Testimony of

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"Head Health Challenge: Preventing Head Trauma from Football Field to Shop Floor to Battlefield"

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Introduction

Chairwoman Comstock, Ranking Member Lipinski, and Members of the Committee, I am Mike Fasolka, Acting Director of the Material Measurement Lab at the Department of Commerce's National Institute of Standards and Technology (NIST). Thank you for the opportunity to appear before you today to discuss our role in the Head Health Challenge III (Challenge), which has helped spur innovation in the development of protective gear for athletes, warfighters, and civilians. This Challenge gained the attention of a diverse set of scientists and engineers and supported small companies seeking to transform these innovations into marketable products. The NIST laboratory programs work at the frontiers of measurement science to ensure that the U.S. system of measurements is firmly grounded on sound scientific and technical principles. Today, the NIST laboratories address increasingly complex measurement challenges, ranging from the very small such as nanoscale devices to the very large like vehicles and buildings, and from the physical as in renewable energy sources to the virtual world of cybersecurity and cloud computing. As new technologies are developed and evolve, NIST's measurement research and services remain central to innovation, productivity, trade, and public safety.

NIST and Challenges

NIST has a long history of using challenges to bring a community together to solve ambitious problems in support of the NIST mission which is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. In the early 1970's, for example, NIST issued a public challenge to develop a data encryption standard[1] to support computer security. Today, many decades later, a challenge is underway with NIST's Post-Quantum Cryptography Project[2] that asks developers to propose new algorithms that will meet security needs in the quantum computing era. Another example is the Global City Teams Challenge,[3] an ongoing effort by NIST to encourage collaboration and the development of standards for the deployment of smart technologies in cities and communities.

Head Health Challenge III was NIST's first prize competition conducted under the "prize competitions" authority in Section 105 of the America COMPETES Reauthorization Act of 2010 (Public Law 111-358), subsequently amended by Section 401 of the American Innovation and Competitiveness Act of 2016 (Public Law 114-329), and codified in 15 U.S.C. 3719. Prize competitions authority allows NIST to offer cash prizes, and further paves the path to partner with private sector for-profit and nonprofit entities as well as appoint judges from outside of NIST, including the private sector. Since the launch of the Head Health Challenge III, NIST has announced many more prize competitions under the prize competitions authority which can be found on the Federal government prize and challenge competitions web portal, www.challenge.gov/list/, and established an institute-wide community of interest in using prizes and challenges to further our mission. NIST greatly appreciates the efforts of the members of

[1] https://www.nist.gov/sites/default/files/documents/2017/05/09/report01-2.pdf
[2] http://csrc.nist.gov/groups/ST/post-quantum-crypto/
[3] https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities

this Committee and other members of Congress to support Federal agency use of prize competitions and challenges.

NIST and the Head Health Challenge

NIST and Under Armour joined with GE and the NFL on Head Health Challenge III with the goal of spurring the creation of innovative impact absorbing materials that will result in increased protection for athletes, warfighters, and civilians. The Challenge partners understood that the experts who could produce better materials could be found in a hugely diverse set of communities, from aerospace to automotive to sports medicine. The national prize competition sought to advance research and technology development in this field by gaining the attention of a wide network of materials scientists and others with an interest in answering this call to action. Together, the Challenge partners decided to reward designers with up to $2 million in prizes to develop or find existing materials that offer improved protection from impacts.

NIST was asked to become a partner in Head Health Challenge III because of its long history of finding new ways of measuring known substances and systems with ever more precision and accuracy, and creating ways of characterizing novel substances and systems for the first time. Participating in the Head Health Challenge III leveraged NIST's technical expertise and allowed NIST to do what it does best—conduct measurement science that helps industries overcome barriers to developing new products and manufacture them efficiently and reliably. As you'll soon hear, the Head Health Challenge III has assisted the participants in these ways.

NIST Measurement Expertise

One of the barriers to innovation in helmet design has been a lack of data about how well new substances absorb the force of hits to the head. Improved data helps helmet manufacturers understand if the risk of developing and manufacturing a helmet with a new material will give them an advantage over their competitors in terms of performance.

