Population Analysis: Communicating About Anthropometry in Context

Sherry Thaxton, Ph.D.
Lockheed Martin
Houston, TX

Sudhakar Rajulu, Ph.D.
NASA-Johnson Space Center
Houston, TX

HSI Knowledge Broadcast
July 21, 2009

Overview

- Presentation background
- Introduction
- Definition of population analysis
- Major applications
- Case studies
- Summary and conclusions
- References

Presentation Background

- Based on a paper submitted to the 2008 Human Factors and Ergonomics Society Conference
  - Presented at HFES in September 2008
- Primarily focused on anthropometry, though other applications exist
- Case studies based on work performed in JSC's Anthropometry and Biomechanics Facility

Introduction

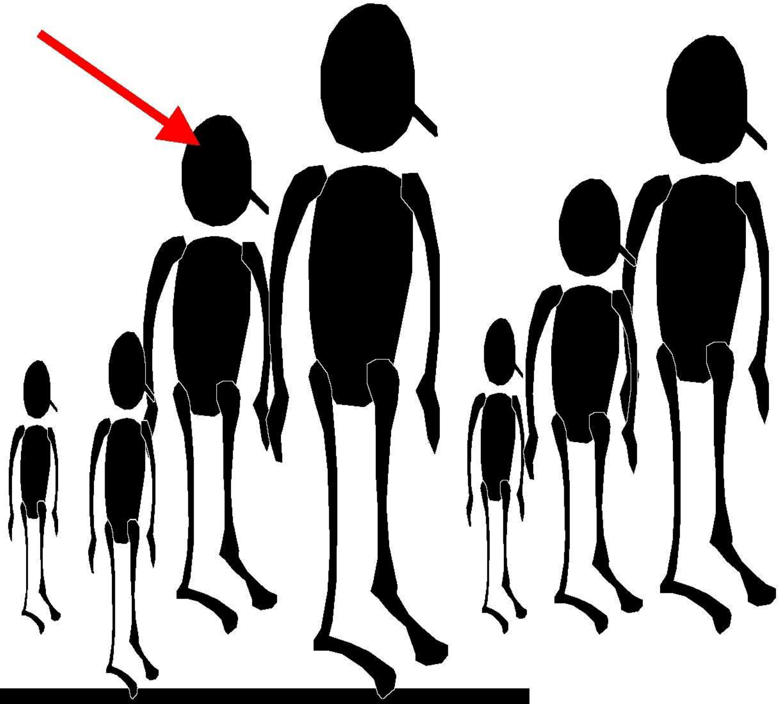
- Providing anthropometric accommodation for an entire range of the population
  - Widely accepted philosophy
  - Not always simple to define or achieve
- Communication of issues with human-system integration is critical
- Population analysis applies existing human factors methodologies in novel ways to assist with this communication

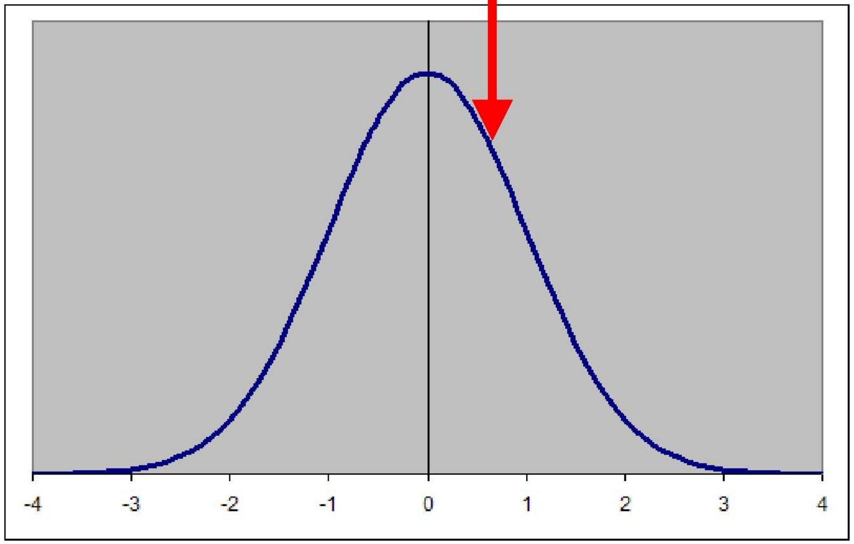
Definition of Population Analysis

- Population analysis places human subject data such as anthropometry and strength into the context of the entire user population
  - Define test subjects based on comparisons to the extremes of the expected population
  - Compare hardware dimensions against a large sample population database of potential users
- End result: better definition of subject accommodation

