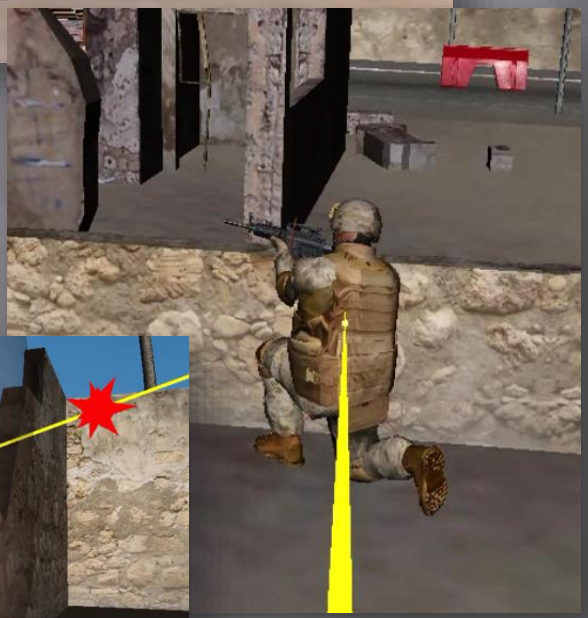
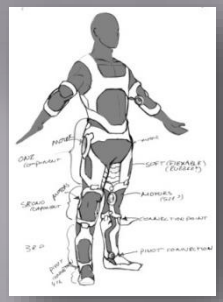
Santos:
Biomechanics, Survivability, and Personal Protective Equipment

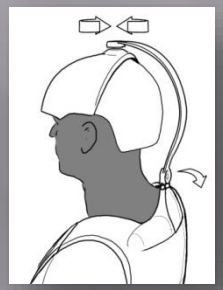


Human system integration (HSI) is insufficiently addressed when designing and analyzing body armor systems

Concepts ➔ Exploration ➔ Iteration ➔ Review ➔ Iteration ➔ Review ➔ Roadmap

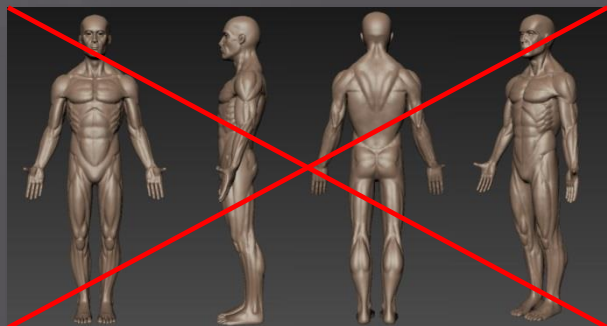




The design process for body armor, and personal protective equipment (PPE) in general is heavily dependent on expensive and time-dependent prototypes.

Given a certain weight to "spend", new tools are needed to determine where should PPE placed in order to maximize mobility and survivability.

The design and effectiveness of PPE, and the propensity for survivability depend critically on the task being completed, on the Warfighter anthropometry, and on the position and motion of internal viscera relative to PPE and threats. A static mannequin is insufficient!



Santos:

1. Provides a tool to help design personal protective equipment (PPE) through virtual comparison of up-stream designs, and to help facilitate next-generation requirements

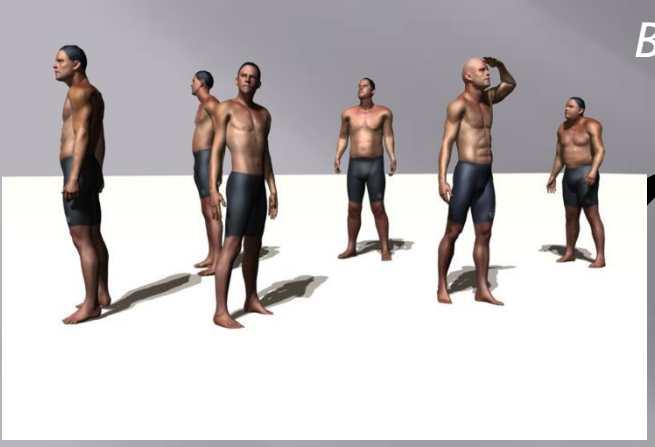
2. Provides real-time virtual biomechanics and mobility analysis

3. Tests the hypothesis that survivability depends on task execution and anthropometry

4. Helps evaluate head borne equipment

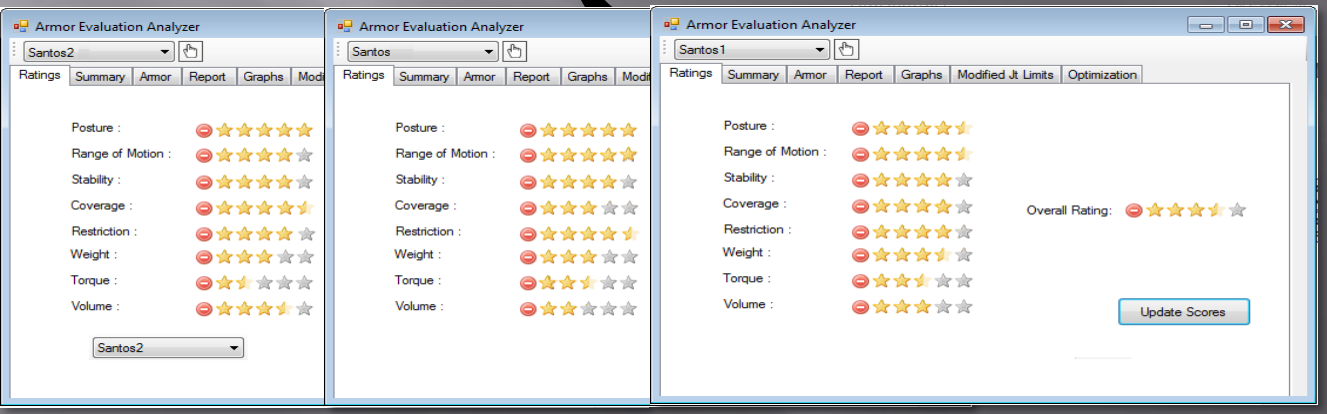
5. Provides new methods for using motion capture to evaluate PPE

