# Cabin Safety Interior Simulation

EMBRAER and DASSAULT SYSTÈMES

Project Name: Digital Human Modeling

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# Agenda

- Project
  - Digital Human Modeling
  - Objectives
- Foundations
- Method
  - Procedure
  - Test Plan
- Test Cases
- Conclusion

# Project: Digital Human Modeling

Embraer and Dassault Systèmes developed a project with one year of duration (2021) aiming create biomechanical interior simulation via digital modeling with bio fidelity; simulating the interaction between humans <passengers and crew> and the aircraft <cabin interior> to optimize human well-being inside the aircraft and comply with Cabin Safety Performance.

# Project Objectives

The initial phase of this project aimed to identify an appropriate tool and method *(2021)* :

- Perform simulations in standard cabin interior of aircraft.

The second phase of the project is being designed *(now and on)* :

- Support cabin safety interior tests;
- Streamlining interior test preparations and;
- In the future, replace some interior certification tests.

# Foundation

How Cabin Interior are developed and certificated nowadays:

- The cabin interior usually are certified using different means of compliance: description reports, analysis, laboratory tests, tests on real aircrafts/mockups or through a cabin inspection <*in some cases to do that the interior shall be completely manufactured and assembled*>.

- This is why Embraer is looking for and researching to develop a proper method to use simulations to develop, to test and in the future to certify cabin interior devices and features.

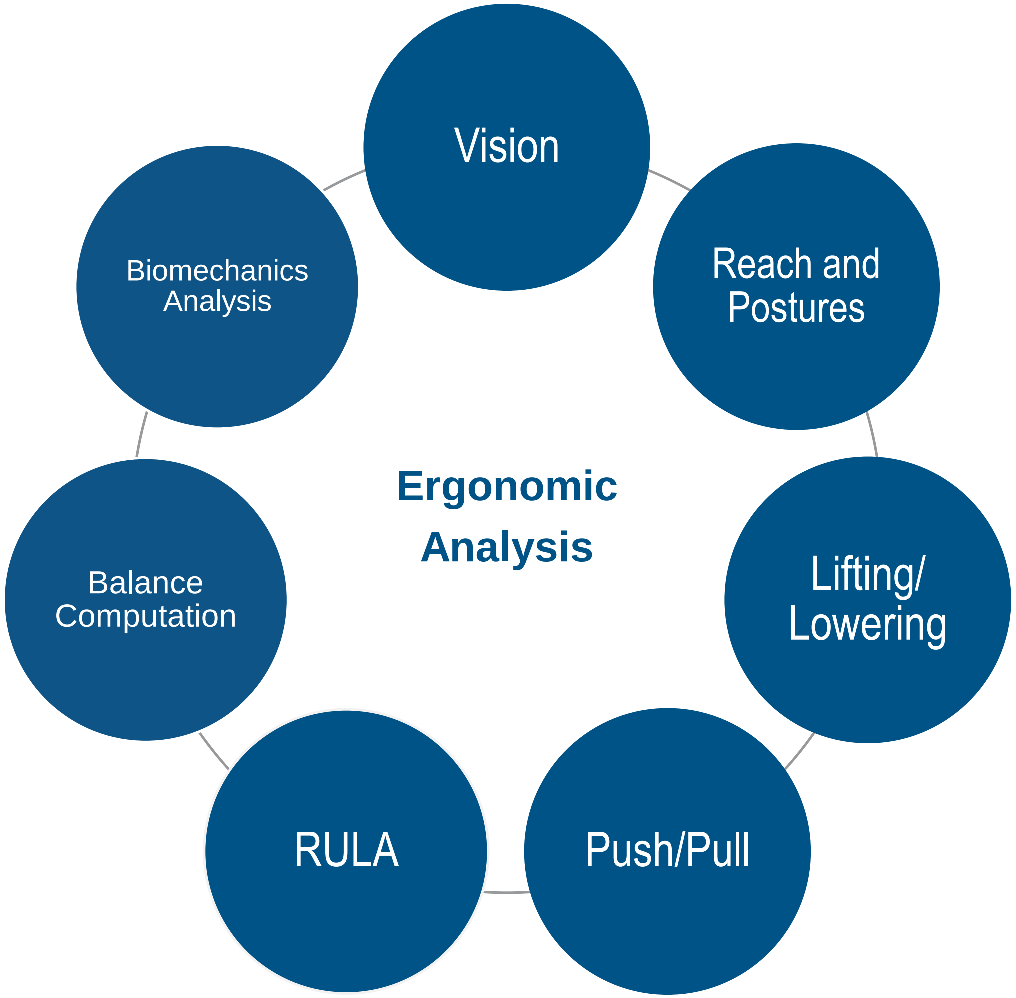
# Foundation <cont.>

How Dassault Systemes's Ergonomics Simulation can help cabin interior simulation:

