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Computer Simulation of Blast Injury, Behind Armor Blunt Trauma, and their Mitigation

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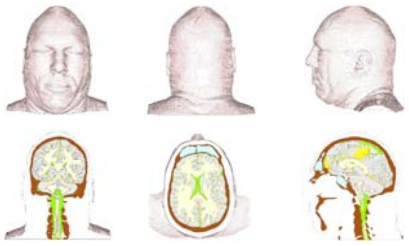
INTRODUCTION

- Warfighter Personal Protective Equipment (PPE) development is based principally on laboratory/field testing of prototype designs
  - Testing usually restricted to protection assessment against ballistic projectiles (bullet, fragments)
  - Very little testing done on blast protection
- We have developed high-fidelity models and simulation tools to study wound injury to head, neck, & torso of warfighter
  - Advantage: Assess protective effectiveness of armor design without use of human cadavers or harm to expensive physical surrogates

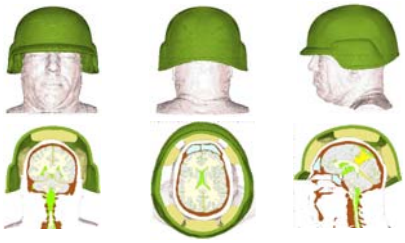
MODELS

- **Digital Head-Neck Model**
  - Anatomically correct distributions of bone, white & gray brain matter, membranes (falx & tentorium), cerebral spinal fluid (CSF), sinus air, & scalp/muscle (1mm resolution)



- **Digital Torso Model**
  - Anatomically correct distribution of bone, cartilage, intervertebral discs, spinal cord/fluid, airways, lungs, heart, vasculature/blood, stomach, liver, kidneys, spleen, muscle, & fat/skin (1mm resolution)

- **Digital Helmet Models**
  - Head-neck model wearing test helmet comprised of Kevlar shell & polyurethane foam pads (1mm resolution)



CONSTITUTIVE MODELS

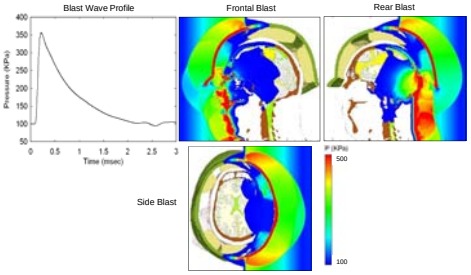
- **Biological Materials**
  - Advanced equation-of-state (EOS) and deviatoric strength models employed to represent bone and soft tissue
    - Life-critical organs represented by finite-deformation, elastic or viscoelastic models
    - Fluid & fluid-saturated tissue represented by Tillotson-Brundage EOS
      - Accurately captures cavitation & associated effects

COMPUTATIONAL SIMULATION METHODS

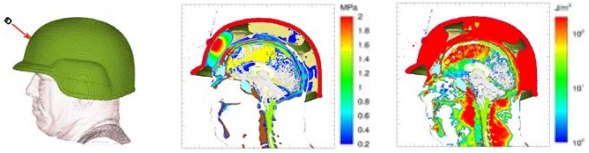
- **Eulerian Methods**
  - Blast, Blunt Impact, Penetration using shock physics code CTH
- **Lagrangian Methods**
  - Blunt Impact & Model validation with Sierra Mechanics code PRESTO
- **Coupled Lagrangian-Eulerian Methods**
  - Blast; using CTH (Eulerian domain) coupled to PRESTO (Lagrangian domain), controlled by ZAPOTEC II

SIMULATIONS

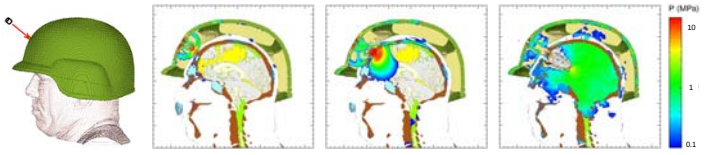
- **Explosive Blast Exposure**
  - 360 KPa blast (260 KPa overpressure)
    - Leads to mild Traumatic Brain Injury (mTBI)



- **Behind Helmet Blunt Trauma (BHBT)**
  - Caused by ballistic projectile stopped by helmet
    - Intracranial waves transmitted into brain leading to TBI



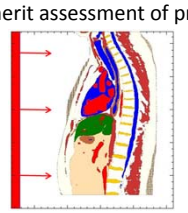
- **Projectile Penetration**
  - Caused by ballistic projectile perforating helmet
    - Intracranial penetration leading to open-head injury & brain trauma



SUMMARY

- **Demonstrated Capabilities**
  - Investigate details of wound injury mechanisms leading to TBI
  - Identify specific wave physics variables leading to localized brain injury
    - Shear wave energy leading to tissue distortion & membrane tearing
    - Dilatational wave energy causing fluid cavitation & associated tissue damage (e.g., axonal cytoskeletal disruption of neurons)
  - Conduct relative merit assessment of protective headwear (helmets)
- **New Near-Term Capabilities**
  - Investigate wound injury mechanisms to life-critical organs in torso
  - Torso model completed; currently undergoing testing & validation
  - Conduct relative merit assessment of protective headwear

Frontal Blast Simulation Test of Torso Model



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