Three Dimensional Design and Simulation of Work Space Layouts and Work Activities that Contribute to Productive and Safe Employees

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August 26, 2009

Biography (to be removed by track lead)

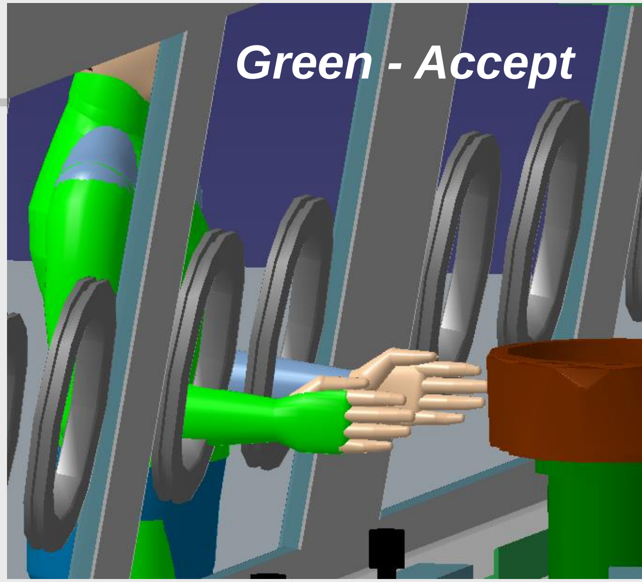
Track 5 – Integration of Safety Into Design: 301 E, Wed. Aug. 26 at 3:00-3:30

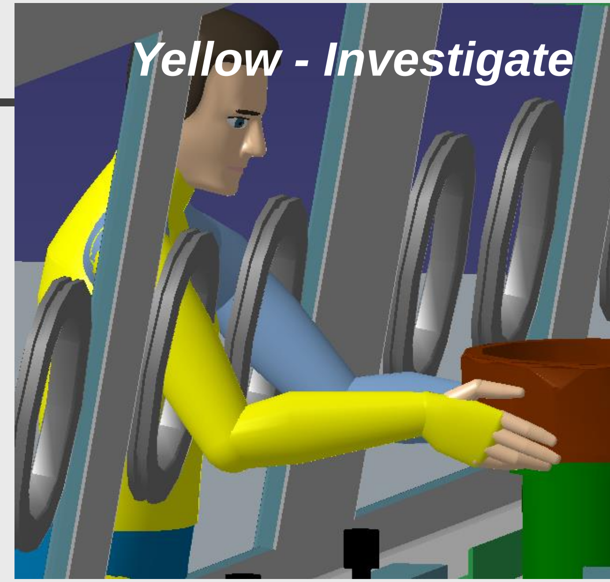
- **Karen Bills** received a B.S. degree in mechanical engineering and a M.S. degree in industrial engineering, in 1980 and 1993, respectively, both from the University of Tennessee, Knoxville. She has worked on simulations of hardware response to earthquakes, graphical simulation of naval and nuclear designs, decision support process simulation, and robotic simulation for deactivation of the Department of Energy (DOE) facilities. She has spent 28 years at the Oak Ridge DOE facilities and is currently working on prevention of ergonomic risk in design using digital human modeling. Vocation includes innovative ways to display and analyze enormous amounts of disparate data to create cohesive information for exchange of ideas in aligning and meeting goals. She may be reached via e-mail at <billskc@y12.doe.gov>.

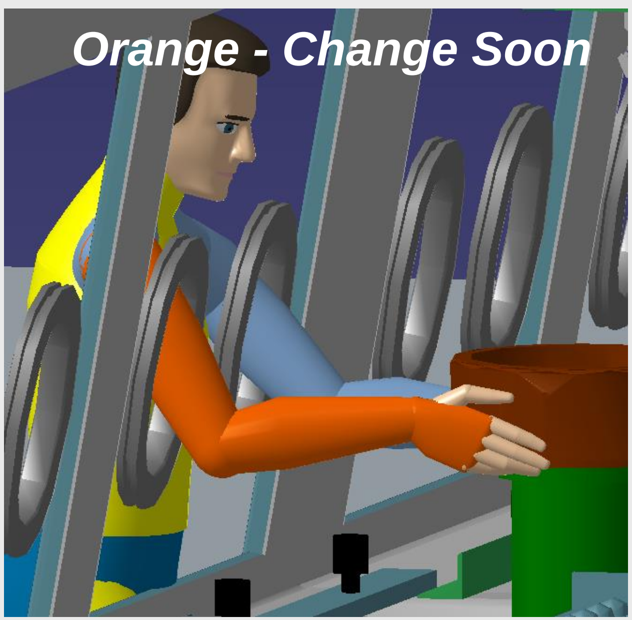
Introduction

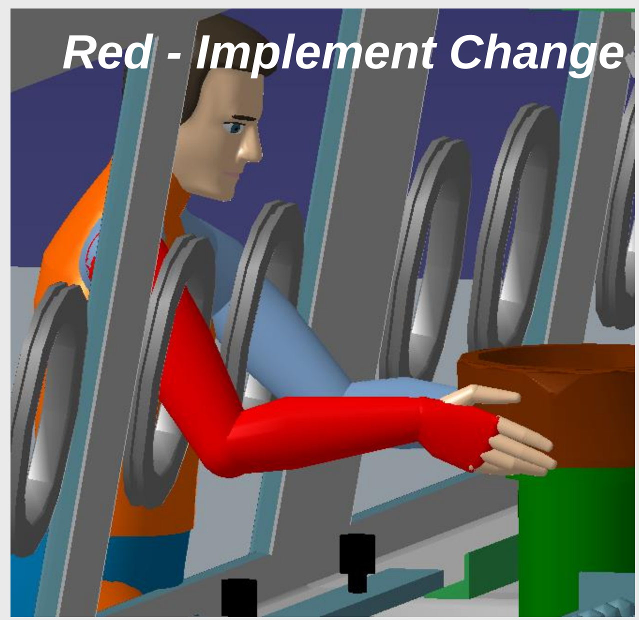
- Workplace ergonomic injuries are significant, costly, and require long recovery periods.
- Design is the best and most economical time to identify problems and find a solution.
- Digital human modeling addresses a wide range of human factors.

