3D Scanning System to Assess Gravity-Dependent Body Shape Changes

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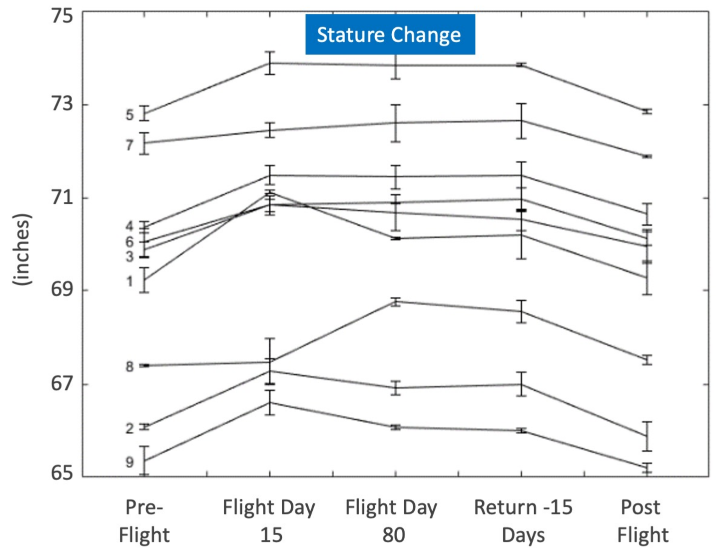
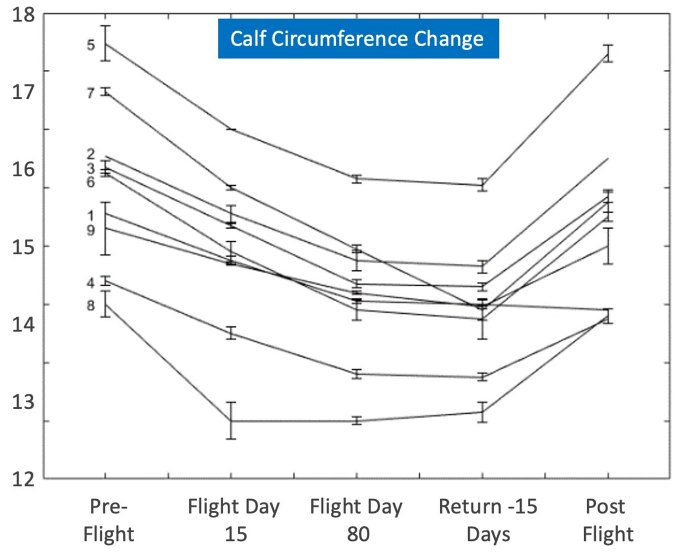
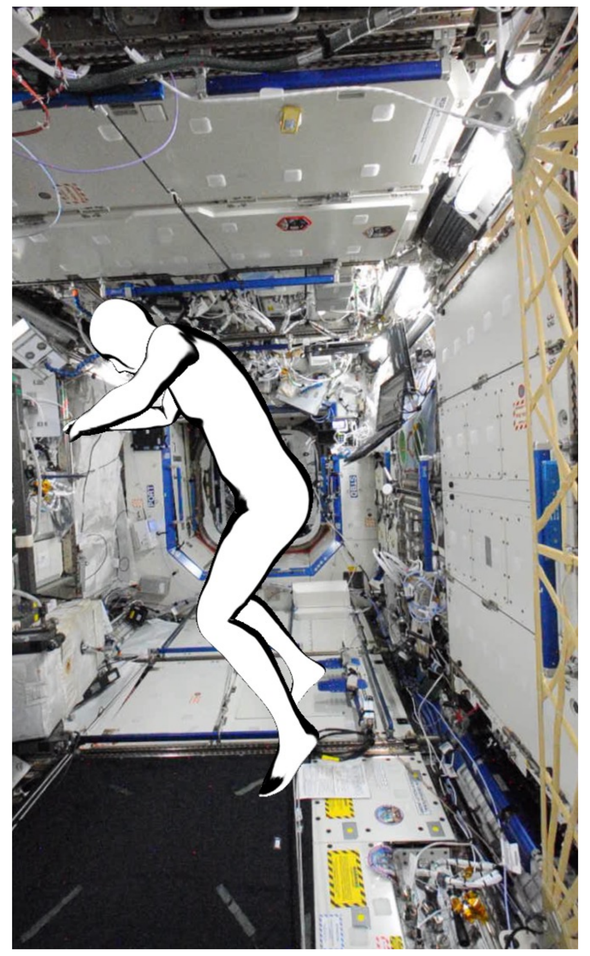
Background

