IFBIC

6th International Forum on Blast Injury Countermeasures

May 9 – 11, 2022

U.S. ARMY

DEVCOM

DEFENSE HEALTH AGENCY · DEPARTMENT OF DEFENSE ·

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Preface

This report documents the proceedings from the 6th International Forum on Blast Injury Countermeasures (IFBIC). IFBIC provides a venue for discussions on critical blast injury research and develop new partnerships to address blast injury research challenges identified during the Forum.

IFBIC 2022 was executed by The MITRE Corporation which is a private not-for-profit company that manages several Federally Funded Research and Development Centers (FFRDC), chartered by Congress to support science and technology challenges facing the federal government in the public interest. In support of the U.S. Army Medical Research & Development Command (MRDC), this task is conducted under the MITRE Operated U.S. Treasury, Internal Review Service FFRDC Center for Enterprise Modernization Indefinite Delivery Indefinite Quantity contract (TIRNO99D0005, delivery order "Support for DoD Blast Injury Research Coordinating Office", W81XWH21F0208).

IFBIC 2022 was sponsored by the Defense Health Agency, the Under Secretary of Defense for Research and Engineering (USD(R&E)), USAMRDC, the U.S. Department of Defense (DoD) Blast Injury Research Coordinating Office (BIRCO), and the National Defense Medical College (NDMC), Ministry of Defense, Japan. The Forum was hosted at the MITRE Corporation's McLean, VA Campus on 9 – 11 May 2022.

This report highlights key themes from the presentations focused on emerging blast injury related research, outcomes from the consensus-building discussions, and peer collaboration and engagement, as well as recommendations for IFBIC 2023.

Executive Summary

The 6th International Forum on Blast Injury Countermeasures (IFBIC), held in May 2022, brought together participants with a broad range of knowledge and expertise, and provided a platform to share national experiences and evidence-based approaches to the scientific study of blast injuries and their prevention, mitigation, and treatment.

The IFBIC provides an international forum where blast injury research experts can engage in active and fruitful discussions and exchange creative ideas on a broad spectrum of blast injuries. Outcomes of previous forums have included identifying critical issues pertaining to experimental and computational studies of blast-induced injuries and creating new partnerships for joint research explorations to address the many scientific and technical challenges facing the field. This report summarizes the 6th IFBIC forum, highlighting emerging research and themes within the blast injury community.

The objectives of the 6th Forum included:

1. Assembly of an international forum focused on multi-disciplinary science and medicine necessary to increase our understanding of blast injury and its countermeasures from bench to bedside
2. Achieving a mutual understanding of international efforts in blast injury research
3. Identifying knowledge gaps requiring collaborative research
4. Increasing understanding and promoting further collaboration to improve prevention, clinical diagnosis, and treatment addressing the entire spectrum of blast-related injuries.

IFBIC 2022 provided the opportunity for participants from the United States, Japan, United Kingdom, Brazil, Canada, Honduras, India, Netherlands, Sweden, South Africa, and South Korea who have a wide array of technical backgrounds to present current, innovative research; discuss pressing issues; and collaborate to identify solutions. In addition, participants discussed efforts supporting NDAA (National Defense Authorization Act) Section 734: Congressionally Mandated Longitudinal Medical Study on Blast Pressure Exposure as well as several preliminary studies, exploratory studies, and other work-in-progress efforts, allowing early feedback and collaboration among forum participants. As this was the first in-person IFBIC since IFBIC 2019, the forum's schedule included time for participants to hold sidebar discussions and identify areas for collaboration and data sharing.

International cross-disciplinary collaboration is regarded as essential to investigate physical causes of blast injury, to characterize the vulnerability of anatomical systems and their functions to blasts, and to develop the means to prevent, mitigate, and treat blast injuries. Countermeasures may include personal protective equipment; weapons and vehicle systems engineered for safety; tactics, techniques, and procedures (TTPs) for injury prevention; and medical interventions tailored to the specific needs of blast injuries.

The forum provided substantial technical and programmatic value to this allied international community of blast injury researchers and their beneficiaries by bringing together researchers with a diverse set of expertise in a single-auditorium format, thus exposing them to subject matter and research techniques that they may not ordinarily encounter at more conventional scientific meetings. Key emerging research themes included Physiologic Blast Responses, Blast Data, Modeling, and Blast Sensor Development / Validation. In addition, briefings presented preliminary studies, exploratory studies, and other work-in-progress efforts, allowing early feedback, work shaping, and collaboration among forum participants.

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Introduction

International cross-disciplinary collaborative research facilitates investigations into blast injury characterization to develop the means to prevent, mitigate, and treat blast injuries. Sharing emerging blast injury research among international partners and providing information on guidance issued by individual governments targeting blast injury prevention and mitigation, accelerates and focuses blast injury research efforts. These research efforts lead to development of blast injury countermeasures such as improved personal protective equipment; weapons and vehicle systems engineered for safety; tactics, techniques, and procedures (TTPs) for injury prevention; and medical interventions tailored specifically to blast injuries.

The DoD Blast Injury Research Coordinating Office (BIRCO), in collaboration with the National Defense Medical College (NDMC), Ministry of Defense, Japan, sponsored the 6th International Forum on Blast Injury Countermeasures (IFBIC), hosted by the MITRE Corporation on 9–11 May 2022 in McLean, Virginia. Over 120 blast injury experts from the United States, Japan, United Kingdom, the Netherlands, Sweden, India, Canada, Brazil, South Africa, South Korea, and Honduras attended IFBIC 2022. Participants shared expertise, experience, and approaches to solving blast injury problems of mutual interest in order to identify knowledge gaps and collaborative opportunities leading to improvements in prevention, clinical diagnosis, and treatment of blast-related injuries.

The IFBIC originated as a Technical Information Exchange Forum between Japan and the United States, known as the Japan-US Technical Information Exchange Forum on Blast Injury (JUFBI)), which provided a platform for individuals with broad knowledge and expertise to share national experiences and evidence-based approaches on the scientific study of blast injuries and their prevention, mitigation, and treatment. JUFBI forums took place in June 2016, April 2017, and May 2018 in Tokyo, Japan, focused on examining a broad spectrum of blast injuries, identifying critical issues involving experimental and computational studies of blast injury, and establishing new partnerships on joint research explorations to address scientific and technical challenges facing blast injury researchers. Following JUFBI 2018, the planning committee changed the name of the forum to its current name to account for the expanding participation by nations such as Australia, Canada, Germany, South Korea, and the United Kingdom. IFBIC features active and fruitful discussions and exchange of creative ideas on a wide range of blast injuries, enabling participants to identify critical issues involving experimental and computational studies of blast-induced injuries, and creating new partnerships on joint research explorations to address the many scientific and technical challenges facing the field.

The 6th forum had four broad objectives:

a. Assembly of an international forum focused on multi-disciplinary science and medicine necessary to increase our understanding of blast injury and its countermeasures from bench to bedside
b. Achieving a mutual understanding of international efforts in blast injury research
c. Identifying knowledge gaps requiring collaborative research
d. Increasing understanding and promoting further collaboration to improve prevention, clinical diagnosis, and treatment addressing the entire spectrum of blast-related injuries.

Emerging Research Related to Blast Injuries

At IFBIC 2022, 53 participants presented their research. Their presentations, delivered in the context of eight sessions, covered all aspects of emerging blast injury research, from different blast injury mechanisms, modeling and simulation of injury, and physiologic responses, preventive measures, and government guidance for monitoring the blast exposure of Warfighters.

Many briefings focused on the multifaceted nature of blast injury, and the diverse approaches and techniques used to identify and understand blast injury mechanisms. Presenters covered a variety of blast injury topics, including auditory injury and dysfunction, fragment penetration, chronic neurological conditions, blast lung injury, and brain injury. The briefings stimulated discussions of the various methodologies and results from animal studies. For example, different research programs used blast gauges and imaging techniques to study auditory responses and damage; imaging techniques to elucidate risk of penetrating injury to the liver; physiologic monitoring devices to study the clinical triad of blast lung injury; and computational models to investigate injury to the brain. One briefing focused on measuring the response of protein biomarkers to better understand the effects of repeated sub concussive blast exposures on the brain. Another study presented work on the development and implementation of a standardized method to identify a blast injury prevention standard for recommendation to the DoD for use in predicting auditory blast injury.

With blast sensors being a key tool in monitoring blast exposure and efforts relating exposure to injury, a tutorial on the comparison of wearable wireless blast sensor technologies for monitoring of blast waves generated lively discussion. The presentation began with an introduction to the goals and objectives of the Walter Reed Army Institute of Research's (WRAIR) Center for Military Psychiatry and Neuroscience. The tutorial included a summary of the Army's Foreign Comparative Testing (FCT) Program, which seeks to efficiently satisfy defense requirements by identifying, assessing, and fielding products with high technological readiness. It covered experimental design to test the accuracy of wearable blast sensors, which included the development of an advanced blast simulator (ABS) apparatus that produces controlled, repeatable shock waves. WRAIR implemented various blast sensors that measured shock waves at various angles of incidence and compared the accuracy of the sensors to a reference blast sensor gauge. The tutorial concluded by presenting considerations and lessons learned for comparing and selecting blast sensors for various use cases.

Blast sensors are not the only technology being used to characterize blasts, as imaging techniques can also illuminate the effects of blast overpressure waves on the human body. A variety of briefings covered imaging and sensing techniques, including shock imaging, imaging pyrometry, pressure and inertial sensors, multi-directional sensors, and nanophotonic probes which are being employed to understand more about blast interaction with the human body (Figure 1). One study presented a cost-effective shock imaging method to aid in validation of reported shock pressures. Another demonstrated the design and performance testing of a minimally powered wearable device consisting of pressure and inertial sensors to quantify loads capable of producing mild traumatic brain injury (mTBI). Other studies focused on the design and testing of multi-directional sensors to measure blast overpressure, and a technique involving the design and use of nanophotonic probes for understanding pressure effects on neuronal cells. Overall, this section of IFBIC 2022 highlighted the promising emerging technologies being designed and tested to rapidly predict and detect blast injury to the Warfighter.

