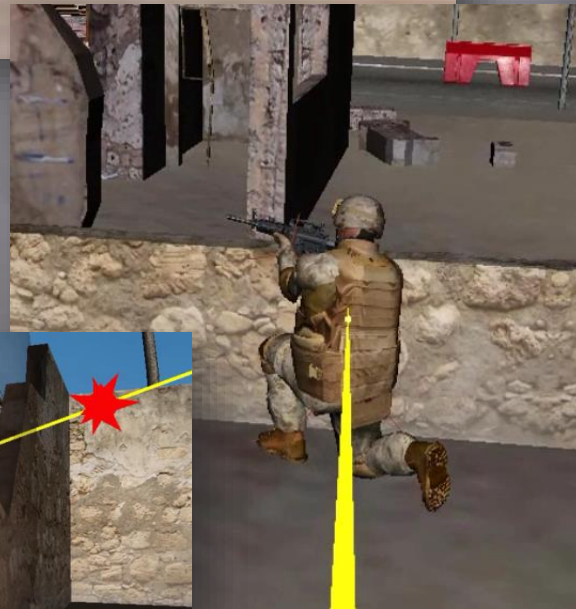




SANTOS:
BIOMECHANICS, SURVIVABILITY,
AND PERSONAL PROTECTIVE
EQUIPMENT

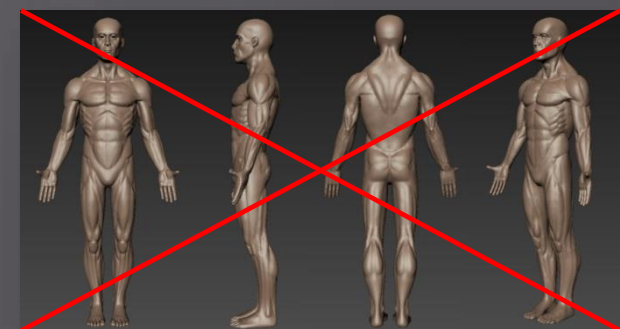




Human system integration (HSI) is insufficiently addressed when designing and analyzing body armor systems



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



The software interface displays biomechanical analysis results for three different armor configurations. Each window shows a list of metrics with a star rating and a red minus sign icon.

Metric	Santos2	Santos	Santos1
Posture	5 stars	5 stars	5 stars
Range of Motion	4 stars	5 stars	5 stars
Stability	4 stars	5 stars	4 stars
Coverage	5 stars	4 stars	5 stars
Restriction	4 stars	5 stars	4 stars
Weight	4 stars	5 stars	4 stars
Torque	4 stars	4 stars	4 stars
Volume	4 stars	4 stars	4 stars

The 'Santos1' window also includes an 'Overall Rating' of 4 stars and an 'Update Scores' button.