- Manikin's Anthropometry (103 variables) based on population studies
- HuMoSim (Human Motion Simulation) equations for realistic manikin posture and motion prediction and evaluation. Assuring the 3D environment link and interaction between the monument and manikin.

# Foundation <cont.>

How Dassault Systemes's Ergonomics Simulation can help cabin interior simulation:




RULA: Rapid Upper Limbs Assessment

# Method - Itens Covered

ACCESSABILITY AND

REACHABILITY

CLEARANCE AND

INTERFERANCE

DYNAMIC

SIMULATION

APPLIED FORCES

ERGONOMIC

EVALUATION

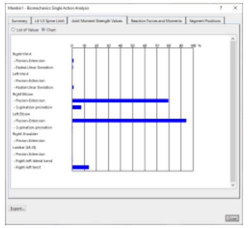
# Method - Procedure

1 Monument 3D Model

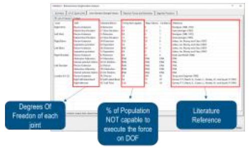
2 Manikin Population Definition

3 Postures, Human Interactions, and Forces

4 Postures Analysis



5 Biomechanical Analysis




6 Definition of Manikin Task

7 Dynamic Simulation

# Method – Test Plan

| GEOMETRY | CASE PARAMETERS | TEST PLAN | SIMULATION OUTPUT | PASS/FAIL CRITERIA |
| --- | --- | --- | --- | --- |
| • The 3D geometry of the cabin interior environment. | • Defined population<br>• Any additional data necessary for the simulation | • Required step-by-step procedure of the cabin interior test | • Defined point of interest of the simulation for analysis. | • Defined requirements for a successful analysis based on the scope of the simulation. |