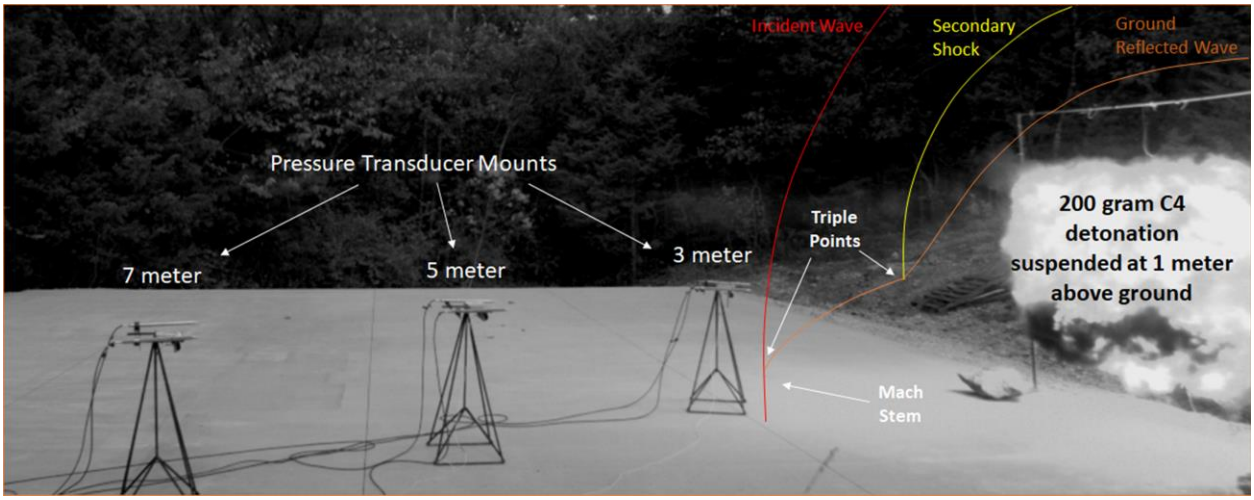

Figure 1: Standoff Blast Measurement
(C. Johnson, *et al.*)

Researchers can leverage both blast sensors and imaging techniques for prediction of blast injury and exposure (Figure 2). Various participants delivered briefings on emerging imaging techniques to measure and predict blast overpressure, incident impulse, and blunt forces as a result of blast in combat and training scenarios. The approaches used to characterize blast injury included the utilization of blast sensors to measure blunt force, the development of physical blast models to measure peak pressure and impulse, and the implementation of numerical modeling techniques to investigate blast-structure interactions and internal fluid dynamics from blast events. Overall, the briefings on blast sensor and modeling techniques highlighted the exciting approaches currently utilized in the field; however, several presenters also highlighted the need for more data and better monitoring/documentation to improve understanding of Warfighter blast exposure.

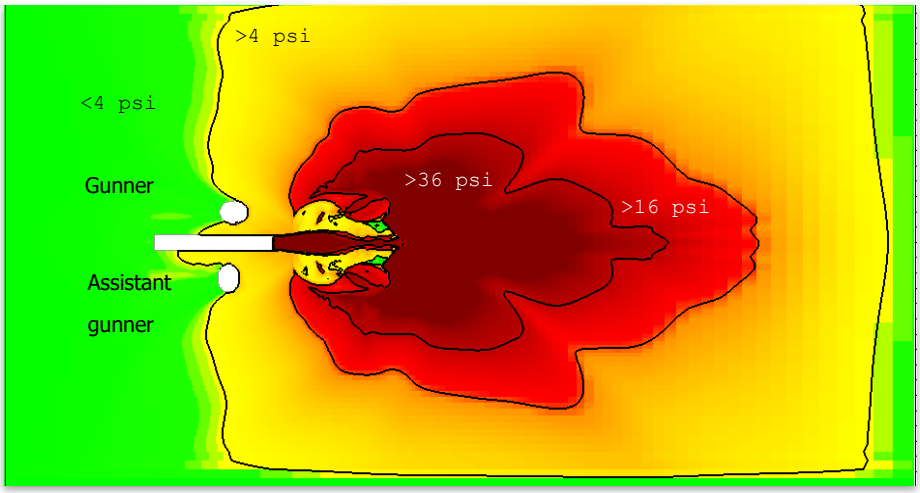

Figure 2: Blast overpressure map from shoulder-fired heavy weapons

(D. V. Agoston *et al.*)

While blast monitoring devices measure the output from blast events, the findings become more meaningful when paired with the physiologic effects on the human body. A set of presentations

assessing human blast exposure focused on methodologies and findings of recent human blast overpressure exposure assessments including: a pilot study, survey, epidemiological investigation, and an exploratory study on blast exposure among Warfighters. One presentation discussed a novel Positron Emission Tomography – Computed Tomography (PET-CT) neuroimaging technique that studies change in neuroinflammation, brain atrophy, and resting state connectivity in Warfighters as a result of low-level blast (LLB) exposure. Two presentations focused on the investigation of blast exposure as a risk factor for adverse clinical outcomes. One of the researchers had conducted a Blast Exposure Threshold Survey (BETS) and interviews investigating lifetime blast exposure in Warfighters, and another had performed a population-based epidemiological study to investigate TBI and concussion-related symptoms caused by TBI. Lastly, a presentation shared work on an exploratory study that used data from the Millenium Cohort Study to assess outcomes of LLB and high-level blast (HLB) and their association with Warfighters' self-reported diagnoses. Together, these presentations covered a variety of critical analytical assessments intended to elucidate information on LLB and HLB and their relation to clinical outcomes.

A frequent topic of discussion with blast injury researchers centers on determining the effect of blast and the resulting neurological injury. To address a current area of investigation, during the blast-TBI discussions one investigator presented a tutorial on anatomical, cellular, and molecular substrates potentially involved in the development of primary blast-induced TBI (pbTBI). After introducing the background and injury mechanisms of pbTBI, the tutorial gave an overview of findings from previous studies investigating the acute and chronic effects of pbTBI on structural and neurological changes in the human brain. It noted the importance of time in the manifestation of changes related to primary blast – a notion supported by results from previous studies that compared characteristics of the brain shortly after injury and several months later. The presenter expounded on the brain's complex biological features cerebral vasculature, and then emphasized that vasculature injury may be one of the hallmarks of pbTBI. Thereafter, the tutorial gave an overview of synaptic injury resulting from blast exposure and its adverse effects on memory and sleep. Finally, the presenter summarized a study linking blast-induced alteration of enzymes to the development of Post-Traumatic Stress Disorder (PTSD)-like symptoms. Overall, this tutorial provided a thorough overview of how primary blast is thought to affect the human brain at numerous interfaces and through various complex mechanisms.

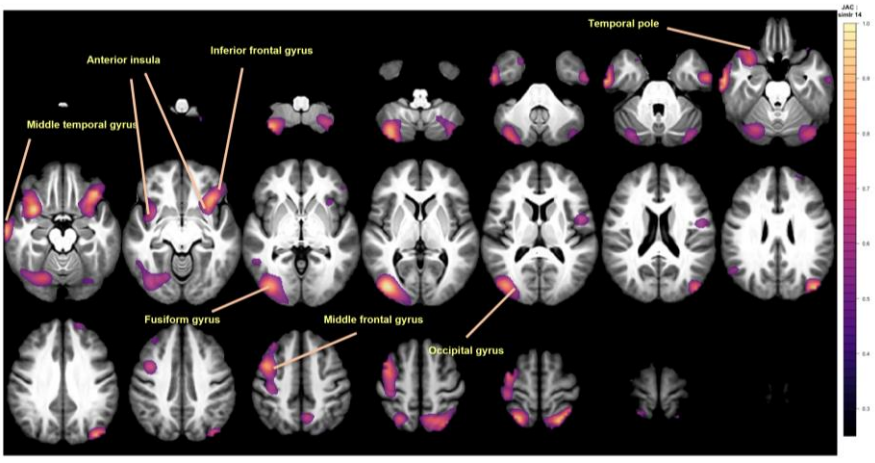

Figure 3: Decreases in Cortical Structures Due to Blast Exposure
(J.R. Stone, *et al*.)

Numerous briefings similarly focused on brain injury and strategies to control and mitigate risk associated with TBI. Researchers presented their methods and results from animal studies as well as hippocampal slice culture studies exploring blast effects; together, their findings elucidated information on the functional and structural changes to the brain in mice after exposure to single and repeated blasts, as well as the effects of age and gender on these effects (Figure 3). Another presentation described a longitudinal study on TBI in Veterans that identified blood biomarkers, demonstrating dose-response relationships with cumulative, chronic blast exposure. Lastly, a presentation covered the NATO HFM 338 Strategy, discussing the development of military loading exposure guidelines aimed at preventing brain injuries associated with blast overpressure. Together, the briefings highlighted a variety of novel methods and strategies being developed and utilized to investigate, mitigate, and prevent TBI in Warfighters.

A keynote address described the DoD Warfighter Brain Health (WBH) Initiative. In 2018, the Deputy Secretary of Defense provided the direction "for a Comprehensive Strategy and Action Plan for Warfighter Brain Health." This direction led to the development of a Department of Defense (DoD)-wide strategy to address brain health (cognitive and physical performance), brain exposures, TBI, and long-term effects. The keynote address discussed in detail the mission, vision, lines of effort (LOEs), action plans, and priorities of the WBH Initiative which looks to maximize Joint Force superiority and lethality through the optimization of Warfighter brain health and performance, requiring rapid action in the development and delivery of products, practices, and policies that impact Warfighter brain health and performance. The five WBH LOEs are: 1) Optimize Cognitive and Physical Performance, 2) Identify, Monitor, and Mitigate Brain Exposures, 3) Prevent, Recognize, and Minimize the Effects of Traumatic Brain Injury, 4) Reduce or Eliminate Long-term/Late Effects, and 5) Advance Warfighter Brain Health Science. Within each LOE, there are defined objectives and activities that serve as an action plan for the WBH Initiative. The keynote then provided details on a WBH Capability-Based Assessment (CBA), approved in a Joint Requirements Council Memorandum in January 2022, which assessed the DoD's ability to support brain health across the Warfighter's lifecycle in the case of blast exposure or other threat events. Requirements and gaps from this CBA led to a suite of recommended materiel and non-materiel solutions across the Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities, and Policy (DOTMLPF-P) spectrum to improve Warfighter brain health.

Another keynote address provided an overview of the Fiscal Year (FY) 2018 National Defense Authorization Act (NDAA) Section 734 (Public Law 115–91), Congressionally Mandated Longitudinal Medical Study on Blast Pressure Exposure (The Blast Overpressure Studies (BOS) Program. The FY18 NDAA Section 734 mandated that the Secretary of Defense conduct a longitudinal medical study on the blast pressure exposure of Warfighters. This led to the formation of a Section 734 Working Group that outlined five Lines of Inquiry (LOIs) within the Section 734 Program structure. The keynote address described the structure, detailed responsibilities, and identified the achievements to date for each of the five Section 734 LOIs. Monitoring neurological health through efforts such as Section 734 produces key metrics in determining blast exposure to the Warfighter that researchers should keep in mind among other physiologic responses throughout the life of the Warfighter.