Definition

- Accommodation, usability, and operability into the context of the overall user population





Value of Population Analysis

- Provides advantages over traditionally used techniques
  - Random sampling may not provide adequate representation of population
  - Methods such as principle component analysis leave a large portion of variance unexplained
  - Statistics can rely on bad assumptions (linearity, normality) and be difficult to communicate meaning to engineers

Major Applications

- Analysis of multivariate problems
  - Analyzing more than one anthropometric variable allows a greater understanding beyond simple one-dimensional cases
- Enhancement of human-in-the-loop testing
  - Subject feedback becomes more valuable when it is examined within the context of the population as a whole

Multivariate Problems

- Design of a doorway
  - One-dimensional problem- height of doorway
    - If height of doorway is equivalent to 90th percentile male stature, about 10 percent of the male population will experience difficulty walking through
  - Two-dimensional problem- height and width of doorway
    - If height and width are both equivalent to 90th percentile male dimensions (stature and bideltoid breadth), additional members of population will experience difficulty
    - Stature is not highly correlated with width measurements (Kroemer, Kroemer, and Kroemer-Elbert, 1994)
      - Percent of population experiencing difficulties with door will fall between 10 and 20 percent
- Analysis of sample database allows determination of reasonable estimate of percent accommodated

Enhancement of Human-in-the-Loop Testing

- Consider doorway from previous example
- A group of 10 subjects walks through and determine that doorway is completely acceptable
    - What were the largest statures and bideltoid breadths?
    - If subjects represented extremes of the population, their evaluation holds more power
    - Even if subjects did not represent extremes, placing their anthropometry into context holds value

Case Studies

- Case study background
  - Performed at NASA-Johnson Space Center (JSC)
  - Associated with development of hardware for the Constellation Program
  - Population analysis performed by staff of the Anthropometry and Biomechanics Facility (ABF)
- Space Suit Critical Dimensions
- Lunar Lander Vehicle Design

Space Suit Critical Dimensions

- Constellation Program anthropometry requirements are defined in Human-System Integration Requirements
  - List of critical dimensions
    - Formulated among spacesuit and cockpit design teams and human factors practitioners
  - 1st percentile female through 99th percentile male accommodated
    - Astronaut database is based on modified 1988 Army data (ANSUR)

Limited Dimensions

- Space suit designers indicated that it was infeasible to accommodate the full anthropometric range
- Provided list of body dimensions they considered to be reasonable
- Further analysis was needed to define accommodation

Population Analysis of Suit Critical Dimensions

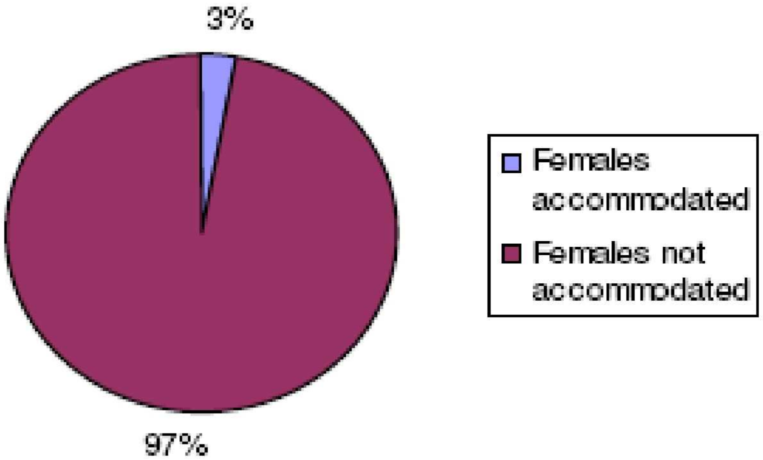
- Entire Constellation database filtered through minimum and maximum values provided by suit designers
  - Fourteen dimensions provided
  - Any subject falling outside of the range for at least one dimension eliminated
  - Resulted in final list of subjects falling within range for all dimensions