It is particularly difficult to test how materials perform in real-world conditions, such as when they are compressed and flexed by the forces of a hit on a playing field or a blast in combat. Small and medium-sized companies often don't have the capital to develop in-house testing facilities or pay for testing, or the in-house expertise to develop new test methods. NIST's participation in Head Health Challenge III helps provide the community with this testing infrastructure. NIST has a long history of producing best-in-the-world materials science measurements, and working with the private sector to help define industry parameters for protective helmets and body armor for law enforcement through private-sector led standards.

Building on these capabilities, NIST applied its technical expertise to build materials testing instruments in the laboratory and even created a new test in support of the Head Health Challenge III, explained below. As NIST learned during the competition, one of the major benefits reported by participants was the opportunity to have their materials assessed by NIST experts.

Head Health Challenge III

Head Health Challenge III asked entrants: "*Can your material withstand a force range of up to 12 kilonewtons, with the potential to withstand 1,200 impacts above 20 KE (J), and perform in the impact velocity range of 3.4 m/s to 11.2 m/s, and in temperatures ranging from 0 to 40 degrees Celsius, with up to 100 percent humidity*?" These parameters translate into real-world use: a broad range of impact conditions from youth leagues to the highest level of professional sports, temperature extremes from freezing to a hot summer day, and a year's worth of repeated impacts. NIST worked closely with the partners at Under Armour, the NFL, and GE throughout the past two years of this challenge to set the technical requirements and overall vision. During phase two of Head Health Challenge III, NIST acted as a neutral third party, generating rigorous technical results. A panel of independent judges, appointed by the NIST Director, made all decisions about the finalists and the grand prize winner. This panel of judges, listed below, represented unique and world-class materials expertise from industry, academia, and the Federal government.

- Jeff Crandall, Ph.D., Professor in Engineering and Applied Sciences at the University of Virginia;
- Sharon Glotzer, Ph.D., Professor of Chemical Engineering at the University of Michigan;
- Heinrich Jaeger, Ph.D., Professor of Physics at the University of Chicago;
- Michael Maher, Program Manager for the Defense Sciences Offices at the Defense Advanced Research Projects Agency (DARPA);
- Tresa Pollock, Ph.D., Chair of the Materials Department at the University of California – Santa Barbara;
- Alton D. Romig, Ph.D., Executive Officer of the National Academy of Engineering and former vice president and general manager of Advanced Development Programs Engineering and Advanced Systems, known as Skunk Works, for Lockheed Martin Aeronautics; and
- Alan Taub, Ph.D., Professor of Materials Science and Engineering at the University of Michigan.

NIST is grateful for the time and commitment of this group of individuals who played a critical role in achieving the ambitious goals set by the Head Health Challenge III.

The Challenge was structured in three phases with awards made in the first and final rounds of the competition.

> First, NIST invited participants to submit an abstract that described a novel material that met specific performance criteria related to maximizing energy absorption while minimizing momentum transfer. Subject Matter Experts evaluated 125 abstracts submitted by participants against the submission evaluation criteria and then invited authors of the 55 top-rated abstracts to submit more detailed proposals with samples of the material.

Next, a panel of judges selected five finalists to receive $250,000 in the First Round and the opportunity to compete for the grand prize of $500,000 in the Final Round. From the full proposals, 21 materials selected by Subject Matter Experts underwent mechanical testing at NIST. The judges evaluated the written proposals and, very importantly, the test results generated by NIST.