- Reach
- Fit
- Vision
- Postures
- Forces

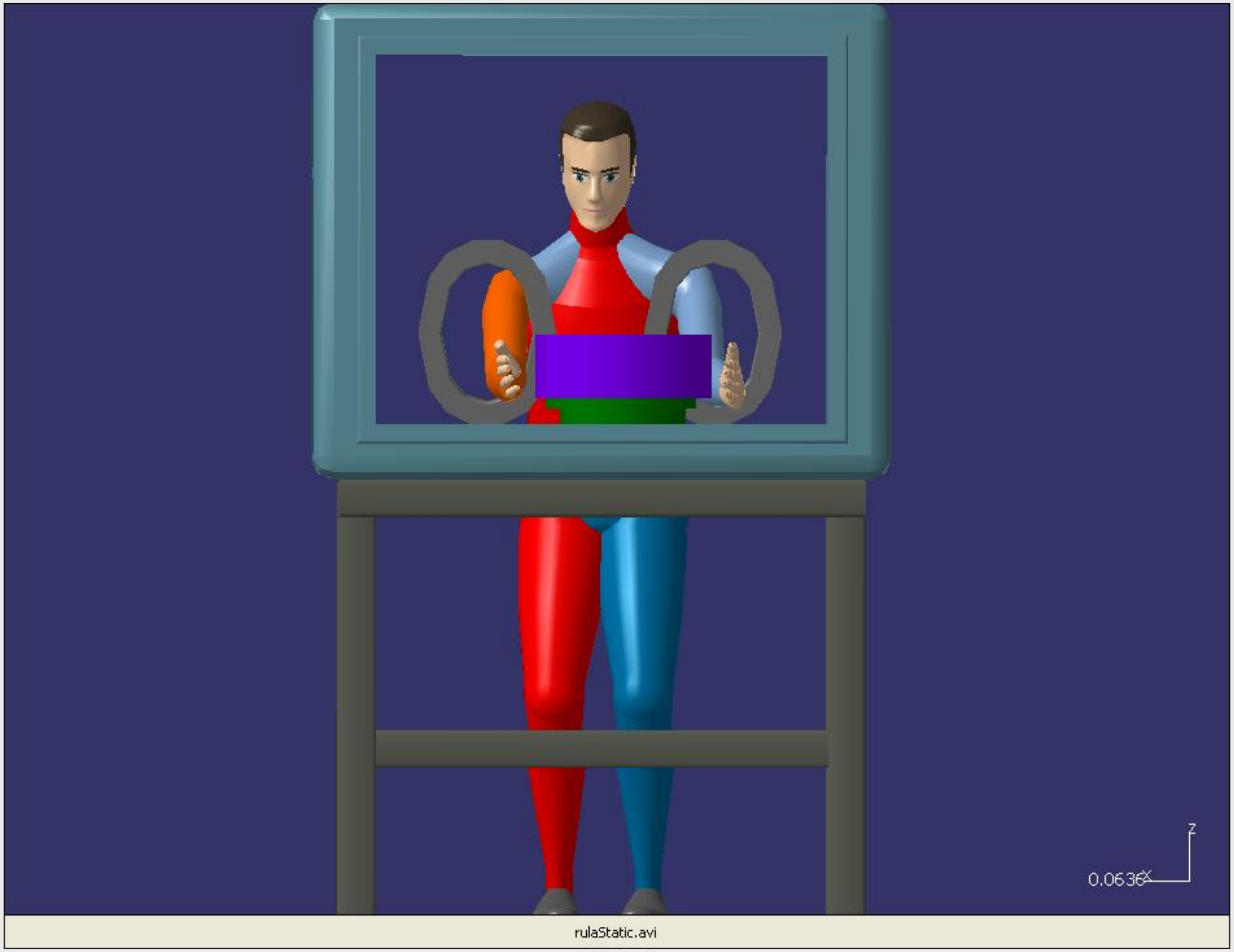

Green - Accept


Yellow - Investigate


Orange - Change Soon


Red - Implement Change

Digital Human Simulation

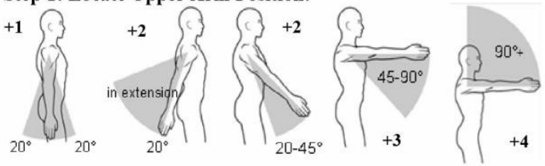


RULA Employee Assessment Worksheet

*based on **RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99***

A. Arm and Wrist Analysis

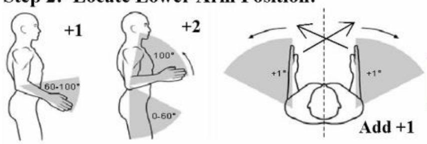
Step 1: Locate Upper Arm Position:



Step 1a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

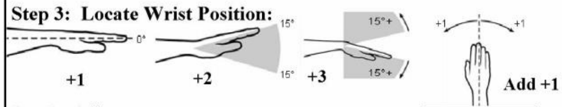
Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust…
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust…
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	1 Wrist Twist 1	1 Wrist Twist 2	2 Wrist Twist 1	2 Wrist Twist 2	3 Wrist Twist 1	3 Wrist Twist 2	4 Wrist Twist 1	4 Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

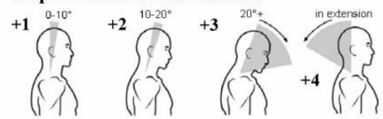
Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

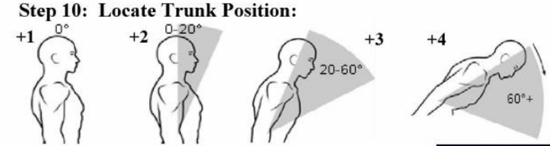
Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Trunk Score

Step 10a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	1 Legs 1	1 Legs 2	2 Legs 1	2 Legs 2	3 Legs 1	3 Legs 2	4 Legs 1	4 Legs 2	5 Legs 1	5 Legs 2	6 Legs 1	6 Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture Score B

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk & Leg Score

Task name: ____________ Reviewer: ____________ Date: ___/___/___

provided by Practical Ergonomics

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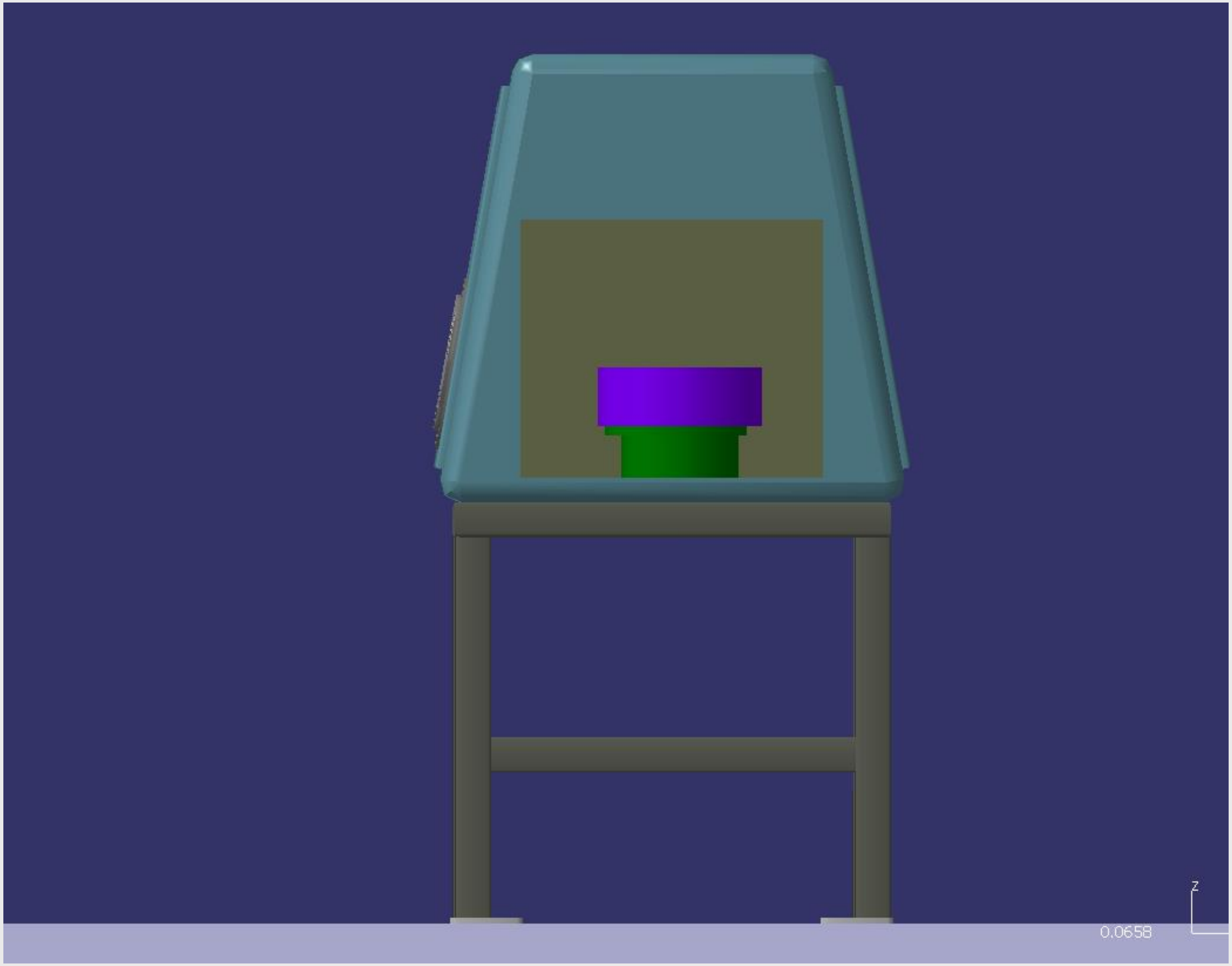
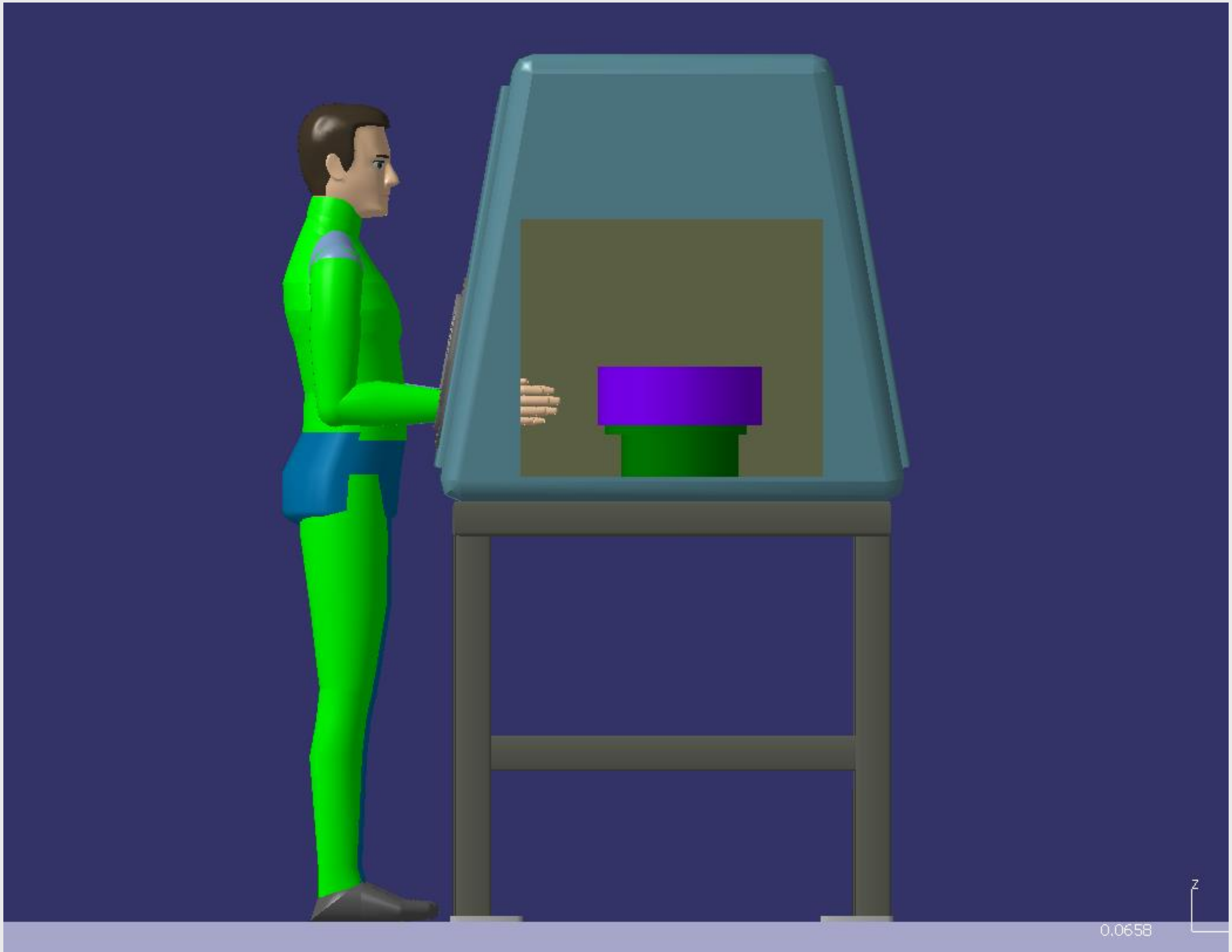
Environment