Analysis

Biomechanical Effects of PPE

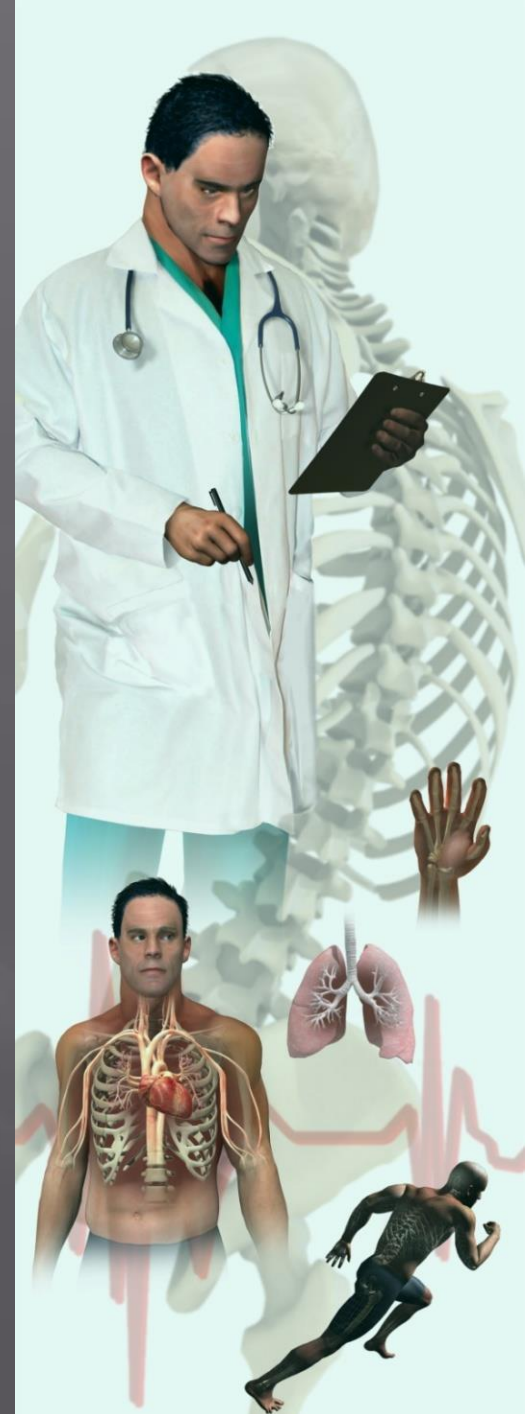
Simulate Warfighter



"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

Soft Armor Modeling

Rigid Armor Modeling

Motion Simulation



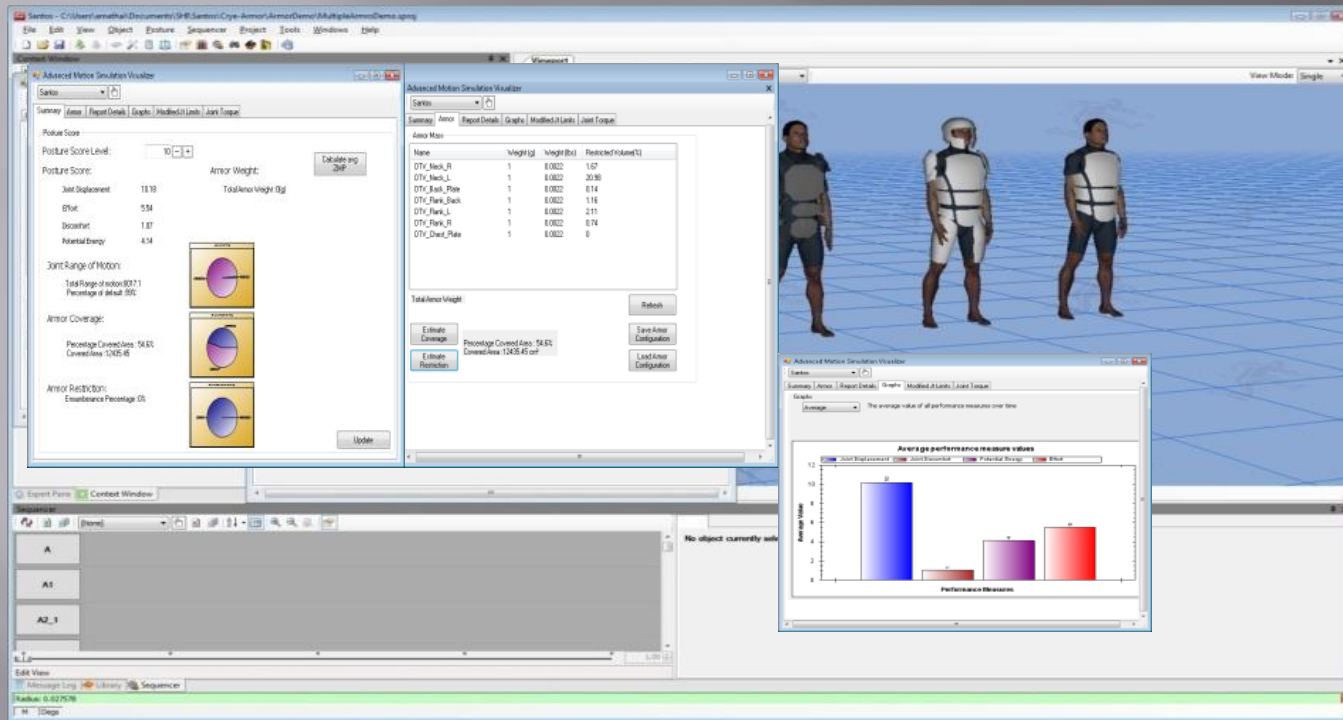
Evaluation Metrics

- 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



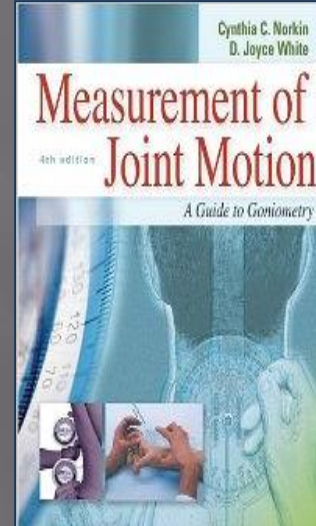
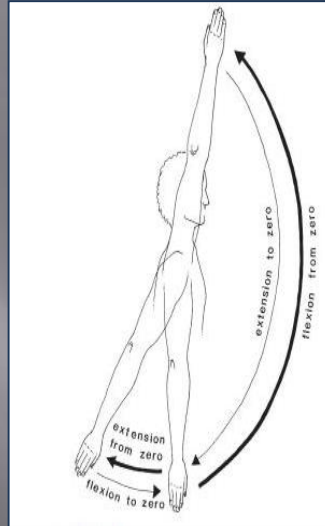
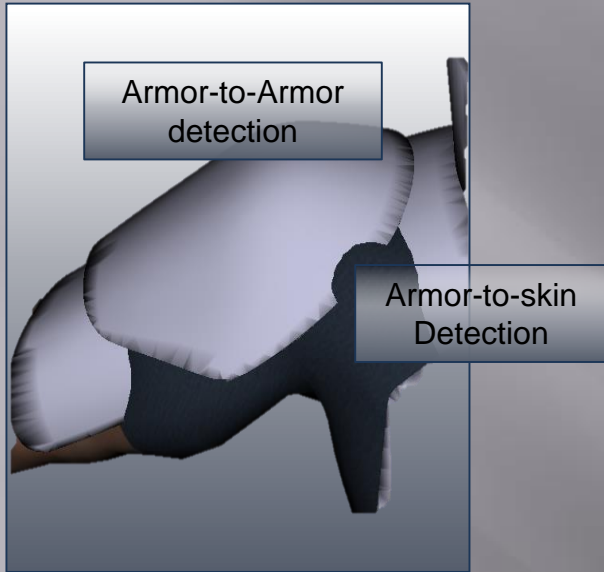
Evaluation Metrics

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

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

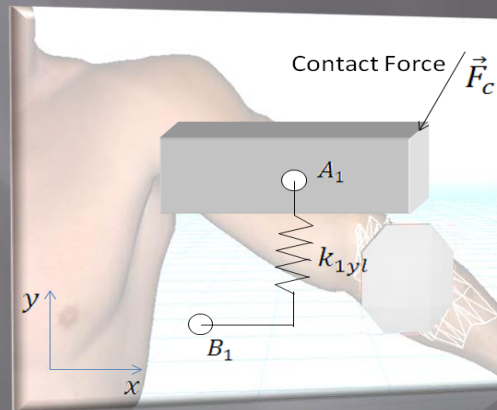
Biomechanical Effects of PPE

Rigid Armor



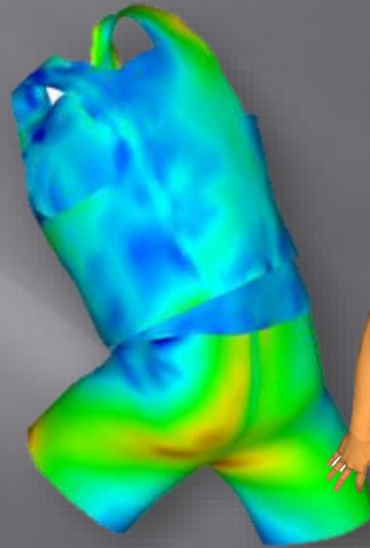
©Measurement of Joint Motion: A Guide to Goniometry, 4th ed , Norkin and White ,2003