Biomechanical Effects of PPE



Simulate Warfighter

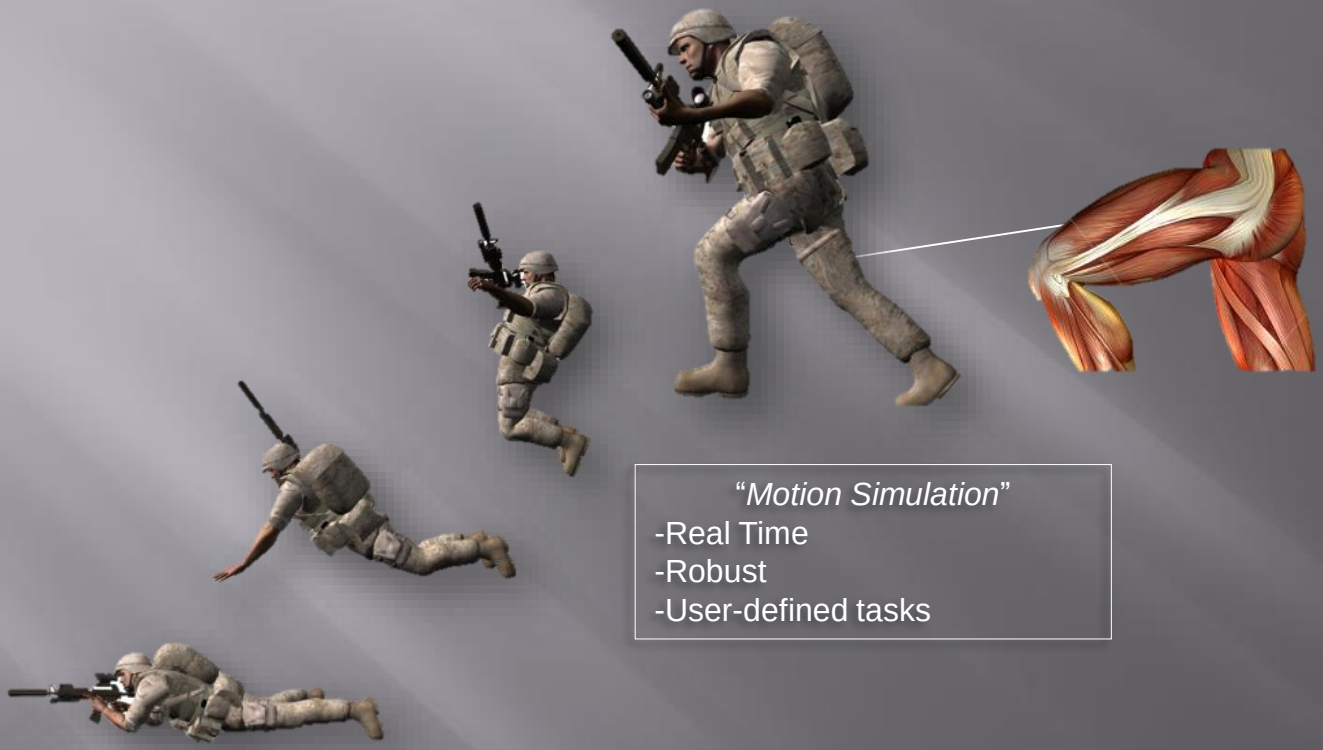
Simulate PPE



Analysis

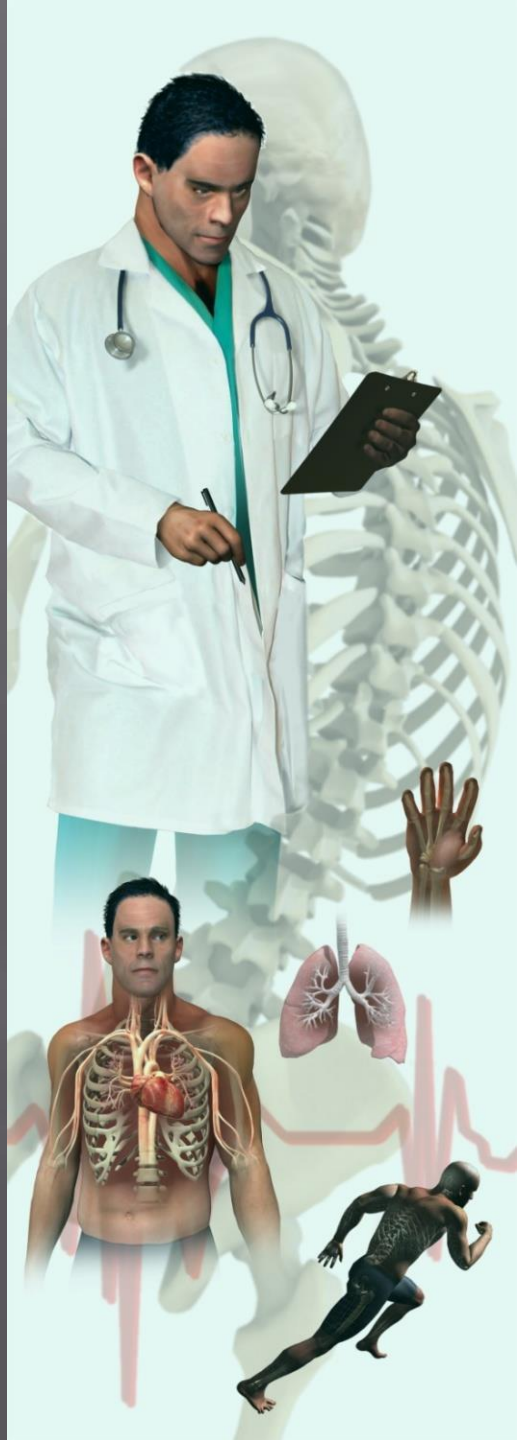
Biomechanical Effects of PPE

Simulate Warfighter



"*Motion Simulation*"
-Real Time
-Robust
-User-defined tasks

Predict human motion for tasks defined by the user on the fly, while considering strength characteristics



Biomechanical Effects of PPE

Simulate PPE

Rigid Armor Modeling

Soft Armor Modeling

Simulate soft armor and rigid armor, and their effects on task performance

Biomechanical Effects of PPE
Analysis

Armor-evaluation Tasks
-Arm raises
-Sitting
-Aiming while standing
-Aiming while kneeling
-Throwing
-Etc.

Strength Modeling

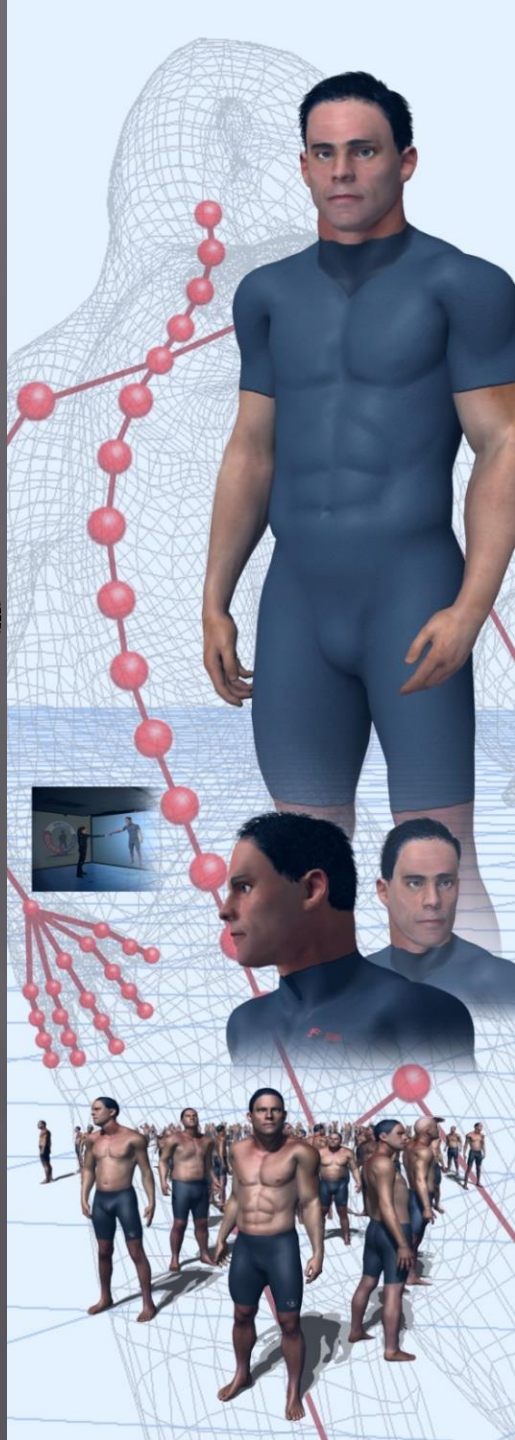
Rigid Armor Modeling

Soft Armor Modeling

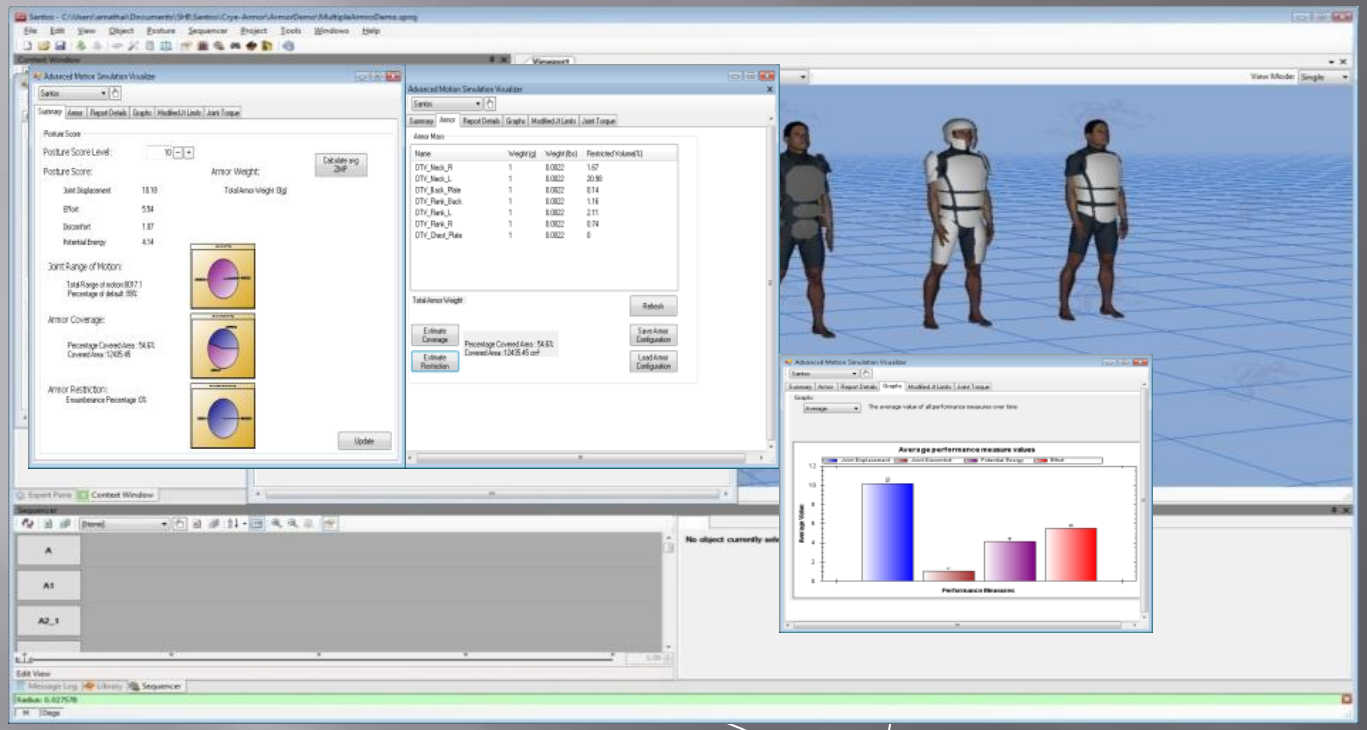
Motion Simulation

Evaluation Metrics
-Performance
-Mobility
-Balance
-Coverage
-Restrictive Volume
-Weight
-Torque
-Bulk