# Method – Test Plan Example

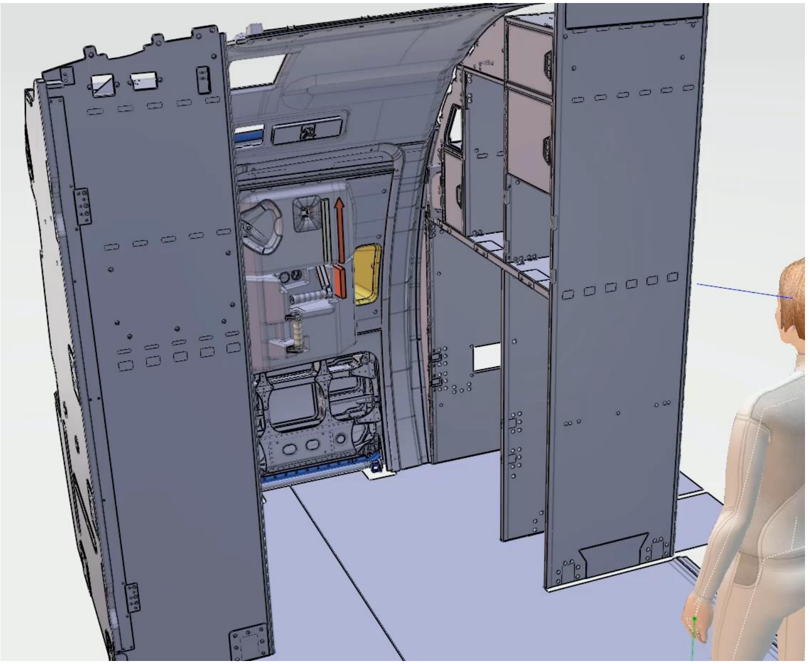
## Forward Service Door Evaluation

| GEOMETRY | CASE PARAMETERS | TEST PLAN | SIMULATION OUTPUT | PASS/FAIL CRITERIA |
|---|---|---|---|---|
| • The 3D geometry of the cabin interior environment. | • 5%ile american female<br>• 95%ile american male<br>• Actuation force of 12 kg | • Procedure A<br>- Initial condition: manikin positioned in the aisle looking to the service door;<br>- Act 1: manikin 1 walks towards the service door;<br>- Act 2: manikin 1 hold the door handle with both hands;<br>- Act 3: manikin 1 raises the door handle. | • Show the dynamic analysis of manikin 1 and manikin 2 interacting with the service door system in a single movement;<br>• Understand the difficulty of a small person, as to the way and the force applied to the opening and a large person in a small space, considering the responses of the human factor. | • The simulation based on the geometry, case parameters and test procedure were possible?<br>• The dynamic simulation results supplied data to support a human interaction evaluation as action forces; biomechanical stresses of the operators; clearance/interference of body segments and reachability's.<br>• Was the software able to detect limitations on the human interaction such as forces, reach and move? |

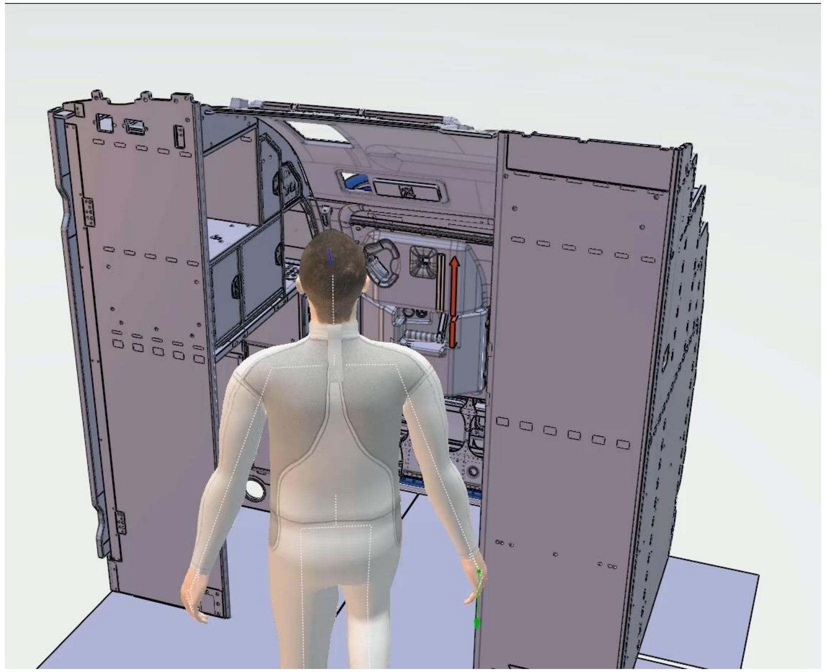
# Test Cases

Test cases were selected among the standard motions <human capabilities> of the passengers and crew inside the cabin while using the interiors features or reaching and moving objects in either seated or standing postures.