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

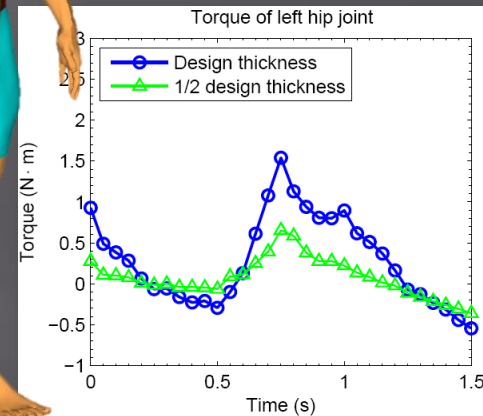


Biomechanical Effects of PPE

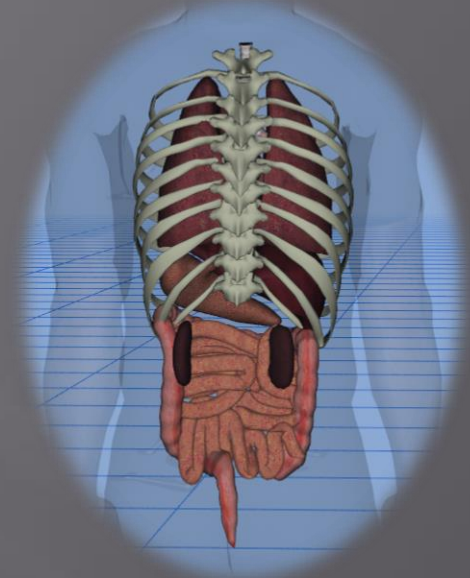
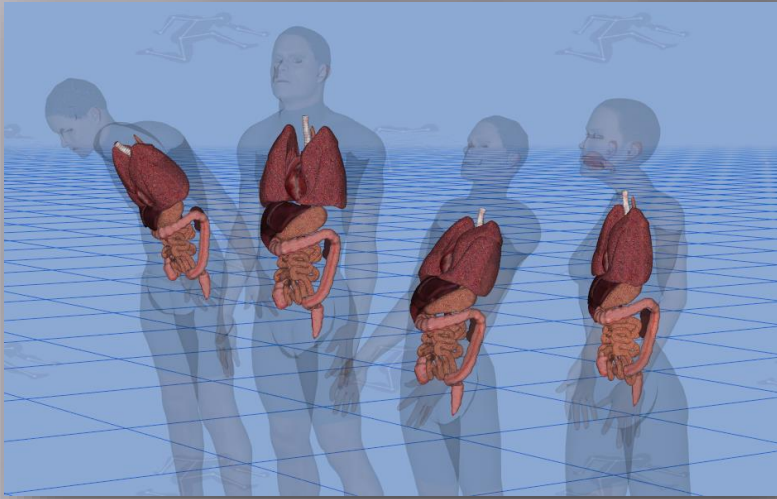
Soft Armor & Clothing



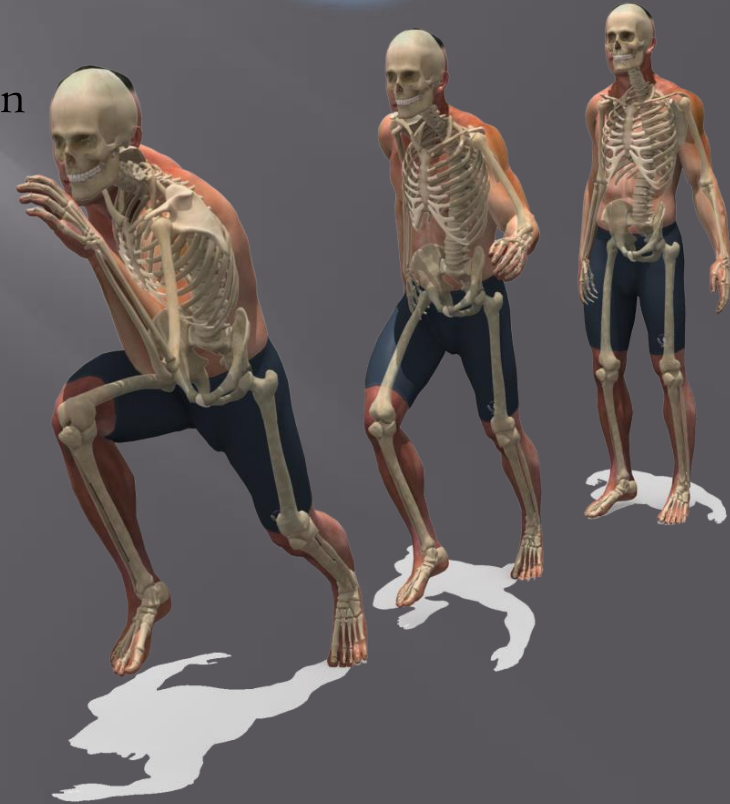
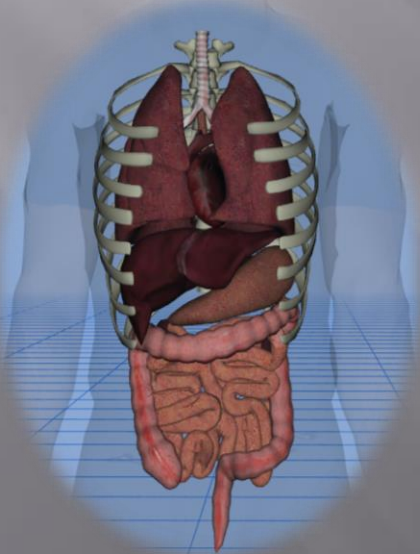
Fast running computational models of soft armor and clothing, fully integrated with a complete digital human model