Evaluate the ability to perform tasks, based on a suite of metrics

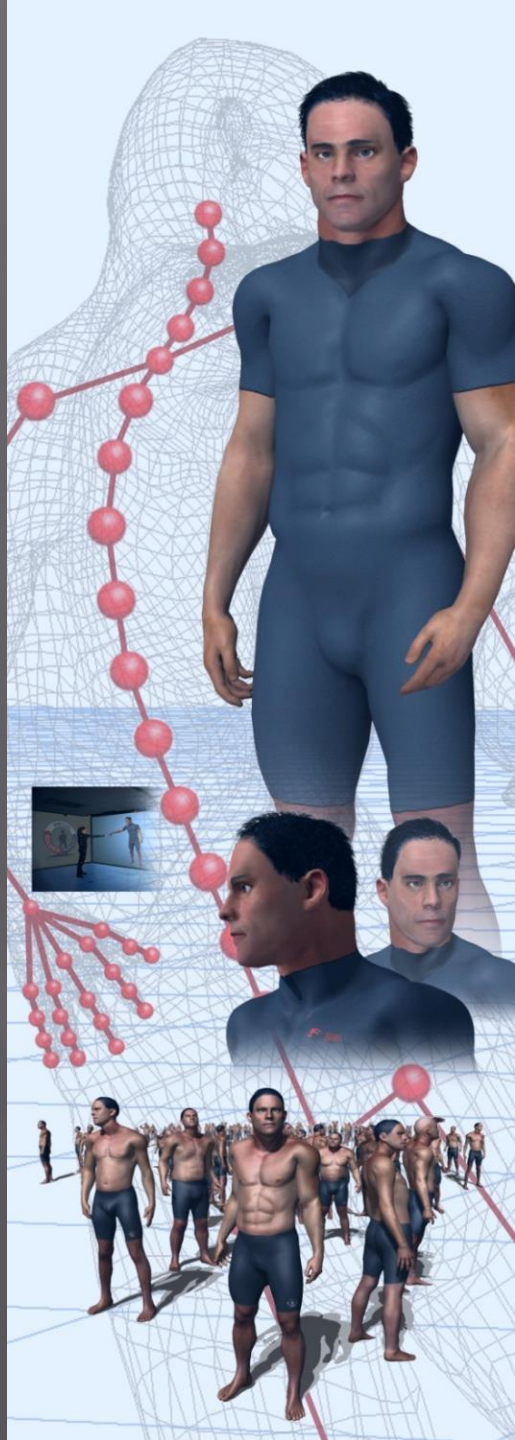


Biomechanical Effects of PPE
Analysis

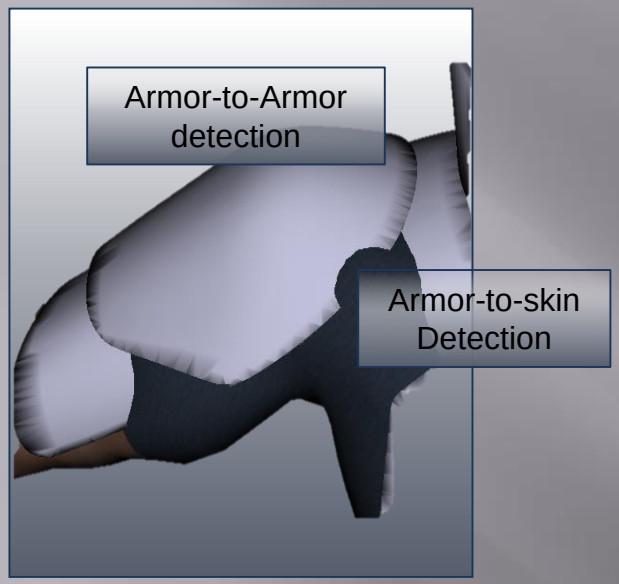


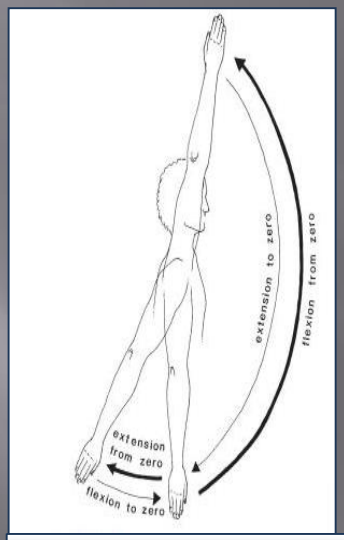
Evaluation Metrics
-Performance
-Mobility
-Balance
-Coverage
-Restrictive Volume
-Weight
-Torque
-Bulk

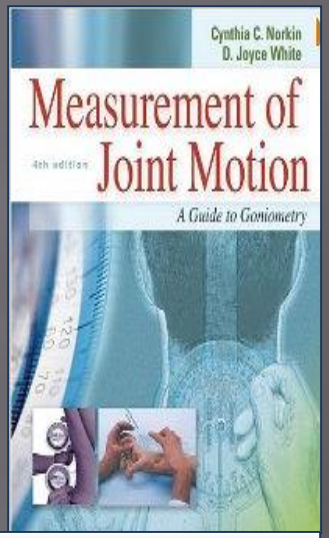
Evaluate the ability to perform tasks, based on a suite of metrics



Biomechanical Effects of PPE
Rigid Armor

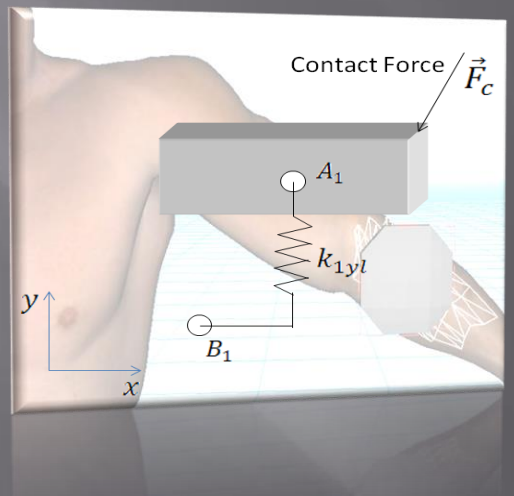






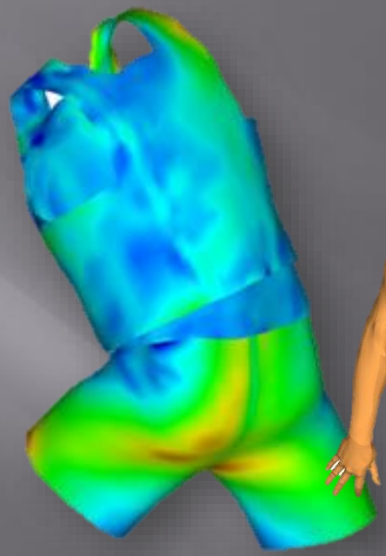
©Measurement of Joint Motion: A Guide to Goniometry, 4th ed , Norkin and White ,2003

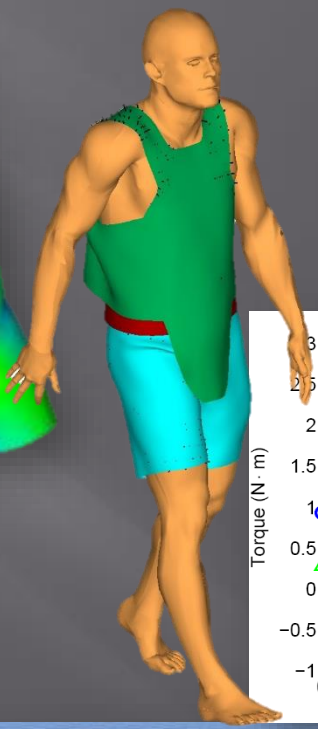
New approaches for fast collision detection and range-of-motion calculation

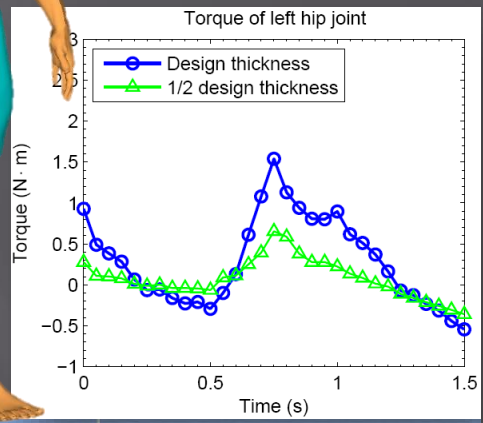


Biomechanical Effects of PPE

Soft Armor & Clothing

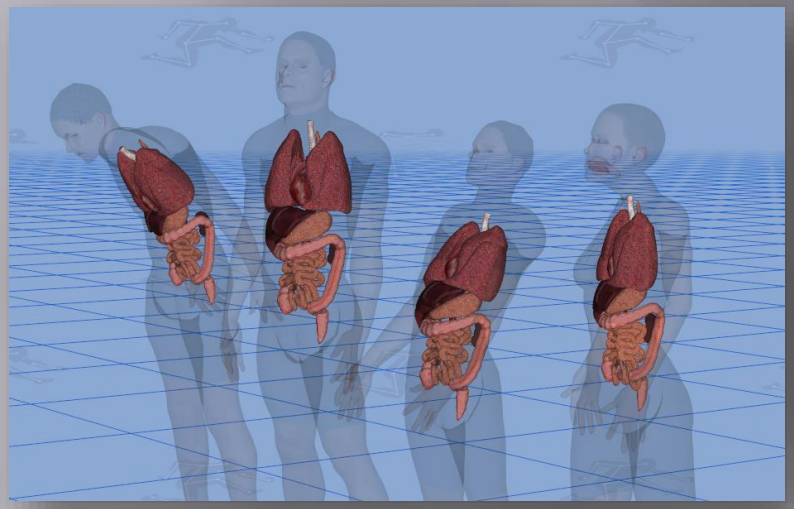


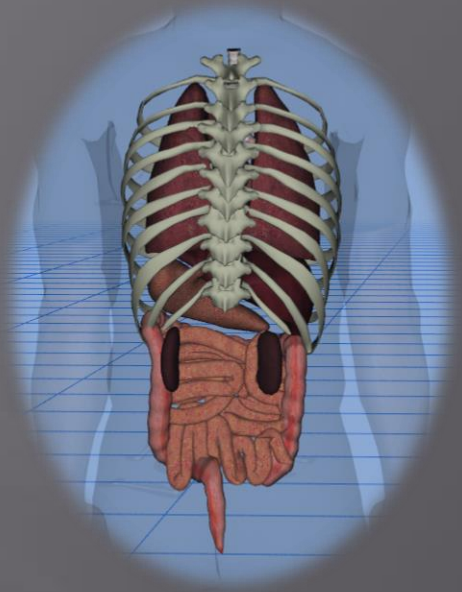




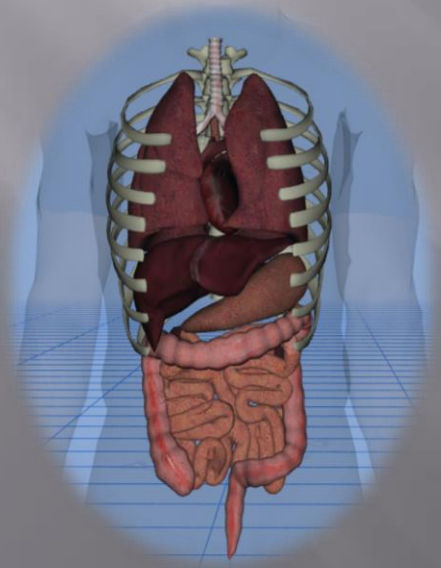
Fast running computational models of soft armor and clothing, fully integrated with a complete digital human model