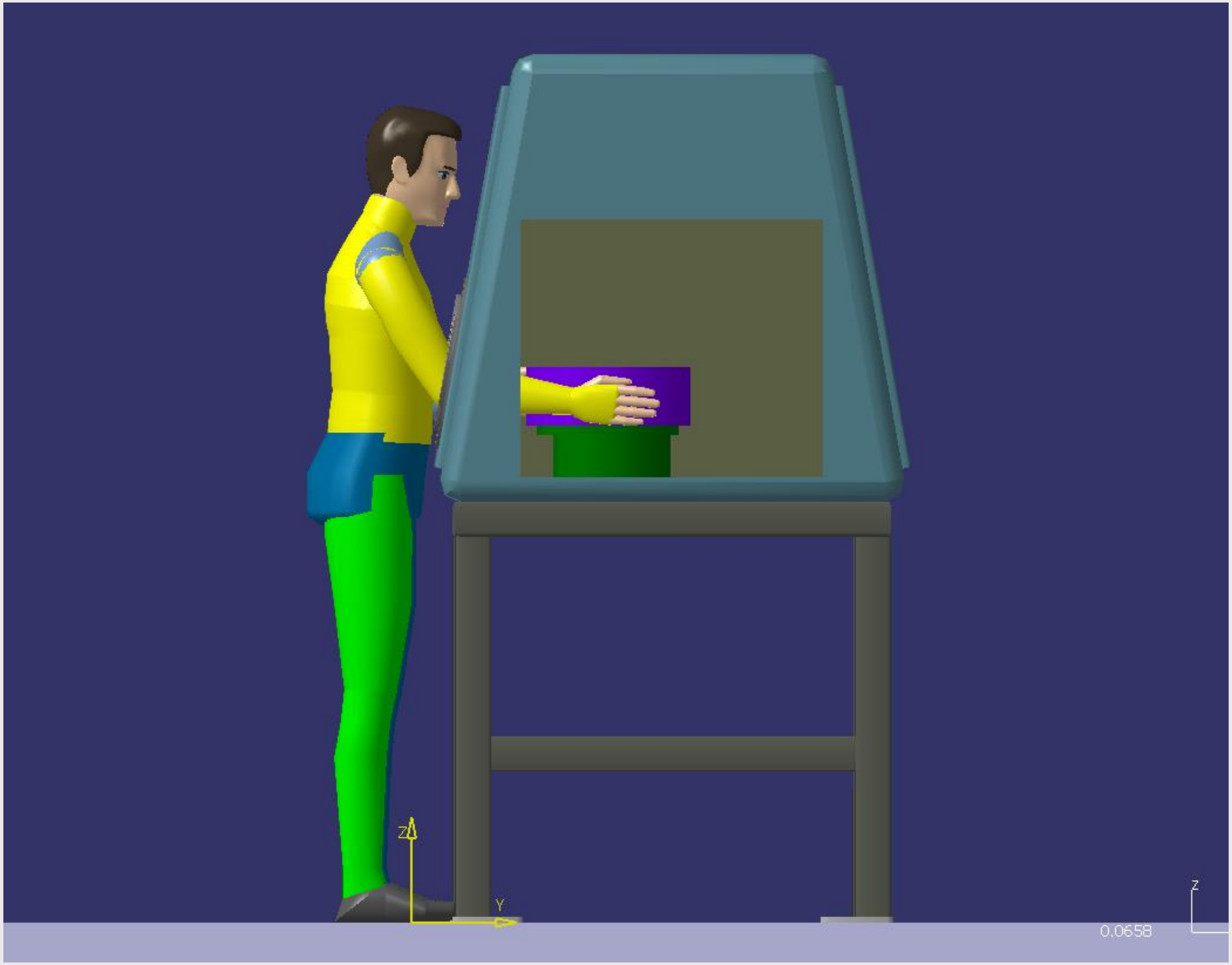


Digital Human

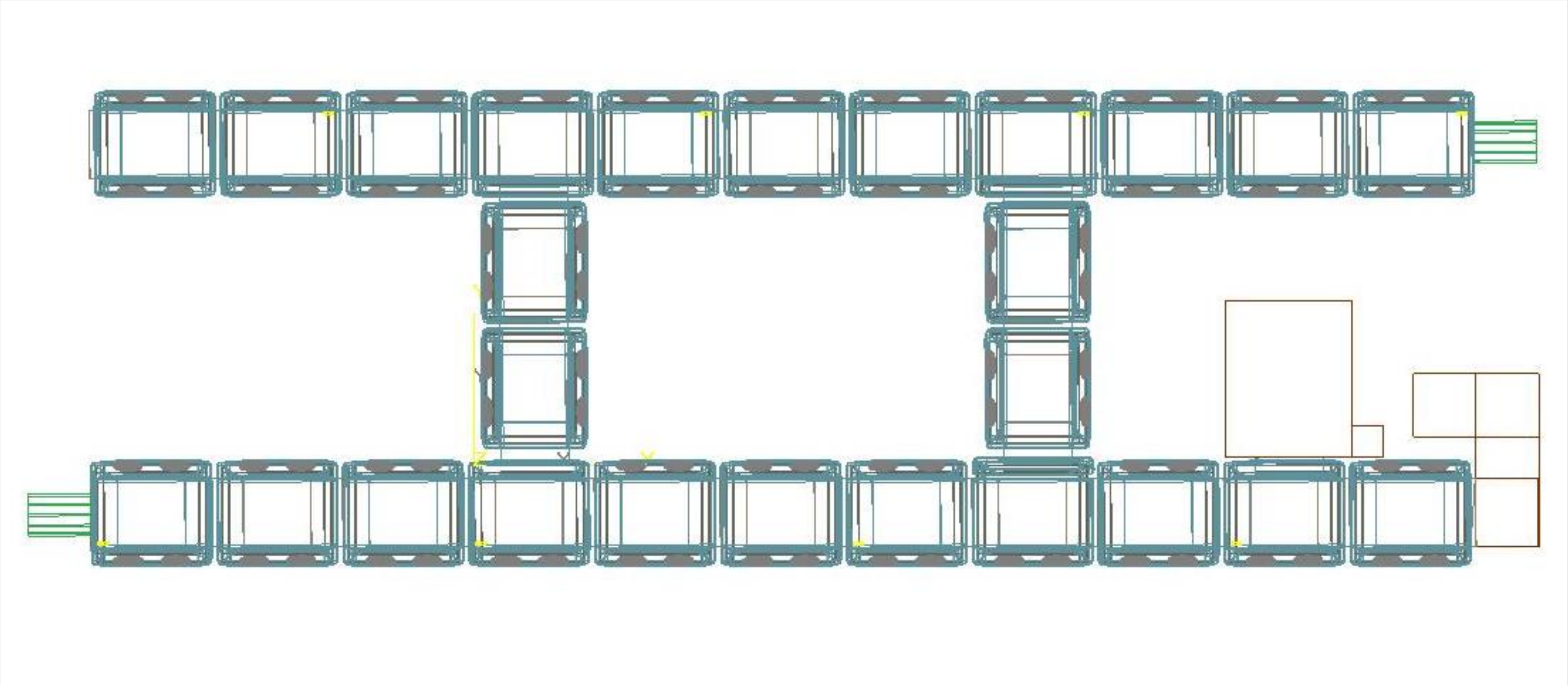


Digital Human Adapts to Environment

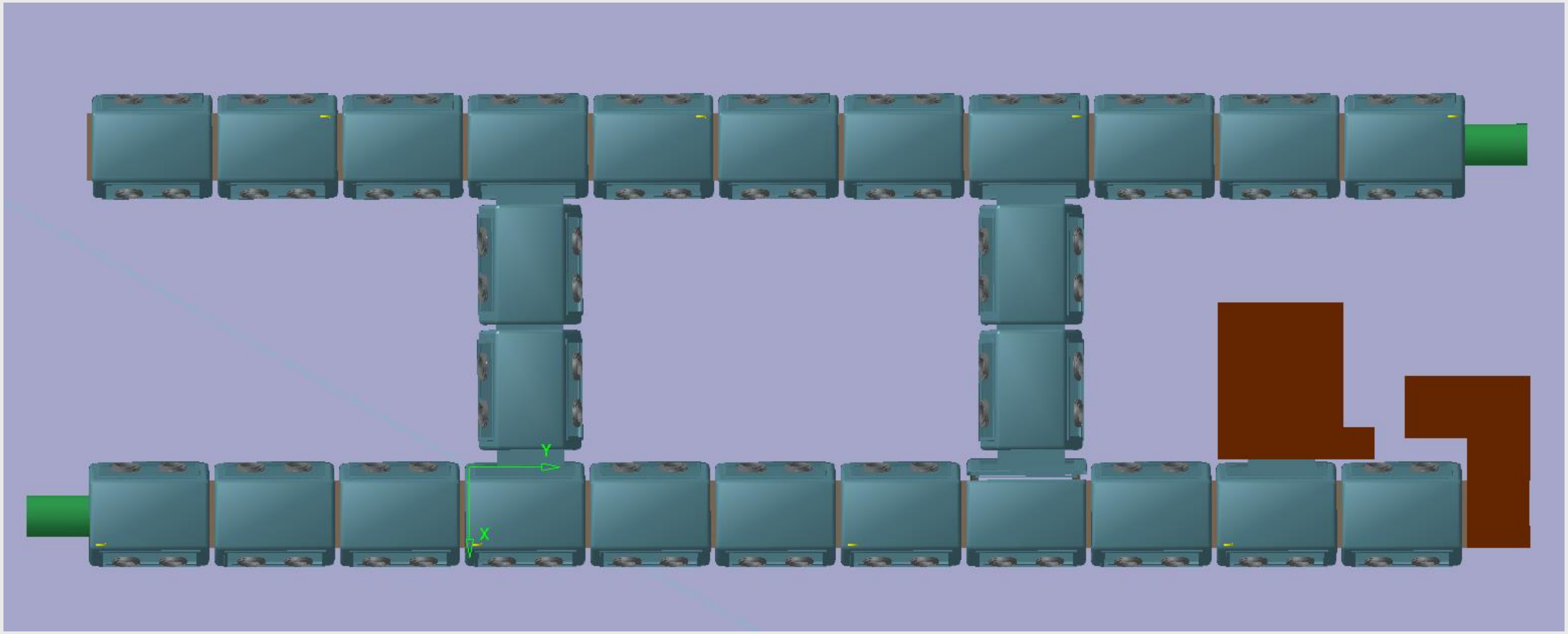
Environment Adapts to Digital Human



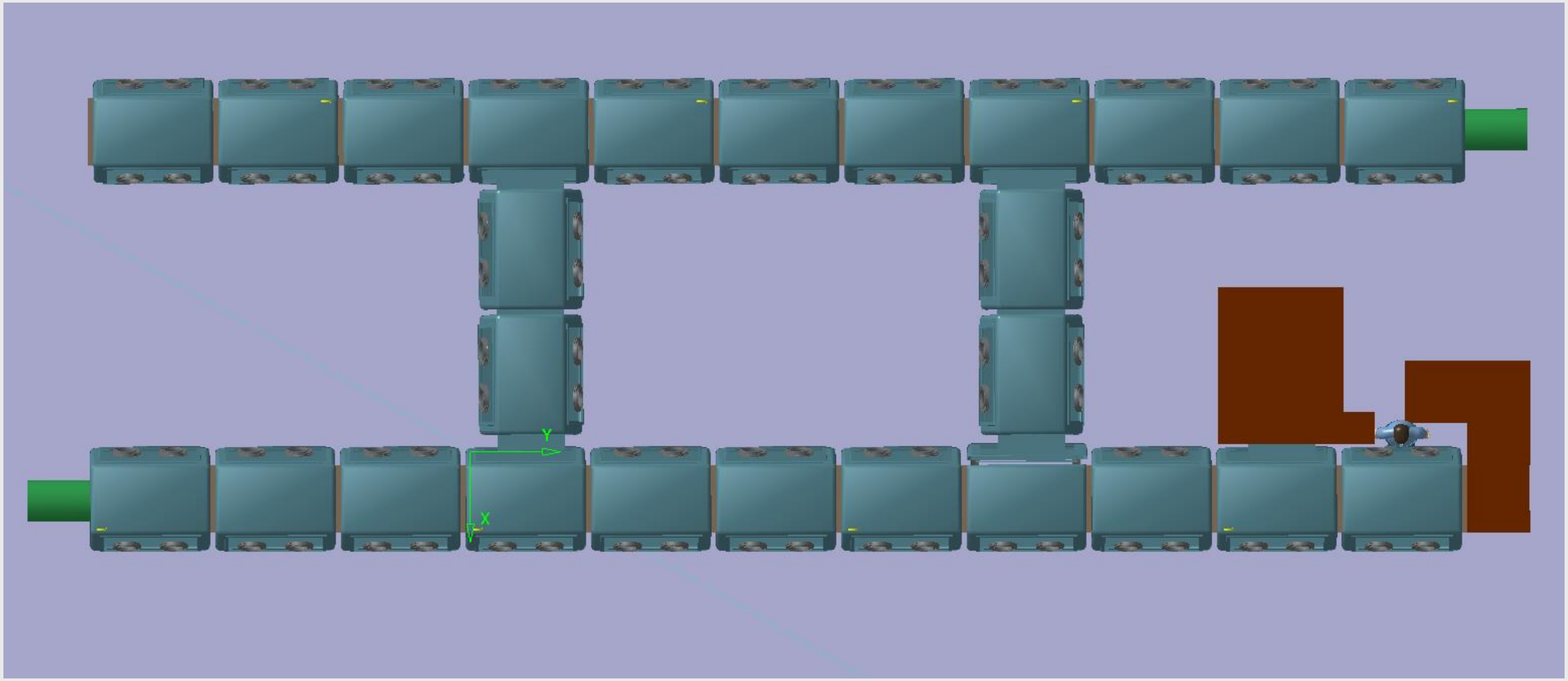