Subsequent legislation expanded on that mandate, including section 253 of the FY19 NDAA, which required a review of the guidance on blast pressure exposure during training; section 717 of the FY20 NDAA, which required the inclusion of blast exposure history in medical records of

Service members; and section 742 of the FY20 NDAA, which added to the requirements for the longitudinal study directed by section 734 of the FY18 NDAA.

Following the keynote address, presenters from each Office of Primary Responsibility delivered briefings corresponding to the five LOIs. The first presentation covered the ongoing efforts of LOI 1 (Surveillance) to assess the feasibility and advisability of including blast overpressure exposure data in Service member records. The briefing included information about a pilot data collection project that monitors exposure of Warfighters to blast overpressure from Tier 1 weapons systems. The next set of presentations centered on LOI 2 (Weapon Systems), highlighting the main objectives which include analyzing information on blast pressure exposure from heavy weapon systems, and identifying emerging research on the effects of blast exposure on the health and performance of Warfighters. Other presentations described the development of a computational framework for monitoring blast exposure during training, and the development of a new capability, a Blast Over Pressure (BOP) Tool Module for use by instructors, range safety officials, and others which shares information on BOP exposure from firing or standing near to weapon systems. Two presentations discussed LOI 3 (Exposure Environment) efforts, which include, but are not limited to, the review of safety precautions for heavy weapon systems, the development of Brain Injury Risk Criteria, how to conduct Soldier Occupational Health Assessments (SOHAs), and the archiving of exposure data. The presentations provided additional information on the Joint Service member Occupational Health Assessment (JSOHA) program and efforts to enhance and advance BOP assessment capabilities. The LOI 4 presentation (Blast Characterization) focused on efforts to develop practicable solutions and foundational tools to understand and predict TBI risk based on blast overpressure exposure data. Finally, a presentation on LOI 5 (Health & Performance) discussed efforts to assess the effects of blast exposure on Warfighter brain health and performance. This presentation focused more specifically on adverse cumulative and acute response to LLB. The last presentation gave an overview of the progress made by the Military Operational Medicine Research Program (MOMRP) in its effort to deliver medical criteria and injury risk evaluation standards that would support development of next-generation personal protective equipment (PPE). Program successes have included, but were not limited to, advances in the monitoring of blast exposure, repeated exposure to LLB, and investigation of whole-body blast injury criteria.

Researchers can leverage the totality of all the information gathered by blast monitoring devices and physiologic responses for therapies, treatments, and protection. For example, several briefings included emerging research on treatments and therapeutic interventions discussed how to protect Warfighters against neurocognitive deficits and organ failure resulting from blast exposure. One research briefing described the effectiveness of pharmacological interventions in reducing adverse effects on the brain resulting from blast exposure in animal studies. The work has shown that PDGFRβ, a cell-surface tyrosine-kinase, and dimethyl sulfoxide (DMSO), inhibit glial scarring in a rat brain. Another study investigated the potential for progesterone to protect against long-term potentiation (LTP) neuronal deficits from repetitive exposure to mild blast. A third study discussed Nomacopan, a pro-survival and organ-protective drug, as a promising adjunct to prolonged damage control resuscitation therapies that may significantly reduce the morbidity and mortality in severe traumatic hemorrhage patients while they await transport to critical care facilities. All three studies showed encouraging results, demonstrating the promise of ongoing and emerging research for pharmacological treatments and therapeutic treatments to protect Warfighters exposed to blast.

Consensus-Building Discussions

IFBIC 2022 included consensus-building discussions during which participants shared their experiences and differing views in an open floor format and discussed ways to define blast exposure to injury characteristics and wearable wireless blast sensor technology. The first consensus-building discussion explored the relationship of defined blast exposure to injury characteristics. Initially, researchers focused on the necessity to decompose different aspects of blast waves to understand correlations with individual injury. Perspectives shared by different categories of end users varied, with device and protective equipment manufacturers expressing the need for a better understanding of the underlying physics to aid them in designing the next generation of their products, and the medical community emphasizing the need for full blast wave information to correlate dose response to clinical manifestations. Participants agreed that the mechanism of injury must first be understood in order to mitigate or prevent injury through engineering or biological effects.

The initial discussion continued by stressing the importance of Warfighters' self-reporting their symptoms and the tracking of medical records in a secure data repository. The speakers noted that mTBI and concussion were the two main injuries chronically underreported. Accurate reporting and documentation of all post-blast exposure symptoms will improve correlation between blast effects and clinical outcomes.

The attendees agreed that recording accurate blast data in austere environments compared to controlled training areas presented increased challenges. A potential solution to determining the optimal blast gauges for recording during deployment could be identified in training (where the environment is more controlled) to correlate blast exposure, Warfighter positioning to the blast, and clinical outcomes.

The second consensus-building discussion focused on wearable wireless blast sensor technologies. To initiate the discussion, the speakers presented the following question to the audience: How/when should the community change fielded devices following initial Blast Surveillance Programs? Some participants suggested programs should not wait for devices with 'perfect' measurement capabilities before fielding a device. As in the prior consensus-building discussion, the audience acknowledged that collecting data in austere environments is different from collecting it in training environments; thus, a blast gauge device has an increased likelihood of providing varying results depending on the environment in which data collection takes place. Participants also agreed that an interval of several years for reevaluating fielded blast sensor devices is insufficient. If novel technology is developed and validated between set evaluation periods, reevaluation can occur sooner. In addition, a set time interval for re-evaluation would ensure that the DoD would select the best devices for fielding and would provide device developers a timeline for development.

Forum Outcomes

Key Emerging Research Themes

Throughout IFBIC 2022, many presentations and discussions centered on four key, related themes: Blast Data, Modeling, Physiologic Blast Responses, and Blast Sensor Development / Validation. Figure 4 shows how these themes interact. As an example, the final session of

IFBIC 2022, “Modeling and Simulation of Blast Exposure and Injury,” consisted of multiple presentations discussing how newly acquired blast data informed computational modeling of the human body and was validated from human performance data. Within the major themes, physiologic blast responses had multiple key points linking them to the other main themes. Figure 5 shows the key points in Physiologic Blast Responses as being Low-Level Blast, Biomarkers, Preventative Medicine, and Long-term / Lifetime Monitoring.

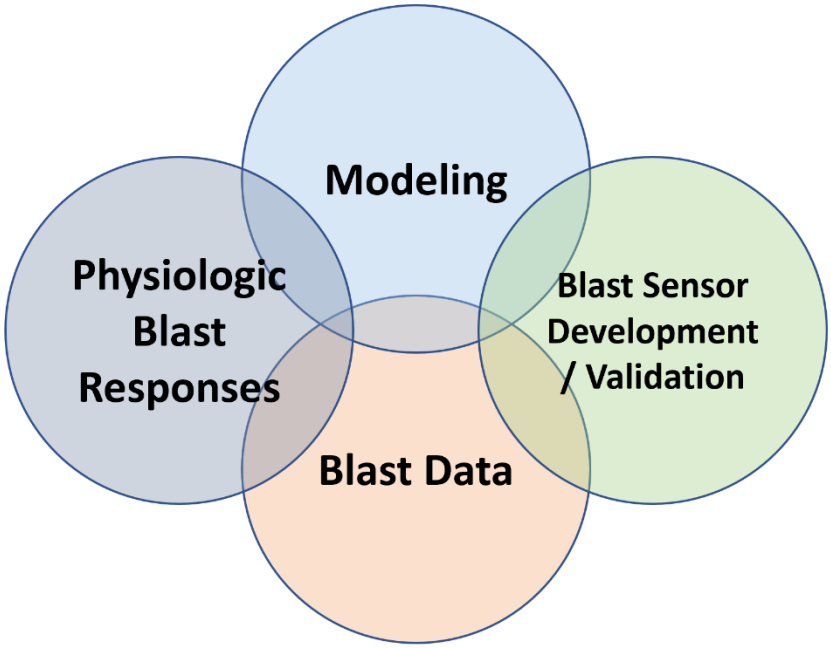

Figure 4: Key Emerging Research Themes

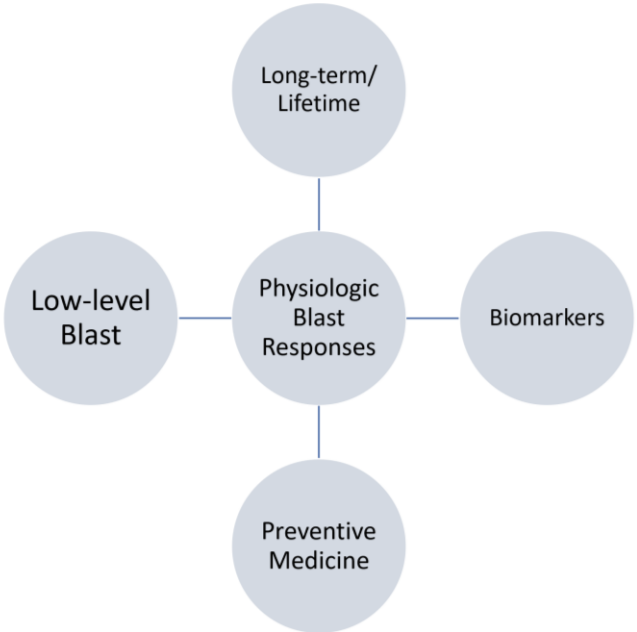

Figure 5: Key Points from Physiologic Blast Responses Presentations and Discussions

Physiologic Blast Responses

Most of the presentation addressed some aspect of Physiologic Blast Responses, including topics such as developing sensors for dosimetry, modeling mechanisms of blast-induced injury, monitoring long-term exposure to blast, and developing guidelines for preventive exposure measures.

Long-Term / Lifetime Monitoring

Presenters throughout the forum discussed how repeated blast exposures are associated with cognitive deficits, headache, tinnitus, behavioral health conditions, alcohol abuse/dependence, delirium/dementia, and PTSD. Multiple novel studies aimed to expand what is known about predicting outcomes of repeated exposure over a Warfighter's lifetime to include neural and psychological metrics. These studies sought to determine expected exposure of specific weapon systems and environments, and to assign a risk of injury associated with that exposure. This work sets the groundwork for future researchers to expand on these monitoring systems, apply them to lifetime monitoring protocols, and decipher the pathogenic vs. immediate responses to blast exposure. Additional studies utilized molecular imaging to determine the neurological effects of long-term exposure on neuronal signaling and behavior changes in animal models.

