Second in the International State-of-the-Science Meeting Series

International State-of-the-Science Meeting on

Blast Injury Dosimetry

June 8–9, 2010

Westfields Marriott Washington Dulles, Chantilly, Virginia

DoD Blast Injury Research Program Coordinating Office, Fort Detrick, Maryland

PREFACE

It is my pleasure to acknowledge the staff of the DoD Blast Injury Research Program Coordinating Office for its work to plan and implement the International State-of-the-Science Meeting on Blast Injury Dosimetry. They successfully assembled subject matter experts from the science, engineering, and health care disciplines to address the critically important topic of recording and documenting blast-related exposures and correlating them with acute injuries and chronic health effects.

I wish to commend the meeting presenters, panel members, and attendees for their excellent contributions, both in their presentations and discussions. Without their active participation, it would not have been possible to critically assess the state of scientific knowledge. I thank all investigators who have conducted research that provides vital information on blast injury mechanisms, on the exposure data needed to predict blast injuries, and on the sensor technologies capable of collecting relevant exposure data. Further, I urge scientists to continue relevant programs of research and instigate novel studies that will answer compelling research questions.

The purpose of this document is to summarize the proceedings of the meeting and to disseminate information regarding what is known and what still needs to be learned about blast injury dosimetry to a broad audience, including scientists, engineers, medical researchers, health care professionals, protection system development experts, and military leaders and decision-makers at all levels.

Thank you for your contributions to make this meeting a great success.

John F. Glenn, Ph.D.
Senior Executive Service
Principal Assistant for Research and Technology
U.S. Army Medical Research and Materiel Command

SUMMARY OF MEETING PROCEEDINGS

INTRODUCTION

Warfighters are routinely exposed to blast-related insults in training and in combat. These insults range from occupational exposures associated with the use of weapon systems to potentially lethal exposures from explosive enemy weapons in combat. Examples of the types of potentially injurious blast insults they encounter include blunt impact, blast overpressure, impulse noise, and inhaled toxic gases.

The Department of Defense (DoD) Blast Injury Research Program Coordinating Office (PCO) hosted the International State-of-the-Science Meeting on Blast Injury Dosimetry on June 8-10 in Chantilly, Virginia to explore ways to objectively record and document blast-related exposures and to correlate these exposures with acute injuries or chronic health effects.

The objectives of this State-of-the-Science meeting were to:

- Identify and prioritize the blast injuries of concern that should be the focus of the DoD's blast dosimeter development efforts,
- Determine if there are blast dosimeters available that can be fielded now or within the next two years, and
- Identify and prioritize the research gaps that exist in the development of blast dosimeters in the areas of both blast-related human effects modeling and sensor development.

Eighty-eight experts representing the DoD, the Department of Transportation, the Department of Veterans Affairs, academia, medicine, and industry attended the meeting. Countries represented at the meeting included Canada, France, Israel, Japan, the Netherlands, the United Kingdom, and the United States (see Appendix A, Meeting Participants).

This document summarizes the proceedings of the meeting. The PCO is writing a more detailed review and will submit it to a peer-reviewed journal for publication.

METHOD

On June 8 and 9, experts from the scientific, medical, and operational communities presented 18 short talks related to blast injury dosimetry. A diverse array of background and state-of-the-science topics was presented, ranging from incident data and biomarker studies to the development of various sensor technologies (see Appendix B, Meeting Agenda).

A five-member panel of accomplished and respected scientists listened to each presentation and stimulated post-presentation discussions. The panel consisted of the following experts:

- Steven G. Kaminsky, Ph.D. (Panel Chair), Vice President of Research, Uniformed Services University of the Health Sciences
- Duane Cronin, Ph.D., P.Eng., Associate Professor, Department of Mechanical Engineering, University of Waterloo, Ontario, Canada
- Emrys Kirkman, Ph.D., Principal Physiologist in Biophysics and Trauma (Surgical Sciences), Defence Science and Technology Laboratory, Porton Down, United Kingdom
- Bruce LaMattina, Ph.D., P.E., Program Manager, Solid Mechanics, U.S. Army Research Office
- Fred Pearce, Ph.D., Assistant Director for Medical Research & Engineering, Office of the Deputy Under Secretary of Defense for Science & Technology

On the afternoon of June 9, participants divided into four workgroups. Each workgroup was charged with discussing and answering the following questions based on the member's individual knowledge and the material presented at the meeting:

- What blast injuries are we interested in addressing with dosimeters?
- What exposure data are needed to predict the likelihood of the injuries of concern?
- What sensor technologies are available to address the required data elements?
- What biomedical research has been done, or is required, to develop human effects models that correlate the blast-related exposures (sensor data) with resulting injuries?