Digital Human Fits Environment



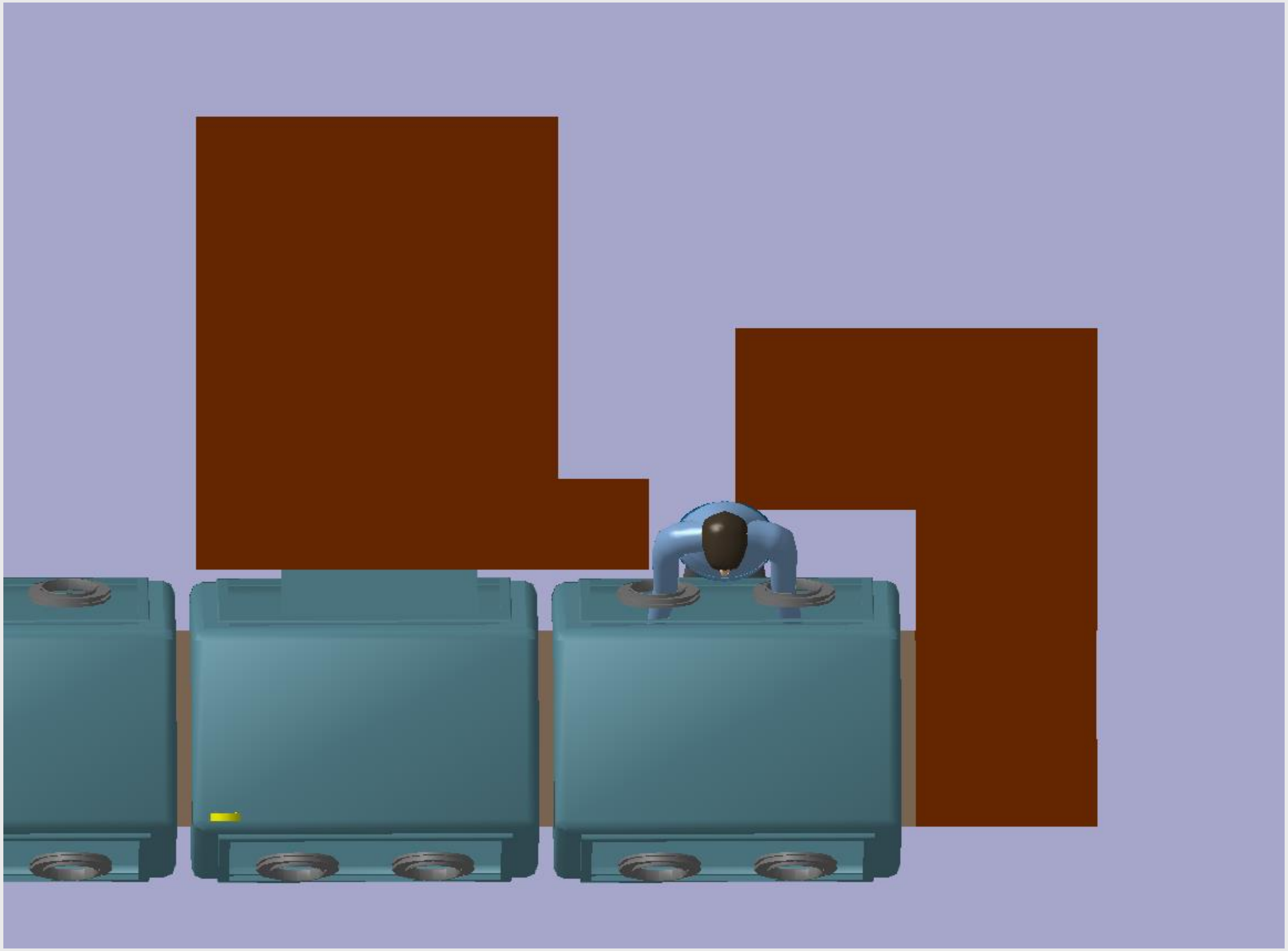
Digital Human Fits Environment



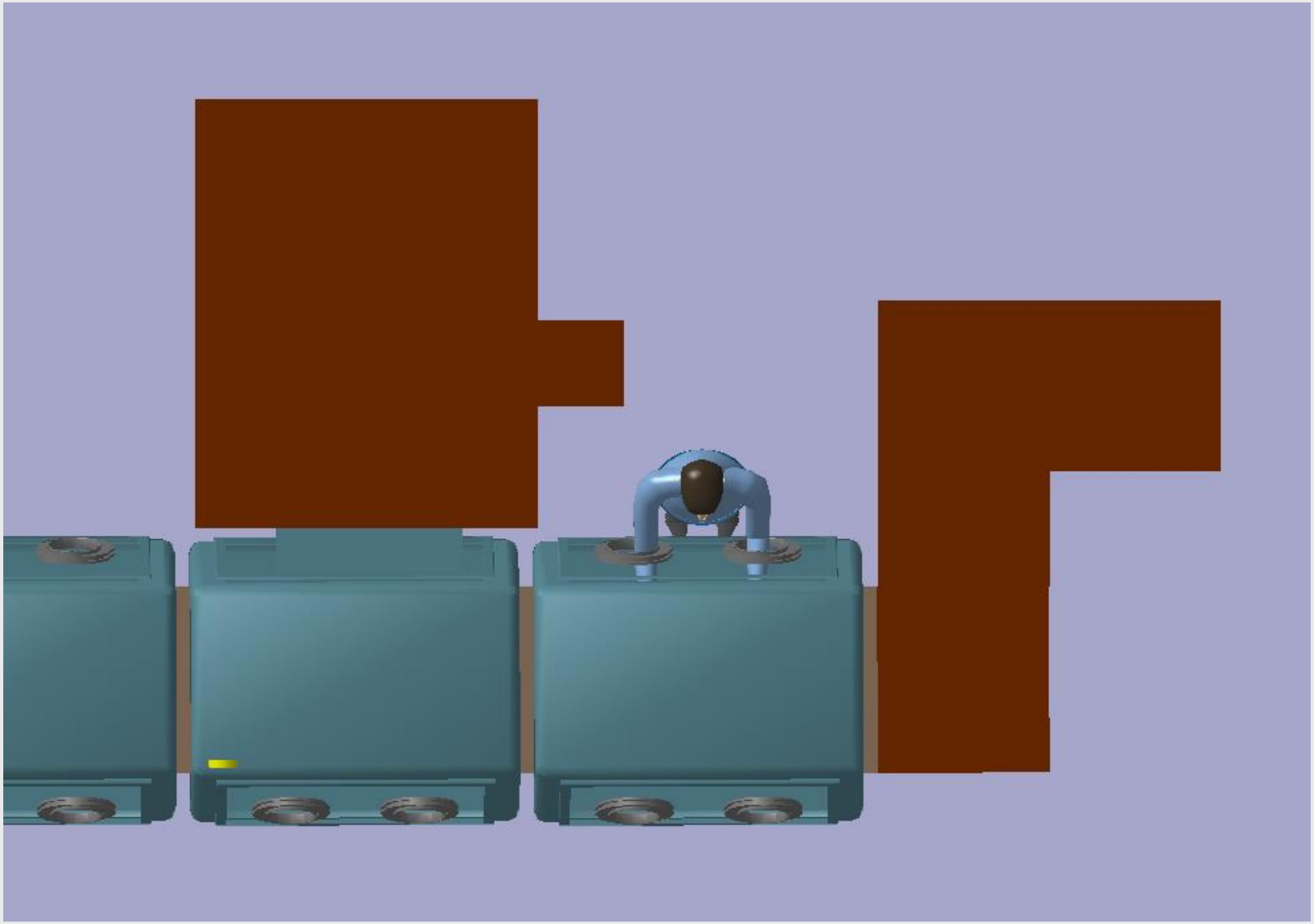
Digital Human Fits Environment



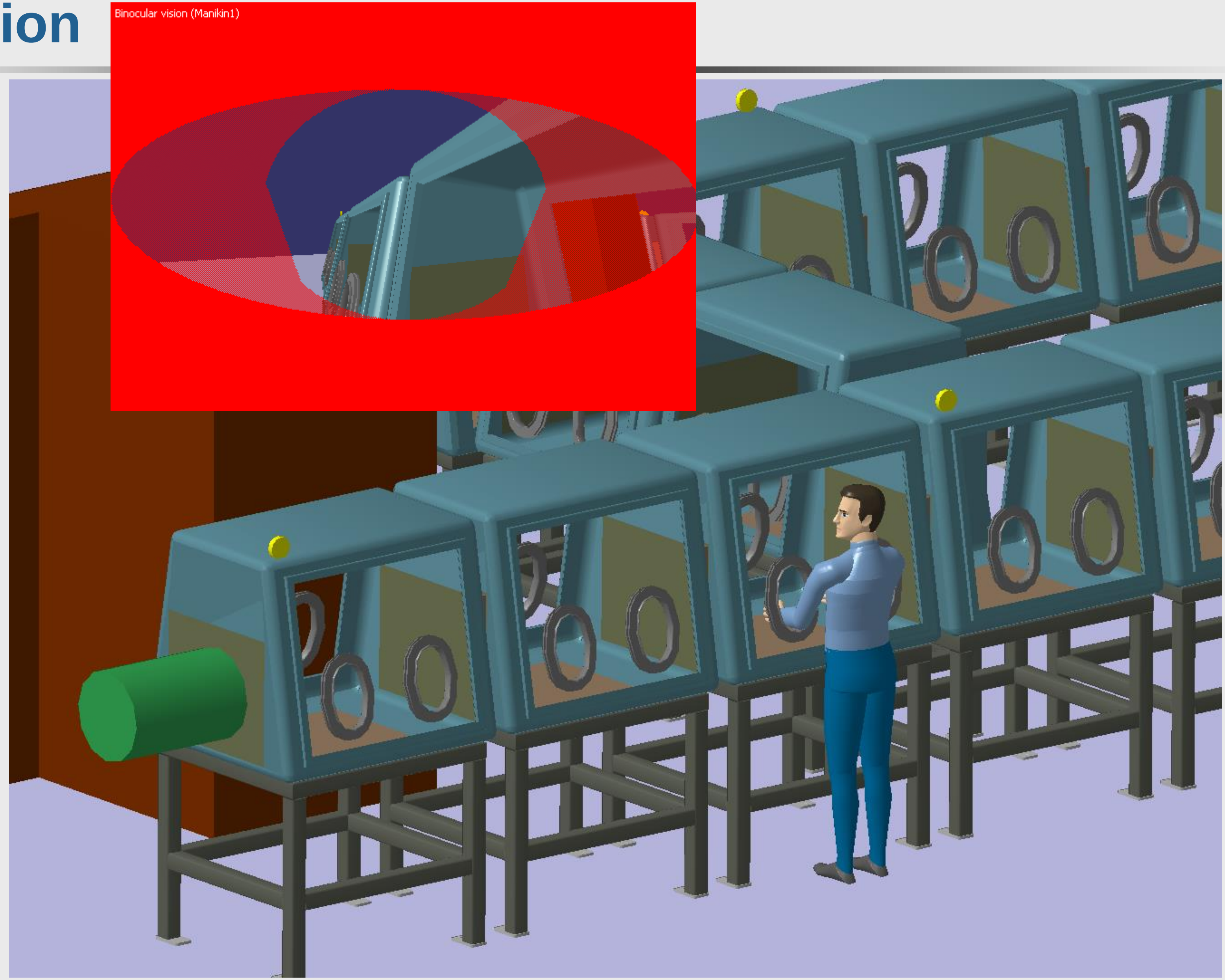
Digital Human Fits Environment



Digital Human Fits Environment



Vision



Posture and Force

BRIEF™ Survey – Baseline Risk Identification of Ergonomic Factors

Version 3.0

Step 1	
Complete Job Information	Job Name: ______ Site: ______ Station: ______ Date: ______ Dept: ______ Shift: ______ Product: ______

