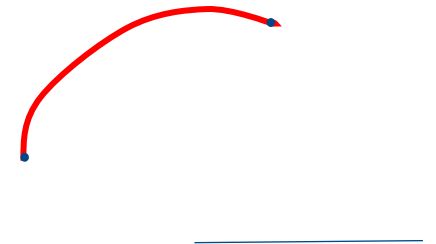
D: Chest Circ
E: Waist Circ
F: Upper Thigh Circ
G: Mid-Thigh Circ
H: Calf Circ



Tape Measure C7-to-L5



Tape Measure C7-to-L5



Tape Measure C7-to-L5 Chin-to-Knee pose

Ground Study - Results

Part A:

- Untrained vs Trained operators: Untrained operators tend to over-estimate dimensions
- Ground vs. ISS protocols:
 - Stature and sitting height consistent as expected
 - Stool-seated (free float) measurements are similar to standing measurements
 - Landmarking on skin is more reliable than on clothing (as presumed)
 - For stature, the differences are not statistically significant between anthropometer and tape measure
 - For torso length, tape measure tends to overestimated with both untrained and trained group

Part B:

- Untrained operators improved after initial session; pre-flight crew training is needed for best data
- Chest and upper-thigh circumference differences between groups were minimal
- Waist and calf circumference are less consistent with untrained group
- For mid-thigh circumference, untrained group tended to slightly overestimate

Overall:

- Ground study helped down-selection of measurements, measurement methodology, and postures

Down Selected Measurements

Final Proposed Measurements	Posture	Applications				
		Clinical	Occ. Surv.	Suit / Seat Fit	OIG Fit	Gravity/Lunar Design
Stature	Standing - up against ISS Rack	X	X	X		X
Head Circumference	Free float/standing		X	X		
Chest Circumference	Free float/standing	X	X	X		
Waist Circumference	Free float/standing	X	X	X	X	
Thigh Circumference	Free float/standing		X	X	X	
Mid-Thigh Circumference	Free float/standing		X		X	
Calf Circumference	Free float/standing		X		X	
Calf Height	Free float/standing		X			
Torso Length (C7-L4/L5)	Free float/standing, Chin-to-Knee		X	X		X
Measurements that were removed from Initial list						
Seated Height			X	X		
Seated Mid-Shoulder Height				X		
Crotch Height				X		
Mid-Shoulder Height				X		
Torso Length (C7-S1)			X	X		X

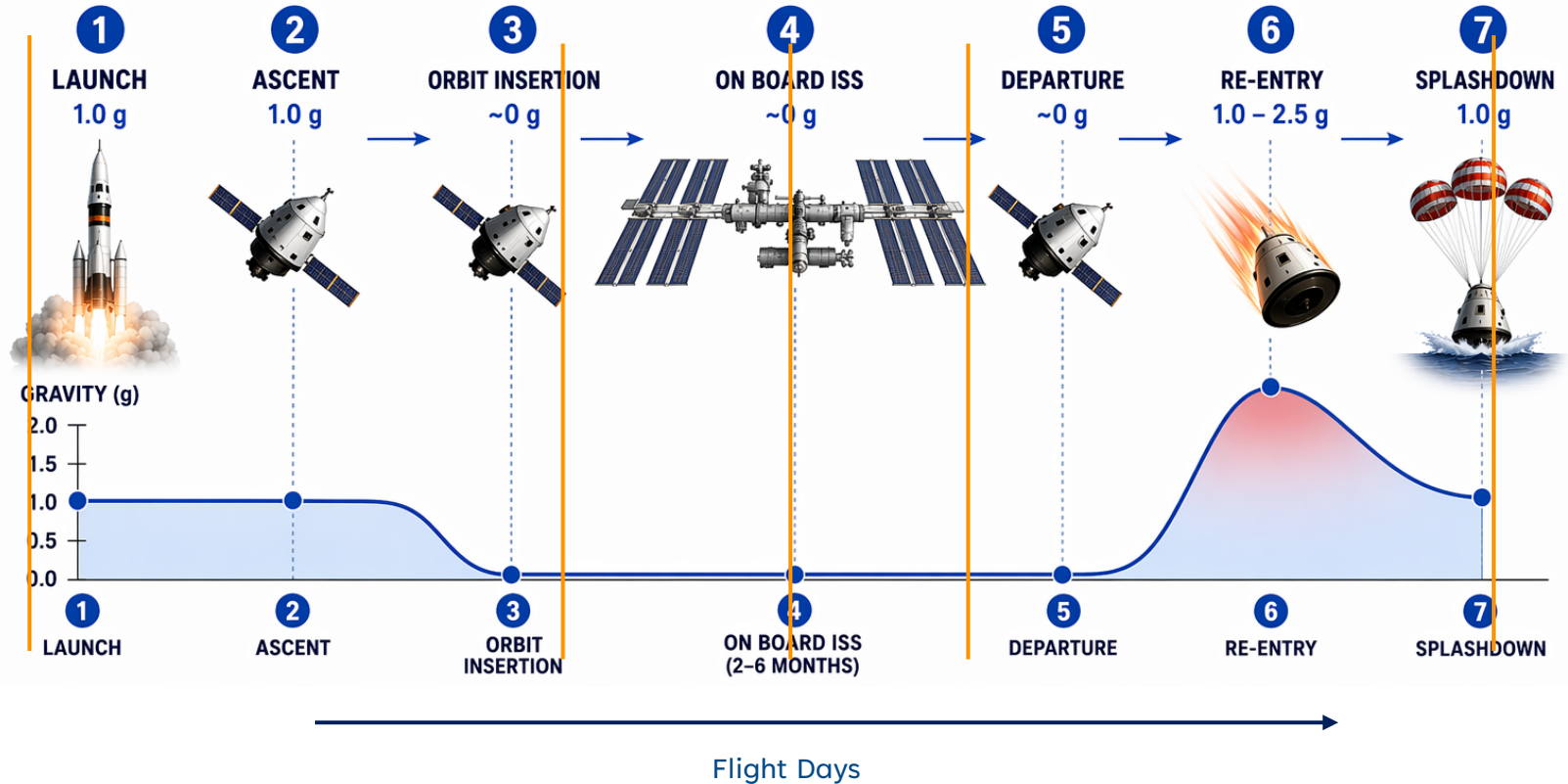
- **Received Aerospace Medical Board concurrence:** Start implementing below measurement set on ISS as soon as feasible
- **Future Work:** Continue investigating video scanning methodologies to reduce crew time and simplify the operation

