REQUEST FOR INFORMATION (RFI)
ONR RFI Announcement # N00014-16-RFI-0012

Incapacitation Prediction for Readiness in Expeditionary Domains: an Integrated Computational Tool (I-PREDICT) Program

I. DISCLAIMER:

This announcement constitutes a Request for Information (RFI) for the purpose of determining market capability of sources or obtaining information. It does not constitute a Request for Proposals (RFP), a Request for Quote (RFQ) or an indication that the Government will contract for any of the items and/or services discussed in this notice. Any formal solicitation that may subsequently be issued will be announced separately through Federal Business Opportunities (FedBizOpps). Information on the specific topics of interest is provided in the following sections of this announcement. Neither ONR nor any other part of the federal government will be responsible for any cost incurred by responders in furnishing this information.

This RFI is for information and planning purposes only and shall not be construed as a solicitation or as an obligation on the part of the Office of Naval Research.

The Office of Naval Research is seeking information to help inform the Incapacitation Prediction for Readiness in Expeditionary Domains: an Integrated Computational Tool (I-PREDICT) Program. I-PREDICT will provide an integrated computational model of the Warfighter's body with component structures (e.g., organs, vessels, musculoskeletal system, etc.) in silico for military injury prediction (i.e., no manikin or physical manifestation). We intend to address the entirety of the body, organs, and systems, but the effort will be limited to the more primary components and core (i.e., simplistically, the head and body from mid-arm and mid-thigh inward to the torso). The intended use of this model is to subject the in silico man/woman to potentially injurious forces and predict the likelihood of non-penetrating injury, location and severity, as well as the subsequent near-term impact to warfighter capability (summarized as the ability to move, shoot and communicate). Submissions will be used to assess the current state of science and technology and to identify opportunities for innovation.

Information is requested on existing and/or proposed innovations in standards-based deformable finite element (FE) modeling and simulation (M&S) technologies that allow the prediction of human injuries in hazardous conditions typical of military service. It is envisioned that a future enabling capability would take the form of a laboratory software pipeline supporting suitably skilled end users to conduct whole body FE model simulations and as needed to assemble and validate customized models tailored to specific injury modeling use cases. Enabling capabilities sought under the program will be limited to models of human injury, and will not involve any specific innovations in modeling of environmental hazards. Injury modeling will address environmental hazards in priority order: accelerative loading and blunt force trauma, blast shockwave pressure effects, and vibration (intense, non-chronic, and short-term; e.g., vehicular transportation over rough surfaces).

Information is also sought concerning experimental efforts to obtain suitable dynamic datasets necessary to support model development, verification, and validation. Information is requested on the physical parameter ranges of aforementioned military hazard environments derived from

direct measurement, forensic simulation, and other means, and comparing those to existing parameter ranges of tissue failure experiments to identify gaps to fill in existing tissue biomechanics research. Where gaps exist in measurement of military hazards, descriptions of appropriate field or laboratory experiments are requested. Where gaps exist in the measurement of tissue response under realistic hazard regimes, descriptions of appropriate field or laboratory experiments are also requested. Where hazard and tissue biomechanics parameters have already been well-studied for the context, for example under conditions for which military hazards are physically equivalent to well-studied automotive or aviation hazards, identification of the appropriate publications and data sources is requested for use in calibrating and validating modeling and simulation efforts.

II. BACKGROUND:

The Office of Naval Research (ONR) Code 34 requests support for the downstream development of safer weapons systems, safer vehicle systems, improved personal protective equipment, and other materiel development; tactics, techniques, and procedures (TTPs) to prevent injury; and predictive estimation for planning military operations that include anticipated needs for medical response, risks to force operational readiness, and needs for protective equipment. ***Technologies sought by this RFI, while intended to target and support such downstream applications, are to be limited to prediction of injuries via simulation*.**

Technical motivation is required for deciding what levels of fidelity to model, whether these should be continuous or discrete, and whether these should be standardized across the community. If standardization of discrete fidelity levels for component anatomical models is warranted, qualitative and quantitative criteria are needed for their definition, for example mesh resolution, scales of inhomogeneous boundary modeling (e.g., organ, tissue, microstructure), complexity of biomechanical response, or other variables impacting fidelity.