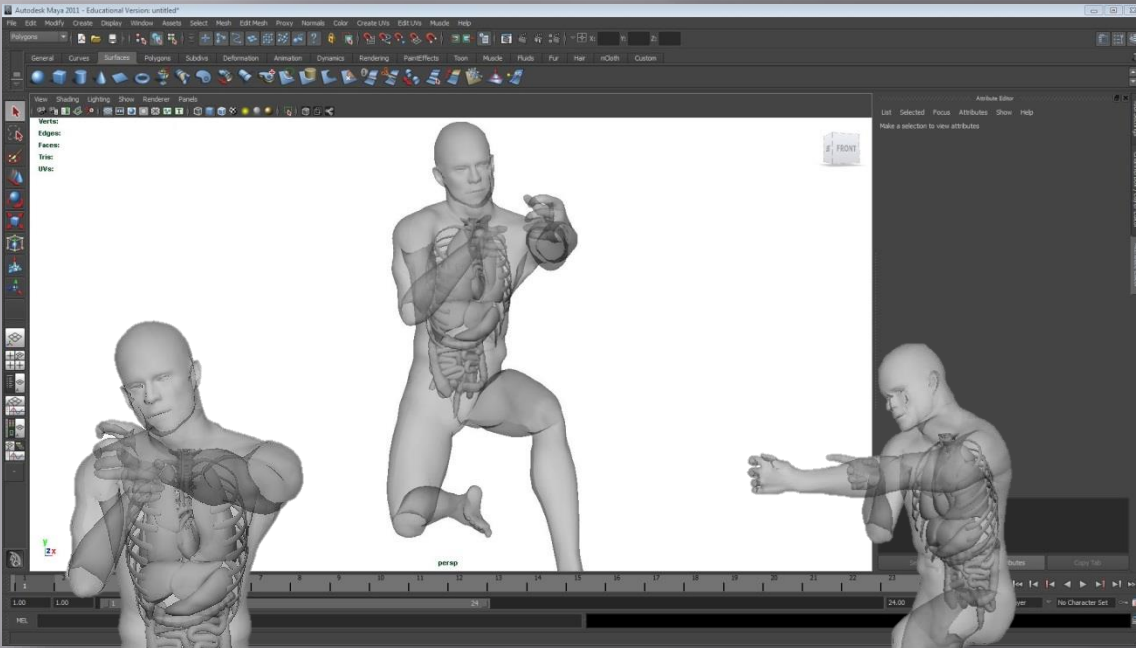
Survivability



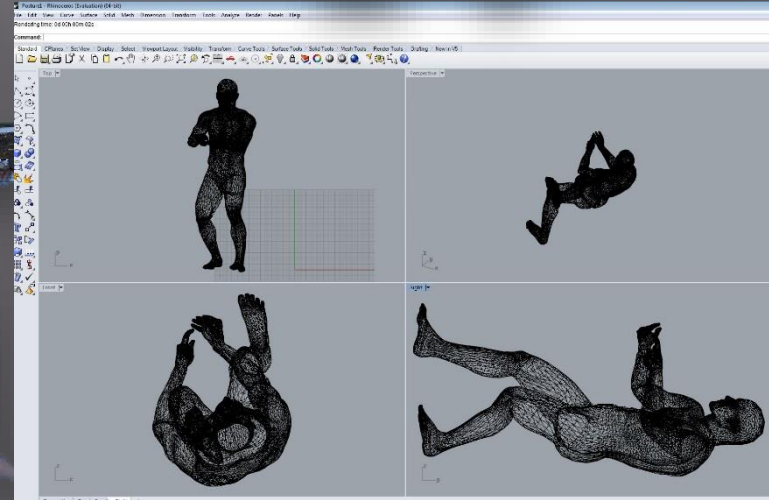
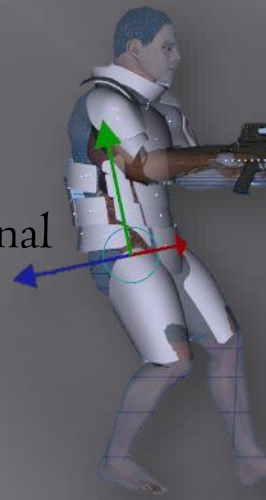
Internal organs and skeletal components that actually move, scale, and morph with body motion and changes in anthropometry



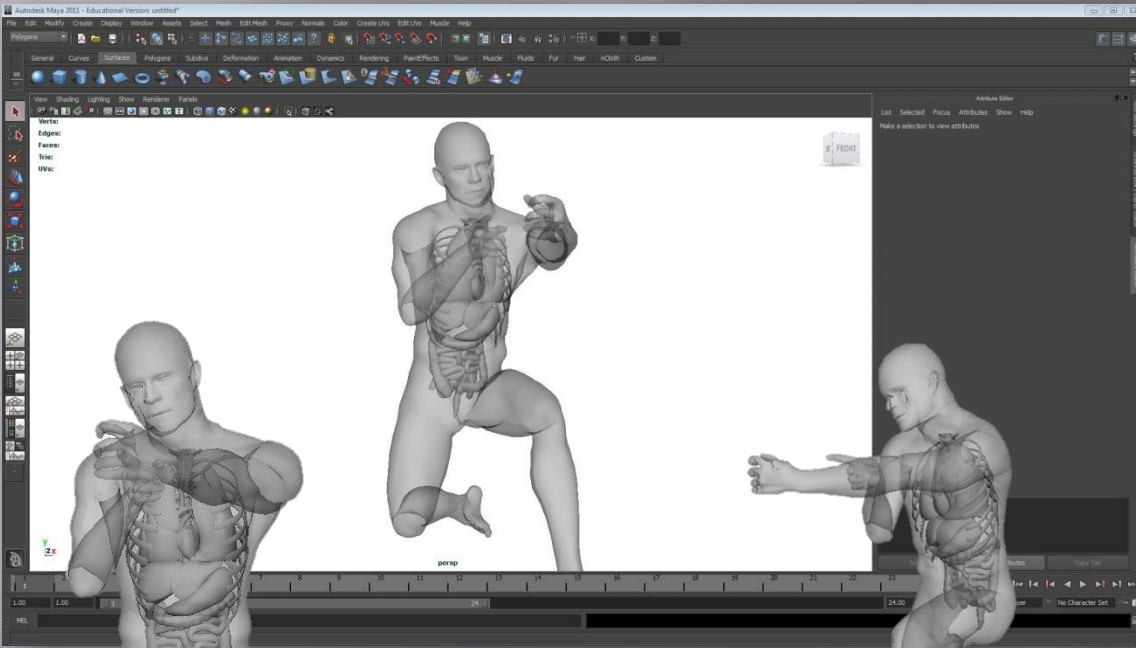
Survivability



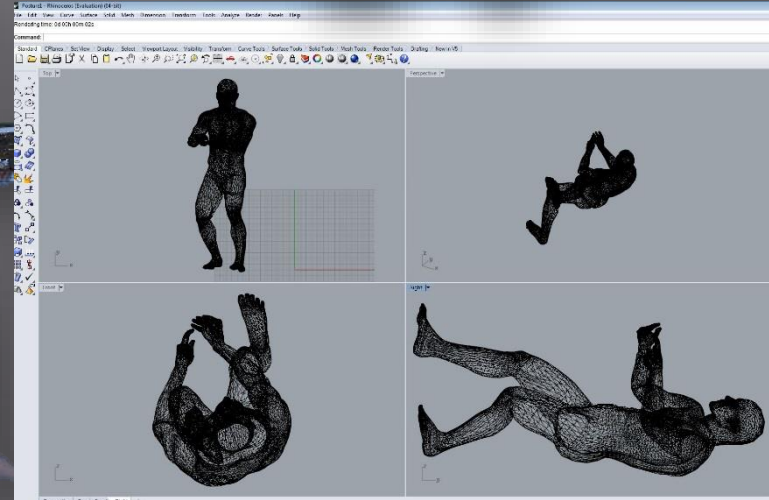
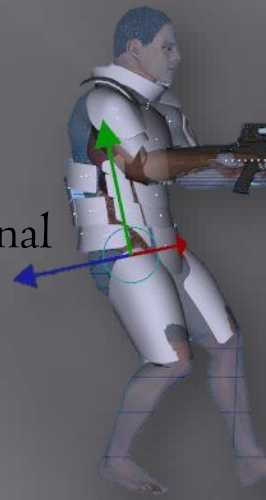
Import geometry in any form, and export avatars of any anthropometry to any external software system



Survivability



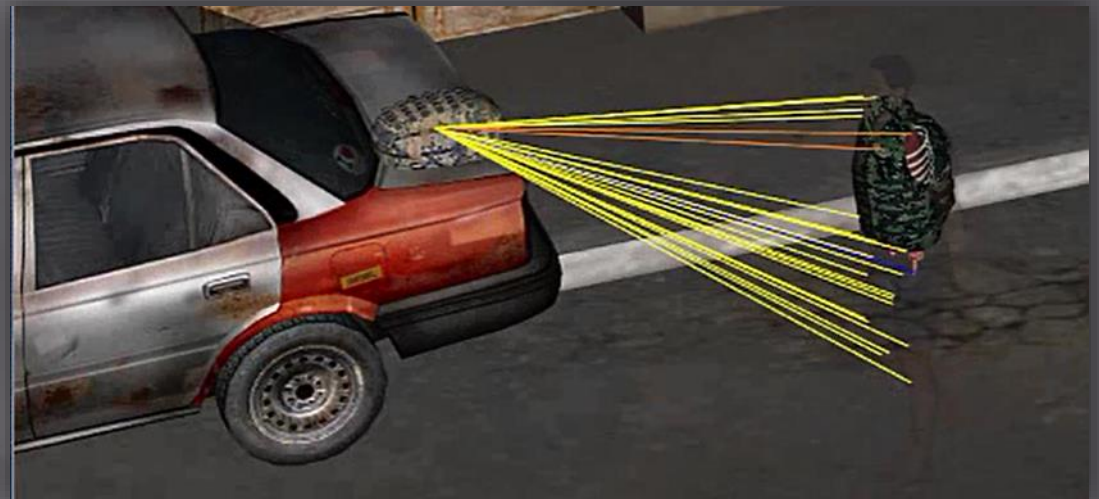
Import geometry in any form, and export avatars of any anthropometry to any external software system



