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

National Institute of Building Sciences (NIBS)

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Digital Twins Research and Development Comments for NITRD NCO

Submitting Organization: National Institute of Building Sciences (NIBS)
NIBS representative: Roger Grant, Vice President Building Technology; Johnny Fortune, Executive Director, US National BIM Program

The National Science Foundation's (NSF) Request for Information (RFI) on Digital Twins Research and Development (R&D) underscores the growing recognition of digital twins as transformative tools across various sectors. Recognizing the potential of digital twins to accelerate innovation, enhance decision-making, and address complex societal challenges, the NSF seeks to develop a National Digital Twins R&D Strategic Plan. The National Institute of Building Sciences (NIBS) is pleased to respond to the Networking and Information Technology Research and Development (NITRD) National Coordination Office (NCO) and National Science Foundation Request for Information (RFI) on the topic of Digital Twins. NIBS provides comments specifically to address the topic of Digital Twins through the lens of **engineered systems of systems** for the **built environment** with an emphasis on **buildings and infrastructure** as integral components of **smart cities**. The built environment is impacted by and in turn impacts **natural systems**. Digital Twins support this relationship. NIBS is uniquely positioned to offer insights on interoperability, standardization, data management, long-term research priorities, and other critical aspects of digital twin development and deployment. Our goal is to contribute to a comprehensive national strategy that fosters a robust, collaborative, and responsible digital twin ecosystem, ultimately benefiting society. This response is structured to provide general information from our existing work and initiatives and communicate our efforts in alignment with the RFI's key topic areas.

NIBS is a crucial nexus for individuals and organizations from the public and private sectors involved in the creation and management of the built environment. NIBS was established by the U.S. Congress in the Housing and Community Development Act of 1974, Public Law 93-383. Congress recognized the need for an organization to serve as an interface between government and the private sector. NIBS convenes experts from throughout the built environment including designers, architects, engineers, constructors, owners, operators/users, technology and service providers, and academia and government representatives. Our work includes public events and publications along with contracted project work with federal and state agencies. NIBS is committed to fostering collaboration on critical topics such as Digital Twins and a unified approach, involving diverse stakeholders, is essential to unlocking the full potential of this technology. We are enthusiastic about facilitating such partnerships and providing a platform for knowledge

exchange and innovation. In our role as convener we work closely with industry associations and standards development organizations; examples include AIA, ASHRAE, bSI, bSUS, CSI, DBIA, DTC, ICC, Global BIM Network, NHBA, SAME, and many more. Digital transformation is addressed with industry stakeholders through our U.S. National BIM Program and our Digital Technology Council. In 2023, NIBS formed a Digital Twin Integration Subcommittee (DTI-S) with support from the Digital Twin Consortium to specifically address Digital Twins for the built environment.

NIBS recently published the DTI-S position paper titled "Digital Twins for the Built World" (DTI-S, 2024), which was the result of over a year of rigorous collaboration among experts in architecture, engineering, construction, and technology. The position paper reflects a thorough understanding and commitment to advancing Digital Twin technology. The position paper emphasizes that Digital Twins are a system of systems, necessitating a collaborative approach that no single entity can achieve alone.

NIBS brings together a diverse array of stakeholders, fostering interdisciplinary collaboration and integration across various systems and domains. This collective effort is essential for understanding and harnessing the full potential of Digital Twins, ensuring that advancements in one area are effectively connected and aligned with developments in other areas. By providing a platform for such comprehensive engagement, NIBS plays an indispensable role in driving innovation and efficiency in the Architecture, Engineering, Construction, Owner (AECO) industry. NIBS sees the effort of NSF to develop a Digital Twin R&D strategic plan as an opportunity for our organizations to collaborate further on advancing this technology into the AECO industry.