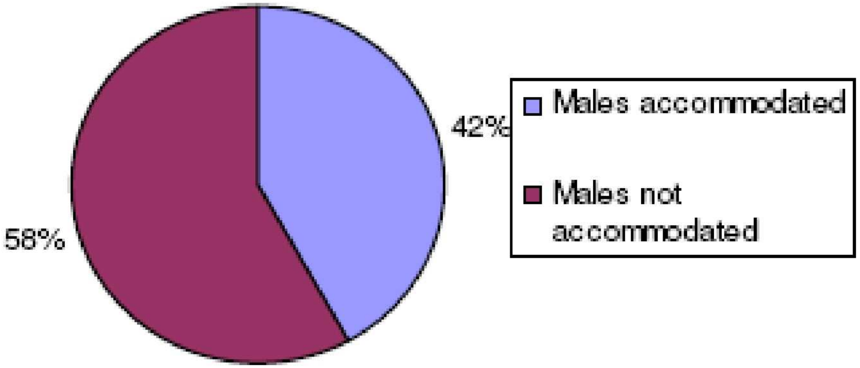
Population Analysis of Suit Critical Dimensions

- Example:
  - Suit design team indicated that it was possible to accommodate between 61.0 and 73.9 inch stature
    - Stature of each subject compared against these limits
    - Any subject falling outside of range removed from pool to compare to additional dimensions
- Percent of male and female subjects in database accommodated calculated directly

Results of Analysis

- Based on initial dimensions provided
  - Female accommodation unacceptable
  - Male accommodation less than expected