NIST's experts conducted a series of impact and compression tests on each sample, as well as on some conventional impact absorbing materials currently used in helmets to establish a baseline. While NIST had the necessary measurement infrastructure on hand because of its existing work supporting the development of improved test methods for ballistic- and stab-resistant body armor, NIST performed a considerable amount of customization to its equipment to subject the materials to the impact energies and velocities that have been reported in different sports and defined in protective equipment standards. NIST's capabilities include sophisticated features like instrumented impact systems and autonomous controls that generate smaller variations in the conditions from test to test. In the measurement science world, this means that it's more meaningful to compare test results from one material to another using NIST's equipment. Variations in results can be more safely ascribed to differences in performance rather than to margins of error in the tests. In December 2015, NIST announced the five First Round winners selected by the judges to move on to the Final Round. They included teams from academic institutions as well as businesses:

- Alba Technic, LLC (Winthrop, Maine) developed a patented, shock-absorbent honeycomb material with an outer layer that diverts the energy from a fall or hit;
- Charles Owen Inc. (Lincolnton, Ga.) made cellular structures that use a stacked, origami-like design to optimize energy absorption;
- Corsair Innovations (Plymouth, Mass.) developed a textile that uses tiny, spring-like fibers to repel rotational and linear impacts, thereby reducing potential damage;
- Dynamic Research Inc. (Torrance, Calif.) and 6D Helmets LLC collaborated to evolve 6D's single-impact suspension technology for use in repeated impact conditions; and
- University of Michigan (Ann Arbor, Mich.) researchers designed a lightweight, multi-layered composite that includes a viscoelastic material.

In addition to receiving a cash prize of $250,000, the finalists received the technical data generated by NIST and advice from the judges to direct the continued development of their materials for the final phase of testing.

Finally, the finalist teams were given about a year to improve their materials for consideration for the grand prize, $500,000. Between March and December 2016, the finalists submitted samples of their materials to NIST for a variety of testing. First, the samples were compressed between two instrumented plates to measure how they compress and rebound, using increasing amounts of force, through three cycles of testing. Second, NIST performed drop testing with an instrumented impactor to measure how

materials respond to sudden impact, progressing through five steps of increasing energy. NIST researchers also performed these tests at 0 degrees Celsius (freezing) and 40 degrees Celsius (104 degrees Fahrenheit). Third, to measure durability, the NIST researchers repeatedly performed drop tests on samples from each competitor 1,200 times before running additional impact tests on them. Importantly, in addition to the regimen described above, NIST developed a fourth, new type of test. A common injury-causing impact is rotational; imagine a glancing blow to the side of the head that sends the head swiveling on the neck. These kinds of hits cause the brain to rotate within the skull, damaging delicate tissues. Inside a helmet that has taken a glancing blow, material is undergoing both compression and shear—the kinds of forces exerted when you press your palms together and one of them slips. When NIST partnered in the Head Health Challenge III, there were only limited approaches to measuring these forces at the same time at high rates, so NIST developed a new method.

Head Health Challenge III Results

After the final testing round, the judges evaluated each Head Health Challenge III participant on innovation, material performance, degree of improvement during the Challenge, and commercialization potential, emphasizing creativity over product maturity.

In September 2017, NIST announced that a team of materials designers led by Dynamic Research, Inc. was the Head Health Challenge III grand prize winner. The Dynamic Research team has received $500,000 to help them progress their product toward commercialization. The team, which includes members from 6D Helmets, used advanced computer modeling and a series of iterative improvements to create a novel material, based on a 6D Helmet proprietary technology, with an unusual geometric structure. The winning entry reduced certain measures of impact by more than 70 percent when compared with baseline foam material that has been commonly used in protective gear, and the material's middle layer of absorbent posts sandwiched between foam helps reduce the shear forces that can cause rotational injuries. The winning concept also can be fine-tuned to a variety of impact environments and adapted to different body types and applications.

Benefits of the Head Health Challenge III

The Head Health Challenge yielded benefits for all involved.

Through the Challenge, NIST saw dramatic technical advances in how well a material can absorb impact. Some of the materials tested reduced the force of an impact by up to 80 percent, compared to conventional materials. The incidence of concussions and severe brain injuries can be significantly reduced with advances like that.

The many measurements performed at NIST amounted to terabytes of data, including high-speed video of samples as they were compressed. Between the first and second phases of testing, some of the contestants used the data provided by NIST to inform computer models of how their

materials might respond to impacts, or to verify models they had made themselves. To help encourage further material design improvements, NIST intends to release to the public large amounts of data generated from tests on the conventional baseline materials.