A panel member was present to lead and facilitate discussions in each workgroup. Following workgroup discussion, the participants reconvened in a general session and each panel member briefed the conclusions of his workgroup.

On June 10, the panel members and Blast PCO staff met for a closed executive session to synthesize information from the meeting and formulate its findings, knowledge gaps, and recommendations.

FINDINGS

A long-term cohesive strategy is needed to leverage near-, mid-, and far-term solutions for blast injury dosimetry (e.g., screening, diagnosis, sensors) as they develop. However, near-term (6-9 months) and possibly incomplete solutions should be accepted now until other options are available. A rapid screening tool using response indicators is needed to identify blast-exposed individuals who require a medical evaluation.

The injuries of concern deemed to have the greatest overall impact to the Warfighter, and which would therefore derive the greatest benefit from a fielded dosimeter, are:

- Impact-Induced Mild Traumatic Brain Injury
- Blast Lung Injury
- Primary Blast Abdominal Hemorrhage and Organ Perforation
- Injuries from Inhaled Toxic Fire Gases
- CBRN-related injuries

Exposure data needed to predict the likelihood of the injuries of concern include pressure loading, acceleration in six degrees of freedom, and chemical and biological profiles. Table 1 illustrates how the exposure data relates to the injuries of concern.

Injury \ Measure	Pressure Loading (Pressure-Time History)	Acceleration Measurements (6° of Freedom)	Chemical Profile (Concentration-Time History)	Biological Profile
Impact-Induced mTBI		X		
Blast Lung	X			
Primary Blast, Abdominal Hemorrhage & Organ Perforation	X			
Toxic Fire Gases			X	
CBRN			X	X

Table 1. Data measurements needed for blast-related injuries of concern.

A standard dataset, to accompany the exposure event data, should include the date, time, individual identification, and a global positioning system (GPS) location. Dosimeter capabilities should include wireless download, a standardized body location for wear, and power consumption and durability to permit 12 months of continuous operation.

Commercial off the shelf (COTS) pressure transducers and accelerometers are available to address near-term requirements for dosimeters and sensors but may require additional modification for military use. Chemical, common fire gas and radiation sensors are also available as COTS items.

Alternate sensing methods that should be pursued if justified by future injury correlations include:

- Material-based strategies: Pressure sensing materials, with different levels of sensing, are available commercially but military applications will require additional development.

- Force measurement: New technologies like smart fabrics may be applicable.
- Acoustic sensors: Sensors are available commercially but military applications require development.
- Biomarkers for the injuries of concern
- CBRN sensors for individual use. The Army Research Office has ongoing efforts to miniaturize CBRN sensors for individual use.

We need a systematic approach to gather, field-validate, and use data to improve triage models and support the development of protection systems. Specific details on the status (research/ knowledge) of the five blast-related injuries of concern are presented below:

- Impact-Induced mTBI: There is a substantial amount of literature and established evaluation criteria. There are injury correlations and general agreement with those correlations.
- Blast Lung Injury: There is extensive literature on the occurrence of injury with validated injury and lethality correlations for conventional and novel explosives in the free field and in enclosures. The Army currently uses a blast lung injury prediction model (INJURY) for health hazard and survivability assessments.
- Blunt Injury (resulting in internal organ injuries): There is extensive literature on the mechanism of injury with good injury correlations. However, field dosimetry may be challenging.
- Inhaled Toxic Fire Gases: There are extensive animal exposure data and established criteria for acute and toxic effects from exposures to individual gases. The Army is sponsoring a biomedical research program that has produced a physiologically-based computational model of injury and performance decrements from exposure to mixed fire gases. This research has been published extensively in the scientific literature. Additional work is required to translate existing knowledge into a field dosimeter capability.
- CBRN: Individual dosimeters exist for exposure to radiation. Area detectors exist for exposure to chemical and biological agents. Additional work is required to translate existing knowledge into an individual field dosimeter capability.