Survivability

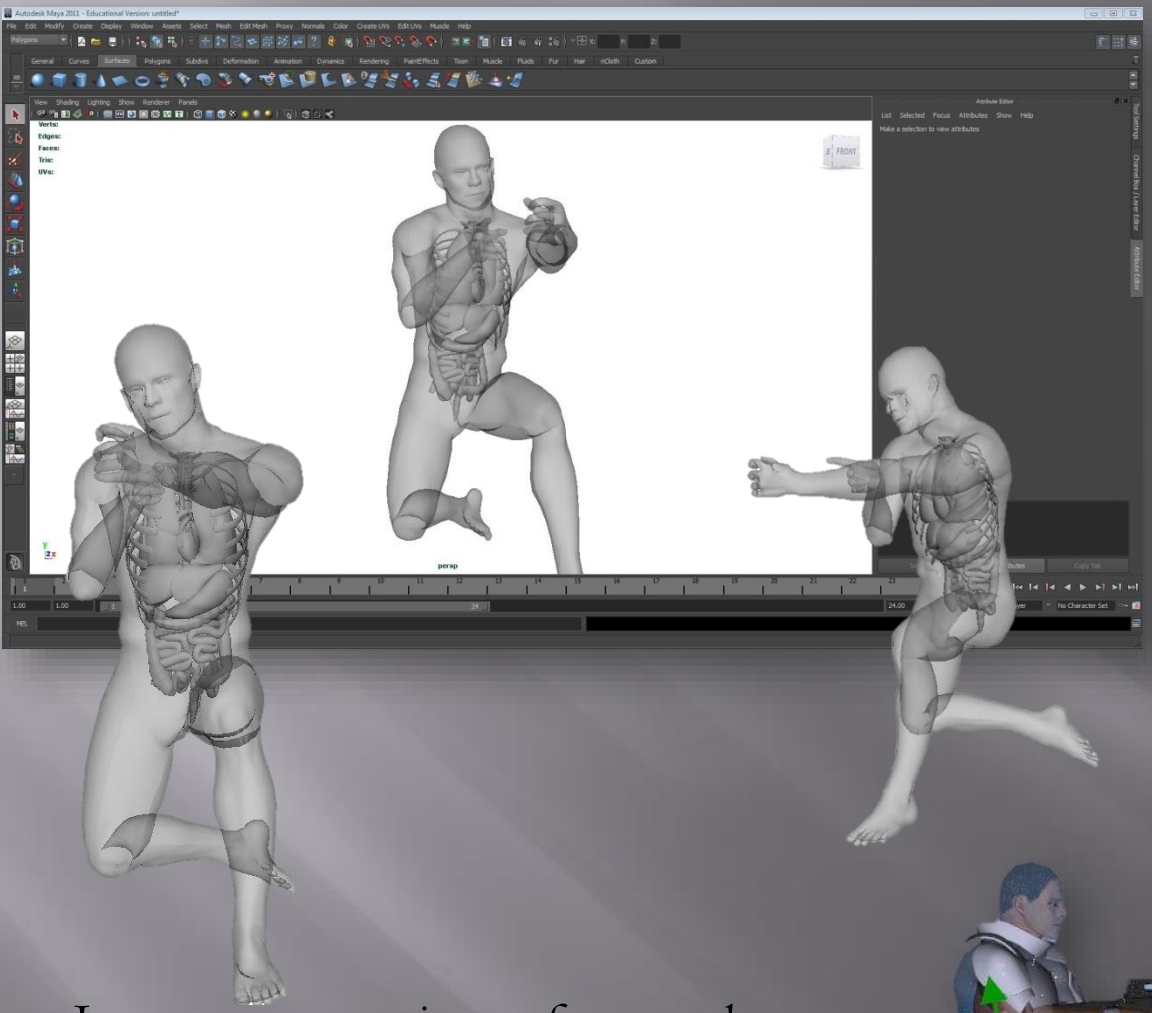


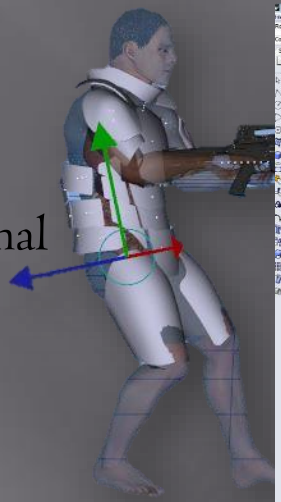


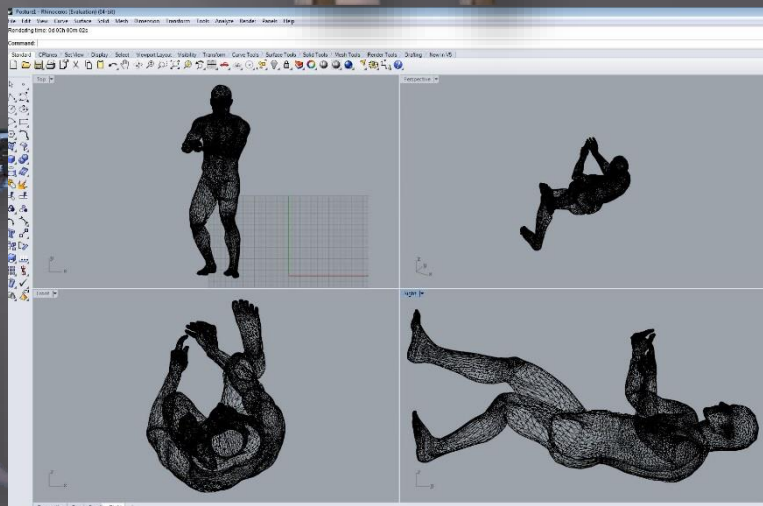
Internal organs and skeletal components that actually move, scale, and morph with body motion and changes in anthropometry