Step 2

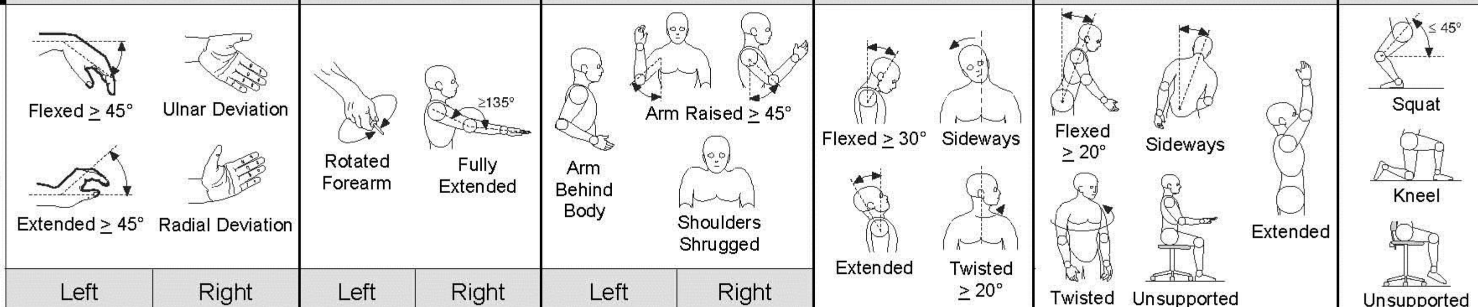
Identify Risks

▼

2a. Mark Posture and Force boxes when risk factors are observed.

