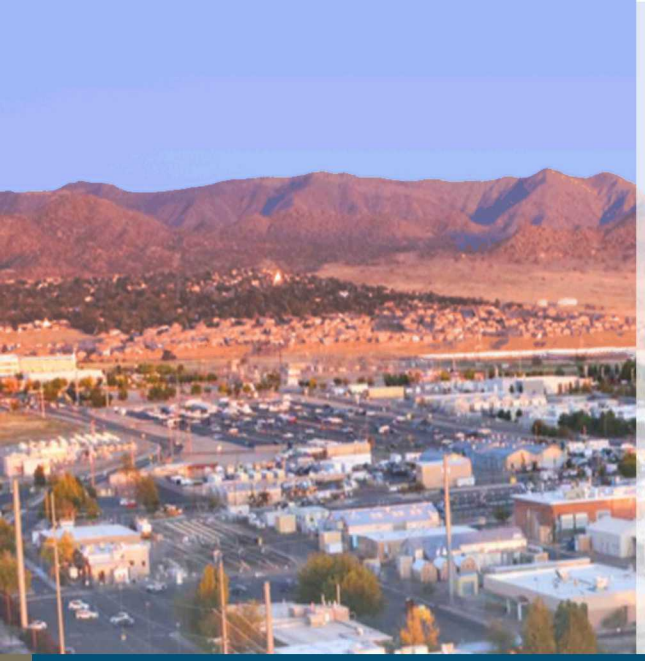

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Naval Force Health Protection Program Review 2020

PANTHER Project

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Sandia Injury Biomechanics Laboratory (SIBL)

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PANTHER: Development of a Predictive Multiscale Traumatic Brain Injury Model

Chad B. Hovey, Sandia National Laboratories

Abstract:

The Advanced Combat Helmet ("ACH") military specification ("mil-spec") requires a helmeted magnesium Department of Transportation ("DOT") headform be dropped vertically, with an impact speed of 10 ft/s (3.1 m/s), onto a steel hemispherical target. The pass/fail criteria is based on translational acceleration (150 G) alone, absent of any rotational component.

Without a rotational component, the specification's injury risk application is limited to skull fracture and peripheral hematomas (subdural, subarachnoid), since this translational acceleration injury risk assessment draws origins from the Wayne State Tolerance Curve (WSTC). To provide a more comprehensive view of injury for the entire brain, an alternative approach is needed.

We have developed a prototypical injury risk criteria based on the neuronal response to abrupt changes in general motion (translation, rotation, or both). The cellular-based mild traumatic brain injury (cbmTBI) criterion utilizes both the strain and strain rate of brain tissue to account for the stretch and rate of stretch that occurs throughout the brain as a result of blunt impact through the ACH.

We ran physical experiments of an ACH-fitted magnesium headform, which produced repeatable headform peak accelerations. Then, we developed a simulation of the experiment, and validated the simulation output with the experimental data. We then substituted the magnesium headform with a human headform, consisting of skin, muscle, bone, gray matter, white matter, and cerebral-spinal fluid.

We quantified brain injury risk using the cbmTBI criterion, both using the current mil-spec test and a modified test. The modified test used a hemispherical target that was located posterior to the crown of the helmet in the axial plane. While the current mil-spec test produced brain deformation from translation alone, the modified test produced brain deformation from translation and rotation, which is closer to most real world and combat theater impacts (e.g., such as occur in tertiary blast exposure).

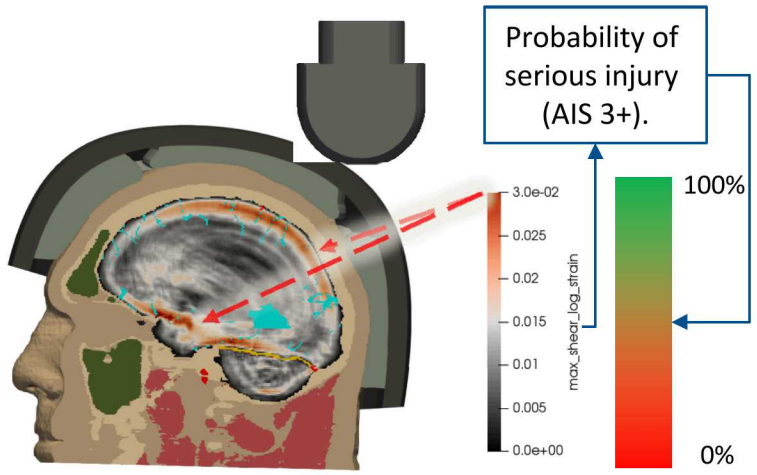
Compared to the current mil-spec test, the modified test produced elevated strain and strain rates in the human digital twin. These data, mapped to the cbmTBI criterion, suggest increased injury risk for blunt impacts that cause rotation and translation, rather than just translation alone. Moreover, these data lead to a rotational performance metric, which is rooted in the actual biology and pathology of the brain's response to impact and blast, and which should be used to improve next-generation helmet designs.

PANTHER: Development of a Predictive Multiscale Traumatic Brain Injury Model

Chad B. Hovey, Sandia National Laboratories

Description: The Sandia Injury Biomechanics Laboratory (SIBL) contributes to the PANTHER team through the development of a numerical framework of a high-fidelity human digital twin. The framework allows for the assessment of injury risk from head impact conditions, such as from the ACH Mil Spec, using PANTHER's cellular-based mild traumatic brain injury (cbmTBI) criterion.

Technical Approach: We created a high-fidelity geometric model of the human head and neck, consisting of 5.7M hexahedral finite elements at a nominal resolution of 1-mm^3. We created high-fidelity material models for the human tissues and helmet constituents, with emphasis on the hard/soft foam layers. With the Sandia Sierra Solid Mechanics (SSM) solver, we quantifed brain strain and strain rate, for use in the cbmTBI criterion.



- **PERFORMERS:** Sandia Injury Biomechanics Laboratory (SIBL)

FY21-FY22 Plans:

- As of this writing, the PANTHER team do not have funding beyond FY20. Were FY21 and beyond funding received, our laboratory would begin work on a **verification and validation** (V&V) effort. The degree to which a framework is predictive and therefore trusted by its users is the single most important element of moving a framework from development into production.

FY23 Plans: (As applicable)

- Following the V&V efforts, our laboratory would focus on **deployment** of the framework, creating a user community within military and university research communities.

FY20-21 Accomplishments:

- Simulation V&V, reproduce unhelmeted magnesium DOT headform impact into MEP target.
- Repeatability and reliability of helmeted simulations:
  - High-fidelity finite element mesh of helmet with hard (protective) and soft (comfort) foam layers.
  - High-fidelity foam material model.
  - Three-point angular velocity algorithm for quasi-rigid bodies.
  - Helmeted high-fidelity digital twin impact into hemispherical target, per the Mil Spec.
  - Offset target simulations, demonstrating difference between translational and rotational head impact responses; prescribed skull rotation responses.

Impact Statement: Through its ability to see into the virtual brain, the framework can predict tissue-level response in-silico, as a complement to in-vitro and in-vivo approaches.

Naval Need: The SIBL high-fidelity digital twin framework can be used to evaluate and improve personal protective equipment (PPE) designs.