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Path to Improving Data Science for Materials in Extreme Environments

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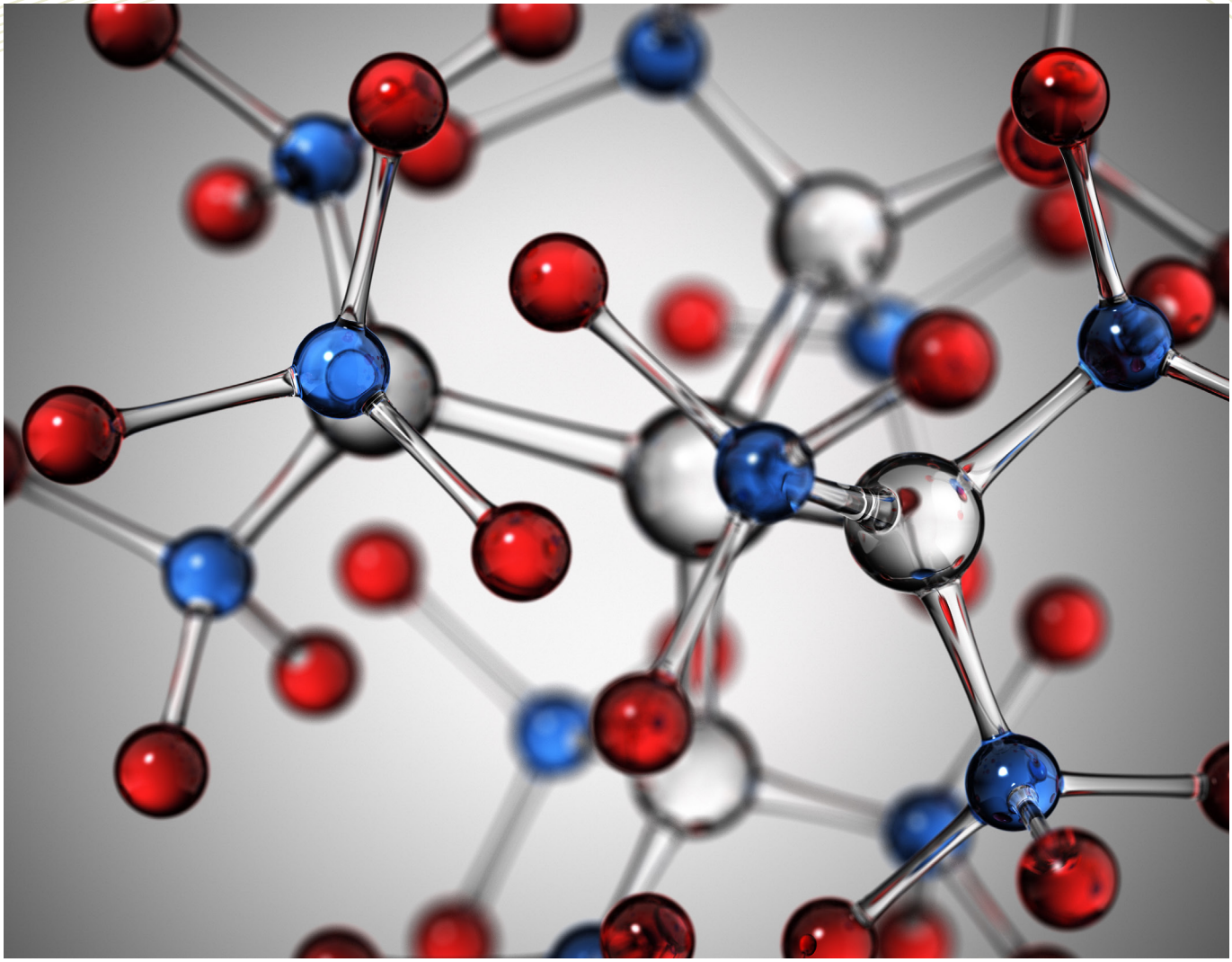

During regular service life, many U.S. military systems are exposed to extreme environments, including high or low temperatures, corrosive environments, radiation, and high strain rates. These environments can affect a material's composition and microstructure, causing changes in material strength or toughness. For example, long-term operation of turbine blades in a marine environment results in corrosion of the blades, while extreme temperatures generated by atmospheric drag limit a hypersonic system's performance. **Designing, modeling, and managing materials for extreme environments play a direct role in determining lifetime, reliability, maintenance, and performance specifications for Department of Defense (DoD) systems.**

Through review of published literature, interviews with researchers and materials testing experts in government laboratories, and case studies on limited sets of experimental data, IDA found that access to data and data

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analytics tools could help the DoD solve some of its critical material design problems. Although materials databases, repositories, registries, and analysis tools exist today in open-source formats, DoD researchers struggle to use them because of lack of awareness, availability, or access. Existing databases that can assist materials scientists have limited processing information, unclear descriptions of database content, and insufficient microstructure information and other metadata. Existing approval processes, publication goals, and intellectual property rules prove to be disincentives to releasing data. Right now government materials data storage, maintenance, and publication is ad hoc and institutional support for curating, storing, and maintaining materials data is lacking.

In particular, the following DoD-relevant material classes would benefit from curated and accessible databases: complex concentrated and high-entropy alloys, corrosion-resistant materials, radiation-resistant materials, and high-temperature structural materials and thermal barrier coatings. A statistical-learning approach is well-suited to these materials problems because complex physical mechanisms are poorly understood or difficult to model with hard modeling approaches.

Several developments are needed before statistical-learning approaches can be widely applied to problems in materials for extreme environments relevant to DoD. These relate to availability and discoverability of data and analysis tools; standardization of data storage, sharing, and curation; and availability of a workforce that is skilled in the application of these methods. The responsibility for providing these pieces is shared between DoD leadership, research communities, professional societies, and academia.

IDA recommends a full review of data management protocols in DoD materials testing and characterization laboratories to identify gaps and best practices. If government organizations implement policy changes that encourage researchers to store their test data in accessible, curated repositories, further loss of useful, expensive data can be prevented.

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