Survivability

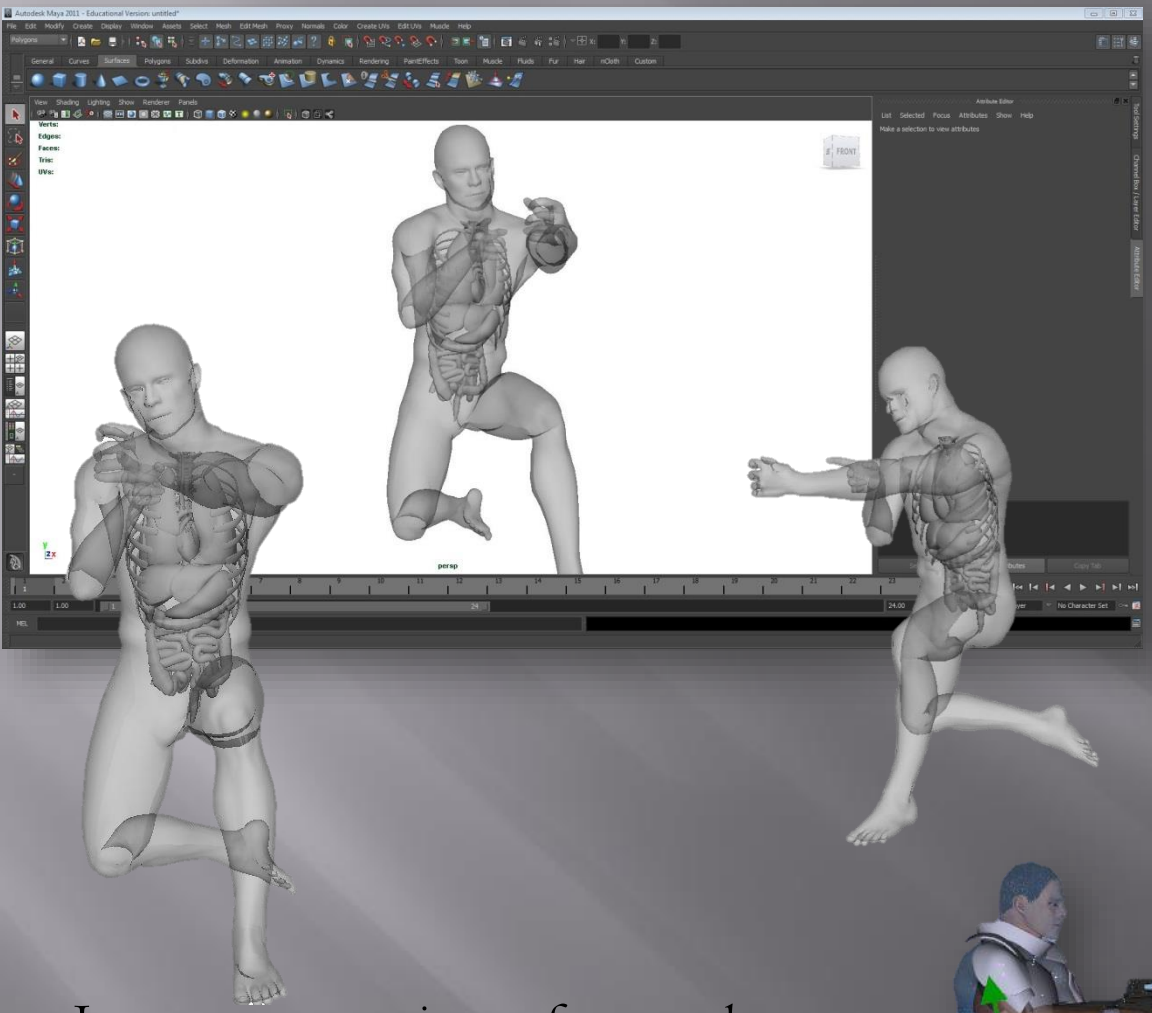


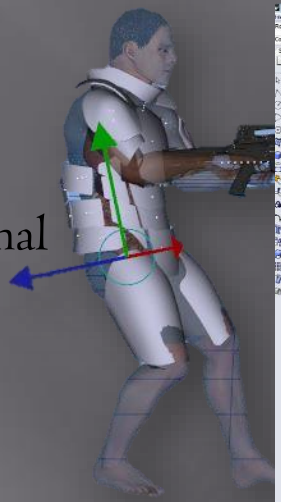


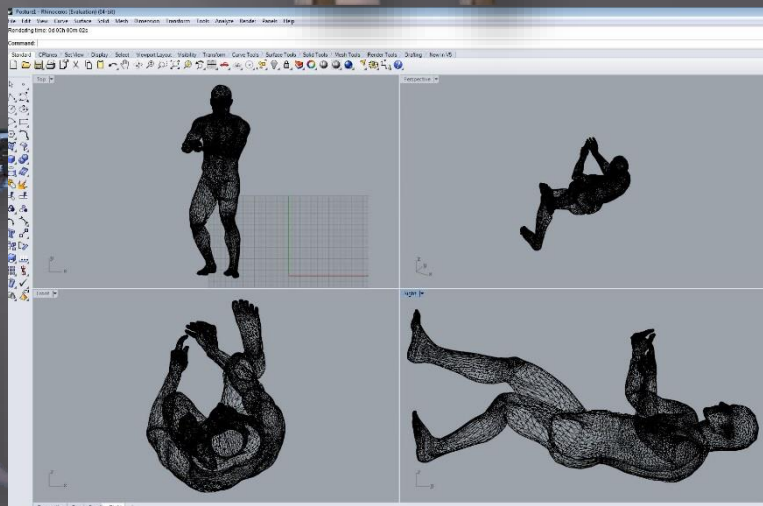


Import geometry in any form, and export avatars of any anthropometry to any external software system

Survivability

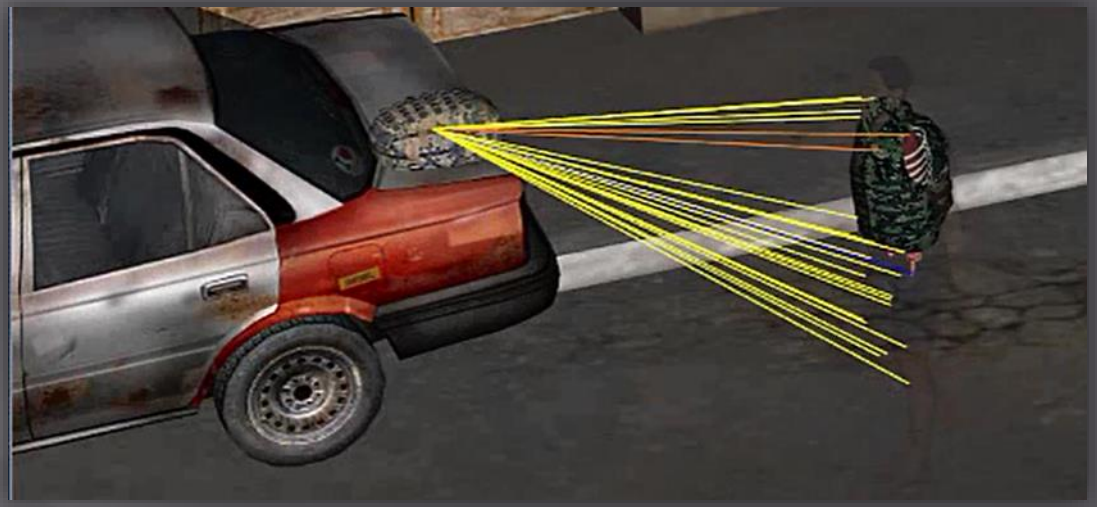






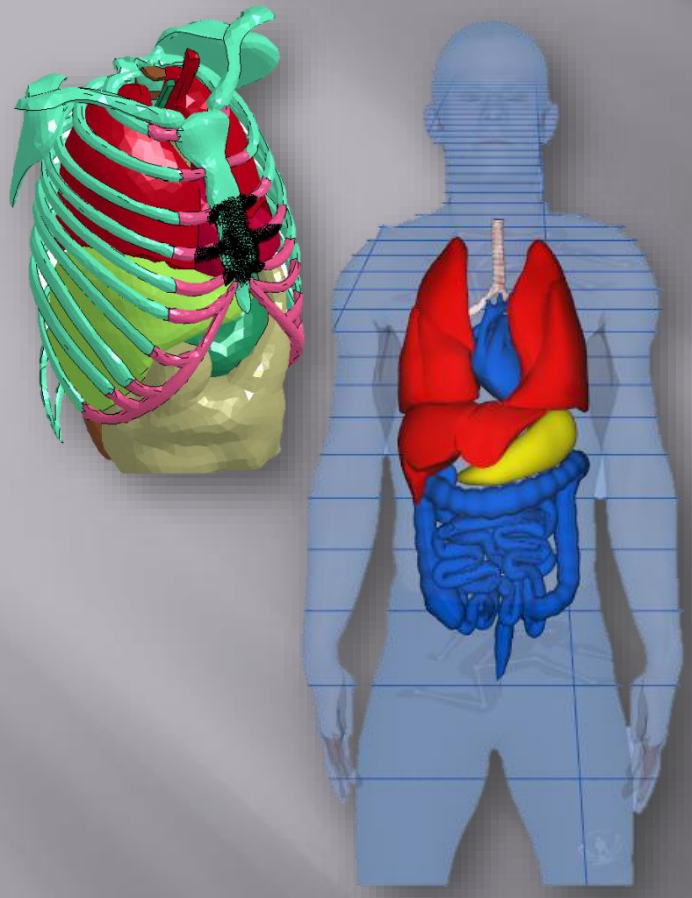
Import geometry in any form, and export avatars of any anthropometry to any external software system

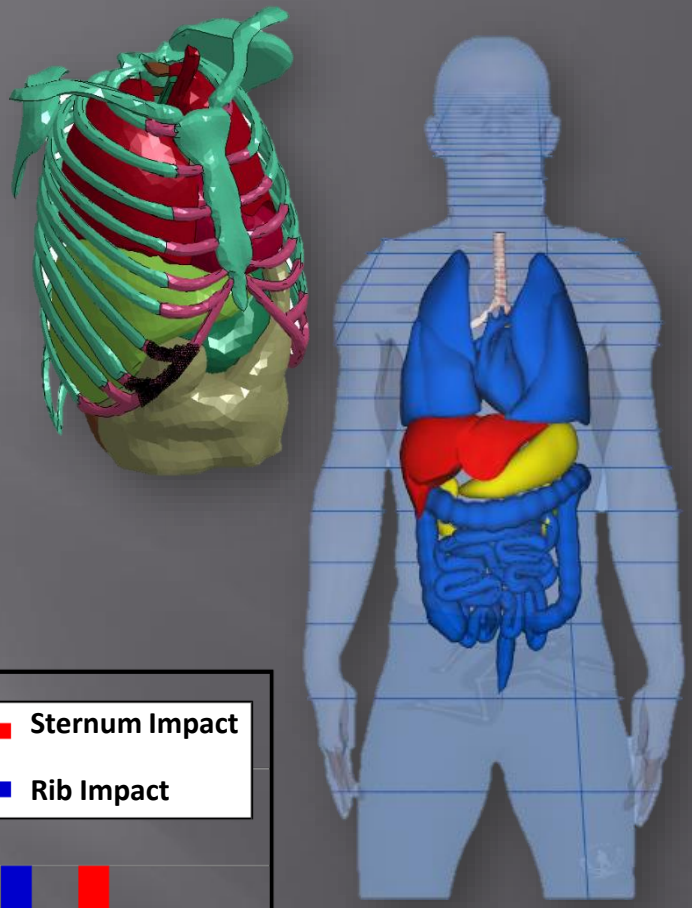
Survivability

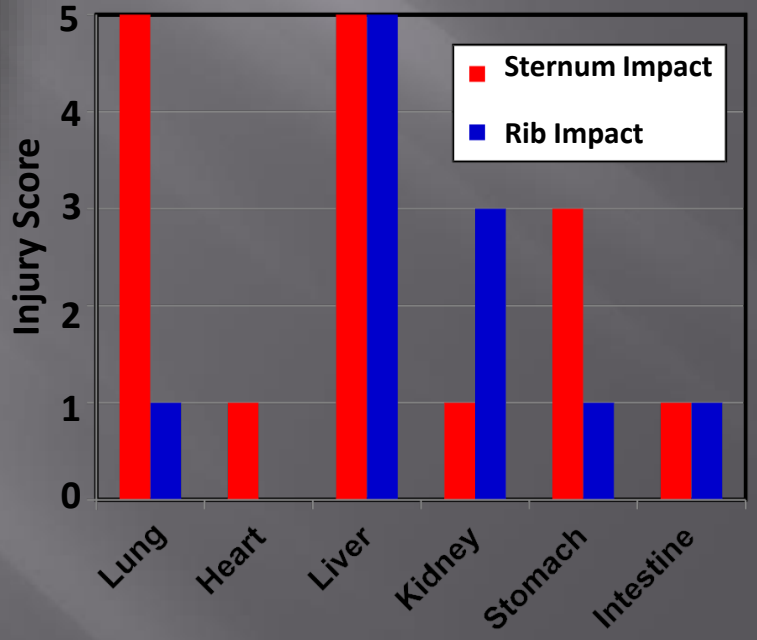


Simulate ballistic impacts in real time and study effectiveness of PPE by monitoring which organs are hit