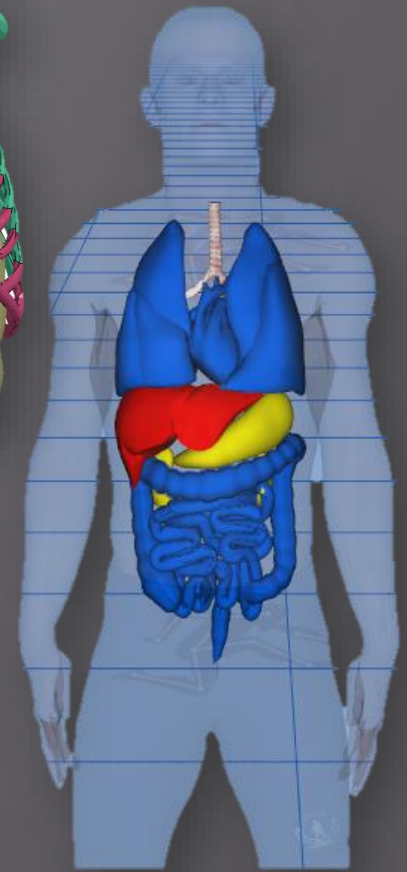
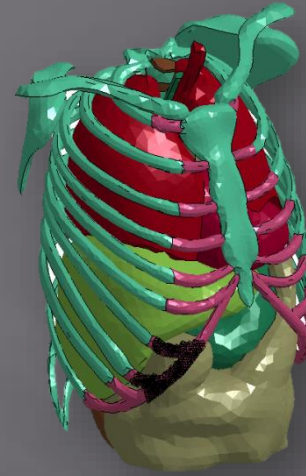
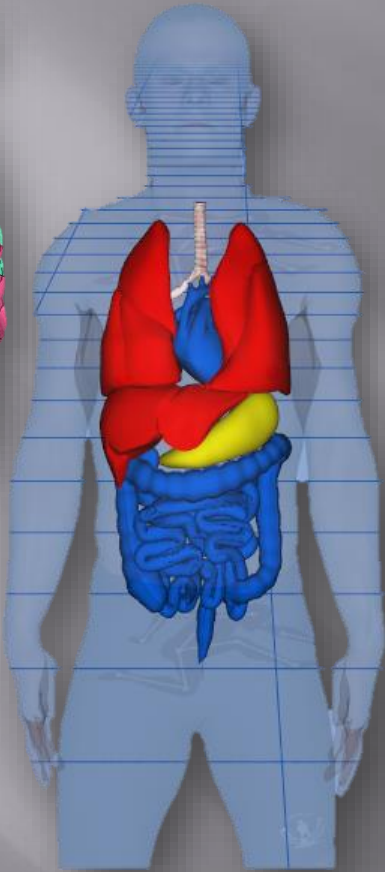
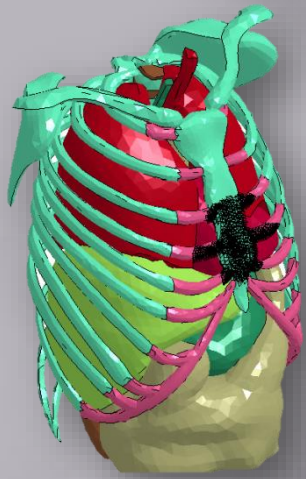
Survivability



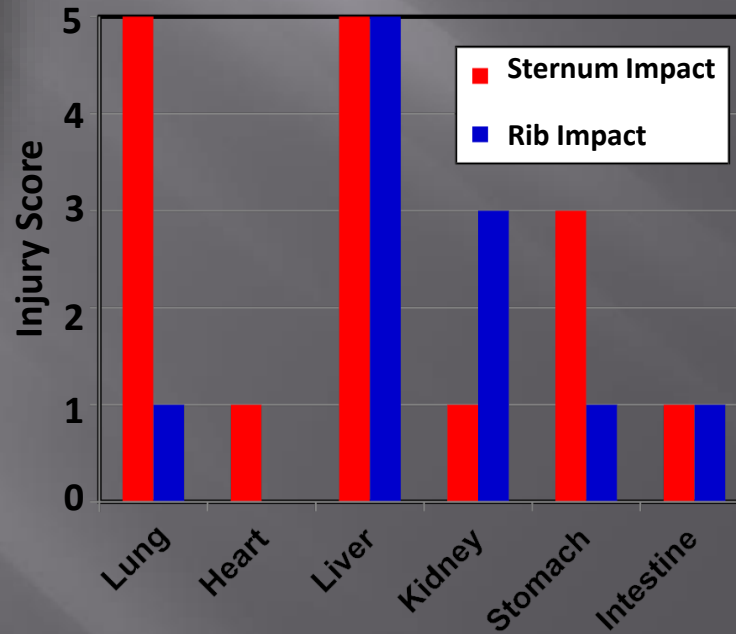
Simulate ballistic impacts in real time and study effectiveness of PPE by monitoring which organs are hit