## Forward Service Door Evaluation



Female 5%

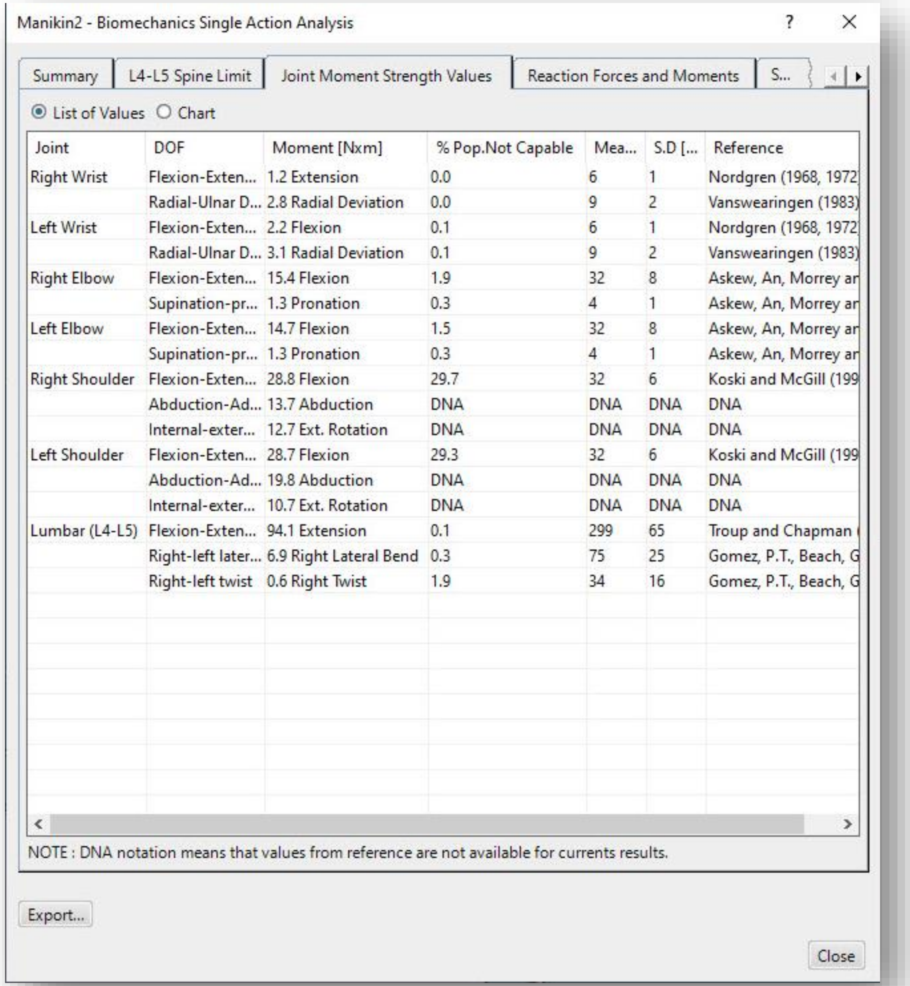


Male 95%

# Test Cases - Fwd. Service Door Evaluation

## Results

- Dynamic simulation for both manikins operating the lever, door and, following the door kinematics;
- Analysis of the female manikin, up to 75% of the female population could operate the lever and open the door;
- Male manikin had a collision between its head and the airplane ceiling when completely standing, being necessary for it to lower its head;
- Standard ergonomic evaluation.


Manikin2 - Biomechanics Single Action Analysis

Summary | L4-L5 Spine Limit | Joint Moment Strength Values | Reaction Forces and Moments | S...

List of Values   Chart

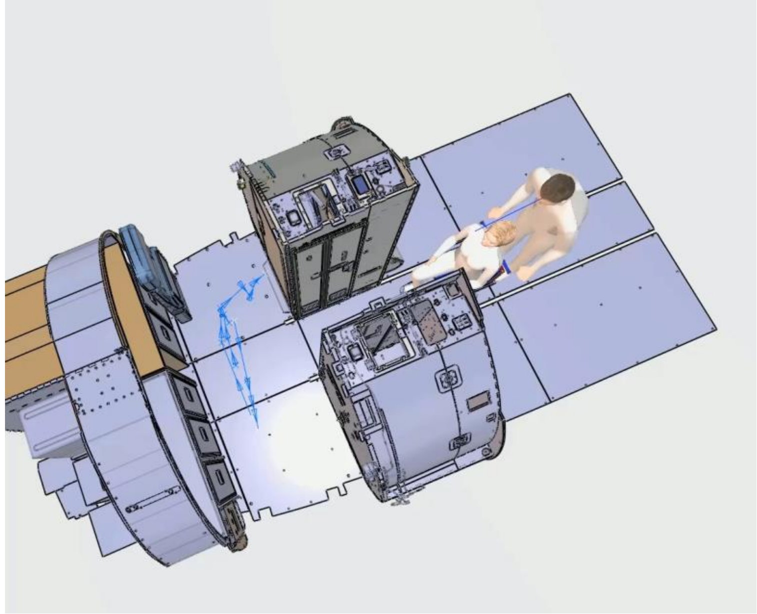
| Joint | DOF | Moment [Nxm] | % Pop.Not Capable | Mea... | S.D [... | Reference |
|---|---|---|---|---|---|---|
| Right Wrist | Flexion-Exten... | 1.2 Extension | 0.0 | 6 | 1 | Nordgren (1968, 1972 |
| | Radial-Ulnar D... | 2.8 Radial Deviation | 0.0 | 9 | 2 | Vanswearingen (1983) |
| Left Wrist | Flexion-Exten... | 2.2 Flexion | 0.1 | 6 | 1 | Nordgren (1968, 1972 |
| | Radial-Ulnar D... | 3.1 Radial Deviation | 0.1 | 9 | 2 | Vanswearingen (1983) |
| Right Elbow | Flexion-Exten... | 15.4 Flexion | 1.9 | 32 | 8 | Askew, An, Morrey ar |
| | Supination-pr... | 1.3 Pronation | 0.3 | 4 | 1 | Askew, An, Morrey ar |
| Left Elbow | Flexion-Exten... | 14.7 Flexion | 1.5 | 32 | 8 | Askew, An, Morrey ar |
| | Supination-pr... | 1.3 Pronation | 0.3 | 4 | 1 | Askew, An, Morrey ar |
| Right Shoulder | Flexion-Exten... | 28.8 Flexion | 29.7 | 32 | 6 | Koski and McGill (199 |
| | Abduction-Ad... | 13.7 Abduction | DNA | DNA | DNA | DNA |
| | Internal-exter... | 12.7 Ext. Rotation | DNA | DNA | DNA | DNA |
| Left Shoulder | Flexion-Exten... | 28.7 Flexion | 29.3 | 32 | 6 | Koski and McGill (199 |
| | Abduction-Ad... | 19.8 Abduction | DNA | DNA | DNA | DNA |
| | Internal-exter... | 10.7 Ext. Rotation | DNA | DNA | DNA | DNA |
| Lumbar (L4-L5) | Flexion-Exten... | 94.1 Extension | 0.1 | 299 | 65 | Troup and Chapman ( |
| | Right-left later... | 6.9 Right Lateral Bend | 0.3 | 75 | 25 | Gomez, P.T., Beach, G |
| | Right-left twist | 0.6 Right Twist | 1.9 | 34 | 16 | Gomez, P.T., Beach, G |