- Different gravity environments change physical, physiological, and morphologic characteristics of the human body, including body shape and posture
- Spacesuit and hardware design should consider anthropometry changes in microgravity, originating from spinal elongation, fluid shift and muscle atrophy
- Study showed characteristic anthropometry changes from crewmembers in International Space Station (ISS) and Shuttles; however, collected measurements were limited to lengths and circumferences without 3D volumetric information





- Human body in 0-g also exhibits a unique posture (neutral body posture; NBP), when relaxed and no external forces are applied
- The early designs for spaceflight hardware were based on upright standing or sitting postures without consideration of NBP, resulting in crew discomfort.
- Maintaining a body posture other than NBP requires significant strength exertions. Newer system designs have adopted NBP as baseline, but the specific patterns or variations of NBP have not been clearly quantified.



Aim of the Study

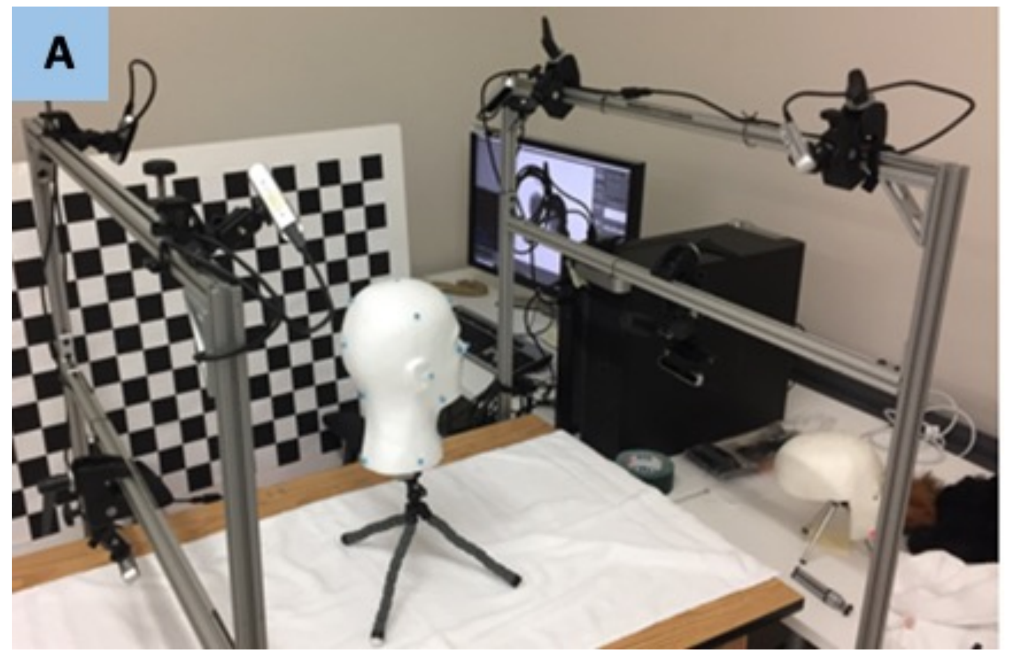
Develop a prototype 3-D body scanning system that is customized for in-flight use to scan crewmembers, with the configuration and performance optimized for detecting known gravity-dependent body shape and posture changes.