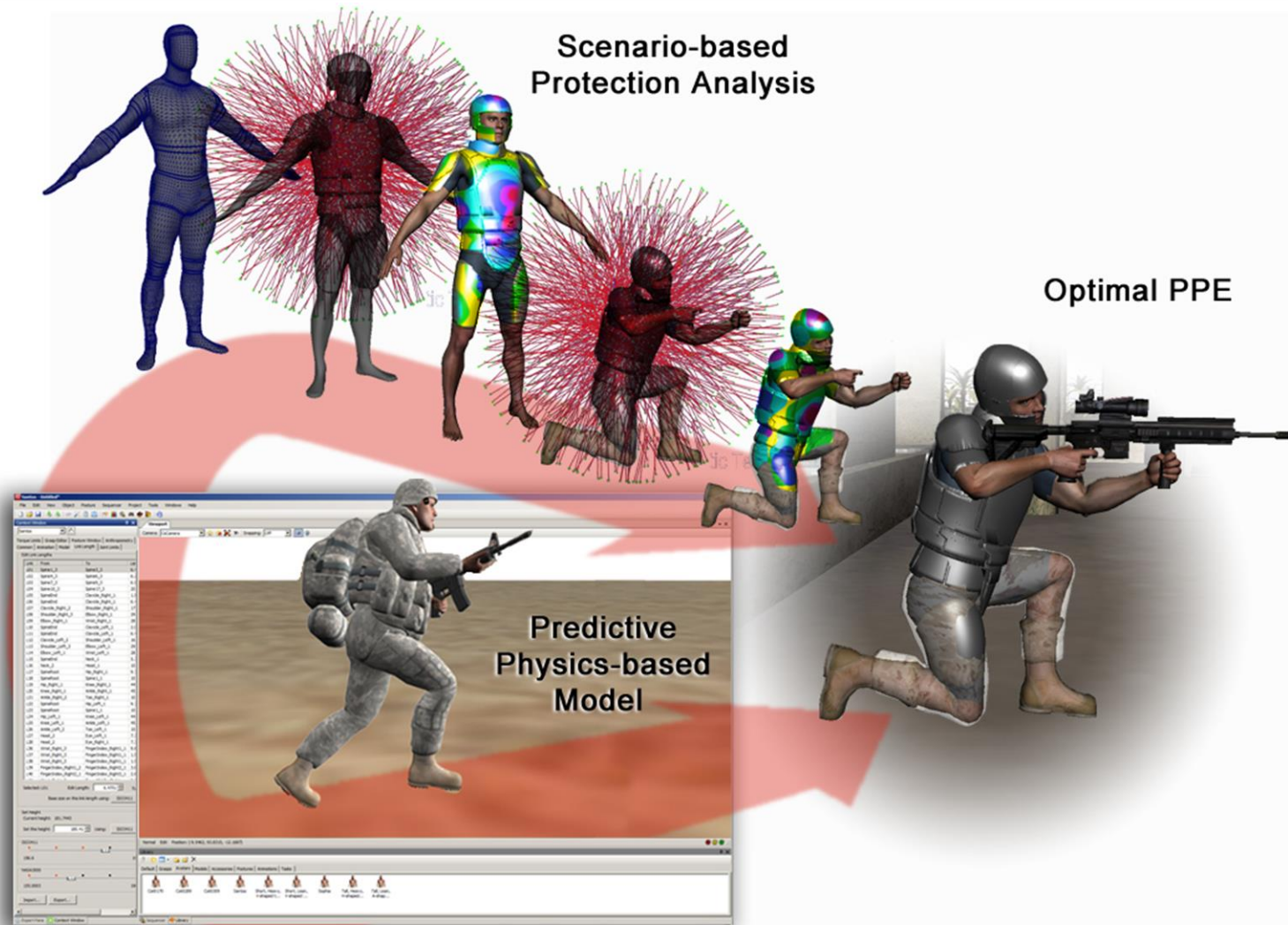
Survivability



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



Survivability Integrating Multiple Models

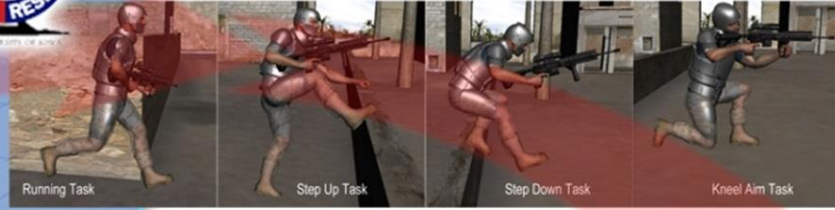
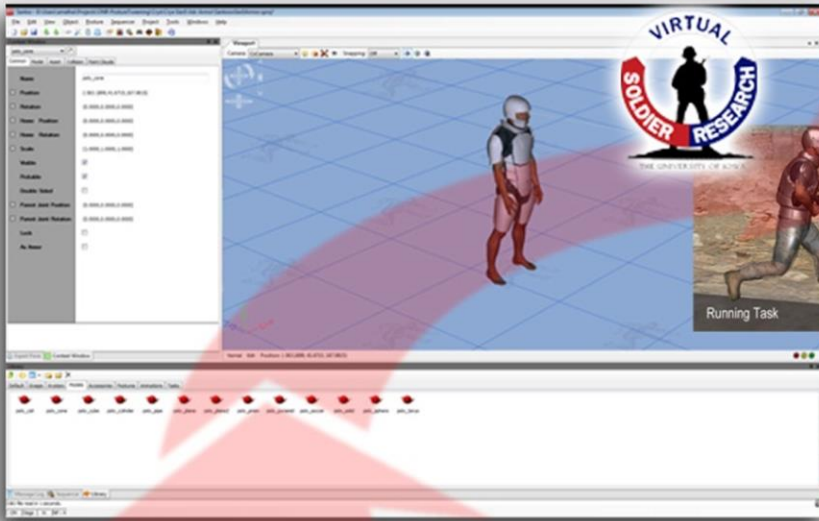


Link Santos task simulation and biomechanical analysis with ballistic protection-analysis software

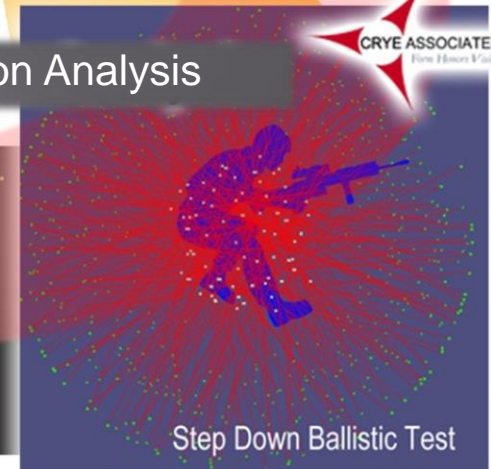
Survivability

Integrating Multiple Models

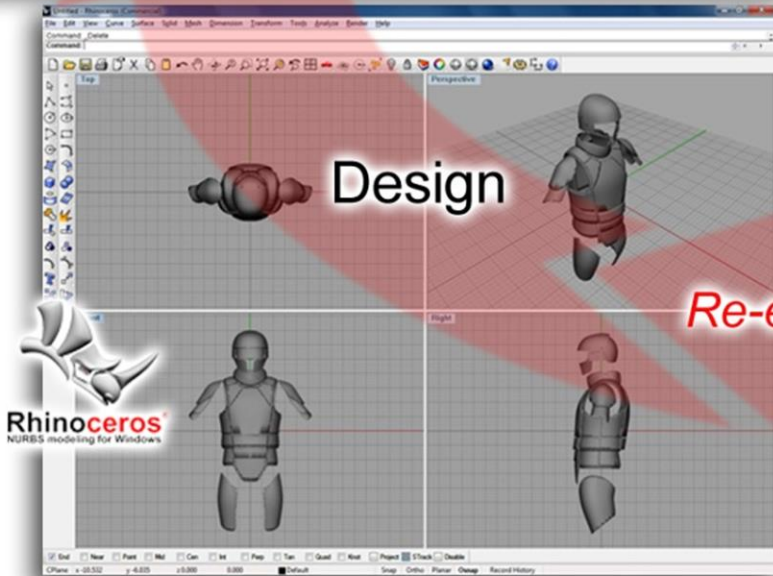
Scenario Based Analysis



Protection Analysis



Design



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

Muscle Model

VzSantosMuscles

Santos ETOWL

Right Arm Left Arm Right Leg Left Leg Right Body Left Body Right Neck Left Neck

Muscle Name	Activate Muscle	Display obstacle	Contraction/Extension
BicepLong_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
BicepShort_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Coracobrachialis_R	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
DeltLateral_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Infraspinatus_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Subscapularis_Rig	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Supraspinatus_Rig	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
DeltPosterior_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
TeresMajor_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
TricepLateral_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
TricepMedial_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
TricepShort_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
DeltAnterior_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Brachialis_Right	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
Brachioradialis_Rig	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Initialize Muscles