NOTE : DNA notation means that values from reference are not available for currents results.

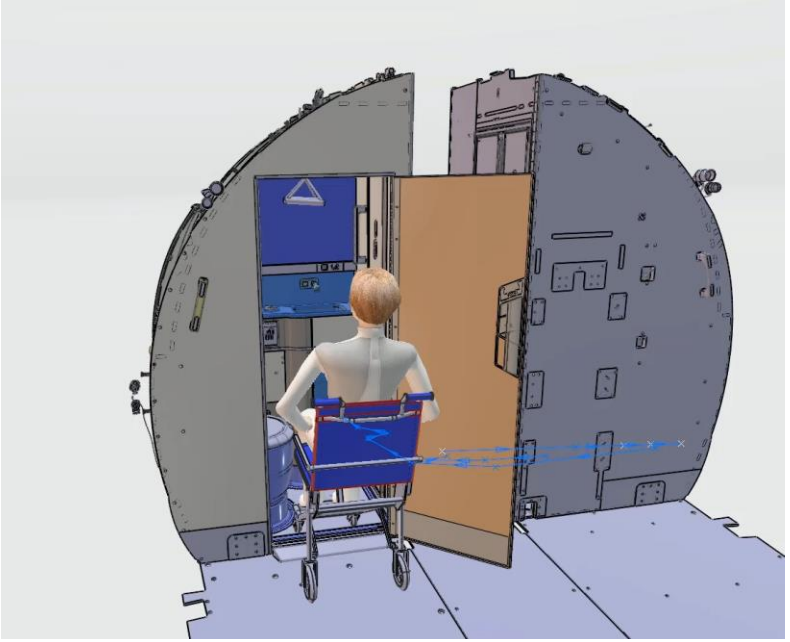
Export...   Close

# Test Cases

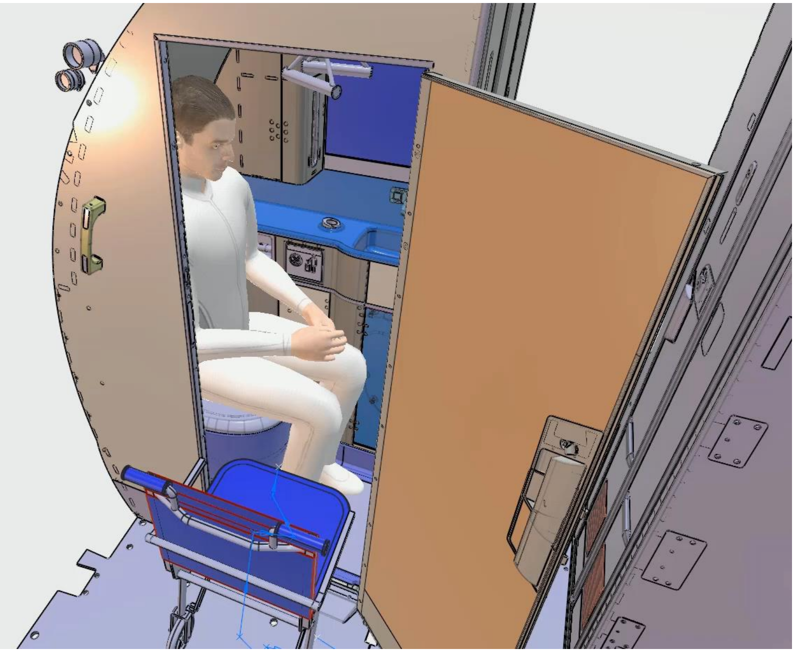
## Aft Accessible Lavatory Accessibility