Presentations on the efforts that supported the BOS Program outlined emerging tools for understanding the impact of blast pressure exposure from weapon systems on Warfighter brain health, and for informing policy on risk mitigation, unit readiness, and health care decisions. Some of these tools would include longitudinal examination and derivation of weapon-based effects (existing and emergent) on Warfighter brain health and performance. These capabilities will provide blast exposure and health data processing and management capabilities, including automated methodologies for generation of computational models supporting finite element analysis from medical imaging data (e.g., computed tomography or magnetic resonance imaging scans). Researchers could use these methodologies to examine factors affecting brain health and cognitive function, and to enhance capabilities for blast data analysis over the lifetime of the Warfighter.

Additional briefings leveraged survey-based methods for tracking Warfighter health. The Office of the Assistant Secretary of Defense for Health Affairs (OASD (HA)) established a pilot effort to determine the feasibility and advisability of monitoring, recording, and analyzing individual blast overpressure exposures throughout a Warfighter's career cycle. The OASD(HA) pilot utilizes experimental monitoring practices while continuously recording, assessing, and addressing the operational and technical requirements of supporting a Service-wide blast exposure surveillance program to longitudinally measure, record, and report information on exposure to blast overpressure to clinical and operational staff.

Low-Level Blast

Multiple presenters discussed repeated exposure of Warfighters to LLB during training and combat. Researchers are leveraging emerging tools such as the Cumulative Blast Equation (CBE) to track daily exposure and identify safety thresholds for Warfighters, both deployed and during training. Additional studies explored the neurological effects of LLB on cognitive behavior, indicating the generation of anxiety-like behavior in both natural and challenging environments. Like long-term monitoring, LLB studies leveraged weapon signature

characterization and forward simulations to predict injuries from LLB and correlate blast loads with chronic neurophysiologic responses, including biomarker kinetics.

Biomarkers

As noted in connection with the LLB research, biomarkers are an area of focus for emerging methods for detecting physiologic responses to BOP exposure and understanding the cellular responses to blast overpressure. One novel technique for investigating cellular responses utilized bio-templated fluorescent nanoclusters (NCs) of a small number of metal atoms. The fluorescence intensity of the bio-nanophotonic probes is very sensitive to applied external pressure and, when embedded within neuronal cells, produces a measure of the local pressure at the cellular level. This approach took advantage of neuronal capabilities, as neurons synthesized their own metal NCs templated with proteins readily available inside the cell. Other studies investigated endogenous biomarkers for chronic-phase TBI diagnostic purposes. These objective biomarker candidates can interrelate the number of blast mTBIs with clinical signs and symptoms of TBI, including changes in brain function and cognitive and behavioral impairments. Thus, these objective biomarker candidates are positioning to provide prognostic value in addition to diagnostic and occupational exposure information.

Preventive Medicine

Emerging research focused on preventive medicine explored novel materials for PPE, applications of medicine for protective effects, and guidance to reduce exposures. Speakers reported that enhancements to current PPE through incorporation of novel shock-absorbent materials into the lining of the Soldier's combat helmet reduced the occurrence of injuries such as mTBI following blast exposure. Administration of molecules such as Progesterone and dimethyl sulfoxide indicated that they produced neuroprotective effects on neurons exposed to blast by lowering inflammatory responses and cellular deficits.

Blast Sensor Development / Validation

Blast sensors are key to both characterizing weapon systems and correlating blast exposure of Warfighters with clinical outcomes. Numerous briefings evaluated current and developing blast sensors for their applicability in multiple environments and compared devices. Speakers noted that sensors have different sampling rates. Some sensor efforts focus on correlating blast exposure to specific injuries; they include the microelectromechanical system (MEMS) pressure and acceleration sensors developed by the Naval Surface Warfare Center, Indian Head Division (NSWC-IHD) for detecting blast-induced loads that potentially cause mTBI. Some of the briefings also demonstrated the placement of blast devices to help determine the Soldiers' posture at the time of the event, which significantly improved the estimation of blast dosage. Several of the methods used sensors traditionally employed in other fields, such as repurposing a blunt force monitoring system to identify range positions with the highest blast dosing in military training. Other environmental blast sensors used data collected by free-field pressure sensors as inputs to an inverse problem solver to calculate weapon blast location, charge mass and detailed pressure loads on human bodies exposed to the blast wave. Researchers used the results of these blast sensor studies to analyze and optimize the training protocols with specific weapon systems such as the M107 SASR and M136 SMAW.

Blast Data

Most of the briefings addressed the common theme of collecting additional blast data through novel blast sensors and physiologic responses. One of the innovative methods for accurately recording blast effects included employing high-speed imaging to capture pressures, temperatures, and time evolution of exposure of equipment and personnel to airborne explosively produced blast and shock waves.

Studies of blast data associated with physiologic responses included investigations into primary shockwaves on surrogate head models. The preliminary results showed the highest intensity impact occurred at the skull frontal region at standoff distances of 140 mm and the lowest intensity occurred at 180 mm standoff from a Research Department eXplosive (RDX) charge. Other studies use ABS to generate several blast loads on a surrogate human skull fitted with and without an Advanced Combat Helmet (ACH) to measure free-field blast loading on, and within, the skull.

Some projects have used models to explore emerging data regarding effects of the blast shockwave on the lung, both in water and terrestrial environments. Researchers have developed these state-of-the-art models of energetics and their blast output for weapon design to resolve the complex wave dynamics that occur at the interface of the lung and the water. Other novel experimental processes address differences between shock wave recordings in shock tubes and blasts occurring in confined spaces by utilizing an Ethylene-Oxygen mixture with an initial pressure of one atmosphere to accurately measure blast levels that cause blast lung injury.

Modeling

Blast modeling capabilities can augment physical experimentation, allowing researchers to explore questions without requiring the actual equipment, and prototype devices, materials, and protocols before validating them in field testing. Additional models discussed included capabilities to establish "scaling laws" that project observed brain injuries in animals to humans. Advances in the development of these scaling models through the inclusion of vasculature effects within the models have demonstrated significant effects on the strain redistribution observed in the simulation of blast effects. One study demonstrated that the inclusion of vasculature when predicting blast-induced brain biomechanics resulted in an approximate 100% decrease in strain in regions near the interface between the vasculature and the brain tissue and an approximate 40% to 70% increase in regions along the mid-sagittal plane of the brain. Another novel mechanobiological model of synaptic damage mechanisms in repetitive LLB exposure incorporated dynamics of synaptic damage and recovery spanning timescales from milliseconds of exposure to minutes of synapse recovery.

Lead by BIRCO, the DoD Working Group on Computational Modeling of Human Lethality Injury and Impairment from Blast-related Threats has proposed the implementation of a modeling capability from the point of interaction with the blast hazard to a return to routine (Figure 6). The blue block on the left of the schematic, labeled "Until homeostasis is reached," represents and focuses on the Warfighter's physical condition from the point of injury until clinical homeostasis is reached – the point at which physiological processes (e.g., injury or degeneration) result in a stable equilibrium condition. The yellow-colored block titled "Recovery and/or further degeneration" represents the Warfighter's physical state or condition from the point of homeostasis as he or she undergoes rehabilitative treatment (i.e., until rehabilitation is no longer needed or is stopped because the physician does not expect treatment

to lead to an improvement in function). The modeling capability will allow coordination of blast injury computational modeling efforts across the DoD, other federal agencies, academia, and industry in a system that is currently siloed. The capability will enable the application of a systems engineering approach to support the development and integration of simulation-based experiments, while also ensuring the capture of all information necessary for sufficient reproducibility of experiments and results.

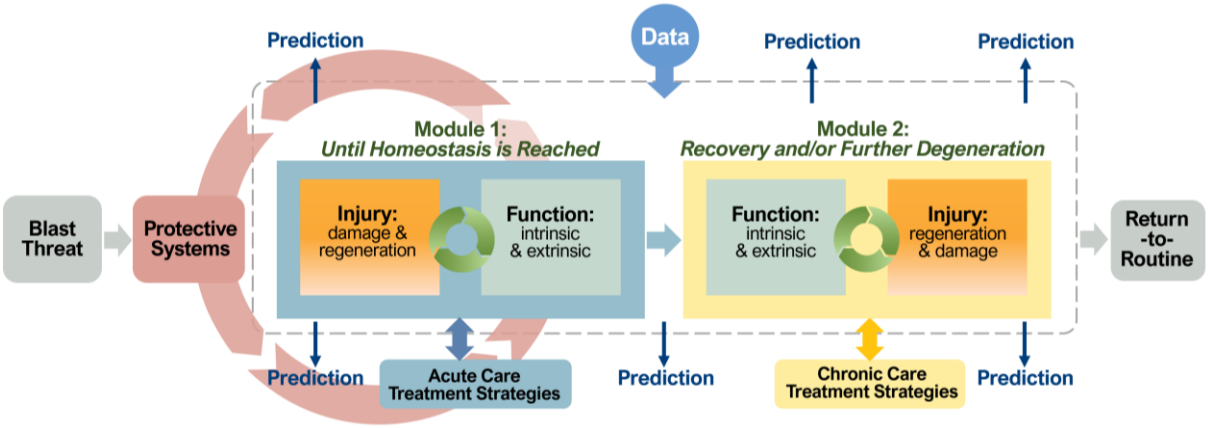

Figure 6: Integrated Human Body Modeling Capability
(Computational Human Body Modeling Working Group)

Peer Collaboration and Engagement

The 6th Forum provided significant opportunities for on-site and follow-up collaboration. Forum participants discussed ongoing work in the field that complemented or was substantially like work described in the presentations, which will help to reduce unnecessary duplication and promote collaboration among researchers with similar goals. The discussions that followed the briefings generated recommendations for additional assessments and comparison strategies (e.g., total energy transmission when comparing blunt object impact versus blast shockwave-based injuries). The size and format of the forum allowed attendees to ask technical questions regarding the methods used in experiments, and then follow up one-on-one with presenters during breaks for further discussion.

In addition to the emerging blast research efforts, the BOS Program overview briefings gave participating nations insight into a current focus of U.S. domestic blast injury research efforts. IFBIC also provided participants from visiting nations a forum at which they could provide actionable feedback and recommendations to enhance the BOS Program and identified opportunities for future collaboration. The discussion of the U.S. Government's approach to blast injury research was well received, indicating that potential future IFBIC sessions could allow other governments to present their guidance for conducting blast injury research within their respective countries.