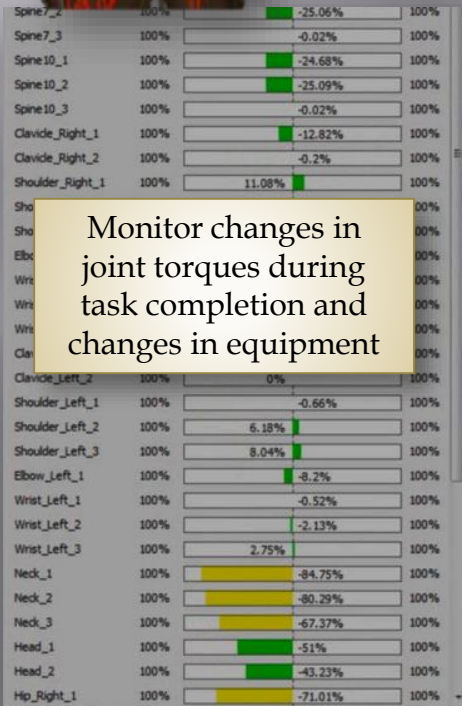
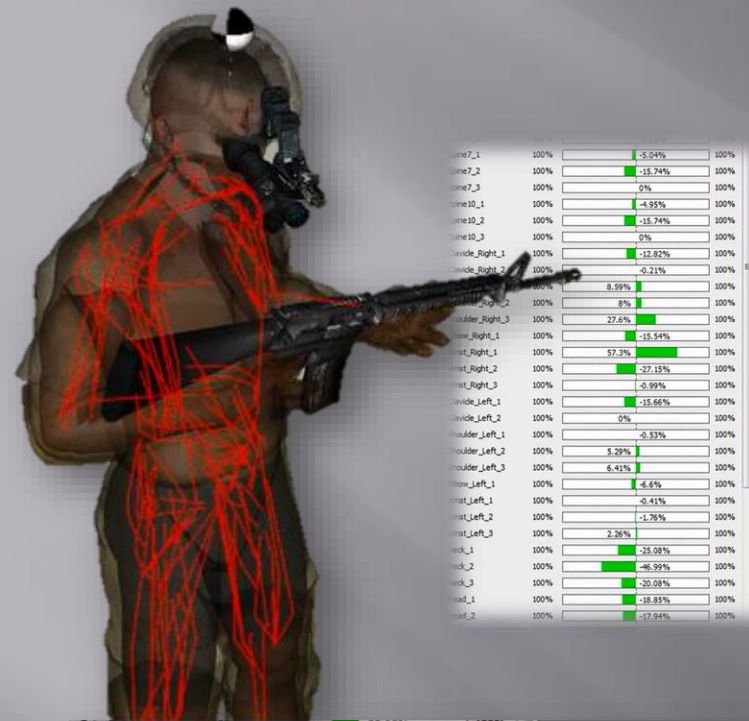
Render Behind Mesh



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

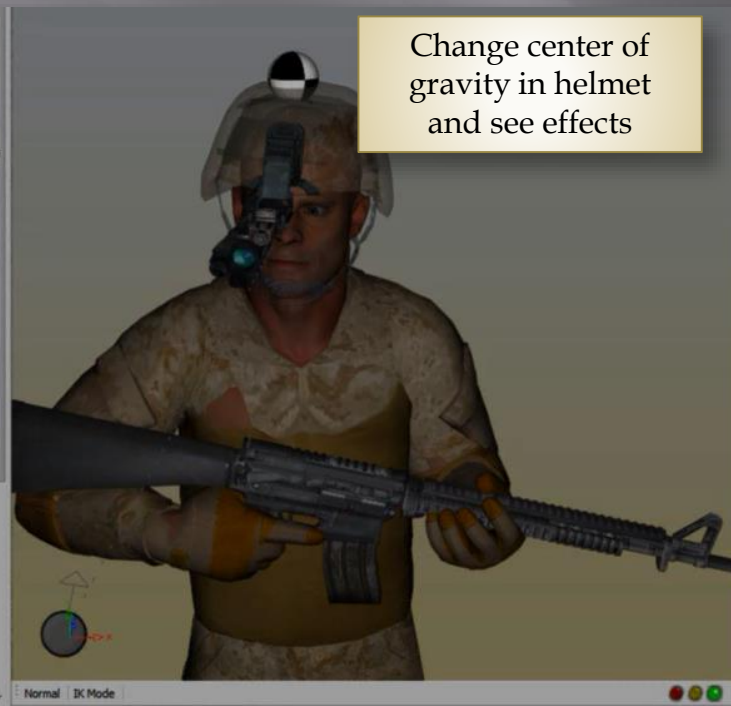
Head/Neck Injury

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



Monitor changes in joint torques during task completion and changes in equipment

Change center of gravity in helmet and see effects



Eye Vision: 0%

Max. Joint Torque: 0%

Total Joint Torques: 0%

Freeze Options

Freeze:

- Position
- Rotation
- Hips
- Spine
- Upper Body
- Lower Body

Lock left hand to: None

Lock right hand to: None

Lock left foot to: None

Lock right foot to: None

Posture Options

Prediction Type: Whole Body

Auto Update: Off

Use strength curve data

Gender: Male

Percentile: 19%

Vision Options

Display Vision: None

Length: 6

Posture Vision Eye: Both

Angle: 1.00

Apply Neutral

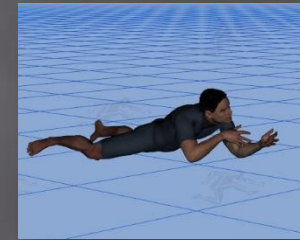
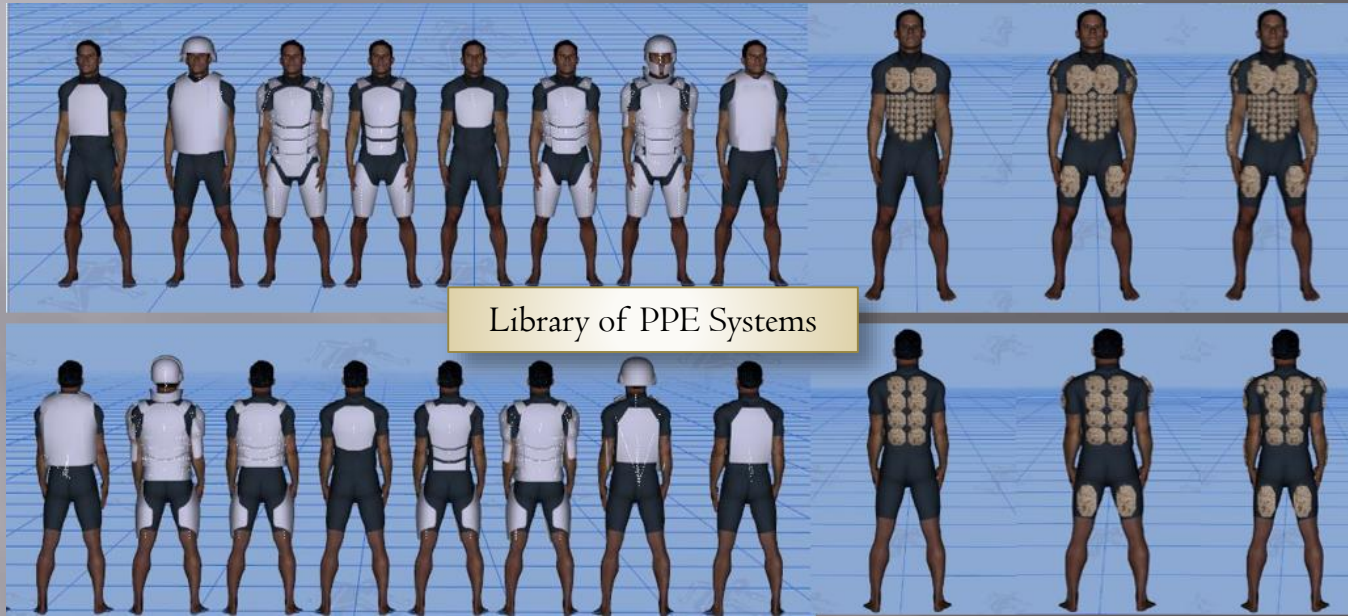
Repredict Posture

