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

International Business Machines (IBM) Corporation

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Networking and Information Technology Research and Development (NITRD) National Coordination Office (NCO), and National Science Foundation (NSF)

Response to Request for Information on National Digital Twins Research and Development Strategic Plan

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IBM Consulting is a global leader in technology and consulting services and brings a wealth of experience across the entire spectrum of projects in Digital Twin technology. IBM Consulting has helped organizations in developing their enterprise strategy for Digital Twins, helped organizations with Digital Twin maturity assessments, frameworks, roadmap planning and prioritization, developed point solutions for specific use cases leveraging Digital Twins, and created full-scale Digital Twins of physical environments with real-time bi-directional data flow. IBM is a leader in this field, and we have over 50 years of experience in connected operations technology with more than 900 IBM Consulting practitioners in Digital Twin services alone. IBM Consulting has been ranked # 1 in Digital Twin services by Everest PEAK Matrix 2022 and 2023 and has assisted 6,000+ clients through our Connected Operations and Digital Twin global practice. At IBM, we also leverage our IBM Research colleagues to develop powerful assets to fast-track innovation and harness emerging technologies for solution development and deployment. With the powerful backing of our experience and expertise, we are pleased to provide perspective on areas which the strategic plan should focus. IBM has chosen the topics below as the focus of our response:

1. Digital Twins to drive Sustainability

IBM believes that Digital Twin technologies will play a significant role in the process of decarbonization, and additional research funding in this space is expected to yield net positive outcomes for humanity. Several key focus areas are detailed below:

1.A - Digital Twin of Ports

According to the Transport and Environment Organization, the shipping industry contributes approximately 3% of global carbon emissions, with expectation to rise to 10% of all global emissions by 2050 and hence this is a key area for research[1].

[1] https://www.transportenvironment.org/topics/ships/climate-impact-shipping#:~:text=What%20is%20the%20impact%20of,emissions%20–%20the%20same%20as%20flying

Digital Twins have shown benefits in reducing carbon emissions using a digital twin of a port to enhance real time operations including optimizing ship berthing time and routing to minimize idle time of ships in the harbor. The IBM solution for this use case features functionality to coordinate pilots, tugboats, captains of the ships, and parties onshore. The solution delivers the application for the harbor master (ships, charts, routes, GPS, sensors all powered by real-time data) and drives intelligence into the operations to enhance safety, **sustainability,** and service. IoT sensors, Augmented Intelligence (AI) and smart weather data measure things like the availability of berths and accurate water (hydro) and weather (meteo) data to allow shipping companies to **predict the best time to enter the port by identifying the most favorable conditions.** With the new digital twin dashboard, the port can view operations of all parties at the same time and increase efficiency of shipped goods that pass through the port.

The solution optimizes Port of Call Services through Real-Time Tracking of vessels arriving and leaving port, along with their size, cargo types, container types; the solution also allows for simulating the unloading of cargo into each port, to identify where ports may be at overcapacity. The **solution includes a predictive feature to identify optimal routes for vessels arriving into port based upon fuel consumption,** arrival time, and other important dimensions which **enables safe entry into the port.**

IBM recognizes that port security supports national security. A robust and efficient supply chain is of national importance, and investment in research in these domains will yield positive outcomes through the increased use of Digital Twins for advanced visibility and monitoring of real time operations to secure the supply chain.

1.B - Digital Twin of Shipping Vessels

In addition to creating Digital Twins for ports, to assist in tracking shipping vessels and optimizing port operations, another critical focus area in the shipping industry is developing Digital Twins for ships. IBM solution for a global energy provider with a large fleet, helps the

client facilitate remote monitoring and performance/voyage analytics, aiming to optimize fuel consumption. The Digital Twin of the vessel is created using IoT and visual sensors to transmit data ashore in real-time for performance monitoring and live voyage analytics. Additionally, the solution equips the ship's machinery with IoT sensors to monitor key parameters and ensure operational efficiency. The solution reduces overall fuel consumption through improved monitoring, and hence performance of the ship's machinery and understanding of weather impact on shipping performance and routing. The improved visibility and monitoring of the ships machinery enables the onshore teams to carry out condition-based maintenance using predictive data analysis from data captures through the digital twin; the proactive condition-based maintenance results in increased efficiency of the equipment, decreasing maintenance costs, reducing unscheduled downtime, and **most critically, reduces failure during voyage**. The twin also helps with **improved carbon emissions tracking**. In addition to sustainability improvements, the client notes the **digital twin of the ship enables improvements in crew safety, and vessel security**.