Survivability



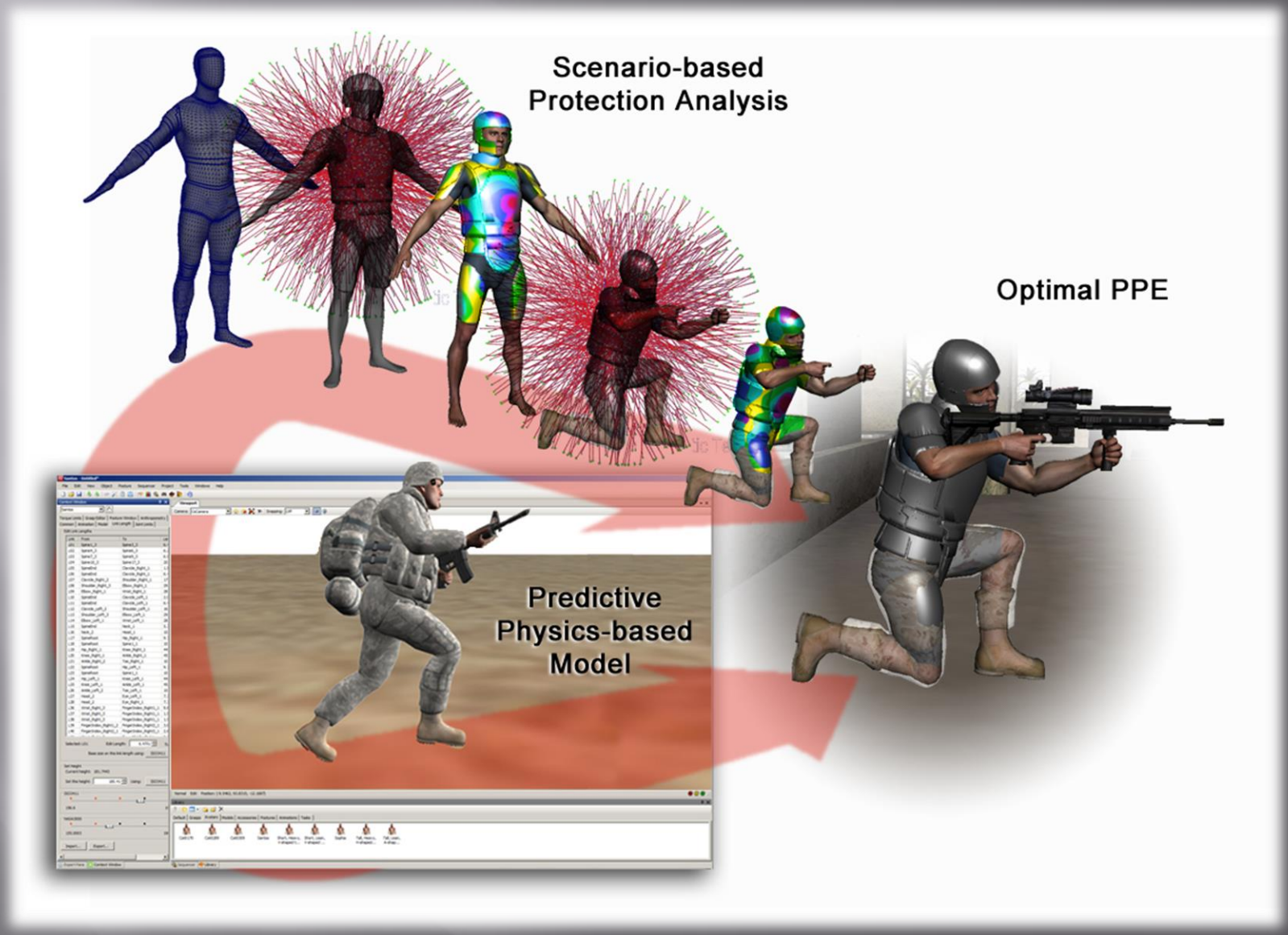




Display injury scores resulting from impact, using external high-fidelity models

Survivability

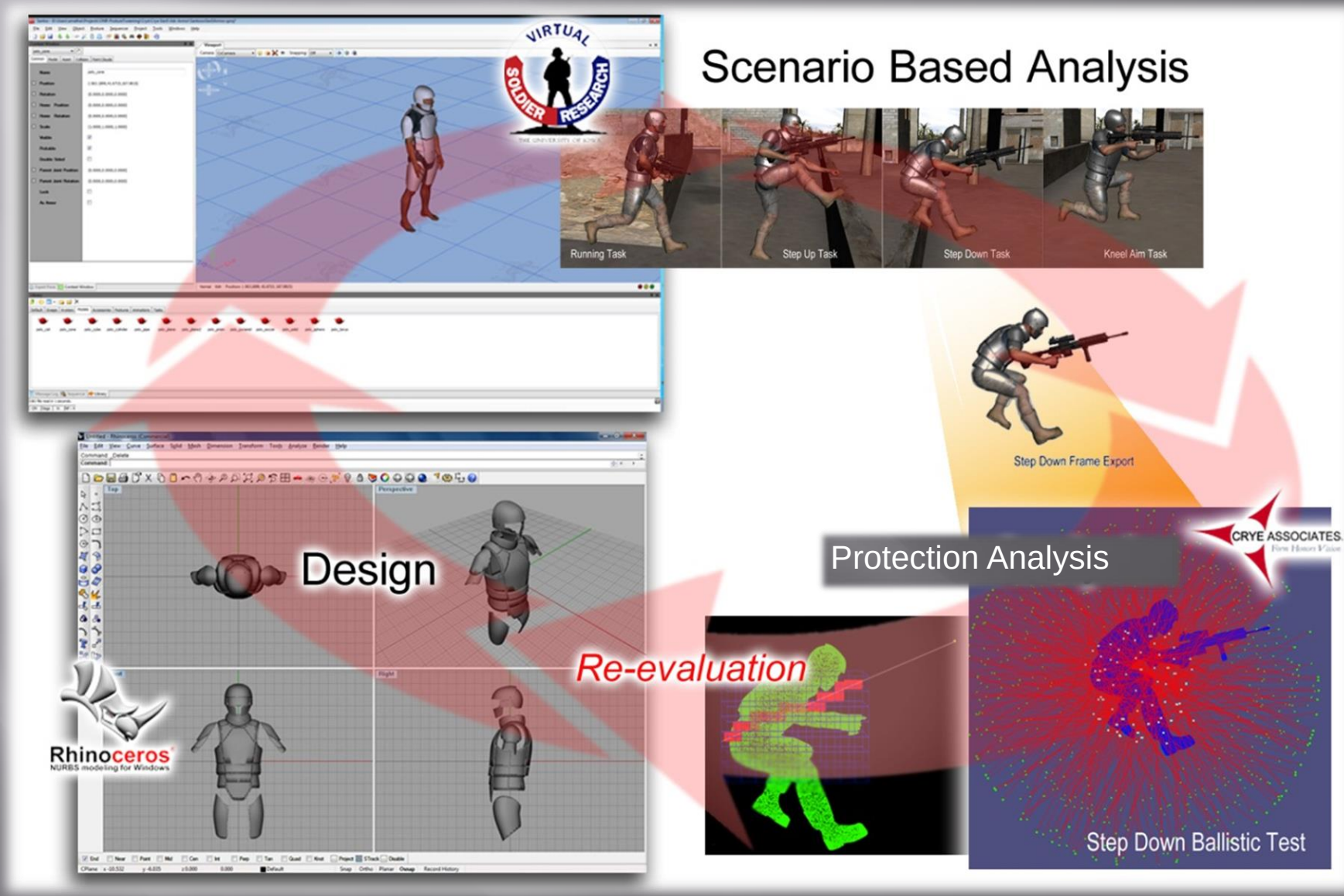
Integrating Multiple Models



Link Santos task simulation and biomechanical analysis with ballistic protection-analysis software