Aim 1. Scan Hardware Development: Build a scanning system hardware using commercial off-the-shelf 3D sensors. Optimize the sensor parameters and settings to sensitively detect small body shape and size changes. Strategically place the sensors to capture the persons from 1st percentile female to 99th percentile male stature with simulated microgravity floating artifacts.
Aim 2. Scan Acquisition Software Development: Develop a scan acquisition software prototype. Optimize software for efficient in-flight operations with minimal overhead and simplified user interface. Eliminate or minimize calibration needs, as the sensors are likely to be under frequent vibration and unexpected position shifts in a space vehicle or reduced gravity flight.
Aim 3. System Performance Assessment: Test the scan system in the ground laboratory. Compare the accuracy and reliability against the laboratory reference scanner. Identify new metrics, including set of joint angles, body surface areas, or segment volumes, to sensitively characterize the body shape and posture changes in different gravity conditions.

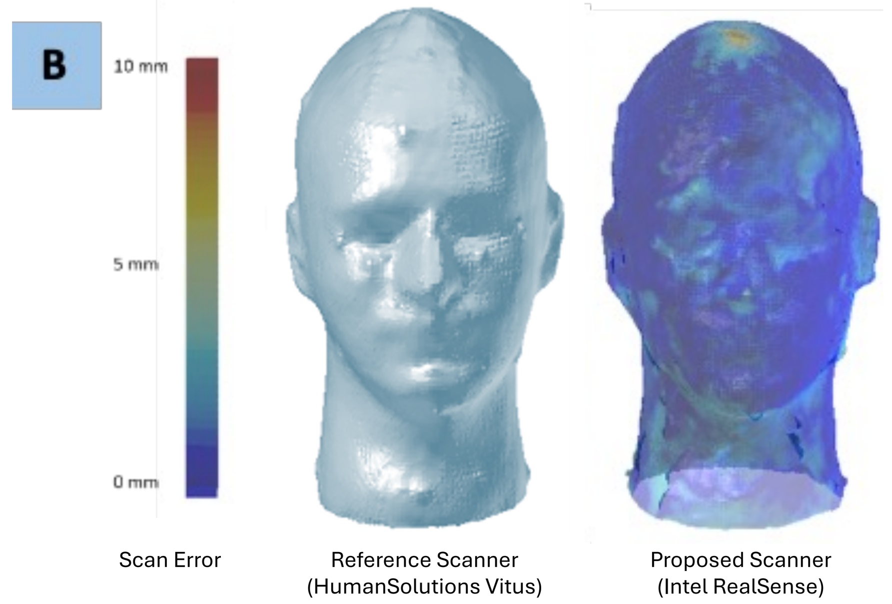
Survey of Existing Technologies

	Laser Booth	Light Sensor Turn Table	Light Sensor Booth	Hand-Held Scanner
Capture Volume	Medium (1.2 x 1.2 x 2.2 m)	Small (1 x 1 x 2.1 m)	Medium to large (3 x 3 x 2.5 m)	Small to large
Scan Time	6-10 seconds	30-40 seconds	Less than 0.5 seconds	Several minutes
Accuracy (Error)	High (error less than 1 mm)	Medium (less than 5-10 mm)	Medium (less than 5 mm)	High (less than 1 mm)
Calibration	Required	Required	Required	Not required
Cost	Approx. $100K	Less than $20K	Approx. $20K-300K	Approx. $20K

Preliminary Work



Proof-of-concept system for 3D head/neck scanning (funded by NASA Innovative Charge Account)