The DTI-S position paper provides a structured exploration of Digital Twins, segmented into major portions including Definitions, Public Perception, Foundations, Data Standards, Use Cases, and Calls to Action. Each section delves into critical aspects necessary for the successful understanding, implementation, and adoption of Digital Twins:

1. **Foundational Information:** The paper clarifies the concept of Digital Twin and establishes a common language for AECO stakeholders. Further, it outlines the foundational technologies and methodologies underpinning Digital Twin development and use in the built environment and highlights the importance of standardized data practices to ensure interoperability and accuracy.
2. **The Importance of Integration:** The paper emphasizes the significance of integrating BIM and Digital Twins to drive innovation, efficiency, and collaboration within the AECO industry. It seeks to address the existing confusion and uncertainty surrounding the interchangeability of these terms.
3. **Target Audience:** The paper caters to a diverse audience within the AECO industry, including executive leaders, technologists, and practitioners. It offers insights into the transformative potential of BIM and Digital Twins, technological intricacies, and the impact on the evolving landscape.

4. **Top-Level Position:** The paper posits that the relationship between BIM and Digital Twins is integrative rather than duplicative, commonly misunderstood, and uniquely suited for solving substantial AECO issues. It advocates for the symbiotic adoption of both technologies in accordance with standards.
5. **Public Perception:** The paper underscores the often-overlooked influence of public perception on the integration of BIM and Digital Twins. It argues that the general public, though not directly involved in technical discussions, significantly impacts the adoption and perception of these technologies.
6. **Use Cases:** The paper explores the practical applications of BIM and Digital Twins, demonstrating how they revolutionize the life cycle of built spaces and the natural environment. It emphasizes the importance of clear and well-defined use cases for successful implementation.
7. **Execution:** The paper delves into how BIM and Digital Twins can be executed by harnessing their differences. It highlights that BIM Models provide detailed and static asset representations, which Digital Twins can animate and operationalize, suggesting a strategy where BIM serves as a foundation for AECO digital twins.
8. **Data Frameworks:** The paper outlines a dynamic approach to managing and harnessing data vital for the evolution of BIM and Digital Twins. It presents strategies for immediate implementation and future growth, emphasizing adaptability and responsiveness to the changing landscape.
9. **Conclusion and Call to Action:** The paper concludes by emphasizing the integrative nature of BIM and Digital Twins and calls for action from industry leaders, technologists, and practitioners. It urges engagement with NIBS and the adoption of interoperability standards, data management optimization, and the refinement of use cases.

The development and publication of the paper resulted in the identification of logical next steps for the NIBS DTI-S as outlined below.

Stakeholder Engagement for National Digital Twin Implementation

- **Reason:** To define Digital Twin in a cross-industry fashion and address the need for liaising and collaboration within the AECO industry.
- **Desired Outcome(s):** Engage stakeholders to discuss BIM-DT relationship, current state of Digital Twins, and requirements for enhancing deployment. Collect insights to develop a comprehensive Digital Twin standard.
- **Resources Needed:** Contracted design facilitation expertise, NIBS staff input.
- **Budget:** Roughly $25k for contracted design facilitation.
- **Timeline:** 1 year recommended.

Agile Testbed for Digital Twin & BIM

- **Reason:** To counter industry trends towards siloed advancements by fostering open collaboration and sharing of innovations.

- **Desired Outcome(s):** Implement and refine use cases within a live testbed, demonstrating practical applications and filling gaps in existing standards.
- **Resources Needed:** Advanced simulation software, real-time data processing tools, user interface technologies, industry-aligned consultant.
- **Budget:** Roughly $100k for contracted design facilitation.
- **Timeline:** Initial effort of 1 year, reassessed annually.

A Technical Approach for Advancing BIM and Digital Twin

- Reason: To transform valuable ideas and insights from DTI-S working groups into actionable knowledge and share it with the community.
- Desired Outcome(s): Provide a technical whitepaper on policy, technical, and organizational requirements for successful Digital Twin adoption. Address action items identified in the DTI-S position paper.
- Resources Needed: Part-time industry-aligned consultant, NIBS staff input.
- **Budget:** Roughly $100k for contracted design facilitation.
- **Timeline:** Generally, 1 year, but depends on topics and format (single vs. modular documents).