When to Measure?

- Previous studies measured:
 - Once during short duration missions (7-14 days)
 - Multiple times during long duration missions (>90 days)
 - Post-flight was R+30 days
- However, those time points don't show how quickly changes or recovery occur
 - Microgravity timeline: Launch-30 days, Launch+7 days, L+90d, L+180d, Return-14 days, Return+1-5 days
 - Lunar surface timeline: soon after land and before ascent

MICROGRAVITY THROUGH THE ISS MISSION

GRAVITY EXPERIENCED BY ASTRONAUTS DURING A TYPICAL ISS MISSION

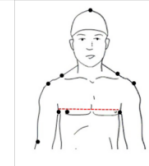


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ISS Protocol and Implementation

- Final measurement list and procedures were sent forward for ISS implementation
 - US and International crew only
 - Stature, torso length, circumferences
 - L-30, L+7, L+90, L+180, R-14, R+1-5
 - Procedures were developed into an iPad app (“EveryWear”) questionnaire
 - Due to constraints, current procedures are currently utilizing ‘traditional’ methods (tape measure)
- Began implantation of new Medical requirement in July 2026

Chest Circumference



Ensure tape measure is level and not too tight (compressing skin), subject may have to assist in setting up tape measure in front of body. Tell subject to breathe normally.

Breathing cycle will cause increases and decreases to the circumference, take the maximum value during the respiratory cycle.

*** Measure the horizontal circumference at nipple level.**

cm

Bent Torso Length

Subject restrains their feet per crew preference. Have subject bring chin to knee (in fetal-like posture).



*** Measure the distance from the neck mark to lower back mark. Ensure tape measure is taut.**

cm

*** Repeat Bent Torso Length measurement.**

cm

With subject in relaxed standing posture (not against Rack) take the following measurements,

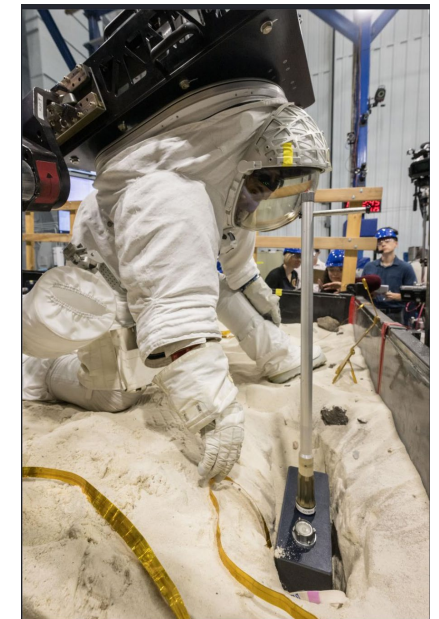
ISS Preliminary Data

- 3 subjects have partial data collection
 - Successfully completed inflight data collection without preflight training (not preferred)
 - However, preflight data was not obtained therefore it is unknown if data is acceptable
- 3 subjects have recently performed training and baseline data collection and will be first group for full dataset
- Data will be analyzed to determine:
 - Spinal elongation (stature, torso length)
 - How soon does this change?
 - How will this impact Artemis missions?
 - Changes in circumferences compared to body mass
 - Can this be used as a health indicator for nutrition, overall health?
 - Change in body size/shape over time for each crewmember
 - Potential sizing adjustments for return hardware
 - Adjustments to suit, seat, hardware sizing/settings

Subject	Training	Preflight	FD7	FD90	R-14	Postflight
P1	*	*	*	*	X	*
1	*	*	*	*	X	
2	*	*	*	*	X	
3	*	*	X			
4	X	X				
5	X	X				
6	X	x				

Summary/Conclusion

- Spaceflight anthropometry is critical for suit and seat fit, human-hardware design, health surveillance, and injury prevention
- Ground-based study was performed to help develop procedures and methodology for inflight implementation
- Medical requirements for both ISS and Artemis are/have been updated to include these measures
- Currently implementing data collection on ISS and planning for future implementation on Artemis missions (lunar surface)
 - In beginning phase of implementation, limited number of subjects/data collected
- Continue to investigate technologies to improve capabilities
- More to come...





Questions?

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