Summary and Recommendations

KEY AREAS IN BLAST INJURY RESEARCH

- Gathering longitudinal blast impulse data on Warfighters
- Improving self-reporting of blast-related symptoms among Warfighters
- Establishing guidelines on the reevaluation of available blast devices for use in training and combat
- Developing additional injury assessment and data translation tools
- Improving understanding of blast injury mechanisms and their clinical context.

The 6th International Forum on Blast Injury Countermeasures offered an international community of blast injury researchers to share knowledge, improving outcomes for their beneficiaries. IFBIC 2022 brought together participants representing a broad range of expertise in a single-auditorium format, with the effect of exposing diverse researchers to subject matter and research techniques that they may not have ordinarily encountered in more conventional scientific or virtual meetings. In addition, speakers presented preliminary studies, exploratory studies, and other work-in-progress efforts, allowing early feedback, work shaping, and collaboration between forum participants.

The forum highlighted recommendations on key areas in blast injury research that warrant further investigation. These included gathering longitudinal blast impulse data on Warfighters; improving self-reporting of blast-related symptoms among Warfighters; establishing guidelines on the reevaluation of available blast devices for use in training and combat; developing additional injury assessment and data translation tools; and improving understanding of blast injury mechanisms and their clinical context.

Following the conclusion of the formal program, participants completed a brief survey. Results indicated that they viewed the forum as a valuable and positive experience for attendees: one that provided significant technical value and opportunity for collaboration. Recommendations for future forums suggested the addition or expansion of several topics, including blast overpressure thresholds, blast monitoring and clinical studies, anomalous events, civilian injury, TBI and PTSD comorbidities, penetrating blast injury, and active-duty Warfighter perspectives on blast injury. Participants also recommended the re-introduction of a poster session to allow more opportunities for interaction and Q&A.

To build upon the successes of the 6th Forum, the collaborative efforts will continue at the 7th International Forum on Blast Injury Countermeasures, to be hosted by NDMC on 17–19 May 2023 in Tokyo, Japan.

Appendix A: IFBIC 2022 Announcement

6th International Forum on Blast Injury Countermeasures (IFBIC) 2022

9 – 11 May 2022

The MITRE Corporation, McLean, Virginia

Blast Injury Research Coordinating Office (BIRCO) – Facilitating Collaboration Within and Outside of the Department of Defense (DoD) (health.mil)

IFBIC 2022 Event Website:

IFBIC 2022 (eventscloud.com)

Note: Registration through the IFBIC 2022 website to is now closed, please use the form attached to the announcement email. Fill out the required fields and e-mail the form to: ifbic2022@mitre.org

Objective and Scope

In recent years, attacks using explosive devices occur frequently, not only on battlefields and in regions of conflict, but also in urban areas in peacetime due to terrorism, resulting in a large number of blast injury victims. The U.S. Department of Defense uses the *Taxonomy of Injuries from Explosive Devices* (as described in DoDD 6025.21E) to organize blast injuries into five groupings based on their approximate order of temporal incidence upon the body following an explosion. Primary injuries result from the blast shock wave. Secondary injuries result from penetrating fragments of material accelerated by the blast. Tertiary injuries result from accelerative loading or blunt impact to tissues. Quaternary injuries include dermal burns and toxic gas inhalation. Quinary injuries include contamination by nuclear, chemical, or biological agents. Primary injuries that are peculiar to blast shockwave exposures include mild blast-induced traumatic brain injury (bTBI), hearing loss, ocular injury, and lung injury. All body systems are

vulnerable to secondary injuries due to penetrating fragments and tertiary injuries due to acceleration and blunt force trauma.

International cross-disciplinary collaboration is regarded as essential to investigate physical causes of blast injury, to characterize the vulnerability of anatomical systems and their functions to blasts, and to develop the means to prevent, mitigate, and treat blast injuries. Countermeasures may include personal protective equipment; weapons and vehicle systems engineered for safety; tactics, techniques, and procedures (TTPs) for injury prevention; and medical interventions tailored to the specific needs of blast injuries.

This International Forum on Blast Injury Countermeasures (IFBIC) started as a Technical Information Exchange Forum between Japan and the United States, which brought together broad knowledge and expertise, and to share national experiences and evidence-based approaches for blast injuries. The previous five Japan-US Technical Information Exchange Forum on Blast Injury (JUFBI) were held in June 2016, April 2017, and May 2018 in Tokyo, May 2019 in McLean, Virginia, and October 2021 virtually (hosted by Japan). At the end of JUFBI 2018, the planning committee decided to change the name to International Forum on Blast Injury Countermeasures to reflect the expanding participation by additional nations such as Australia, Italy, Canada, Germany, South Korea, and the United Kingdom.

These meetings have been very productive, involving active and fruitful discussions and exchange of creative ideas on a broad spectrum of blast injuries; identifying critical issues involving experimental and computational studies of blast-induced injuries; and creating new partnerships on joint research explorations to address the many scientific and technical challenges facing the field.

Building upon these successful meetings, the next IFBIC will be held from 9 – 11 May 2022 at The MITRE Corporation in McLean, Virginia.

The objectives for the 6th Forum include:

e. Assembly of an international forum focused on multi-disciplinary science and medicine necessary to increase our understanding of blast injury and its countermeasures from bench to bedside
f. Achieving a mutual understanding of international efforts in blast injury research
g. Identifying knowledge gaps requiring collaborative research
h. Increasing understanding and promoting further collaboration to improve prevention, clinical diagnosis, and treatment addressing the entire spectrum of blast-related injuries

The meeting agenda includes the following broad topic areas. Innovative research beyond this topic list will also be considered:

1. **Blast injury epidemiology and environmental sensing of blast shockwave hazards**
    a) Clinical prevalence of varieties of blast injuries sorted by context, anatomy, and severity
    b) Blast energy / physics / waveforms, reflections, effects of media (e.g., air vs. water vs. solid material)
    c) Blast sensor engineering, test and evaluation, fidelity, usability
    d) Correlation of blast sensing with clinical outcomes
    e) Use of multiple sensors to reconstruct blast phenomena
2. **Primary blast injury (due directly to shockwave effects)**
    a) Experimentally derived injury risk criteria for anatomical structures and their functions, including brain, ocular, auditory, and lung
    b) Predicted incapacitation due to blast injuries (e.g., loss of neuromuscular control, reduced sensory or cognitive function, reduced respiration)
3. **Secondary (penetrating ballistic fragments) and tertiary (acceleration and blunt force) blast injury**
    a) Experimentally derived injury risk criteria for anatomical structures and their functions
    b) Predicted incapacitation due to blast injuries (e.g., loss of musculoskeletal force)
4. **Long-term effects, cumulative effects, and chronic symptoms due to blast exposure**
    a) Brain: aberrant protein expression and accumulation (e.g., phosphorylated Tau)
    b) Brain: chronic traumatic encephalopathy (CTE)-like symptoms
    c) Brain: correlation and comorbidity with post-traumatic stress disorder (PTSD)
    d) Effect of cumulative subclinical (i.e., not provoking diagnosis) exposures to blast phenomena for all body systems
    e) Effect of repeated clinical (i.e., provoking diagnosis) exposures to blast phenomena for all body systems
5. **Prevention, mitigation, treatment of blast injuries**
    a) Personal protective equipment (PPE) such as helmets, body armor, eye protection, hearing protection, etc.
    b) Weapon and vehicle systems engineered for safety in blast environments
    c) Tactics, techniques, and procedures (TTPs) for Warfighter safety in blast environments
    d) Operational mission planning for needed medical response
    e) Lessons learned from military operations
    f) Resilience training (e.g., stress inoculation, mindfulness-based cognitive therapies to prevent sequelae of psychological trauma from blast exposures)
    g) Biomedically-based design and acquisition standards for military equipment (materiel)
    h) Biomedically-based health hazard assessments
    i) Clinical current practices, interventions, surgeries, rehabilitative therapies
6. **Diagnostic measures / biomarkers**
    a) Innovations in self-reported symptom inventories
    b) Innovations in diagnostics based on observations by clinical staff
    c) Innovations in molecular markers of blast injury
    d) Innovations in biomedical imaging measures of blast injury
    e) Innovations in behavioral or functional tests for blast injury
7. **Computational modeling and simulation of blast phenomena and blast injury**
    a) Deformable finite element modeling (FEM) of stresses and strains
    b) Injury risk criteria applied to force-time histories from FEM
    c) Incapacitation risk criteria applied to injury predictions from FEM
    d) Shockwave modeling
    e) Innovations in coupling between computational fluid dynamics (CFD) and FEM
    f) Integration of computational models with blast sensors and other sensors (e.g., strain gauges or force transducers on cadavers or simulant manikins)
8. **Characteristics comparisons between blast-related TBI and blunt TBI**
9. **New technology and methods for blast injury research and medicine**

Contributions from all countries, as well as from young investigators, are welcome.

General Information

Meeting title:

The 6th International Forum on Blast Injury Countermeasures (IFBIC 2022)

Organized by:

U.S. Army, Medical Research and Development Command (USAMRDC)

U.S. Army Combat Capabilities Development Command (DEVCOM)

National Defense Medical College Japan (NDMC)

Important dates:

Abstract submission deadline:	28 February 2022
Abstract acceptance notification:	15 March 2022
Preregistration deadline:	8 April 2022
Hotel reservation deadline:	15 April 2022
IFBIC 2022:	9 – 11 May 2022

A closed meeting for planning committee members will be held on 12 May 2022 at The MITRE Corporation in McLean, Virginia following the main portion of the meeting.

Venue:

MITRE Corporation Headquarters, Building 4, Robb Conference Room, 7515 Colshire Drive, McLean VA 22102 USA

Abstract Submission

Please prepare your abstract using the template provided at the conference website and the attachment template. Abstract submissions should be emailed or faxed directly to the IFBIC point of contact no later than close of business 28 February 2022, 5:00 p.m. U.S. Eastern Standard Time.

IFBIC 2022 Point of Contact e-mail: IFBIC2022@mitre.org
IFBIC 2022 point of contact FAX number: US 703 -983-6501, please mark ATTN: Matthew E. Downs

All submitted abstracts will be reviewed by the IFBIC 2022 Program Committee and notification of abstract acceptance will be made by 15 March 2022.

Registration

Pre-registration is required for all participants, and participation will be limited by venue capacity. The pre-registration deadline is 8 April, 2022. The registration website (found at the top of this announcement) is now live.

"On-site" meeting registration will not be offered.