Implement a Modern Foundation for Digital Collaboration

- **Reason:** To overcome inefficiencies of traditional file-based systems and support dynamic, interconnected environments for effective Digital Twin operations.
- **Desired Outcome(s):** Establish interconnected digital tools embodying Digital Twin principles, enhancing communication and data accessibility. Develop leadership training materials.
- **Resources Needed:** Acquisition of software licenses, standards, and training programs. Integration of legacy systems with advanced web-based tools.
- **Budget:** Amount unknown without further study.
- **Timeline:** Immediate initiation with rapid deployment. Initial 3-month review phase for feasibility.

Identify Use Cases for Digital Twin & BIM

- **Reason:** To extend Digital Twin applications beyond architectural models to encompass environmental interactions and foster sustainable urban planning.
- **Desired Outcome(s):** Develop integrative use cases adhering to existing standards and create new standards where needed. Highlight practical benefits and facilitate deployment across sectors.
- **Resources Needed:** BIM, GIS, and collaborative platforms for stakeholder engagement, part-time industry-aligned consultant, NIBS staff input.
- **Budget:** Roughly $25k for contracted design facilitation.
- **Timeline:** One-time effort of 3 months, with annual review for updates.

NIBS welcomes the opportunity to collaborate with NSF on executing these next steps.

Topic Areas

NSF requested comments on various topic areas. Below are aligned responses to the topic areas suggested.

- **Artificial Intelligence (AI):**
    - Generative AI applications have the potential to effectively align with and enhance the physical counterparts of digital twins. NIBS' has begun to look into this potential working with our network of experts in Building Information Management, digital twin, and simulation, coupled with their understanding of the built environment. For example, we have started an AI in the Built Environment Interest Group and recently hosted a workshop on Digital Twins and AI at our annual conference.

- **Business: Business Case Analysis:**
    - The are numerous potential use cases for BIM and Digital Twins, use cases are the cornerstone of successful integration. Here are some key business cases that could be explored:
        - **Enhancing Efficiency and Sustainability:** BIM and Digital Twins can optimize energy use, benefiting individual buildings and the broader community. For instance, a digital twin of an electrical utility system could interact with a facility's mechanical system to improve efficiency.
        - **Streamlining Asset and Project Management:** BIM and Digital Twins offer capabilities for effective asset lifecycle management. This includes tasks such as asset maintenance scheduling, space utilization planning, design development, generative design, value engineering, construction sequencing, and quality control.
        - **Monitoring and Control:** Digital Twins can monitor building systems and occupant patterns in real-time. This can be used to optimize performance, ensure loaned asset value, and foster trust between stakeholders.
        - **Data-Driven Decision Making:** Integrating BIM and Digital Twins provides a comprehensive view of an asset, enabling informed decision-making. This is particularly valuable for complex systems where real-time data and predictive analytics can drive efficiency and innovation.
    - These use cases can be applied across different phases of an asset's lifecycle, from design and construction to operation and maintenance. Clearly defining use cases before implementing BIM and Digital Twin technologies is an important first step to ensure that the solutions are tailored to specific needs and deliver maximum value.
    - Evaluating the foundational research costs and return on investment for Digital Twins requires expertise and understanding of the built world, infrastructure, and smart cities. NIBS and our community of AECO organizations can provide invaluable insights into the cost and time required for implementation, ensuring

that NSF's efforts are informed, strategic, and impactful in advancing smart city initiatives and infrastructure development.

- **Data**:
    - Data quality, management, and accessibility are critical for the success of digital twin initiatives:
        - **Data Quality Assurance:** Emphasize the need for high-quality, reliable, and timely data to ensure the accuracy and effectiveness of digital twin models. Establish guidelines and best practices for data collection, curation, and management to maintain data integrity and reliability. A roadmap of how to transition from a low level of maturity to the level of maturity needed to leverage a digital twin.
        - **Data Sharing & Accessibility:** Advocate for the creation of shared public datasets and repositories to facilitate research, development, and innovation in the digital twin space. Encourage data sharing across different domains and sectors while adhering to privacy and security regulations.
        - **Privacy & Security:** Address privacy and security concerns related to data collection, storage, and sharing in digital twin applications. Implement robust security measures and adhere to relevant data protection regulations to safeguard user privacy.
    - See the position paper (DTI-S, 2024) for more information on this topic. The position paper highlights the importance of a **dynamic approach to managing and harnessing data** vital for the evolution of BIM and Digital Twins. This aligns with the RFI's emphasis on **encouraging the adoption of data management best practices**. The DTI-S's expertise in data frameworks can inform the development of **governance methods for data collection, curation, sharing, and usage**, as well as the establishment of **shared public datasets and repositories**.
    - NIBS can support NSF in establishing effective governance methods for data collection, curation, sharing, and real-time integration, thereby enhancing the efficiency and resilience of smart city and infrastructure projects.

