The Virtual Soldier Research Program

Background
History
Physics-based
Strength
Applications
An Integrated Human
Open architecture
Why the Virtual Soldier?

Physical prototypes

Engineering Analysis

Stress
Vibration
Sound
Structural
Aerodynamics
Thermal
Fluid
Power

Virtual Soldier
The Santos® Model

- Predicts behavior
- Physics-based
**Objective:**
Minimize $F(q)$ e.g., Energy

**Find:** $\text{DOF}(q)$

**Constraints:**
- Range of motion
- Distance to target
- Physical constraints
In 2004/2005
Objective:
Minimize $F(q)$ e.g., Energy

Find: $\text{DOF}(q)$

Constraints:
- Range of motion
- Distance to target
- Physical constraints
- Equations of Motion (Newton’s Laws)
Understanding limits of Human Strengths

Male knee flexion with 40lb loaded walking simulation

gait with 40 lb backpack knee joint 50% strength
Stability - ZMP

Stability analysis
Hand

9.1. General Capabilities
   9.1.1. 25-DOF model
   9.1.2. Literature-based joint limits/range of motion (ROM)
   9.1.3. Variable ROM
   9.1.4. Flex-joint utility (auto finger range of motion)
   9.1.5. Carpel Tunnel risk calculator
   9.1.6. Force-torque calculator
   9.1.7. Hand Posture Prediction

9.2. Zone Differentiation

9.3. Grasping
   9.3.1. Manual hand morphing
   9.3.2. Precision grasping
   9.3.3. Power grasping
Analysis: strength, joint range of motion, spine shear and compression
Santos has Biomechanics & Physiology
Egress-Ingress Analysis
Seat and Cab design
Analysis of function, form, and fit
Reach, Vision, and Collision Detection
HF Analysis Tools
History of Santos

An Integrated Human


Robots
Optimization
Biomechanics
Interactive
Real time
High fidelity
CAD import

Posture prediction
Ergonomics

Vision

Realism
Anthropometry
Physics based

Strength & fatigue
Task simulation

Physiology

Thermal, hydration, energy
PPE-Blast

Psychological

Human Predictive dynamics

Artificial intelligence – Deep Learning

Clothing/armor

Validation       Validation       Validation       Validation
Human Variability

- Anthropometry
- Weight
- Body type
- Strength
- Fatigue
Soldier Lethality

- Operational effectiveness
- Individual load configuration
- Weight distribution on squad
- Human performance
- Mobility
- Survivability, PPE, and vulnerability
- Soldier/Squad specific

**mobility versus protection versus lethality**
Warrior Performance

• Effects of Load
• Effects of gravity
• Muscle fatigue
• Muscle strength
• Clothing restrictions
• Terrain
• Energy expenditure
Conduct trade off analysis
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Injury, blast, internal organs
Survivability Analysis

MUVES – simulates various threats against personnel with armor. It is a stochastic, component level survivability, lethality, and vulnerability (SLV) software suite. Simulates direct and indirect fire munitions against vehicles and personnel with armor.
ORCA – a high-resolution computerized human vulnerability model that is used to assess the impact of various casualty-causing insults on personnel. Insults include penetration, blast effects and thermal effects.
ORCA:

- Is the DoD’s high-resolution computerized human vulnerability model that is used to assess the impact of various casualty-causing insults on personnel.

- Calculates injury severity trauma metrics that may be used to characterize both an individual injury as well as multiple injuries to a single person.

- Assesses the impact of various casualty-causing mechanisms on the ability of military personnel to perform battlefield tasks.

- Considers the operational tasks that personnel must perform, and determines the extent to which penetration and other battlefield insults degrade the ability to perform these tasks.

- May be used to provide medical and operational casualty data of the human system.
Lighten The Load
• Mobility
  (RoM, weight, speed, agility, recovery, extended load carriage)
Mobility versus weight versus protection

Range of Motion
Recovery
Survivability

Armor (PPE), cover and concealment
Biomechanical Effects of PPE
Soft Armor & Clothing

Fast running computational models of soft armor and clothing, fully integrated with a complete digital human model.
Intellectual Property
- All IP is owned by the University of Iowa

Open Architecture
- API and Scripting

Validation & Verification
- Significant work at various organizations

An Integrated Approach
Virtual Humans

- Hand signals
- Training procedures
- Enemy combatants
Scenario Generation
Santos can make a difference

- Trade off analysis
- What if scenarios
- Survivability/Mobility Assessment
- Scalable: soldier to battalion
- Reduction of cost & time to acquisition
Human Simulation Systems

- **Santos** - Overall M&S environment
- **GruntSim** - Mobility, human performance, equipment, evaluation, soldier
- **Lighten the Load (LTL)** - soldier squad, equipment, load, distribution
- **Ektimo** - Mobility, survivability, PPE
- **MALUM** - Injury prediction, human performance, soldier squad
- **Santos-R & Puppeteer** - Posture/movement simulation and muscles
- **SimBioSys** - Physiology simulation
Thank you!
Variations in Soldiers

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Biometrics

Network training data

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Subject 1
- Age
- Gender
- Weight
- Strength
- Flexibility
- Physiology
- Expected Training Load
- Past injuries
- FMS
- Proxies

Adaptation

Strengthening & Conditioning

Santos Malum Terminus

Simulation Injury Prediction Framework

Propensity for Injury
- Physiological performance
- Biomechanical performance

Time to failure

DASHBOARD

DASH BOARD

Biometrics

Subject 1
- Age
- Gender
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Strengthening & Conditioning

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Time to failure

DASHBOARD

DASH BOARD

Biometrics
Training

Synthetic Training Environment
Human simulation can reduce injuries

- Majority of injuries (~86.5%) are non-battle injuries.
- In 2006 (Hauret, et al.) reported 743,547 MSK injuries
Thermal Considerations
Experiment with new weapons
Anthropometry is