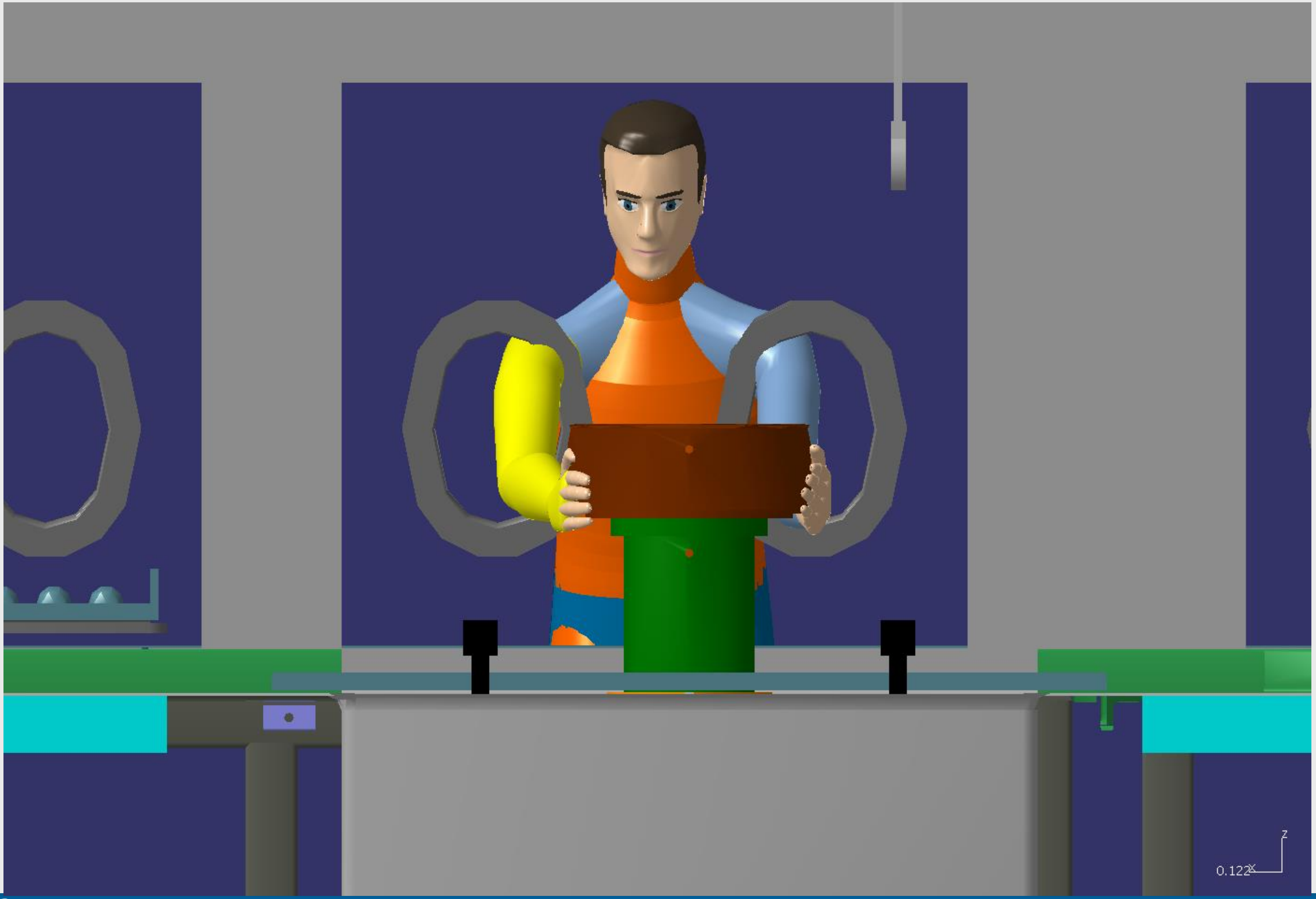
▼

2b. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

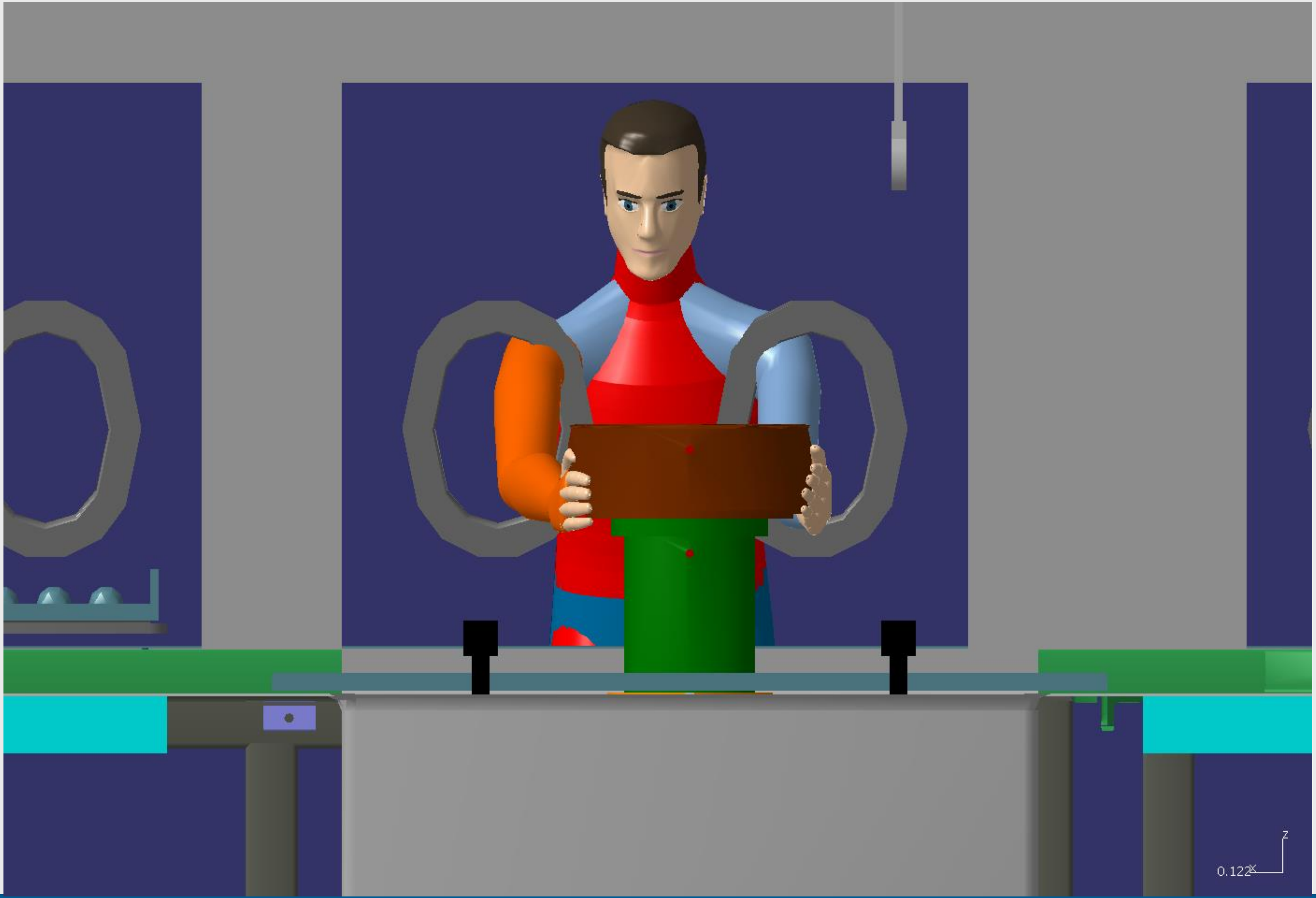


	Hands and Wrists		Elbows		Shoulders		Neck	Back	Legs
	Left	Right	Left	Right	Left	Right			
2a. Posture	☐	☐	☐	☐	☐	☐	☐	☐	☐
Force	Pinch Grip or Finger Press ≥ 2 lb (0.9 kg), or Power Grip ≥ 10 lb (4.5 kg) ☐	☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 2 lb (0.9 kg) ☐	≥ 25 lb (11.3 kg) ☐	Foot Pedal ≥ 10 lb (4.5 kg) ☐
2b. Duration	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 30% of day ☐
Frequency	≥ 30/min. ☐	≥ 30/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐	≥ 2/min. ☐
Score									
Risk Rating	H M L	H M L	H M L	H M L	H M L	H M L	H M L	H M L	H M L

Zero (0) Weight at Arms Length



Five (5) Pounds at Arms Length



Options to Analyze

- Automated tools to analyze
- Analyze by hand to lesser degree
- Field adjust
- Do nothing

Productivity & Cost Avoidance

600 procedures (4 to 10 tasks within each) 6 used for estimate

Manual Calculation

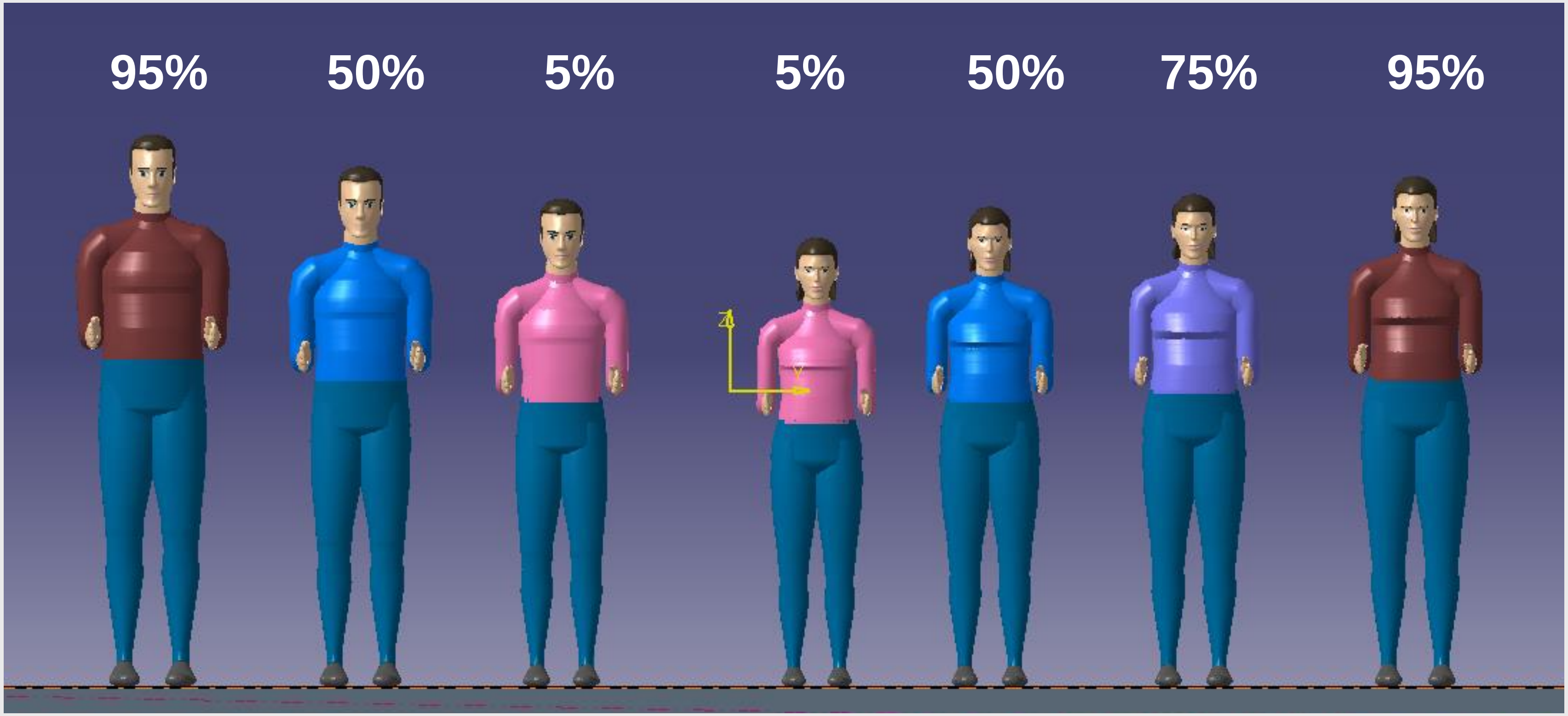
- Review 2 dimensional drawing
  - 450 man-hours
- Reach Test
  - 4500 man-hours
- Vision Test
  - 2700 man-hours
- Force over range of motion
  - 7200 manhours

Human Modeling

- Download 3D depictions of area
  - 45 man-hours
- Reach Test
  - 600 man-hours
- Vision Test
  - 300 man-hours
- Force over range of motion
  - 600 man-hours

Questions

Sample Population
(percentile male and female)

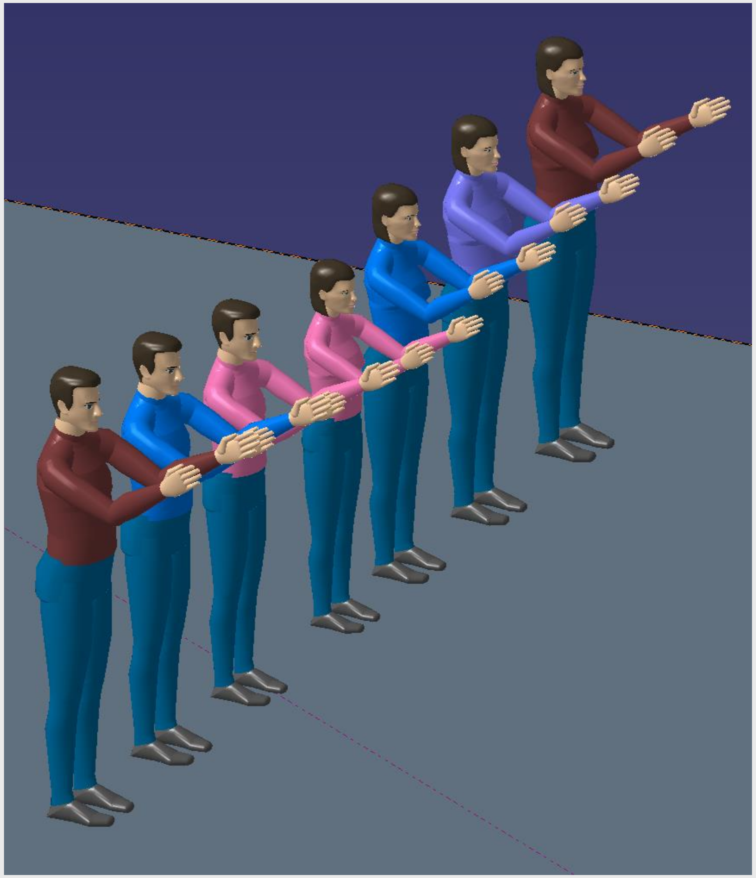


Ergonomic Analysis Tools

- Rapid Upper Limb Assessment (RULA)
- NIOSH 1981 and 1991 Lift Equations
- Snook and Ciriello – Lift/Lower, Push/Pull, Carry
- Biomechanics Single Action Analysis

