Modeling Brain Response to Blast and Ballistic Loading

S&T Campaign: Sciences for Lethality and Protection
Kinetic Protection
Soldier Protection

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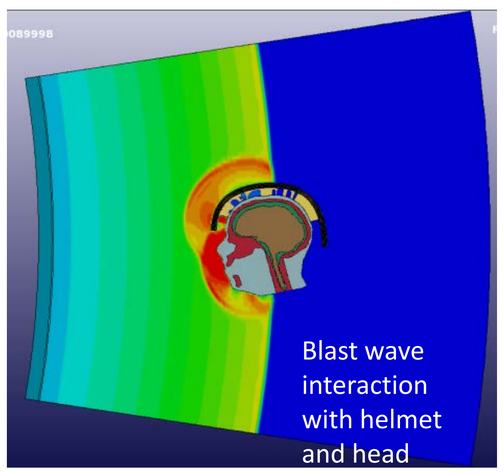
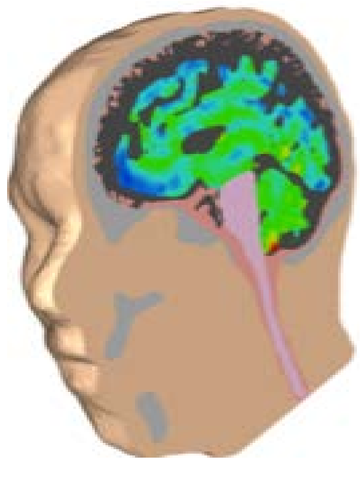
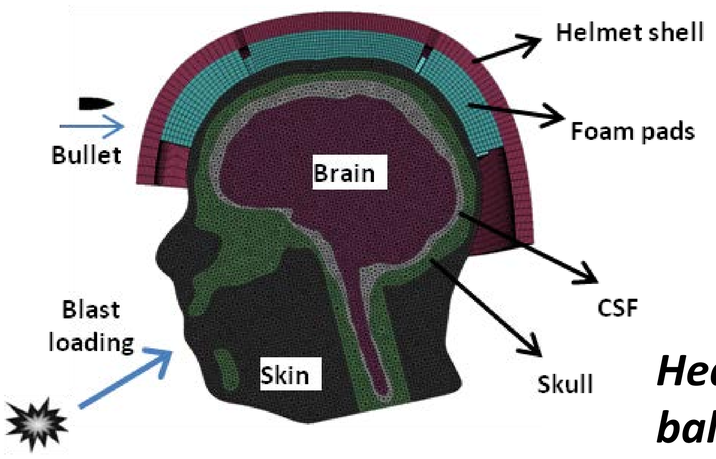
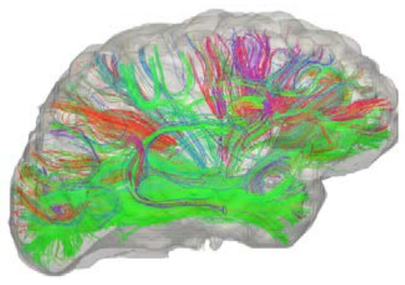
Research Objective

- **Understand loading mechanisms leading to brain injury**
  - **Transmission of blast and ballistic loads through helmet and pad system to the head and brain**
  - **Relate transmitted load to injury mechanisms**
- **Evaluate and improve head protection systems**
  - **Optimized composite shell**
  - **Novel pad systems**