- **Ecosystem**:
    - To establish a thriving national digital twin ecosystem, it is crucial to prioritize:
        - **Interoperability:** Develop and adopt standardized frameworks, ontologies, and protocols for seamless data exchange and integration between diverse digital twin platforms. This will enable the creation of a unified ecosystem where digital twins from various domains can interact, share information, and collaborate effectively.
        - **Collaboration & Knowledge Sharing:** Establish platforms (e.g., online forums, workshops) and mechanisms for collaboration between researchers, industry stakeholders, and government agencies to share

knowledge, best practices, and lessons learned in digital twin development and deployment.
        - **Open Innovation:** Encourage the development and adoption of open-source tools, platforms, and datasets to accelerate innovation, reduce barriers to entry for new players, and democratize access to digital twin technologies.
    - See the position paper (DTI-S, 2024) for more information on this topic. The position paper emphasizes the need for **clarity and guidance** in the AECO industry regarding BIM and Digital Twin integration. This aligns with the RFI's focus on establishing a **national digital twin R&D ecosystem** and addressing **foundational research gaps and opportunities**. The DTI-S's expertise in integrating these technologies can provide valuable insights into **collaborations across agencies** and the development of **common mathematical, statistical, and computational foundations**.
    - NIBS' expertise in the built world, infrastructure, and smart cities, combined with its ongoing effort to create an inventory and collaborate with nearly 50 Digital Twin public and private organizations, uniquely positions it to contribute significantly to establishing a National Digital Twin R&D Ecosystem. By leveraging its deep understanding of interdisciplinary collaboration and data integration, NIBS can help NSF identify and address foundational research gaps, facilitating advancements in areas such as sustainability, climate change, and smart and connected communities in the built environment.

- **International:**
  Along with Building Information Modeling and Management (BIM) there is extensive activity around the world on Digital Twins. Because many large private sector service and technology companies operate globally and several federal agencies (Department of Defense and Department of State Overseas Buildings Operations) also operate globally, it is important to look at what others outside our borders are doing. Also, other countries such as the UK and many EU countries have advanced further in adopting common BIM processes and standards that form a solid foundation for Digital Twins. This has allowed them to advance their focus to innovation which has included establishing national Digital Twin programs (UK Digital Twin Centre) and several EU initiatives. In the same way NIBS is involved with global BIM efforts, we also have connections with Digital Twin work in other countries such as the UK and EU countries through membership in the Global BIM Network and buildingSMART International and can leverage these connections to assess and potentially connect for what can be shared to advance efforts here.

- **Long Term**:
    - To ensure the continued advancement of digital twin technology, it is essential to prioritize long-term research investments in the following areas:

- **Novel Modeling & Simulation:** Invest in research to develop novel modeling and simulation techniques, including integrating AI and machine learning algorithms, to enhance the predictive capabilities and accuracy of digital twins.
- **Bidirectional Data Flow:** Research and develop technologies to enable seamless bidirectional data flow between virtual and physical assets, ensuring that digital twins are continuously updated with real-time data and can effectively inform decision-making in the physical world.
- **Sustainable High-Performance Computing:** Invest in developing sustainable high-performance computing infrastructure and energy-efficient algorithms to support the computational demands of large-scale digital twin implementations.