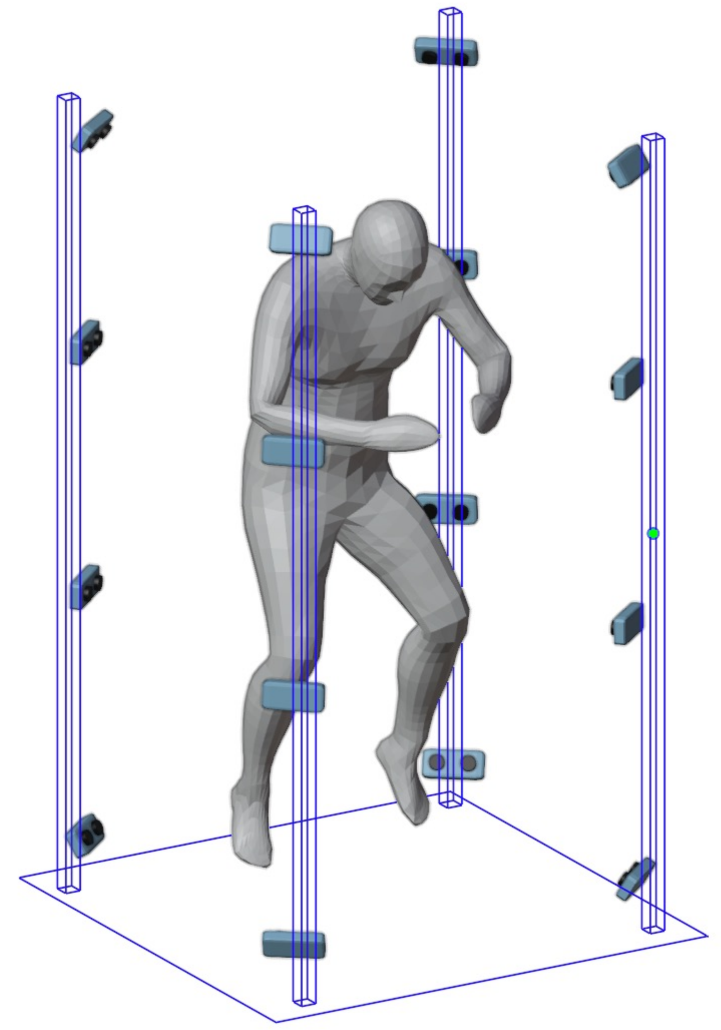


Execution Plan and Preliminary Results

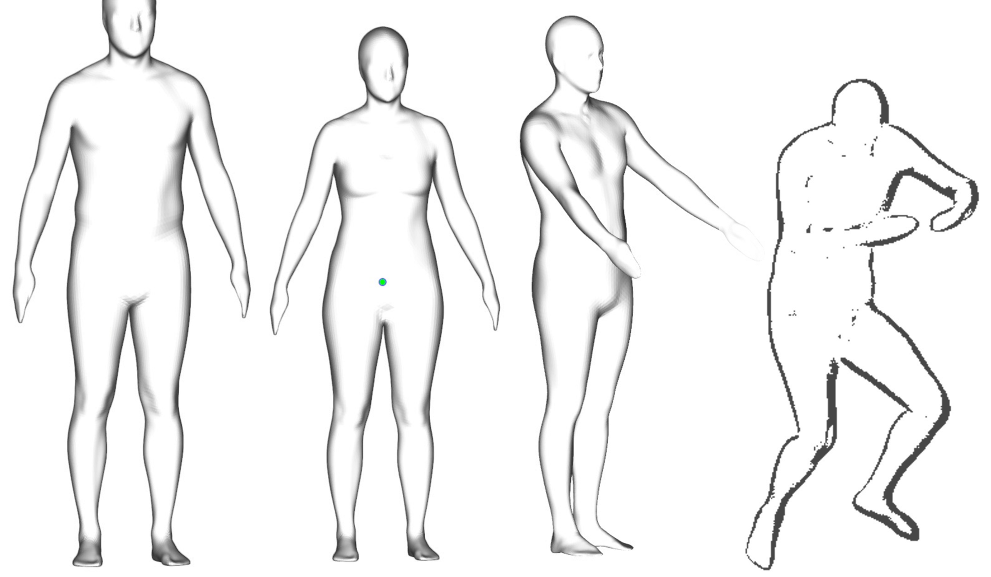
1. Develop a system using commercial 3D sensors Intel RealSense, which was selected for customizability and performance. Define scan protocols and calibration procedures
2. Build custom fabricated manikins in a required range of anthropometry and postures
3. Assess and analyze system accuracy and reliability for detecting simulated body shape and posture changes

Intel RealSense 3D depth sensors

Preliminary scans: reference (HumanSolutions Vitus) vs. proposed hardware (Intel RealSense)



Multiple sensor integration and system evaluation



Proposed manikin shapes customized for range of anthropometry and postures

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