An extensive research program exists to investigate non-impact blast-induced mTBI. While there is a growing amount of literature, there is no consensus on mechanisms, thresholds, and neuropathology of non-impact blast-induced mTBI. Additional research is needed in:

- Advanced neuroimaging, neuropsychology, human neuropathology, and biomarkers (proteomic/genomic approaches)
- The cross-corroboration of human data with animal models

We should take advantage of voluntary training exposure data from the field (i.e., the Breacher studies).

In addition, we need to develop accurate high strain rate models for tissue response related to blast exposure.

KNOWLEDGE GAPS

There are knowledge gaps regarding our ability to record and document blast-related exposures and correlate those exposures with acute injuries or chronic health effects. These gaps include:

- An objective measure of actual exposure to blast effects
- An understanding of the mechanisms of blast injury and how they affect the nature of the resulting insult or injury, including:
  - The range of inputs applicable to human injury
  - Individual variations in susceptibility to injury
  - Appropriate data for predicting injuries of concern
  - Scaling research results for animal models to humans
  - Differentiating between blunt versus blast injury
  - The effects of repeated blast exposures
  - The effect of multiple injuries
  - Linking pressure and acceleration data to the injury
- A correlation of data from blast physics dosimeters with devices that measure biological responses (“responsimeters”)
- Diagnostic tests to differentiate among physiologic sources of mTBI, post-traumatic stress disorder (PTSD), and chronic pain
- Delineation of the role of toxic gas inhalation and other factors on mTBI
- Validation and correlation of biomarkers with blast injury (e.g., peripheral blood markers for neuronal injury or galanin message-associated peptide [GMAP])
- Well-characterized pressure and time-history data (multi-point measurements)
- A data fusion system for managing and streamlining all the data that are being generated
- Sensors that are fast, can record meaningful data, and are able to decouple pressure from acceleration
- Lightweight, inexpensive, and battery-free blast wave sensors
- Sensor networks and suites that can collect data on the environment (i.e., sensor fusion)

RECOMMENDATIONS

- Establish a site at which sensors and testing methods (e.g., shock tubes, blast loads, etc.) from new and historic studies are evaluated to enable standardization of methods and measurements across studies.
- Field sensors or dosimeters only when there is a clear connection between the data being collected and a specific injury.
- Ensure fielded dosimeters are as seamless as possible to the wearer by evaluating and minimizing the physical, logistic and administrative impacts on the Warfighter prior to fielding.
- Proceed with the second generation of helmet-mounted sensors and a concussion screening tool that uses well-known, well-documented concussion criteria.
- Establish a task force composed of sensor/dosimeter experts, engineers, modelers, mathematicians, and medical experts to review, interpret and integrate existing historical datasets.
- Determine the upper and lower limits of blast energy or exposure that cause survivable injury for the injuries of concern so that sensors can be calibrated to detect within that range.
- Collect as much sensor data as possible from Warfighters exposed to blast and then decide what areas of research are most worthy of development
- Expand the Breacher studies to investigate changes in the olfactory response pre- and post-exposure to repeated blasts.
- Conduct an extensive literature review to determine what has been done with regard to biomedical research on human effects models that correlate blast-related exposures with resulting injuries.