Male assistant pushes wheelchair to lavatory



Female manikin manuever to lavatory seat



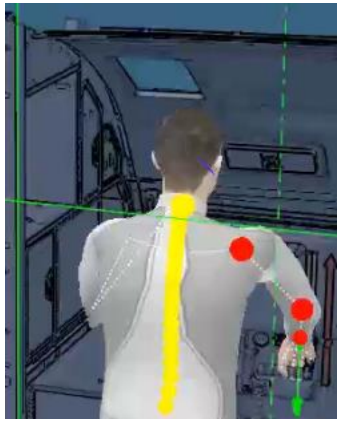
Male manikin manuever to wheelchair

# Test Cases - Aft Accessible Lavatory Accessibility

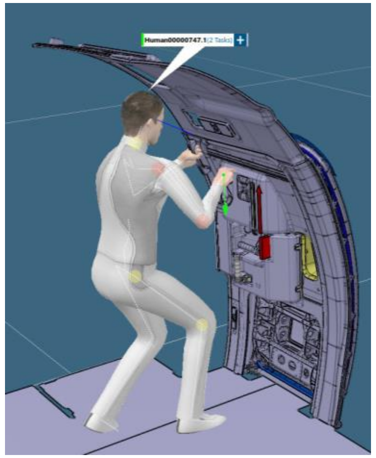
## Results

- The manikin was able to pick up the wheelchair and manipulate it, also the manikin was able to open the lavatory's door with door kinematics;
- The solution was capable to display all the movements that the small person need to do to maneuver to the lavatory seat using the support handle;
- The solution was capable to display all the movements for a large person to maneuver from the lavatory seat to the wheelchair due to several interferences on manikin knees;

# Test Cases Results Summary



- Ergonomics **analysis** with realistic manikins
- Human activities **validation** for different population
- **Early** product design validation
- "With design visualization, ***everyone*** sees the same *image* or *simulation,* and you can build consensus much **easier**."



# Discussion

- The solution was capable to perform dynamic simulation in the cabin interior;
- The manikin was able to interact and operate cabin interior features;
- The solution was capable to detect and show limitations in the human interactions, based on the simulation outputs (forces, reach, movement etc);
- The dynamic simulation results supply data to support cabin interior human interaction evaluation.

# Conclusion / Next steps

- The solution demonstrated that is capable to perform biomechanical cabin interior simulation using digital aircraft model, this enables:
  - Support cabin safety interior tests;
  - Streamlining interior test preparations and;
  - In the future, replace some interior certification tests.

Next Step

- We need now to identify with regulatory authorities an acceptance method to use these simulations as alternative means of compliance for interior validation and certification.

# References

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*Étude anthropométrique des forces terrestres-1997, 98-CR-15,Department of National Defence, Mars 1998.*

*Étude anthropométrique des personnels miltaires des armées, Enquête 1991 sur les personnels masculins et féminins, ConventionDRET 90/120, Doc. AA 274/92, Mars 1992.*

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*1988 Anthropometric survey of U.S. Army personnel : Summary statistics interim report , NATICK/TR-89/027, United States Army Natic research, development and engineering center, March 1989*

# References

## Manikin Motion Studies:


*Human Scale*

*NASA-STD-3000*

*AAOS  (American Academy of Orthopedic Surgeons)*

*AMA  (American Medical Association)*

*Boone and Azen*

*Roach and Miles*

*Harris (1968)*

*WADC TR 55-159*

*Dreyfuss (1966)*

*U.S Armed forces Medical Journal*

*Norkin, C. C., White, D. J.¸ Measurement of Joint Motion – A guide to goniometry. Edition 2, F.A. Davis Company, Philadelphia, 1995.*

*Safework Inc. is a Technical Member of the HUMOSIM Consortium*

# THANK YOU!