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*Title:* A Summary Report on the 21st Century Needs and Challenges of Compression Science

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**A Summary Report on the 21st Century Needs and Challenges of Compression Science**

**Executive Summary**

The influence that compression science has had on national security science and its manifestation through discovery and application cannot be over-stated. In addition to supporting the certification of our nuclear stockpile in the absence of underground testing, as well as a broad spectrum of engineering and defense applications, compression science has altered our view of the material world around us. The discovery of unexpected chemistry and new materials through application of compression science techniques has led to a new and refined understanding of the nature of chemical bonding in extreme environments. However, it is clear that many of the details regarding the response of materials to compressive loading are still not understood, let alone modeled in a predictive mode, and as a result, we have not derived the full benefit that a complete understanding would bring. One product of our workshop has been the identification of five challenges that capture the scientific needs required to achieving full understanding and that ultimately, support our end goal of moving from *"observation to control"*.

These are:

- Acquire time and spatially resolved *in situ* measurements at all length scales (i.e., atomistic, meso-, micro-).

- Discover new physics and chemistry in extreme environments.

- Incorporate material complexity into multi-scale simulations to achieve predictive capability.

- Unify static and dynamic compression understanding across relevant length and time scales.

- Leverage scientific knowledge derived from theory and experiment to the design and control of real materials (i.e., microstructure, defects, etc.)

To make progress on these challenges will require a suite of new experimental tools and diagnostics as well as a suite of conceptual frameworks and theoretical constructs. Experimentally, this suite must include the development of diagnostic capabilities, such as high brightness fourth generation light sources, for peering into and diagnosing compressed materials at the lowest relative length scales while simultaneously characterizing them at higher length scales. Theoretically, this suite must include new frameworks of computation that will allow the incorporation of the stochastic nature of matter, as well as the ability to accurately describe the essential physics without the invocation of phenomenological models, while linking the atomistic to the continuum response.

Progress on these challenges will not only enable the development of full understanding, it will create an environment in which we can train the next generation of scientists and provide them with the tools needed to make progress and move from the "Ideal" to the "Real".