APPENDICES

A

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B

MEETING AGENDA

Tuesday, June 8, 2010

Time	Topic	Lead	Location
7:30 AM	**Registration/ Continental Breakfast**		Grand Dominion Foyer/ Fairfax
8:00 AM	Introduction	Mr. Michael Leggieri and Lt Col Robert Shull DoD Blast Injury Research PCO	Grand Dominion V & VI
8:30 AM	Illnesses in Veterans of the 1990–91 Gulf War: The Need for Objective Assessment of Exposures and Diseases	Dr. Kelley Brix Office of Assistant Secretary of Defense (Health Affairs)	Grand Dominion V & VI
9:00 AM	JTAPIC Summary of Injuries Observed in Current Operations	Mr. John Uscilowicz Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC)	Grand Dominion V & VI
9:30 AM	Injury/Casualty Prediction Requirements and Approaches for Ship Vulnerability Studies	Dr. E. Thomas Moyer/ Mr. Daniel Platt Naval Surface Warfare Center, Carderock Division	Grand Dominion V & VI
10:00 AM	The Blast Badge	Mr. Lance Brown Naval Surface Warfare Center, Indian Head Division	Grand Dominion V & VI
10:30 AM	Break		
10:45 AM	Quantico Breacher Study	LCDR Walter Carr Naval Medical Research Center	Grand Dominion V & VI
11:10 AM	Brain Injury Biomarkers and Behavioral Characterization of mTBI in Soldiers Following Repeated, Low-Level Blast Exposure	Dr. Gary Kamimori Walter Reed Army Institute of Research	Grand Dominion V & VI
11:35 AM	Blast Dosimetry for the Quantico and Kiwi Breacher Injury Studies: Description, Specifications, Data and Next-Generation Plans	Dr. Tim Walilko Applied Research Associates	Grand Dominion V & VI
12:00 PM	Lunch		Fairfax
1:00 PM	Blast Dosimeter	Dr. James Stuhmiller L-3 Communications/Jaycor	Grand Dominion V & VI
1:30 PM	Sensor Tape Program	Mr. Jeffrey Rogers Defense Advanced Research Projects Agency	Grand Dominion V & VI
2:00 PM	A Passively Activated Shockwave Sensor for the Detection of Blast	LTC Timothy Haley/Dr. David Bahr US Army Research Institute for	Grand Dominion V & VI

	Wave Overpressure in the Screening of mTBI	Environmental Medicine/Washington State University	

Tuesday, June 8, 2010 (cont.)

2:30 PM	**Break**		
2:45 PM	Earpiece Instrumentation as a Means of Measuring Head Acceleration	Dr. Joseph Pellettiere Air Force Materiel Command	Grand Dominion V & VI
3:15 PM	Correlating Blast-Induced Color Change in Photonic Crystalline Nanostructures with Brain Pathology	Dr. Douglas Smith University of Pennsylvania	Grand Dominion V & VI
3:45 PM	Head Impact Telemetry System	Mr. Jeff Chu Simbex, LLC	Grand Dominion V & VI
4:15 PM	Daily Wrap-Up	Lt Col Robert Shull DoD Blast Injury Research PCO	Grand Dominion V & VI

Wednesday, June 9, 2010

Time	Topic	Lead	Location
7:30 AM	**Registration/ Continental Breakfast**		Grand Dominion Foyer/ Fairfax
8:00 AM	Administration and Goals for the Day	Lt Col Robert Shull DoD Blast Injury Research PCO	Grand Dominion V & VI
8:30 AM	Development of a Ballistic Impact Detection System	Mr. Stephen VanAlbert Walter Reed Army Institute of Research	Grand Dominion V & VI
9:00 AM	Relating Engineering Measurements from Helmet-Mounted Personal Blast Dosimeters to TBI Predictions and Blast Strength	Dr. Jean-Philippe Dionne Allen Vanguard	Grand Dominion V & VI
9:30 AM	Blast Event Analysis and Recorder System	Mr. Scott Badenoch Badenoch, LLC	Grand Dominion V & VI
10:00 AM	**Break**		
10:30 AM	Vehicle Black Box	Mr. Steve Pruitt Diversified Technical Systems, Inc.	Grand Dominion V & VI
11:00 AM	Helmet-Mounted Sensor System Study	Mr. Michael Leggieri DoD Blast Injury Research PCO	Grand Dominion V & VI
11:30 AM	Orientation to Workgroups	Mr. Michael Leggieri DoD Blast Injury Research PCO	Grand Dominion V & VI

Wednesday, June 9, 2010 (cont.)

12:00 PM	**Lunch**		Fairfax
1:00 PM	Workgroups	1 – Dr. Bruce LaMattina 2 – Dr. Emrys Kirkman 3 – Dr. Duane Cronin 4 – Dr. Fred Pearce Chair – Dr. Steven Kaminsky	Grand Dominion I Grand Dominion II Grand Dominion III Grand Dominion V & VI
2:30 PM	Break		
2:45 PM	Workgroups	1 – Dr. Bruce LaMattina 2 – Dr. Emrys Kirkman 3 – Dr. Duane Cronin 4 – Dr. Fred Pearce Chair – Dr. Steven Kaminsky	Grand Dominion I Grand Dominion II Grand Dominion III Grand Dominion V & VI
3:30 PM	Brief Back – Workgroup 1	Dr. Bruce LaMattina US Army Research Office	Grand Dominion V & VI
3:45 PM	Brief Back – Workgroup 2	Dr. Emrys Kirkman Defence Science and Technology Laboratory	Grand Dominion V & VI
4:00 PM	Brief Back – Workgroup 3	Dr. Duane Cronin University of Waterloo	Grand Dominion V & VI
4:15 PM	Brief Back – Workgroup 4	Dr. Fred Pearce Office of the Deputy Under Secretary of Defense for Science & Technology	Grand Dominion V & VI
4:30 PM	Wrap-Up and Closing Remarks	Mr. Michael Leggieri DoD Blast Injury Research PCO	Grand Dominion V & VI