There is no event fee, only an optional catering fee. The optional catering fee will be **$120** USD which will be collected online, or in person upon arrival as part of the pre-registration process. **Due to the lack of restaurants convenient to the meeting location, meeting attendees are encouraged to sign up for catered lunch and refreshments provided on-site.** This charge covers hot and cold beverages including coffee, green tea, snacks, and lunch during the three meeting days and the social gathering the first evening. Options will be available on-site for gluten-free, dairy-free, vegetarian, and vegan dietary restrictions. As online registration is closed , please use the form attached to the announcement email. Fill out the required fields and e-mail the form to:

IFBIC 2022 Point of Contact e-mail: IFBIC2022@mitre.org
IFBIC 2022 point of contact FAX number: US 703-983-6501, please mark ATTN: Matthew E. Downs

Hotel Accommodations

For the participants who wish to stay near the Forum venue, a block of rooms have been reserved at both the Residence Inn Tysons Corner Mall and at the Archer Tysons Hotel. A list of other hotels in the area is also available on the registration website. Please be advised that May is a busy time in Washington, DC and rooms should be booked early.

Hotel Information:
You may contact the Residence Inn Tysons Corner directly at (703) 917-0800 or the Archer Tysons Hotel directly at (703) 912-0488 to reserve a room within the group block by mentioning that you are reserving with the 'IFBIC 2022' group or use the following reservation links:

Residence Inn Tysons Corner: Click Here

Archer Tysons Hotel: https://archerhotel.com/tysons/book/ifbic-2022

Keynote and Tutorial Speakers

Keynote speakers will be announced closer to the meeting date.

Social Gathering

Optional evening social events include a meet-and-greet social with hors d'oeuvres the evening of Monday 9 May with self-pay cash bar for beer and wine. All food service will provide on-site options for gluten-free, dairy-free, vegetarian, and vegan dietary restrictions. Registration for this social event is done using the meeting registration.

Meeting Organization Committee

General Chair:

Jacob (Jake) Johnson (USAMRDC, USA)

General Co-Chair:

Daizoh Saitoh (NDMC, Japan)

Program Chair:

Raj Gupta (USAMRDC, USA)

Program Co-Chair:

Shunichi Sato (NDMC, Japan)

Members:

James Batchelor (Univ. of Southampton, UK)

Kyosuke Mani (ATLA, Japan)

Shashi Karna (US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL), USA)

Satoko Kawauchi (NDMC, Japan)

Emrys Kirkman (DSTL, UK)

Yukihiro Nakamura (NDMC, Japan)

Izumi Nishidate (TUAT, Japan)

Kyungho Park (US Army DEVCOM, International Technology Center-Pacific (ITC-PAC), USA)

Richard Shoge (USAMRDC, USA)

Masaki Takeda (ATLA, Japan)

Yuya Tanaka (JGSDF & MoD, Japan)

Akimasa Tashiro (NDMC, Japan)

Satoshi Tomura (NDMC, Japan)
Therese West (USAMRDC, USA)

Meeting Secretaries:
Raj Gupta (USAMRDC, USA)
Kyungho Park (US Army DEVCOM, ITC-PAC, USA)
Shunichi Sato (NDMC, Japan)
Izumi Nishidate (TUAT, Japan)
Matthew E. Downs (MITRE, USA)

Contact/Questions:
Raj Gupta, Ph.D., BCE
Deputy Director
DoD Blast Injury Research Program Coordinating Office
US Army Medical Research and Development Command
504 Scott Street, Fort Detrick, MD 21702
Telephone: (301) 619-9838
Email: raj.k.gupta.civ@health.mil
https://blastinjuryresearch.health.mil

Event Point-of-Contact (POC):
Ifbic2022@mitre.org

Partners and Sponsors

Appendix B: IFBIC 2022 Program

The IFBIC 2022 Program spanned the three days from May 9 to May 11 and included a variety of topical talks and discussions.

6th International Forum on Blast Injury Countermeasures 2022

9-11 May 2022

The MITRE Corporation, McLean, VA

Program Day 1 (09 May 2022)

Registration and Introductions (08:30-10:00)	
Monday, 9 May 2022:	
08:30	**Registration**
09:00	**MITRE Welcome & Facilities Overview** *Dr. Matthew E. Downs*
09:05	**MITRE Leadership Welcome and Introduction** *Mr. Paul Bonnewitz*
09:15	**Program Chair Introductions and Meeting Overview** *Dr. Raj K. Gupta / Prof Shunichi Sato*
09:25	**General Chair Welcome Remarks** *LTC Jacob Johnson*
09:35	**General Chair Welcome Remarks** *Prof Daizoh Saitoh*
Session 1: Measurements and Prediction of Blast Injury and Exposure ***Co-chairs: Dr. R. Gupta & Dr. S. Sato***	
10:00	**Accurate quantification of the number and magnitude of overpressure events in highly dynamic military training environments** A. Bartsch[1], M. Skotak[2], and W. Carr[2] *[1]Prevent Biometrics, [2]Walter Reed Army Institute of Research*
10:15	**Global overpressure measurement for blast loading assessment** T. Mizukaki[1], R. Shimizu[2], and D. Numata[1] *[1]Dept. of Aeronautics and Astronautics, Tokai University, [2]Course of Mechanical Engineering, Graduate School of Engineering, Tokai University*
10:30	**Blast-structure interaction effects on primary blast injury risk and the suitability of predictive injury criteria** J. Denny[1], G. Langdon[2], S. Rigby[2], A. Dickinson[1], J. Batchelor[1], L. Surey[1] *[1]University of Southampton, [2]University of Sheffield*
10:45	**Morning break**
11:00	**Bridging the Gaps Between Blast Exposure Measurement, Blast Induced Traumatic Brain Injury Diagnosis, and Prevention** C. E. Johnson[1], M. Langenderfer[1], E. Johnson[1], R. Bauer[1], C. Thomas[1], and B. Rutter[1,2] *[1]Missouri University of Science and Technology, [2]Rocky Mountain Scientific Laboratory*

11:15	**Cumulative blast exposure estimate model for Special Operations Forces combat Soldiers** SFC C. McEvoy[1,2], SFC A. Crabtree[1], J. R. Powell[3], J. S. Meabon[4,5], and J. Mihalik[3] *[1]US Army Special Operations Command, [2]University of Colorado School of Medicine, [3]University of North Carolina, [4]VA Puget Sound Health Care System (VA Puget Sound), [5]University of Washington*
11:30	**Session Discussion**
11:45	**Lunch**
13:00	**Tutorial #1: Comparison of Wearable Wireless Blast Sensor Technologies** *LTC Brian Johnson*
Session #2: Investigation of Blast Injury Mechanisms ***Co-chairs: Dr. R. Shoge and Dr. A. Makris***	
13:30	**Potential Mechanism of Auditory Dysfunction after Blast Exposure** Y. Wang[1], D. Wilder[1], P. Arun[1], V. S. Sajja[1], I. Gist[1], and J. Long[1] *[1]WRAIR*
13:45	**Blast Injury Prevention Standards Recommendation Process for Auditory Blast Injuries** E. B. Brokaw[1], R. M. Byrne[1], R. W. Spencer[1], L. Lalis[1], R. Gupta[2] *[1]The MITRE Corporation, [2]US DoD Blast Injury Research Coordinating Office*
14:00	**Comparison of fragment penetration into hepatic tissue to ballistic gelatine** H. Tsukada[1], T-T Nguyen[1], J. Breeze[1,2], N. Baxan[1], I. E. Gibb[1,3] and S. D. Masouros[1] *[1]Imperial College London, [2]Royal Centre for Defence Medicine, [3]HMS Nelson*
14:15	**Repeated Exposures to Low Level Primary Blasts; Identification of Pathomechanism(s) that Can Lead to Chronic Neurological Conditions** D. V. Agoston[1], A. Kamnaksh[1], J. McCullough[1], R. Aniceto[1], I.-L. Lin[1], M. Eklund[1], W. M. Graves III[2], L. S. Russeth[2], F. Leonessa[1] and J. L. Duckworth[1,2] *[1]Uniformed Services University, [2]Camp Pendleton*
14:30	**A study on the clinical triad of blast lung injury in a closed space** N. Kiriu[1], D. Saitoh[1], Y. Sekine[1], K. Yamamura[1], M. Fujita[1], and Y. Tanaka[1] *[1]National Defense Medical College*
	Cerebral Vasculature Influences Blast-Induced Biomechanical Responses of Human Brain Tissue D. R. Subramaniam[1,2], G. Unnikrishnan[1,2], A. Sundaramurthy[1,2], J. E. Rubio[1,2], V. B. Kote[1,2], and J. Reifman[1] *[1]United States Army Medical Research and Development Command, [2]The Henry M. Jackson Foundation for the Advancement of Military Medicine, Inc.*
15:00	**Session Discussion**
15:15	**Afternoon break**
Session #3: Imaging and Sensing of Blast Injury ***Co-chairs: Dr. B. Brokaw & Dr. N. Kiriu***	
15:30	**Evaluation of the Blast Injuries using the Blast Gauge Sensor (BGS) and Pencil Probe in an Open Field Blast Environment** T. Pandelani[1], S. Hamilton[1] and D. Reinecke[1] *[1]CSIR Defence and Security Cluster*
15:45	**Imaging State Variables Associated With Blast Wave Evolution** K.L. McNesby[1], D.G. Scott[1], and R.A. Benjamin[1] *[1]CCDC-Army Research Laboratory*
16:00	**Low-Power, Long-Lifetime MEMS-Based Sensing System for Wearable Blast Detection** M. Khan[1], T. Luong[1], M. Winnick[1] and O. Barham[1] *[1]Naval Surface Warfare Center – Indian Head Division*
16:15	**RGB camera-based simultaneous measurements of percutaneous arterial oxygen saturation, tissue oxygen saturation, pulse rate and respiratory rate** I. Nishidate[1], R. Yasui[1], N. Nagao[1], H. Suzuki[1], Y. Takara[2], K. Ohashi[2], F. Ando[2], N. Noro[2] and Y. Kokubo[3] *[1]Tokyo University of Agriculture and Technology, [2]EBA JAPAN CO., LTD., [3]Yamagata University, Japan*