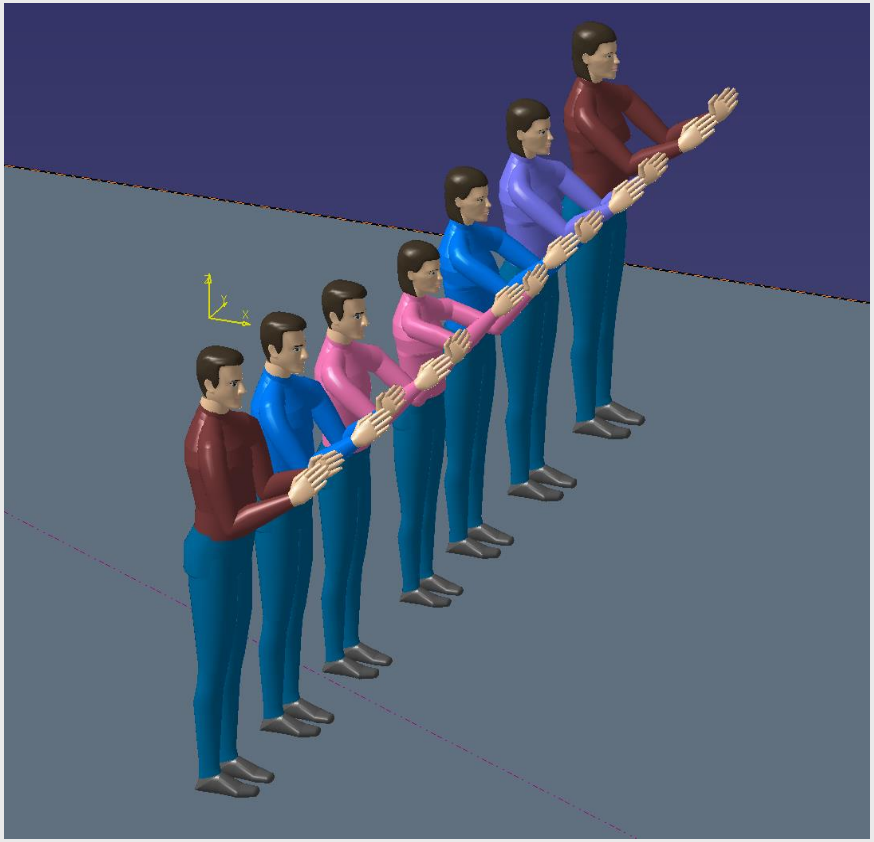
Identical Postures

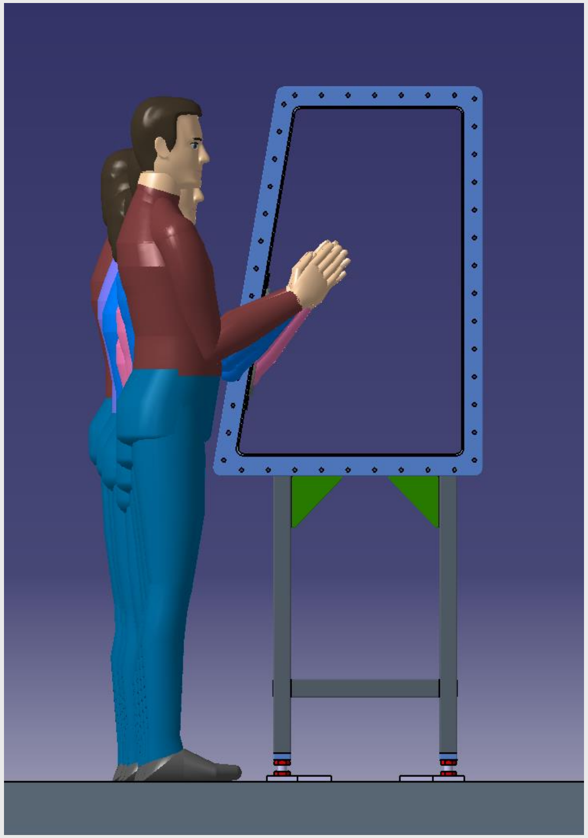
NIOSH 1991 Lifting Equation Recommended Weight Limit
Average = 19 pounds (range 16 to 22)



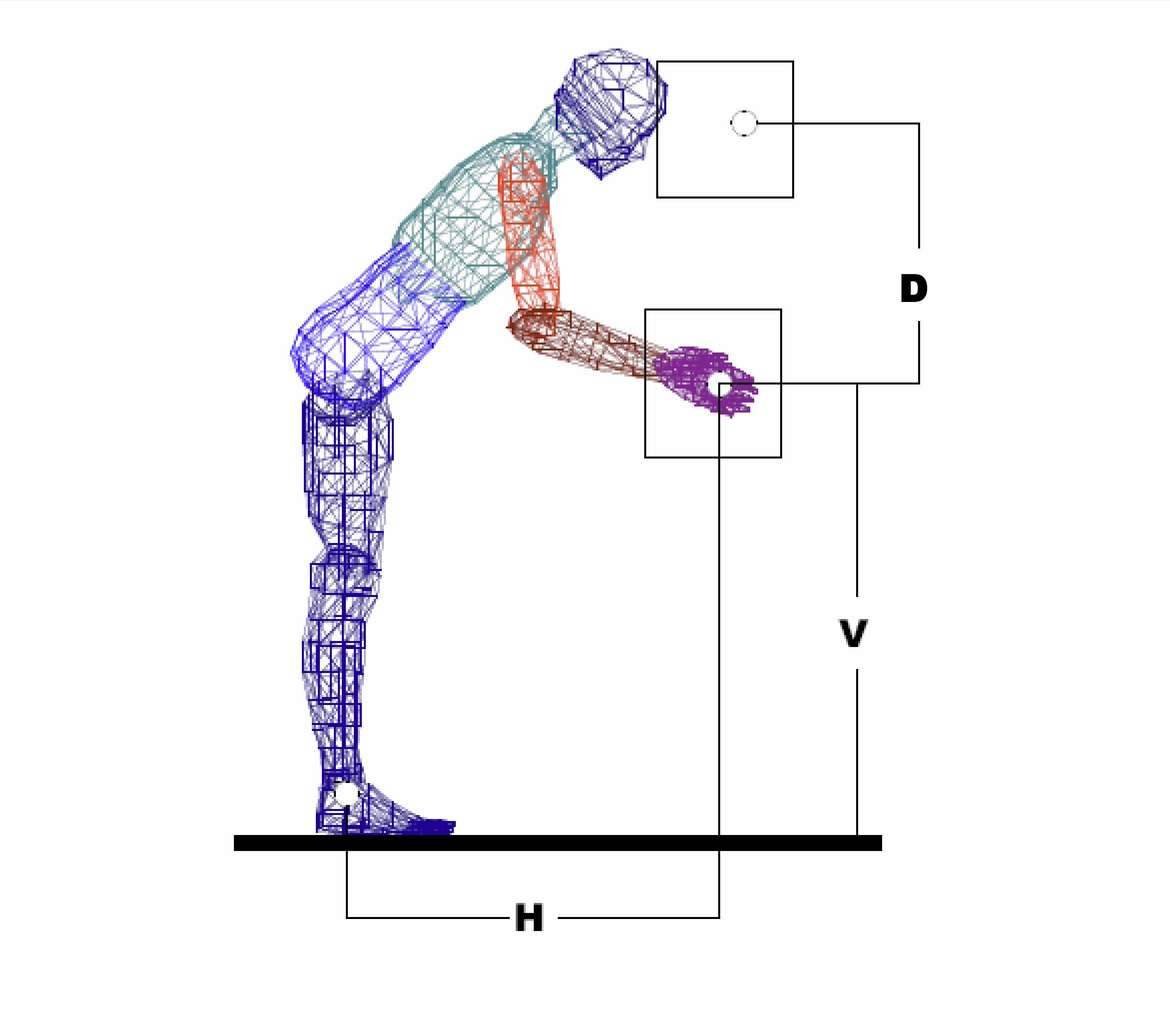
Identical Location

NIOSH 1991 Lifting Equation Recommended Weight Limit
Average = 23 pounds (range 20 to 25)





NIOSH (1991) Lifting Equation Variables



Assume:

•A = angle of asymmetry is zero, no twist

•1 lift every 10800 seconds (3 hours)

•Duration of lift is 1 hour or less

•Coupling Condition is Good

Multipliers:

1) horizontal location (HM) = 10/H
2) vertical location (VM) = 1 – (.0075*|V-30|)
3) vertical travel distance (DM) = .82 + (1.8/D)
4) asymmetry (AM) = 1 – (.0032 * A) = 1
5) frequency (FM) = 1
6) coupling (CM) = 1

All Multipliers are ≤ 1

Recommended Weight Limit (RWL) =

51 lbs × HM × VM × DM × AM × FM × CM

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