Thursday, June 10, 2010

Time	Topic	Lead	Location
7:30 AM	**Continental Breakfast**		Fairfax
8:00 AM	Introduction	Dr. Steven Kaminsky Panel Chair Uniformed Services University of the Health Sciences	Treaty
8:10 AM	Executive Session	Panel Members	Treaty
10:00 AM	**Break**		
10:20 AM	Executive Session	Panel Members	Treaty
12:00 PM	**Lunch**		Fairfax
1:00 PM	Executive Session	Panel Members	Treaty
2:00 PM	Closing Remarks	Mr. Michael Leggieri DoD Blast Injury Research PCO	Treaty

C

CROSS-ANALYSIS OF BLAST-RELATED INJURIES OF IMPORTANCE TO SPECIFIC CRITERIA

Key
Green = Satisfies criteria
Yellow = Partially satisfies criteria
Red = Does not satisfy criteria

Criteria	Impact-Induced mTBI	Non-Impact Blast-Induced mTBI	Auditory Injuries	Long-term Mental Health Sequelae	Blast Lung Injury	Primary Blast Abdominal Hemorrhage & Organ Perforation	Spinal Cord/Column Injuries	Eye Injuries	Low Rate Non-Head Blunt Trauma (vehicle rollover)	High Rate Non-Head Blunt Trauma (blast-specific)	Injuries from Inhaled Toxic Fire Gases	CBRN Injuries
An established relationship between dose and injury exists.												
Injury is not immediately obvious to first line responders.												
Injury progresses (worsens) over time.												
Injury has cumulative effects (e.g., concussion).												
Early* intervention is effective for the injury.												
Concurrent/combined injuries amplify negative effects of an injury.												
Injury has a high operational impact.												

* Definition of "early" depends on the tactical situation at hand.

Some notes to this analysis:

- Injuries were assessed against the criteria based on the present day scenario; rankings may change in time depending on emerging threats.
- Time scale is an important factor to consider in the table, especially for the criterion focused on cumulative effects of an injury.
- The location and type of an auditory injury would affect whether the injury is immediately obvious to first line responders and/or can benefit from early intervention.
- A spinal cord/column injury may or may not be immediately obvious to first line responders depending on its seriousness.

D

DEFINITIONS

Taxonomy of Injuries from Explosive Devices

- Primary: Blast overpressure injury resulting in direct tissue damage from the shock wave coupling into the body.
- Secondary: Injury produced by primary fragments originating from the exploding device (preformed and natural [unformed] casing fragments and other projectiles deliberately introduced into the device to enhance the fragment threat) and secondary fragments, which are projectiles from the environment (debris and vehicular metal).
- Tertiary: Displacement of the body or part of body by the blast overpressure causing acceleration/deceleration to the body or its parts, which may subsequently strike hard objects causing typical blunt injury (translational injury), avulsion (separation) of limbs, stripping of soft tissues, skin speckling with explosive product residue and building structural collapse with crush and blunt injuries, and crush-syndrome development.
- Quaternary: Other "explosive products" effects—heat (radiant and convective) and toxic toxidromes from fuel and metals—causing burn and inhalation injury.
- Quinary: Clinical consequences of "post detonation environmental contaminants" including bacteria (deliberate and commensal, with or without sepsis), radiation (dirty bombs), and tissue reactions to fuel and metals.