16:30	**Synchronized multi-sensor approach to soldier-borne dosimetry** D. Wong[1], J.P. Dionne[1], A. Makris[1], J. Levine[1], and G. Vander Veer[1] *[1]Med-Eng Holdings ULC*
16:45	**Wearable 3-D Blast Sensors for In-Air Explosions** K. Willens[1], B. Muzinich[1], B. Kavlicoglu[1] and F. Gordaninejad[1] *[1]Advanced Materials and Devices, Inc.*
17:00	**Nanophotonic Probes for Understanding Pressure Effects on Neuronal Cells** K.J. Perry[1], S.P. Karna[1] and R.K. Gupta[2] *[1]Aberdeen Proving Ground, [2]US Army Medical Research a*nd Development Command
17:15	**Session Discussion**
17:30	**Daily closing remarks, and adjourn** *Dr. Raj K. Gupta*
17:35	**Optional meet-and-greet with heavy hors d'oeuvres and cash bar until 7:30 pm EST** **(For attendees who elected to participate in social event during registration)**

Tuesday, 10 May 2022:	
08:30	**Registration**
09:00	**MITRE Welcome & Facilities Overview** *Dr. Matthew E. Downs*
09:05	**Keynote Address #1: NDAA Section 734 Program Overview** *Dr. Sean Biggerstaff*
Session #4: Congressionally Mandated Longitudinal Medical Study on Blast Pressure Exposure ***Co-chairs: COL (Ret) Michael Evans, Dr. Shashi Karna & Mr. John Lenox***	
09:35	**Implications of a Surveillance Program for Blast Overpressure Monitoring** M.D. Nieves[1], M. Wong[2], T. Whieldon[2], E. Brokaw[2], R. Gaskins[1], S. Jones[1] *[1]OASD Health Affairs, [2]The MITRE Corporation*
09:50	**FY18 NDAA Sec 734 Program Line of Inquiry 2 Weapon Systems: An Overview** R. Spencer[1], M. Ghebremedhin[1], E.B. Brokaw[1], W. Carr[4], Z.J. Chen[5], B.A. Garfield[4], H.T. Garimella[5], H. Gharahi[5], J. Iampaglia[3], L. Lalis[1], A. Przekwas[5], M. Skotak[4], M.A. Xynidis[1], S.L. Yablonski[1], and R.K. Gupta[2] *[1]The MITRE Corporation, [2]US Army Medical Research and Development Command, [3]US Army Training Doctrine and Command, [4]Walter Reed Army Institute of Research, [5]CFD Research Corporation*
10:05	**Computational Framework for Monitoring of Blast Exposure during Training of Sniper and Shoulder Mounted Weapon Systems** H.T. Garimella[1], H. Gharahi[1], A. Przekwas[1], Z.J. Chen[1], W. Carr[2], M. Skotak[2], B. Garfield[2], R.K. Gupta[3] *[1]CFD Research Corporation, [2]Walter Reed Army Institute of Research, [3]US DoD Blast Injury Research Coordinating Office*
10:20	**Transition of New Capability – From Science to Operational Use: Integration of A Blast Overpressure Tool** S.L. Yablonski[1], M.A. Xynidis[1], G.M. Dias[1], R. Spencer[1], H.T. Garimella[4], M. Ghebremedhin[1], J. Iampaglia[3], L. Lalis[1], A. Przekwas[4], W. Skiles[3], and R.K. Gupta[2] *[1]The MITRE Corporation, [2]US Army Medical Research and Development Command, [3]TRADOC, [4]CFD Research Corporation*
10:35	**Morning break**
10:45	**FY18 NDAA Section 734 Blast Overpressure Study: Line of Inquiry 3 of 5-Exposure Environment** T.A. Kluchinsky[1] *[1]US Army Public Health Center*
11:00	**Assessing Risk of Adverse Health Outcomes due to Blast Overpressure Exposures** O. Webster[1] *[1]US Army Public Health Center*
11:15	**FY18 NDAA Sec 734 Program Line of Inquiry 4 Blast Characterization: Technical Challenges, Knowledge Gaps, And Considerations For Future Efforts To Monitor, Record And, Analyze Blast Pressure Exposure** T.B. Bentley[1], and A.E. Eidsmore[2] *[1]Office of Naval Research, [2]US Army Combat Capabilities Development Command*
11:30	**Identifying an interim blast overpressure safety guidance to mitigate adverse brain health and performance outcomes following repetitive, occupational low-level blast exposure** S. Turner[1, 2], S. Sloley[1, 2], E. Gregory[2], and S. Cota[2] *[1]General Dynamics Information Technology, [2]Traumatic Brain Injury Center of Excellence*
11:45	**The Military Operational Medicine Research Program – Blast Induced Injury Prevention Overview** T. Piehler[1], and R. Shoge[1] *[1]US Army Medical Research and Development Command*
12:00	**Session Discussion**
12:15	**Lunch**

Session #5: Assessments of Human Blast Exposure ***Co-chairs: Dr. T. Piehler and Dr. S. Kawauchi***	
13:45	**Occupational Risk of Low-Level Blast Exposure and TBI-Related Medical Diagnoses: A Population-Based Epidemiological Investigation (2005–2015)** J.N. Belding[1,2], R. Englert[1,2], J. Bonkowski[1,2], and C.J. Thomsen[1] *[1]Leidos, Inc., [2]Naval Health Research Center*
14:00	**Increased measures of neuroinflammation in special operators with a history of blast overpressure exposure** J.R. Stone[1], B.B. Avants[1], N.J. Tustison[1], J. Gill[2], E.A. Wilde[3], K.D. Neumann[1], L.A. Gladney[1], M.O. Kilgore[1], LT C.M. Modica[4], F. Bowling[4], C.M. Wilson[4], J.F. Detro[4], H.R. Linsenbardt[5], and S.T. Ahlers[5] *[1]University of Virginia School of Medicine, [2]Johns Hopkins University School of Nursing, [3]University of Utah School of Medicine, [4]US Special Operations Command, [5]Naval Medical Research Center*
14:15	**Blast Interview and Quantification of Lifetime Blast Exposure** H.R. Linsenbardt[1], LT C.M. Modica[1], M.J. Egnoto[2,3,4], J.K. Statz[1,5], W. Carr[2], and S.T. Ahlers[1,6] *[1]Naval Medical Research Center, [2]Walter Reed Army Institute of Research, [3]Katmai Government Services, [4]Ensco, [5]The Henry M. Jackson Foundation for the Advancement of Military Medicine, [6]Uniformed Services University of the Health Sciences*
14:30	**Self-Reported Single and Repeated High-Level Blast Exposure, Occupational Risk of Low-Level Blast, and Self-Reported Diagnoses: A Millennium Cohort Study Investigation** J.N. Belding[1,2], C.A. Kolaja[1,2], R.P. Rull[1], and D.W. Trone[1] *[1]Naval Health Research Center, [2]Leidos, Inc.*
14:45	**Session Discussion**
15:00	**Afternoon break**
15:15	**Discussion on Defined Blast Exposure to Injury Characteristics**
Session #6: Therapies, Treatments, and Protection ***Co-chairs: Dr. J. Batchelor & M. Risling***	
15:45	**Pharmacological reduction of shock wave-induced astroglial scarring in the rat brain** S. Kawauchi[1], S. Seki[2], Y. Muramatsu[1], A. Kono[1], Y. Komuta[1], I. Nishidate[3] and S. Sato[1] *[1]National Defense Medical College Research Institute, [2]Japan Self Defense Force Central Hospital, [3]Tokyo University of Agriculture and Technology*
16:00	**Progesterone protects against repetitive mild blast induced long-term potentiation deficits in organotypic hippocampal slice cultures** C. Kim[1], and B. Morrison III[1] *[1]Columbia University Department of Biomedical Engineering*
16:15	**Pathobiology of terminal complement activation and inhibition of complement C5 creating a pro-survival and organ-protective phenotype in a rat model of blast injury and hemorrhage** Y. Li[1,2], M.A. Nunn[3], Z. Yang[1], T.D. Le[1], M.O. Simovic[1,2], P.R. Edsall[1], B. Liu[1], J.L. Barr,[1], B.J. Lund[4], C.D. Hill-Pryor[5], A.E. Pusateri[6], L.C. Cancio[1] *[1]US Army Institute of Surgical Research, [2]The Geneva Foundation, [3]Akari Therapeutics, [4]59th Medical Wing Operational Medicine, [5]US Army Medical Research and Development Command, [6]Naval Medical Research Unit San Antonio*
16:30	**Session Discussion**
16:45	**Daily closing remarks, and adjourn** *Dr. Raj K. Gupta*

Wednesday, 11 May 2022:	
08:30	**Registration**
09:00	**MITRE Welcome & Facilities Overview** *Dr. Matthew E. Downs*
09:05	**Keynote Address #2: DoD Warfighter Brain Health Initiative** *Capt Scott Cota*
Session #7: Blast-induced Brain Injury ***Co-Chairs: Ms. Stephanie Turner and Dr. E. Kirkman***	
09:35	**Development of diagnostic and prognostic biomarkers for chronic repetitive mild traumatic brain injury** J.S. Meabon[1,2], SFC A. Crabtree[3], SFC C. McEvoy[3], I. Lee[4], K. Wang[4], K. Pagulayan[1,2], G. Terry[1,2] and E.R. Peskind[1,2] *[1]Mental Illness Education and Clinical Center, [2]Dept of Psychiatry, University of Washington, [3]United States Army Special Operations Command, [4]Institute of Systems Biology (ISB)*
09:50	**Effect of Age and Gender on Clinical Scores of Mice Exposed to Blast Induced Traumatic Brain Injury** C.E. Johnson[1], E. Johnson[1], D. Gines[1], J. Harrell[1], Y.S. Song[1], and J.A. Semon[1] *[1]Missouri University of Science and Technology*
10:05	**Long-term effects of low-intensity blast primary brain injury on learning deficits and anxiety-like behaviors associate with glutamatergic hyperexcitability and altered protein expression in mouse hippocampus** Z. Gu[1,2], S. Chen[1,2], H.R. Siedhoff[1,2], H. Zhang[1], P. Liu[3], A. Balderrama[1,2], C. Johnson[4], C.M. Greenlief[3], D. Li[1], R.G. DePalma[5,6], and J. Cui[1,2] *[1]University of Missouri School of Medicine, [2]Truman VA Hospital Research Service, [3]University of Missouri, [4]Missouri University of Science and Technology, [5]Department of Veterans Affairs, [6]Uniformed Services University of the Health Sciences*
10:20	**Morning break**
10:30	**Partial depletion of microglia attenuates long term potentiation deficits following repeated blast traumatic brain injury in organotypic hippocampal slice cultures** N. Varghese[1], and B. Morrison III[1] *[1]Columbia University*
10:45	**Distinct Brain Vulnerabilities produced by Military Blast-Induced Synaptic Pathology** M.F. Almeida[1], M.H. Giang[1], M. Yorio[1], C.J. Norton[1], K.L.G. Farizatto[1], and B.A. Bahr[1] *[1]Biotechnology Research and Training Center, University of North Carolina – Pembroke*
11:00	**Development of military loading exposure guidelines for prevention of blast overpressure related brain injuries** M. Philippens[1], and M.K. Sköld[2,3] *[1]The Netherlands Organization, [2]Karolinska Institutet, [3]Uppsala University Hospital*
11:15	**Session Discussion**
11:30	**Tutorial #2: Anatomical/biological substrates and pathobiology of primary blast induced TBI** *Dr. Denes Agoston*
12:00	**Lunch**
13:00	**Debate: Wearable Wireless Blast Sensor Technologies**
Session #8: Modeling and Simulation of Blast Exposure and Injury ***Co-chairs: Dr. Denes Agoston & Dr. M. Sköld***	
13:30	**Characterization of a ferret model of under-vehicle blast-induced traumatic brain injury (TBI)** G. Fiskum[1], J. Proctor[1], M. Goodfellow[1], M. Shaughness[1], B. Piskoun[1], A. Hrdlick[1], and P. Rangghran[1] *[1]University of Maryland School of Medicine Department of Anesthesiology and the Center for Shock, Trauma, and Anesthesiology Research (STAR)*