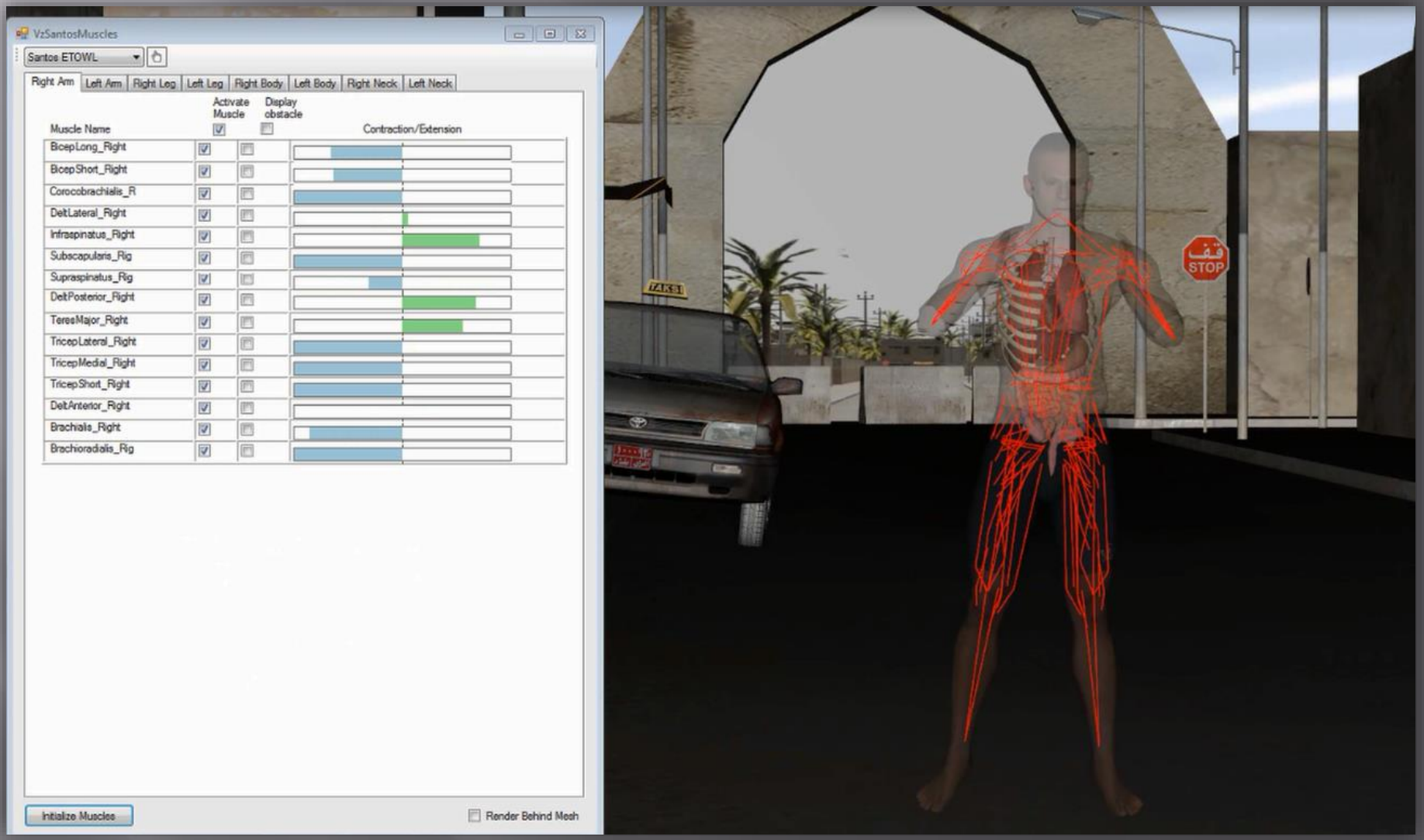
Survivability

Integrating Multiple Models



A unique underlying software structure allows users to link with Santos in real time from different locations, for concurrent design and analysis.

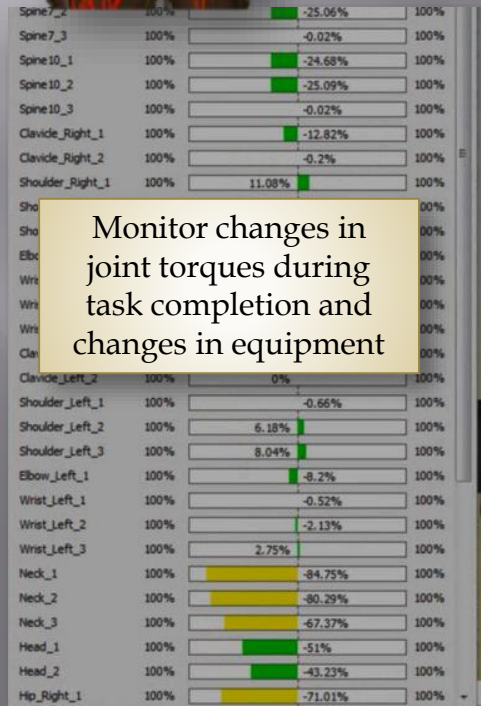
Muscle Model

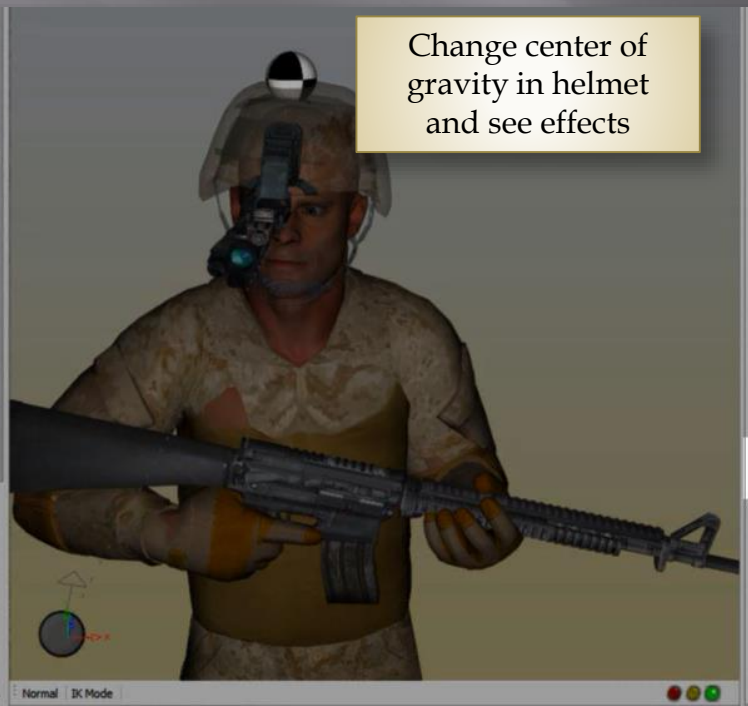


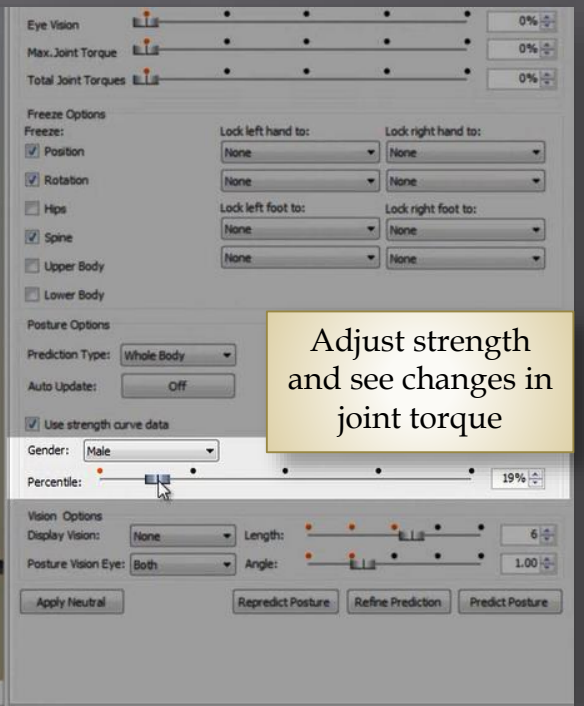
Evaluate muscle elongation in real time and relate to propensity for injury

Head/Neck Injury

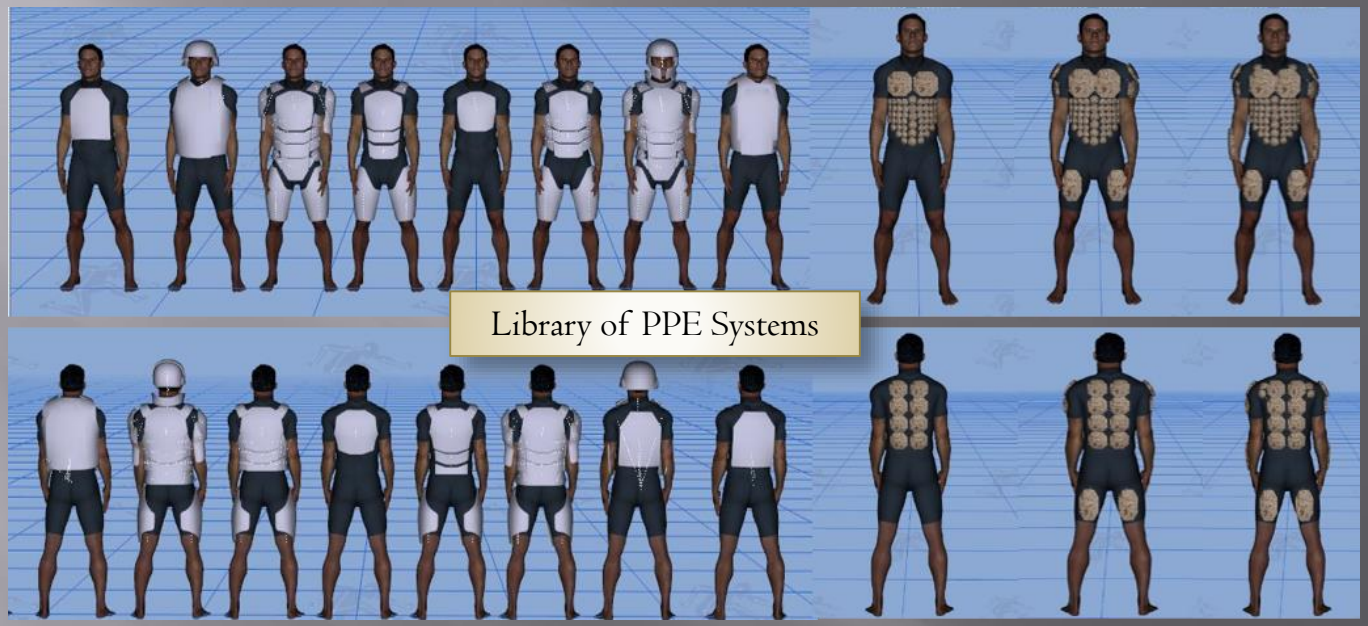
Integrate underlying predictive strength model and muscle model to help avoid injuries and study changes to head-borne equipment