Computer modelling is used increasingly in materials development to predict performance before developers spend time and money making an actual material. This approach is promoted throughout many industries. It is supported by infrastructure being developed by the Federal government's multi-agency Materials Genome Initiative, which has the goal of bringing new materials to the marketplace faster than traditional trial-and-error invention. Currently, the materials genome approach is more commonly used for new metal alloys than for soft materials like shock-absorbing foams. NIST foresees that its new measurement capabilities for soft materials will provide data for predictive computer modelling, accelerating research and development of soft-materials so that more people will benefit from higher-performing materials, sooner.

The finalists reported that they have benefitted from their participation in the Head Health Challenge III in many ways. For example, they found they could adjust material to meet a wide variety of impact scenarios, making it possible to expand into new product lines and markets. They attracted commercial partners for further development of their material and integration into helmets and pads for further testing. Participants also reported that they integrated their novel material into an existing product. They verified that industrial 3D printing, also known as additive manufacturing, could be used to make their novel material, which will be incorporated into a new product. They also worked with a major materials manufacturer to develop and combine materials for optimum performance, now with patents pending.

This work demonstrated that there is significant opportunity to develop new designs and techniques for testing the performance of soft materials used in protective gear and other applications. What NIST has learned from testing will help inform future standards for the performance of such gear. NIST's new testing device, developed for this challenge, has already provided valuable data to the Head Health Challenge III participants, and will enable the development of future standards for new generations of protective equipment for athletes, first responders, soldiers, and others.

NIST is proud to have partnered with the NFL, Under Armour, and GE in Head Health Challenge III. Such a public-private partnership approach can leverage the best the public and private sectors have to offer, to solve pressing problems that would be hard for any one group to solve on its own. NIST was honored to have been recognized for its efforts with an award for "Public/Private Partnership Collaboration" by the General Services Administration (GSA) in GSA's first-ever Five Years of Excellence in Federal Challenge and Prize Competition Awards.[4]

Thank you for the opportunity to testify today. I would be happy to answer any questions you may have.

[4] https://www.challenge.gov/challenge-gov-celebrates-five-years-of-open-innovation/

Michael J. Fasolka

Michael Fasolka is Deputy Director and Acting Director of the Material Measurement Laboratory (MML), at the National Institute of Standards and Technology (NIST). MML, one of seven research laboratories within NIST, has nearly 1,000 Federal employees and guest researchers from industry, universities, and foreign laboratories.

MML provides a measurement science and standards infrastructure for the nation's industries based in the biological, chemical and materials sciences, promoting U.S. innovation and industrial competitiveness in ways that enhance economic security and improve our quality of life. MML is a source of unbiased measurement standards, data, and cutting-edge methods and technologies that promote innovation, market readiness, and quality control in vital economic sectors.

MML develops measurement standards in the form of documented measurement methods and instrument calibrations, and coordinates the NIST-wide Standard Reference Material® and Standard Reference Data programs. MML provides more than 1,200 Standard Reference Materials that ensure the accuracy of millions of measurements vital for efficient manufacturing, acceptance of American-made goods in international markets, regulatory approval of new technologies and medical treatments, and consumer confidence.

In his role of Deputy Director of MML, Dr. Fasolka is responsible for strategic planning, strategic communications, and operations for the laboratory. He has held this position since 2012. Previously at NIST, Dr. Fasolka has been a Senior Scientific Advisor or Deputy to several NIST laboratory Directors. From 2005 to 2010, Dr. Fasolka was Director of the NIST Combinatorial Methods Center and Leader of a Combinatorial Methods Research Group, established to provide industry with guidance and tools for the high throughput discovery of polymers and other soft materials. Before that, he was a Staff Scientist conducting research in polymer self-assembly and advanced scanning probe microscopy techniques. Dr. Fasolka received his doctorate degree in polymer science from MIT in 2000.

Education

Ph.D. in Materials Science and Engineering from Massachusetts Institute of Technology

B.A. in Liberal Studies from the University of Pittsburgh