Refine Prediction

Predict Posture

Adjust strength and see changes in joint torque

System Optimization



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

System Optimization

Armor Evaluation Analyzer

Summary | Ratings | Armor | Report | Graphs | Modified & Limits | Optimization | Settings

Performance: 0.000
Minimum Performance (%): 25.00

Restriction: 0.000
Maximum Restriction (%): 25.00

Range Of Motion: 0.000
Minimum ROM (%): 25.00

Balance: 0.000
Minimum Balance(%): 25.00

Coverage: 0.000
Minimum Coverage (%): 25.00

Weight: 1.000
Maximum Weight (kg): 15.00

Torque: 0.000
Maximum Torque (%): 25.00

Bulk: 0.000
Maximum Bulk (%): 25.00

Accept All Modified Joint Limits

Dynamic Optimization

Scale Chicklets

Update Texture

Optimize

Heart

Liver

Minimize Weight

Armor Evaluation Analyzer

Summary | Ratings | Armor | Report | Graphs | Modified & Limits | Optimization | Settings

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Torque: 0.000
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Accept All Modified Joint Limits

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Heart

Liver

Maximize Coverage

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Accept All Modified Joint Limits

Dynamic Optimization

Scale Chicklets

Update Texture

Optimize

Heart

Liver

Maximize Coverage & Minimize Weight

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

System Optimization

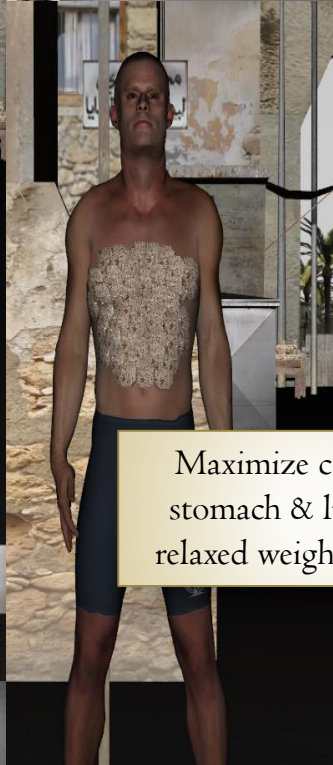
Maximize coverage of
stomach



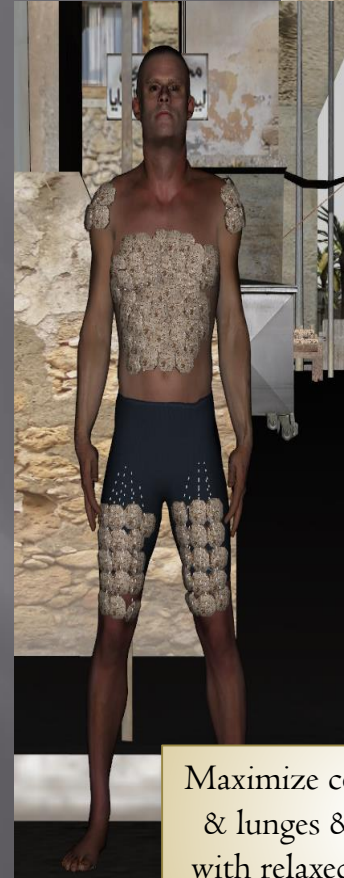
Maximize coverage of
stomach & lungs



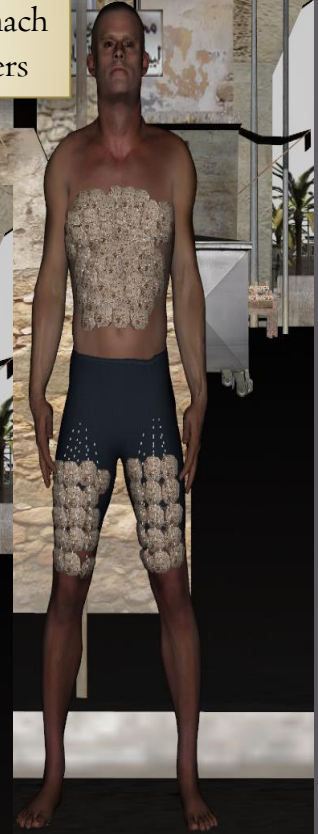
Maximize coverage of
stomach & lungs with
relaxed weight constraint



Maximize coverage of stomach
& lungs & legs & shoulders

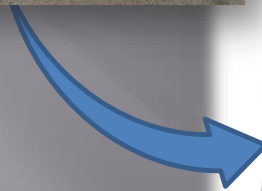
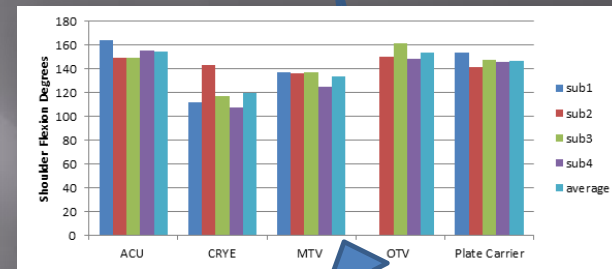
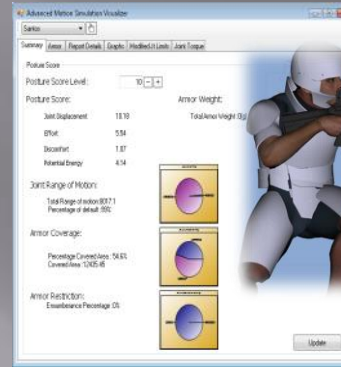


Maximize coverage of stomach
& lungs & legs & shoulders
with relaxed weight constraint



Automatically *design* optimal PPE system concepts 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