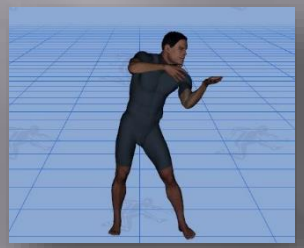


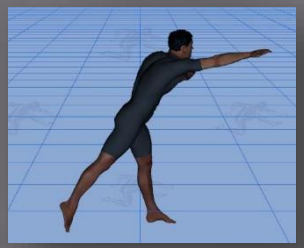


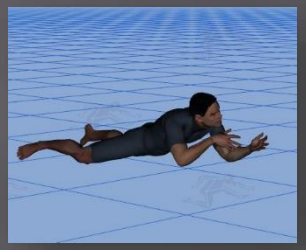


System Optimization



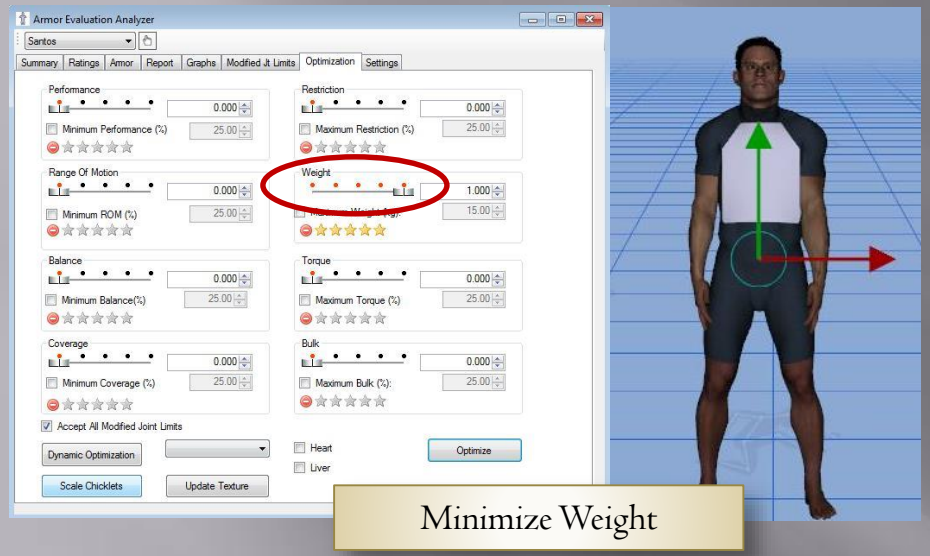




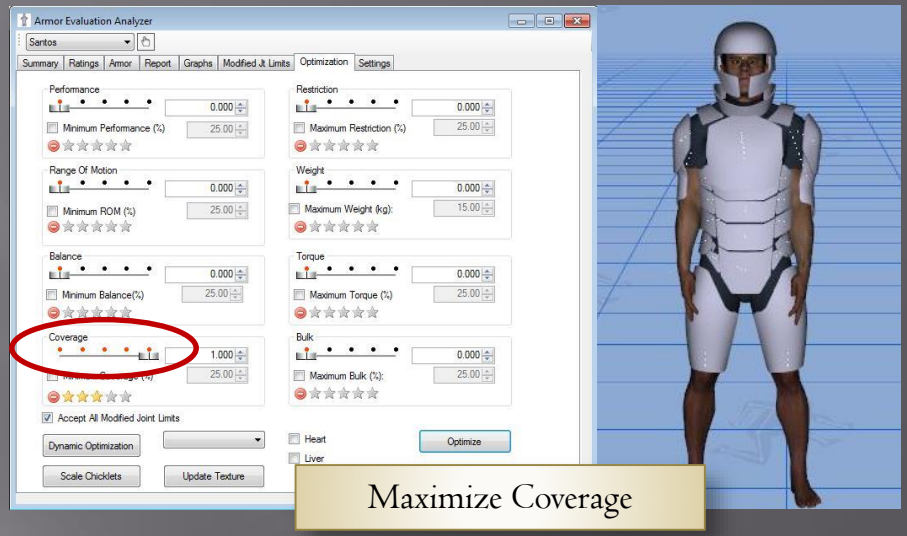


Automatically evaluate PPE (or other products) based on simulated tasks and specified objectives, and identify optimum systems

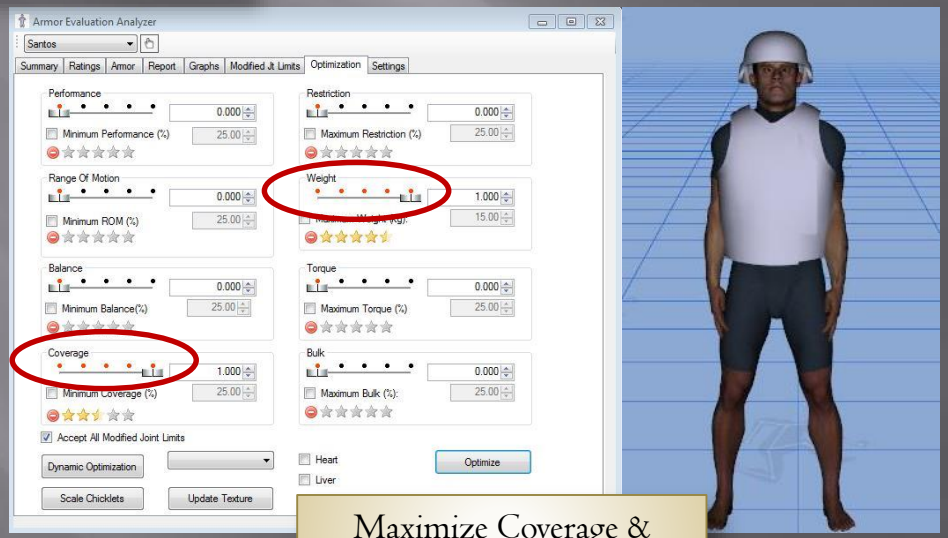
System Optimization



Minimize Weight



Maximize Coverage



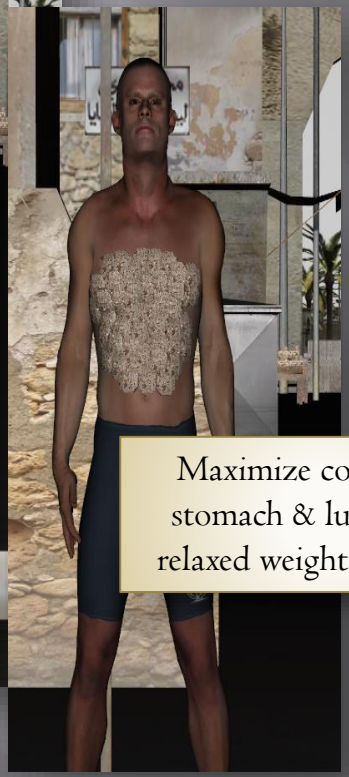
Maximize Coverage &
Minimize Weight

Automatically evaluate PPE (or other products) based on simulated tasks and specified objectives, and identify optimum systems

System Optimization

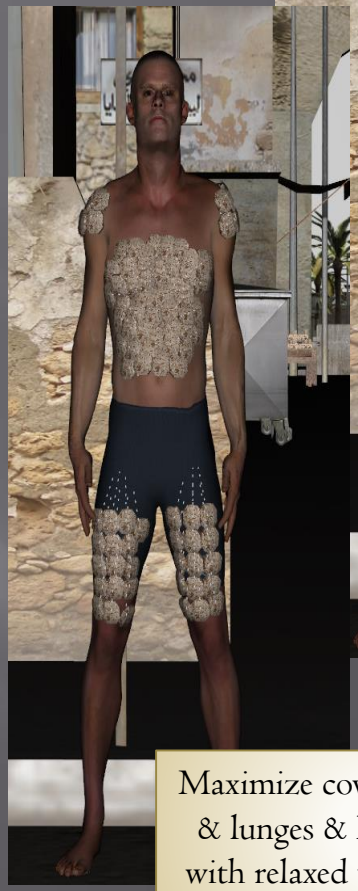
Maximize coverage of stomach

Maximize coverage of stomach & lunges



Maximize coverage of stomach & lunges with relaxed weight constraint

Maximize coverage of stomach & lunges & legs & shoulders



Maximize coverage of stomach & lunges & legs & shoulders with relaxed weight constraint

Automatically ***design*** optimal PPE system concpets based on specified objectives, potentially from external systems/software

Motion Capture Engine

Drive Santos with motion capture from any type of system, determine joint angles with high accuracy, and objectively score the effects of different PPE systems on mobility

Santos:
Biomechanics, Survivability, and Personal Protective Equipment