The I-PREDICT program seeks to supply the desired enabling capabilities by judicious division of labor among a set of eventual program performers, including but not limited to complete coverage of component body part models and integration into customized whole-body models. To gain a complete understanding of the state-of-the-science, it is requested that responses to this RFI should include as many the technical needs as possible discussed herein.

Proposed innovations beyond those enumerated above that could advance modeling and simulation of military injury are encouraged.

III. SPECIFIC INFORMATION OF INTEREST:

Specific areas of research include:

1. Enabling capabilities

The following innovations in whole-body human injury FE M&S are sought, in order of priority:

1a. *Standardized semantics:* Composability and interoperability will require common computable semantics for models, their assembly, and their validation. M&S standards will be required that specify semantics for FE geometry, constitutive material properties in response to dynamic loading, injury criteria

(including probability corridors to account for uncertainties), human anatomical architecture, variations in body part biofidelity, interfaces among local body part models, contact mechanics, and any required systems engineering to support all desired I-PREDICT enabling capabilities.

1b. *Composability:* It is envisioned that users will have the ability to compose customized whole body models from interchangeable local body part models, potentially sourced from a wide variety of contributing organizations, or that users have produced *de novo* in their own laboratories. M&S standards for anatomy and the interfaces among local body part models will be required to produce this capability. Datasets to build the component models, as well as specific validation datasets for injury modeling will also be needed to gauge the accuracy of customized whole-body models.

1c. *Varying fidelity:* Use cases for injury modeling may require biofidelity in certain local body parts far more than other body parts. It is envisioned that users will be able to deliberately lower simulation fidelity for less essential body parts in order to achieve computational savings, improved simulation turnaround time, and greater exploration of variations in model conditions, while maintaining necessary accuracy for specific structures and phenomena of interest to each use case. M&S standards will be required for varying fidelity of body parts and for interfacing between body part models of different fidelity. Validation datasets for injury modeling will also be needed to gauge accuracy of whole-body models with locally varied fidelity.

1d. *Platform-independence:* In order to allow whole-body models to be composed of component models with varying fidelity sourced from a wide community of researchers, it is envisioned that representations of models must be separated from the simulators that iterate them. M&S standards will be required for Computer-Aided Design (CAD) geometry, material response, and for contact among FE component models that can be imported and exported across FE simulator platforms.

2. Specific technological products

The following items represent desired tangible work products resulting from identification and/or development of technologies, to be sourced and assembled collectively across potential program performers, in priority order:

2a. *M&S standards:* Industry-wide M&S standards are required to support the capabilities described in *Section 2: Enabling capabilities* above. In order to be relevant, durable, and to encourage industry-wide adoption, standards must be developed in consultation between program performers, government staff, advisory committees, and any existing industry working groups or communities of interest. Standards will not be provided prior to a period of program performance, but will be one of the primary tangible technological work products to emerge from the program. A suitable community-wide organization will take responsibility for maintaining and improving M&S standards after the period of program performance.

2b. *Open source reference digital anatomy:* Existing or novel CAD geometry for FE structures and their contact interfaces are required for a single representative midsize male with anthropometry typical of military service. Such standardized human body geometry must supply landmarks or other suitable reference information for anthropometric morphing.

2c. *Tissue Response to High Strain Rates*: It is desired that strain-rate dependent tissue constitutive properties be addressed. In some circumstances, sufficiently equipped laboratories may be asked to perform novel tissue injury biomechanics studies to fill specific knowledge gaps. Prior quantification of the mechanical response of soft tissues often involved measurements separate from the body, quantified under non-physiologic conditions, isolated from the integrated system and normal constraints within the skin, including contextual support, load distribution, and other characteristics derived from the context of being within an integrated body. Additionally, high strain rate characteristics of soft tissues have suffered

from a lack of methodology that allows loading under appropriately high military incident rates and accelerations.

