Federal Register Notice: 89 FR 51554, Federal Register :: Networking and Information Technology Research and Development Request for Information on Digital Twins Research and Development, June 18, 2024.

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

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July 17, 2024

NITRD National Coordination Office
[redacted]

Dear NITRD,

RE: RFI Response: Digital Twins R&D Plan

The memo below is a response to the RFI for **Networking and Information Technology Research and Development Request for Information on Digital Twins Research and Development** on behalf of UC Berkeley. UC Berkeley has had a long history in the pioneering of modeling and computational methods, such as Finite Element Methods, Optimization, High-Performance Computing, Artificial Intelligence, etc. which are the backbone of industrial-scale digital twin technologies, across a vast spectrum of engineering design and analysis as well as across several other fields. We wish to comment that our campus view is largely consistent with the report of the US National Academies of Sciences, Engineering, and Medicine have recently (2024) on digital twins, *Foundational Research Gaps and Future Directions for Digital Twins,* which makes recommendations to advance mathematical, statistical, and computational foundations for digital twins. The report identifies use case examples in the domains of biomedical sciences, climate change, smart cities, and scientific discovery. In that report, their working definition of a digital twin is a set of virtual information constructs that mimics the structure, context, and behavior of a natural, engineered, or social system (or system-of-systems), is dynamically updated with data from its physical twin, has a predictive capability, and informs decisions that realize value. The report also emphasizes a key characteristic of a digital twin, namely the bidirectional interaction between the virtual and the physical worlds. Furthermore, they list a number of related topics that have synergy with digital twins, namely:

- Artificial Intelligence (AI);
- business case analysis;
- data management best practices;
- establishment of a national and international digital twin ecosystem;
- identification of long term research investments;
- development of regulatory systems;
- ethical development and deployment of digital twins;
- development of evaluation tools and methodologies;
- design and development of systems and architectures for digital twin sustainability;
- trustworthiness of digital twins;
- development of rigorous methods for verification, validation, and uncertainty quantification for digital twins; and

- workforce development and training to advance digital twin research and development.

As the report indicates, there is quite a lot of potential growth in this field, which represents a logical next stage of scientific computing. The topics above are actively being investigated by several of the faculty on our campus. Some further topics which we believe should be considered are:

- Climate change, infrastructure vulnerabilities, urban resilience;
- Social-ecological systems;
- Ecosystem development for sustainable responsible digital twins; and
- Providing precise clean data to digital twin structures.

We emphasize that modern rapidly computable scientific models facilitate the concept of a digital twin of physical reality, i.e., a digital replica of an engineering design, device or process, that can be safely manipulated and optimized in a virtual setting and then deployed afterwards in the physical world, with the goal being to reduce costs of experiments and to accelerate the development of new technologies. Equally as critical is that the digital twin run in tandem with the physical counterpart. Advanced semiconductor manufacturing provides one very critical example, requiring spatio-temporal multiscale-multiphysics analysis, chiplet design and assembly, novel materials, cross cutting enabling technology, supply chain integration methodology and education and workforce development. In this case, the objective is to enable the seamless integration of digital twin models into U.S. semiconductor manufacturing, advanced packaging, assembly and chiplet paradigms, enabling rapid adoption of digital twin innovations and enhancing domestic competitiveness for decades. This is one of many examples that UC Berkeley faculty actively work in, related to digital twins. In general, we wish to:

- Advance digital twin-enabled curricula and best practices for training workforces nationwide;
- Create a digital twin marketplace for industry, including entrepreneurs, to access digital models and to de-risk digital twin development and implementation;
- Develop a shared marketplace that enables data aggregation across companies, while protecting proprietary data, to make powerful digital twins available at low cost; and
- Develop an education and workforce development program, which may include partnerships with a network of educational institutions.

The overall goal is to construct a robust Digital Twin library of experimentally validated tools for engineers and scientists to easily use across a wide spectrum of applications of interest to society and industry. We wholeheartedly support the development of a national initiative on **Digital Twins Research and Development.**

Regards,
Prof. Tarek Zohdi (on behalf of UC Berkeley)
Associate Dean for Research, College of Engineering, UC Berkeley