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Request for Information on the National Digital Twins R&D Strategic Plan

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Response to the Request for Information: Digital Twins R&D Plan

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Digital twins present tremendous – but as yet unrealized – potential as a technology for accelerating innovation in the design of instruments and sensors that monitor the behavior of physical systems. These devices are crucial to modern society affecting everything from critical systems for cyber- and energy security, to commuter vehicles and aircraft, and even household appliances and the Internet of Things. This transformational potential is amplified when coupled with data assimilation, uncertainty quantification and modern machine learning.

Historically, in the physical sciences, digital twins (in conjunction with data assimilation) have been used to *predict* the future behavior of complex systems, most notably in weather forecasting. For ***design***, it is the ability of digital twins to rapidly iterate and optimize the conceptual development and prototyping process that will be transformative.

Impact: Leveraging digital twins to advance scientific measurement capabilities would accelerate scientific discovery and, simultaneously, catalyze translational R&D into sensor innovations with the potential to impact day-to-day life and society more broadly. Increasingly, advancing the frontiers of human knowledge requires probing physical systems in extreme environments and harsh conditions. In Department of Energy priority areas such as fusion energy systems and advanced nuclear reactors, this includes extreme temperatures (150,000,000 °C) and unprecedented neutron-rich environments. Existing electronics and instrumentation for detecting light and other electromagnetic radiation simply cannot survive in these conditions. This necessitates developing new measurement tools. However, the design and prototyping of such tools is a labor and resource intensive endeavor. This creates a bottleneck for innovation, as the design→prototype→test sequence is usually repeated several times during a typical development project. The equipment and materials used for the prototyping process directly affects sustainability, from both a financial and environmental perspective. Using digital twins for design has the potential to substantially reduce the labor and resources needed to develop new sensors and advance measurement capability.

Needs: Harnessing the potential of digital twins for accelerating instrument and sensor design is impossible without a concerted, coordinated effort across disciplines and federal agencies. Inter-agency funding mechanisms that enable interdisciplinary collaboration are needed to simultaneously advance the underpinning science and application-specific computational system modeling needs. A key requirement is that these digital twins must be incorporated into frameworks designed for optimization and rapid iteration, rather than real-time prediction, as is needed in forecasting applications. A key component of what is currently missing is mechanisms that facilitate bridging and translation of research in foundational methods to application domains. **In the public research sector**, this necessarily requires (i) cooperation between funding agencies and, equally, (ii) unambiguous delineation of how funding programs supported by these agencies interact in scope and priorities.