2d. *Validation datasets:* Individual component body part models will require their own validation datasets for calibration and testing. These may include constitutive biomechanical responses, tissue failure biomechanics, impact or crash data, or other experimental tissue injury data. Interfaced adjacent body part models and whole-body models will require validation datasets at the appropriate anatomical scales. The majority of such datasets will be identified from existing biomechanics literature.

2e. *Component body part models with varied fidelity:* Existing or novel deformable body part FE models are required at multiple levels of biofidelity, including geometries, contact interfaces with other parts, biomechanical responses, and validation datasets for injury modeling. A draft architecture for human body modeling, subject to revision during the period of program performance, includes the following coarse component body parts: brain, head, spine, upper extremities, thorax, abdominal viscera, pelvis, and lower extremities.

2f. *Interfaced adjacent body part models:* Demonstration of interfaces between adjacent body part models of differing fidelity, satisfying validation datasets for injury modeling with sufficient accuracy, are required.

2g. *Multiple customized whole-body models:* Demonstration of multiple customized whole-body models tailored to specific injury modeling use cases is required, using body part models sourced from different laboratories for at least one anatomical structure, and with at least one local body part model differing in biofidelity.

2h. *Software and systems engineering:* Software support compatible with all standards and semantics is required for composing integrated whole-body models based on injury modeling use cases, for varying local body part fidelity, for running verification and validation against community-established validation datasets to estimate accuracy, for systematically varying model parameters or external hazard parameters, for applying injury criteria, and for aggregating, analyzing, and/or visualizing simulation results.

2i. *Positioning and interaction:* The model must be able to be positioned to assume different postures (e.g. seated with seatbelts or standing), and incorporate the interaction with clothing, equipment, seating, restraints, and surfaces surrounded it (e.g. model kinematics of contacting surfaces within a vehicle during impact loading).

DISCLAIMERS AND IMPORTANT NOTES

This RFI is issued solely for information and program planning purposes; it does not constitute a formal solicitation for proposals. In accordance with FAR 15.201(e), responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. Submission is voluntary and is not required to respond to a subsequent Broad Agency Announcement (BAA) (if any) or other research solicitation (if any) on this topic.

The Office of Naval Research will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that the Office of Naval Research is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Information in responses will be held confidential to the extent permitted under applicable laws and regulations. Any proprietary, non-public information should be marked so.

IV. SUBMISSION INSTRUCTIONS and FORMATTING REQUIREMENTS

a. Responses are requested by **30 August 2016.**

b. All responses must be in PDF format and emailed to the technical point of contact: Dr. Timothy B. Bentley, timothy.b.bentley@navy.mil. The subject line of the email shall read as follows **"RFI:** Incapacitation Prediction for Readiness in Expeditionary Domains: an Integrated Computational Tool (I-PREDICT) Program."

All responses shall be unclassified. If desired, a classified supplement may be submitted separately. Please contact the Technical Point of Contact for directions on submission of any sensitive or classified information. All information received in response to this RFI that is marked proprietary will be handled accordingly. Responses to this notice will not be returned.

c. Responses shall not exceed 10 pages **and** shall be typed in 12- point Times New Roman font, single spaced, with 1-inch margins.

d. A suggested submission organization:

1. Cover Sheet – RFI number and name, address, company, technical point of contact, with printed name, title, email address and date.
2. Table of Contents with page numbers
3. Technical Approach and Justification
4. Management Approach
5. Personnel Qualifications
6. Relevant Experience

No cost or pricing information should be provided. Any received will be deleted and destroyed.

V. QUESTIONS AND POINT OF CONTACT

Questions of a technical nature regarding this RFI may be sent to the following Technical Point of Contact:

Timothy B. Bentley, Ph.D.
Deputy, Force Health Protection
Code 342, Office of Naval Research
875 N Randolph Street
Arlington, VA 22203
Timothy.B.Bentley@navy.mil

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