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Conduction and Narrow Escape in Dense, Disordered, Particulate-based Heterogeneous Materials

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For optimal and reliable performance, many technological devices rely on complex, disordered heterogeneous or composite materials and their associated manufacturing processes. Examples include many powder and particulate-based materials found in pyrotechnic devices for car airbags, electrodes in energy storage devices, and various advanced composite materials. Due to their technological importance and complex structure, these materials have been the subject of much research in a number of fields. Moreover, the advent of new manufacturing techniques based on powder bed and particulate process routes, the potential of functional nano-structured materials, and the additional recognition of persistent shortcomings in predicting reliable performance of high consequence applications; leading to ballooning costs of fielding and maintaining advanced technologies, should motivate renewed efforts in understanding, predicting and controlling these materials' fabrication and behavior. Our particular effort seeks to understand the link between the top-down control presented in specific non-equilibrium processes routes (i.e., manufacturing processes) and the variability and uncertainty of the end product performance. Our ultimate aim is to quantify the variability inherent in these constrained dynamical or random processes and to use it to optimize and predict resulting material properties/performance and to inform component design with precise margins. In fact, this raises a set of deep and broad-ranging issues that have been recognized and as touching the core of a major research challenge at Sandia National Laboratories. In this talk, we will give an overview of recent efforts to address aspects of this vision. In particular the case of conductive properties of packed particulate materials will be highlighted. Combining a number of existing approaches we will discuss new insights and potential directions for further development toward the stated goal. Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a Lockheed-Martin Company, for the U. S. Department of Energy's National Nuclear Security Administration under Contract No. DE-AC04-94AL85000.