- **Standards**:
  - A robust standardization framework is essential for the widespread adoption and integration of digital twins:
    - **Comprehensive Standards:** Advocate for developing comprehensive standards covering data formats, communication protocols, security measures, evaluation methodologies, and AI integration for digital twin development, testing, and interoperability.
    - **Active Participation:** Encourage active participation of all stakeholders in relevant standardization bodies and initiatives to ensure diverse perspectives and expertise are incorporated into the development process.
    - **Widespread Adoption:** Promote the adoption of these standards by industry stakeholders and government agencies to ensure consistency, compatibility, and interoperability across different digital twin implementations.
  - See the position paper (DTI-S, 2024) for more information on this topic. The paper advocates for the **symbiotic adoption** of BIM and Digital Twin technologies **in accordance with established standards**. This directly addresses the RFI's call to **promote the development of evaluation tools, methodologies, and consensus standards** for digital twin development, testing, and interoperability. The DTI-S's focus on standards can contribute to the creation of a **community of practice** and the development of **ontology and data exchange protocols**.

- **Trustworthy**: Data integrity is foundational to the implementation of Digital Twins. To address cybersecurity challenges and data integrity. NIBS has several initiatives that relate to this topic area. NIBS' Digital Technology Council produced a series of events addressing cybersecurity of AECO data. See website links below for the resource. NSF and NIBS can work collaboratively to continue to convene experts to help strike the balance between security and innovation.

- **Workforce**: To take advantage of using digital twins to improve the operations of buildings and infrastructure requires a workforce that knows how to use digital processes to visualize, monitor and optimize operations. Digital Twins is a topic that is in high demand currently as the industry is grappling with the concept and implementation. NIBS produces various educational webinars, podcasts, and training material for the AECO industry. NSF and NIBS could collaborate on educational materials to advance workforce development. NIBS also manages the Whole Building Design Guide (WBDG), which includes a wide range of criteria as well as training and educational material. The WBDG can be used as an outlet to advance the work of educating the industry on Digital Twins.

Additionally, the position paper's (DTI-S, 2024) emphasis on the **integrative relationship between BIM and Digital Twin** and its exploration of **practical use cases** can further contribute to the RFI's topics on **AI integration, long-term research investments**, and **responsible development and use of digital twins**. The paper's focus on the **execution and implementation** of BIM and Digital Twin can also inform the RFI's discussion on **sustainability and the design and development of systems and architectures**.

Conclusion

NIBS believes that a unified approach, involving diverse stakeholders, is essential to unlocking the full potential of Digital Twin technology. We are enthusiastic about facilitating such partnerships and providing a platform for knowledge exchange and innovation. NIBS welcomes the opportunity to engage in deeper discussions and collaborate closely with the NSF to accelerate the widespread adoption of Digital Twins across diverse sectors of the built environment. NIBS can help expand the reach of strategic development and together, we can drive the creation of smarter, more efficient, and resilient built environments. Collaborating with NSF on this effort and partnering with others is crucial in transforming findings into impactful, real-world applications. Please contact NIBS representatives Roger Grant (rgrant@nibs.org) and Johnny Fortune (jfortune@nibs.org) for additional engagement and support.

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References:

Digital Twin Integration Subcommittee. (2024). Digital Twins for the Built Environment: A Position Paper on Integrating BIM and Digital Twin. National Institute of Building Sciences, Digital Technology Council. https://www.nibs.org/files/pdfs/DigitalTwinsBuiltEnvironment.pdf

Website links:

National Institute of Building Sciences: https://www.nibs.org/
NIBS U.S. National BIM Program: https://www.nibs.org/usbimprogram
NIBS Digital Technology Council: https://www.nibs.org/bimc
Introduction to DTI-S Paper: https://qrco.de/bfECJL or https://www.nibs.org/blog/new-paper-bim-and-digital-twins-coexist-drive-sustainability
NIBS report: Collaborative Digital Delivery in the Age of Information Privacy and Cybersecurity: https://www.nibs.org/reports/collaborative-digital-delivery-age-information-privacy-and-cybersecurity
Whole Building Design Guide: https://wbdg.org/

Additional Resources:

Digital Twin categories paper: Ghorbani, Zahra, and John I. Messner. “A Categorical Approach for Defining Digital Twins in the AECO Industry.” Journal of Information Technology in Construction (ITcon), vol. 29, no. 10, Mar. 2024, pp. 198–218, https://doi.org/10.36680/j.itcon.2024.010.