Definitions of Blast-related Injuries Featured in this Report

- Blast Injury: Injury that occurs as the result of the detonation of high explosives, including vehicle-borne and person-borne explosive devices, rocket-propelled grenades, and improvised explosive devices.
- Non-Impact Blast-Induced mTBI: Non-impact blast exposures occur when Warfighters are close enough to an explosion to experience the high pressures created by the blast itself but far enough away to avoid penetrating injuries caused by fragments and blunt impact injuries caused by debris or by whole-body translation.
- Impact-Induced mTBI: mTBI in military operational settings is defined as an injury to the brain resulting from an external force and/or acceleration/deceleration mechanism from an event such as a blast, fall, direct impact, or motor vehicle accident which causes an alteration in mental status typically resulting in the temporally related onset of symptoms such as: headache, nausea, vomiting, dizziness/balance problems, fatigue, insomnia/sleep disturbances, drowsiness, sensitivity to light/ noise, blurred vision, difficulty remembering, and/or difficulty concentrating. (DVBIC definition)

- Hearing/Auditory Injuries: Those injuries caused by exposure to hazardous levels of noise brought on by an explosion.
- Long-term Mental Health Sequelae: Caused by those traumatic events that would have negative mental health effects upon the individual over a number of years.
- Blast Lung Injury: A direct consequence of blast on the body. An injury resulting in tearing, hemorrhage, contusion or edema of the respiratory system.
- Primary Blast Abdominal Hemorrhage & Organ Perforation: Injury caused by the intense over-pressurization impulse created by an explosion. Blast injury to the gastrointestinal tract.
- Spinal Cord/Column Injuries: An insult to the spinal cord resulting in trauma created by a blast.
- Eye Injuries: Any resultant ocular injury, such as corneal abrasions, fragments, debris, eyelid lacerations, open globe injuries and intraocular foreign bodies, created by a blast event.
- Low Rate Non-Head Blunt Trauma (Vehicle Rollover): A non-head injury occurring when the individual hits or is hit by a large outside object (vehicle rollover).
- High Rate Non-Head Blunt Trauma (Blast-Specific): Any non-penetrating injury occurring to the body, except the head, when the individual is subjected to a blast.
- Injuries Related to Toxic Fire Gases: An injury to an individual who was exposed to a mixture of inhaled toxic fire gases, such as carbon monoxide, hydrogen cyanide, and nitrogen dioxide resulting from a blast event.
- Injuries Related to CBRN Exposure: An injury related to the exposure of chemical, biological, radiation, and nuclear contaminants created by a blast.

Other Definitions

- Blast Injury Dosimeter: Measures an exposure to blast (also called an “event”) and relates it to a known injury outcome.
- Response Meter: Measures a functional response to an exposure/event. Can involve a physical test, sniff test, or stand-on-a-leg test. Biomarkers may be included as a functional response.

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WELCOME LETTER

Dear Colleague,

On behalf of the DoD Executive Agent for Medical Research for Prevention, Mitigation and Treatment of Blast Injury, welcome to the International State-of-the-Science Meeting on Blast Injury Dosimetry. This meeting will focus on the ability to record and document blast-related exposures and correlate these exposures with acute injuries or chronic health effects. Approximately 80 subject matter experts have volunteered to participate in this meeting, and I look forward to the important work that we will accomplish.

Warfighters are routinely exposed to blast-related insults in training and in combat. These insults range from occupational exposures associated with the use of weapon systems to potentially lethal exposures from explosive enemy weapons in combat. Examples of the types of potentially injurious blast insults they encounter include blunt impact, blast overpressure, impulse noise, and inhaled toxic gases. The DoD is seeking a way to objectively record and document blast-related exposures and to correlate these exposures with acute injuries or chronic health effects.

During the meeting, experts from the scientific, medical, and operational communities will present their work and participate in working groups. Your participation will help achieve the objectives of the meeting that are to:

1. Identify and prioritize the blast injuries of concern that should be the focus of the DoD's blast dosimeter development efforts.
2. Determine if there are blast dosimeters available that can be fielded now or within the next 2 years.
3. Identify and prioritize the research gaps that exist in the development of blast dosimeters in the areas of both blast-related human effects modeling and sensor development.

The key questions to be addressed during the meeting are:

1. What blast injuries are we interested in addressing with dosimeters?
2. What exposure data are needed to predict the likelihood of the injuries of concern?
3. What sensor technologies are available to address the required data elements?
4. What biomedical research has been done, or is required, to develop human effects models that correlate the blast-related exposures (sensor data) with resulting injuries?

Please accept my gratitude for your active participation in this meeting.

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