13:45	**Computational Mechanobiology of Synaptic Injury and Biomarker Kinetics following Repeated Blast Exposures** H. Gharahi[1], H.T. Garimella[1], A. Przekwas[1], and R.K. Gupta[2] *[1]CFD Research Corporation, [2]US DoD Blast Injury Research Coordinating Office*
14:00	**Does blast exposure to the torso of a rat cause blood surge to the brain?** J.E. Rubio[1,2], M. Skotak[3], E. Alay[3], A. Sundaramurthy[1,2], D.R. Subramaniam[1,2], V.B. Kote[1,2], S. Yeoh[4], K. Monson[4], N. Chandra[3], G. Unnikrishnan[1,2], and J. Reifman[1] *[1]United States Army Medical Research and Development Command, [2]The Henry M. Jackson Foundation for the Advancement of Military Medicine, Inc., [3]New Jersey Institute of Technology, [4]The University of Utah*
14:15	**Effects of an Anti-Inflammatory Diet on Gut-Brain Axis in Experimental Traumatic Brain Injury Model** N. Chakraborty[1], A. Hoke[1], A. Gautam[1], S. Ann-Miller[1], L. Naidu[1], M.L. Condlin[2], R. Hammamieh[1], and A.G. Scrimgeour[2] *[1]Walter Reed Army Institute of Research, [2]US Army Research Institute of Environmental Medicine*
14:30	**Primary blast wave impact on a surrogate head model subjected to varying standoff distances** R. Banton[1], T. Piehler[1], N. Zander[1], R. Benjamin[1] and O. Petel[2] *[1]US Army Research Laboratory, Aberdeen Proving Ground, [2]Carleton University*
14:45	**Measuring blast loads over a surrogate skull using an advanced blast simulator and a CFD solver** J. Hamilton[1], K. Espinoza[1], J. Magallanes[1], A. Nelson[2], and P. VandeVord[2] *[1]Karagozian & Case, Inc., [2]Virginia Tech*
15:00	**Afternoon break**
15:15	**Application of a Multi-Material AMR Strategy for UNDEX Injury Simulations and Analysis** J.K. Clutter[1] *[1]Integrated Solutions for Systems (IS4S), Inc.*
15:30	**A 3-D Finite-Element Minipig Model to Assess Brain Biomechanical Responses to Blast Exposure** A. Sundaramurthy[1,2], V.B. Kote[1,2], N. Pearson[3], G.M. Boiczyk[3], E.M. McNeil[4], A.J. Nelson[4], D.R. Subramaniam[1,2], J.E. Rubio[1,2], K. Monson[3], W.N. Hardy[4], P.J. VandeVord[4], G. Unnikrishnan[1,2], and J. Reifman[1] *[1]United States Army Medical Research and Development Command, [2]The Henry M. Jackson Foundation for the Advancement of Military Medicine, Inc., [3]The University of Utah, [4]Virginia Tech*
15:45	**Enabling Computational Model Interoperability for Human Lethality, Injury, and Impairment from Blast-Related Threats** N. Davis[1], A. Tolk[1], R. Byrne[1], R. Gupta[2], A. Santago[1] *[1]The MITRE Corporation, [2]US Army Medical Research and Development Command*
16:00	**Session Discussion**
16:15	**Daily closing remarks and final meeting adjournment** *Dr. Raj K. Gupta*

Appendix C: IFBIC 2022 Registered Participant List

Full Name	Organization
Michael Addis	U.S. Air Force Human Performance Wing
Denes V. Agoston	USUHS
Stephen Ahlers	Naval Medical Research Center; USUHS
Michael Fernandes de Almeida	The University of North Carolina at Pembroke
Peethambaran Arun	WRAIR
Amit Bagchi	U.S. Naval Research Laboratory
William Bagley	Johns Hopkins University
Ben A. Bahr	University of North Carolina – Pembroke
Rohan B. Banton	U.S. Army Research Laboratory
Oliver Barham	Naval Surface Warfare Center – Indian Head Division
Adam Bartsch	Prevent Biometrics
James Batchelor	University of Southampton
Jennifer N. Belding	Leidos, Inc.; Naval Health Research Center
Timothy Bentley	Office of Naval Research
Sean Biggerstaff	Defense Health Agency (DHA)
David Brody	USUHS
Elizabeth Brokaw	The MITRE Corporation
Rebecca Brown	University of Southampton
Ryan Byrne	The MITRE Corporation
Walter S. Carr	WRAIR
Nabarun Chakraborty	WRAIR
YungChia (YC) Chen	Naval Research Laboratory
Elizabeth Chipriano	Supporting the Military Infectious Diseases Research Program, USAMRDC
Ben Churn	NIH
Severn Churn	NIH
J. Keith Clutter	Integrated Solutions for Systems (IS4S), Inc.
Ian Cochrane	Office of Naval Research
Scott Cota	USN
Adam Crabtree	USASOC
Jiankun Cui	University of Missouri
Timothy Davis	USUHS; University of Southampton
Nichole Davis	The MITRE Corporation
Thomas DeGraba	National Intrepid Center of Excellence
James C. DeMar	WRAIR
Jack Denny	University of Southampton
George Dias	The MITRE Corporation
Jean-Philippe Dionne	Med-Eng; A Brand of the Safariland Group
Andrew Dominianji	The MITRE Corporation
Matthew Downs	The MITRE Corporation
Michael Evans	DoD Explosives Safety Board
Gary Fiskum	University of Maryland
Nico Flierman	The Netherlands Organization
John Frucci	Oklahoma State University
Ryan Gaskins	DHA

Full Name	Organization
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Molly Goodfellow	University of Maryland
Emma Gregory	TBICoE, DHA
Zezong Gu	University of Missouri; Trauman VA Hospital Research Service
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Joseph Hamilton	Karagozian & Case, Inc.
Rasha Hammamieh	WRAIR
Daniel Jean	CCDC ARL
Marti Jett	WRAIR
Catherine E. Johnson	Missouri University of Science and Technology
Brian R. Johnson	WRAIR
Jacob Johnson	BIRCO; JTAPIC
Steven Jones	DHA
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Yansong Li	U.S. Army Institute of Surgical Research; The Geneva Foundation
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Thanyani Pandelani	CSIR Defence and Security Cluster
Matthew Panzer	University of Virginia

Full Name	Organization
Kyungho Park	U.S. Army DEVCOM, International Technology Center-Pacific (ITC-PAC), USA)
Steven Patrick	
Karima "Jeneh" Perry	DEVCOM Army Research Center
Anthony Petro	The MITRE Corporation
Mat(hieu) Philippens	TNO Defence, Security, and Safety
Thuvan Piehler	MOMRP
Julie Proctor	University of Maryland
Andrzej Przekwas	CFD Research Corp
Jaques Reifman	USAMRDC
Mårten Risling	Karolinska Institutet Biomedicum 8B
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Sujith Sajja	WRAIR Blast Induced Neurotrauma Branch (BINT)
Anthony Santago	The MITRE Corporation
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Paul Schroeder	Applied Research Associates
Richard Shoge	USAMRDC
Mattias Sköld	Karolinska Institutet; Uppsala University Hospital
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Stephen Yablonski	The MITRE Corporation
Koji Yamamura	National Defense Medical College
Narayan Yoganandan	Medical College of Wisconsin
Sandra Young	U.S. Army DEVCOM

Appendix D: Abbreviations

- ABS – Advanced Blast Simulator
- ACH – Advanced Combat Helmet
- BETS – Blast Exposure Threshold Survey
- BIRCO – Blast Injury Research Coordinating Office
- BOP – Blast Overpressure
- BOS – Blast Overpressure Studies
- bTBI – blast-induced Traumatic Brain Injury
- CBE – Cumulative Blast Equation
- CFD – Computational Fluid Dynamics
- CTE – Chronic Traumatic Encephalopathy
- DEVCOM – U.S. Army Combat Capabilities Development Command
- DMSO – Dimethyl Sulfoxide
- DoD – Department of Defense
- DOTMLPF-P – Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities, and Policy
- FCT – Foreign Comparative Testing
- FEM – Finite Element Modeling
- FY – Fiscal Year
- HLB – High-level Blast
- IFBIC – International Forum on Blast Injury Countermeasures
- JSOHA – Joint Service member Occupational Health Assessment
- JUFBI – Japan-US Technical Information Exchange Forum on Blast Injury
- LLB – Low-Level Blast
- LOE – Lines of Effort
- LOI – Lines of Inquiry
- LTP – Long-term Potentiation
- MEMS – Microelectromechanical System
- MOMRP – Military Operational Medicine Research Program
- mTBI – mild Traumatic Brain Injury
- NC – Nanoclusters
- NDAA – National Defense Authorization Act
- NDMC – National Defense Medical College Japan
- NSWC-IHD – Naval Surface Warfare Center, Indian Head Division
- OASD(HA) – Office of the Assistant Secretary of Defense for Health Affairs
- pbTBI – primary blast-induced TBI
- PET-CT – Positron Emission Tomography – Computed Tomography
- PPE – Personal Protective Equipment
- PTSD – Post-traumatic Stress Disorder
- SOHA – Soldier Occupational Health Assessments

- TTP – Tactics, Techniques, and Procedures
- WBH – Warfighter Brain Health
- WRAIR – Walter Reed Army Institute of Research