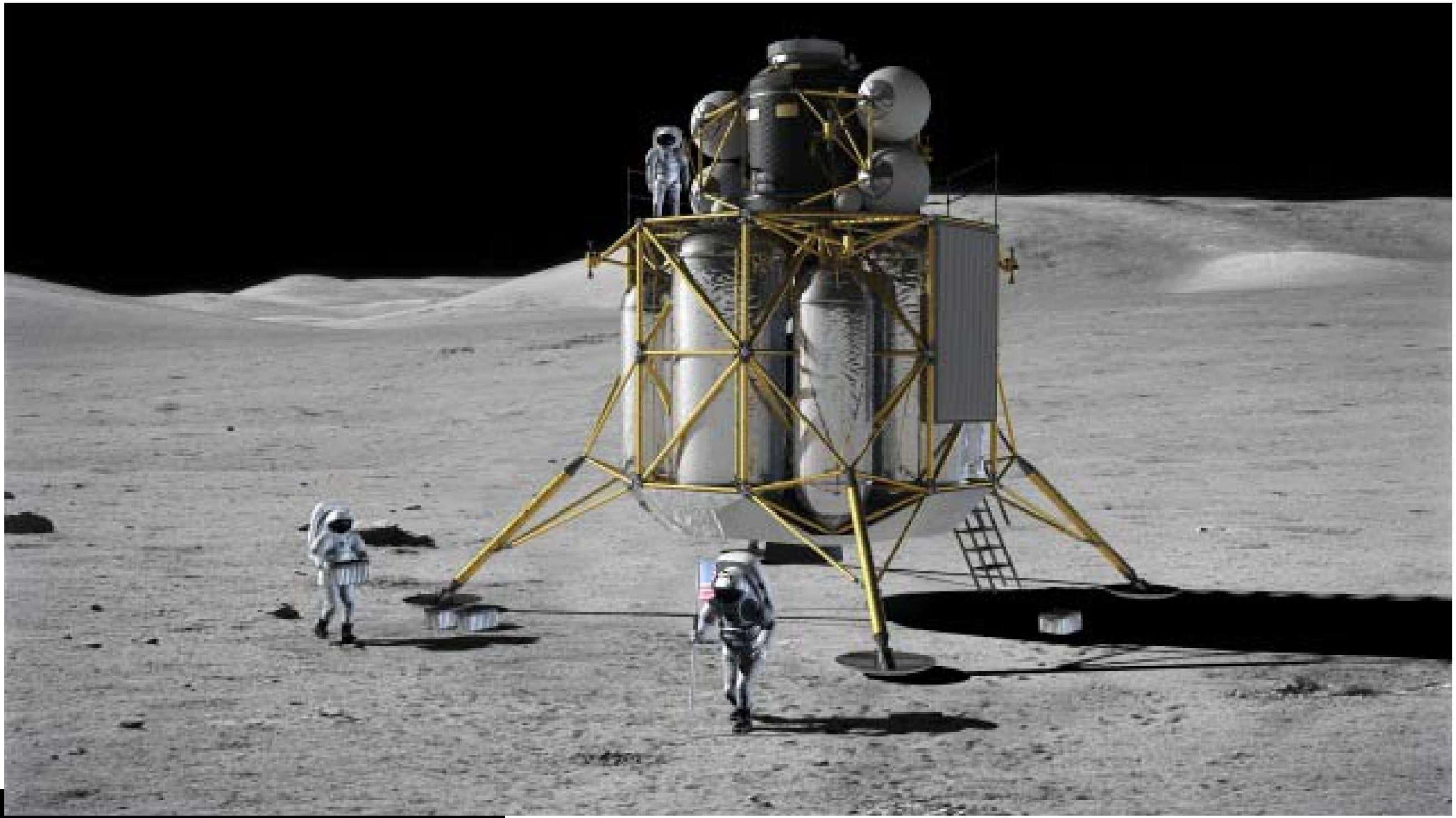
Contribution of Population Analysis

- Illustrating the levels of accommodation added significant value to communication between HF practitioners and suit designers
- Ultimately, designers concluded that their perceived limitations were more stringent than was realistic
- Analysis of the same 14 critical dimension with 1st percentile female to 99th percentile male performed
  - Yielded better than 90 percent accommodation for both genders

Lunar Lander Vehicle Design

- Altair ascent stage will carry astronauts between the Orion capsule and the surface of the moon
- JSC's Habitability Design Center built a low-fidelity mock-up to evaluate the interior dimensions of the vehicle
- Goal of testing- determine whether internal volume provides space for tasks such as accessing storage and using vehicle controls while wearing a spacesuit

Concept Art of Altair



Suits Tested

- Vehicle designed to carry four suited astronauts
  - Limited prototype suits available (number and sizes)
  - Tested subjects in two types of suits
    - Mark III- lunar surface prototype
    - Advanced Crew Escape Suit (ACES)- launch/re-entry suit for Shuttle
  - Also used a non-functional simulated Mark III suit

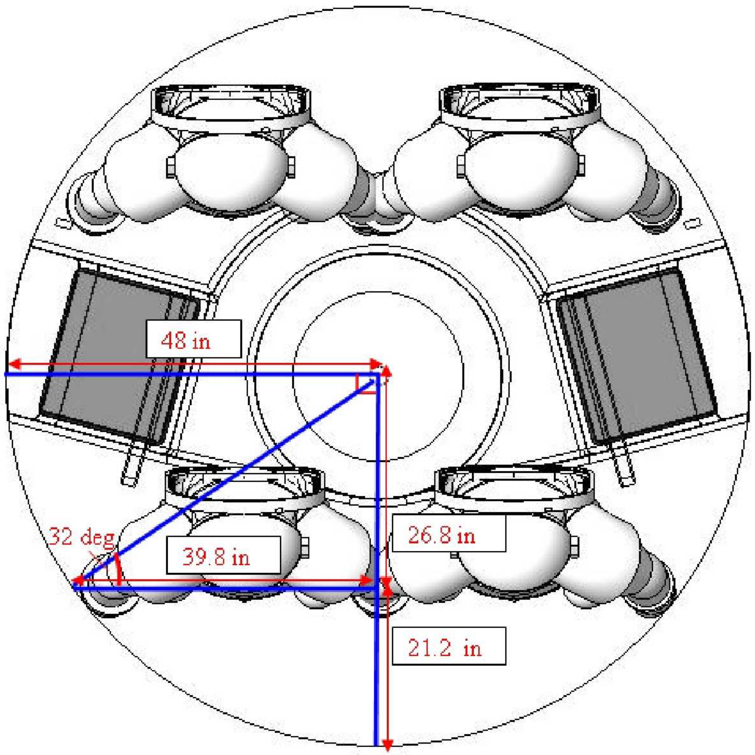
Data Collected

- Video data
  - Detect collisions
- Anthropometry
  - Minimally clothed data collected from subjects
  - Allowed for comparison against expected population
- Major focus of analysis: Larger suit

Results of Altair Evaluation

- Subject's bideltoid breadth and forearm-forearm breadth were smaller than average male values
- Collisions still occurred between subject and person wearing mock-up suit
- This highlights likelihood of larger subjects experiencing more difficulty

Additional Analysis



- Mathematical analysis
  - Four hypothetical large males wearing spacesuits
- Provided information concerning clearance and fit issues

Contribution of Population Analysis

- Placing the single subject into the context of population provided perspective
  - Highlighted need to examine extreme bideltoid and forearm-forearm breadth
  - Testing multiple subjects of varying sizes was unrealistic
  - Additional analysis added value to the single subject evaluation

Conclusions

- Quantifying accommodation levels enables human factors practitioners and design engineers to understand the impact of design decisions
- Placing human factors information into context is an important step in the design process
  - Utilizing databases to quantify accommodation
  - Defining human subjects against the population

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Questions?

Sherry Thaxton, Ph.D.
CxP Human SIG/Orion Human Engineering
Lockheed Martin
281-483-7413
sherry.s.thaxton@nasa.gov