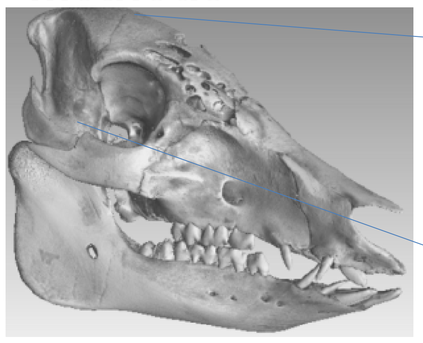


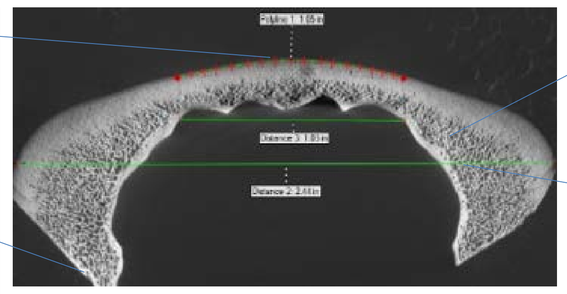


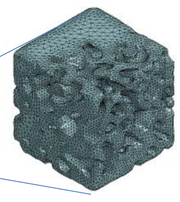
Head-helmet model to assess ballistic load transfer to brain and consequent injury

Challenges

- **Accurate material models for composite shell, polymeric pad, skull, and brain tissues**
- **Experimental data on surrogate systems (animal models, cadaveric subjects, and instrumented head-forms)**
- **Transfer functions that relate surrogate systems to human models**
- **Injury criteria and threshold for soft and hard tissues**
- **Biofidelic models and convergent numerical methods**





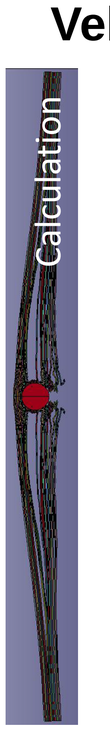


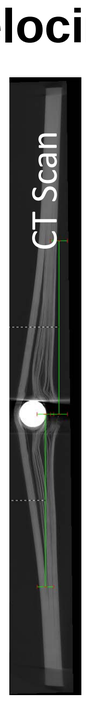
$$\sigma = \sigma\left(\varepsilon, \dot{\varepsilon}, \rho, t_{cortical}, t_{trabecular}, \text{topology}\right)$$

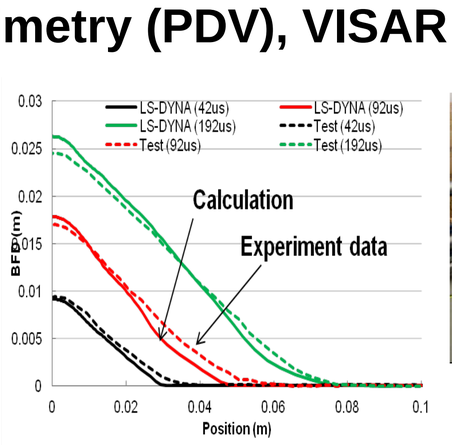
Multiscale tissue model development using porcine skull as surrogate

ARL Facilities and Capabilities Available to Support Collaborative Research

- **Expertise in biomechanics, constitutive model formulation, numerical analysis and high rate experiments**
- **Computational modeling and simulation**
  - **Segmentation of MRI/CT images**
  - **Biofidelic model generation**
  - **Parallel Lagrangian and Eulerian hydrocodes**
- **Ballistic-rate experimental facilities**
  - **Ballistic ranges for characterizing V50 and BFD**
  - **Gas guns for shock experiments, Split Hopkinson Pressure Bars (SHPB) for high rate, and load cells for low rate characterization**
  - **micro-CT, high speed cameras, Photonic Doppler Velocimetry (PDV), VISAR**







Shock Experiment Facility

psf	V_{50} difference
1.6	2%
1.8	7%
2.2	5%

SHPB Experiment Facility

Simulations of ballistic experiment captures ballistic limit, backface deformation and delamination of ultra high molecular weight polyethylene (UHMWPE) composite.

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Tissue injury criteria and threshold for hard and soft tissues**
- **Biofidelic computational models with relevant topology and finite element discretization**
- **Accurate numerical tools for fluid-structure interaction and damage analysis**
- **Multiscale, multiphysics models for injury biomechanics**
- **Biomechanics research to establish transfer function between surrogate models and human**