1.C - Digital Twins in Manufacturing

According to research conducted by the Boston Consulting Group, the Consumer-Packaged Goods (CPG) industry will play a central role in the ultimate success or failure of decarbonization efforts because the agri-food supply chain (in which CPG is a prominent player) accounts for an estimated 31% of annual global GHG emissions.[2]

IBM's work with a leading global consumer packaged goods (CPG) organization to advance their factory of the future project, which is part of their broader Industry 4.0 and supply chain initiatives has yielded positive results. IBM has helped the client to develop a transformation roadmap using Digital Twins technology, and to design a scalable template for global factory rollouts of Digital Twins. The platform places data and connectivity as the foundation, enabling the client to replicate digital capabilities across multiple factories

[2] https://www.bcg.com/publications/2023/why-cpg-leaders-must-reimagine-business-models

easily. IBM helped the client create a Digital Twin of the factory and its underlying assets to support three primary use cases: Overall Equipment Effectiveness (OEE), factory maintenance, and energy efficiency and sustainability. The solutions are designed for ease of use and ensure data visibility from the factory floor to the boardroom. The IBM solution helps enhance and improve operational and manufacturing efficiency by improving visibility of real-time operations through the "Connected OEE" solution, which automatically collects productivity data and provides monitoring of factory assets. Operators now have access to real-time information at their fingertips through a powerful digital UI. The increased visibility to equipment data is brings insight for root cause analysis that drives significant productivity gains. The client also wanted to improve energy efficiency by connecting their energy meters to the cloud platform. Now, **site managers use digital twins / dashboards to track energy use, spot trends or anomalies, and track their progress towards ambitious sustainability targets**. The solution has resulted in 3% decrease in electric power consumption annually.

1.D - Digital Twins in Infrastructure

IBM, in collaboration with Autostrade Tech Group, developed a Digital Twin system for road network security and infrastructure monitoring. The client, an integrated mobility manager responsible for maintaining infrastructure across road networks in Italy, faced significant challenges in collecting asset information, visualizing current data and asset status, and comparing this information with historical data. This comparison was crucial for understanding asset degradation and planning maintenance and replacement of infrastructure-related assets. The newly built Digital Twin platform uses IBM AI, drones, IoT (Internet of Things) and 3D digital modeling to deliver innovation in the surveillance and monitoring activities of the more than 4,500 structures managed by the client including bridges, viaducts, flyovers and tunnels, resulting in improved efficiency and transparency in these processes. The system also introduces advanced technologies never used before on

Italian road networks, i.e., **the ability to analyze a structure through three-dimensional Digital Twins**. These Digital Twins reproduce a structure's features using drones equipped with topographic laser-scanners and high-resolution cameras, which can then be analyzed by AI to assist in the detection of imperfections. This visual defect detection model is specifically developed to support technicians to recognize and classify defects and better plan maintenance activities.

The platform improves the process of conducting civil infrastructure inspections in several ways. Engineers can carry out inspections on the condition of each structure and access key information in the field via a mobile device updated in near real time, including calculations and drawings of the original project and subsequent interventions; scheduled checks and maintenance; investigations and tests on materials; and the results and details of previous inspections. Additionally, the solution traces and manages the various steps necessary for the care of each structure, from inspections to planning and maintenance following activities according to the priority criteria developed with the Ministry of Infrastructure and Transportation.

The work in building a Digital twin of the network infrastructure, modeling & 3D reconstructions of different assets and building maintenance assistance for engineers helped the client **increase the total lifespan of the assets by decades**, hence **reducing thousands of tons of CO_2 emission** related with decommissioning and reconstruction of such large infrastructure assets.

As outlined in the above use cases, IBM has witnessed the power of Digital Twins in sustainable development and sustainable supply chains; a continued and sustained investment in R&D to further enhance Digital Twin implementations for sustainability should be considered by the NITRD.

2. Digital Twins and Smart Cities

IBM believes that Digital Twin technologies will play a significant role in improving city operations, both from the viewpoint of the city manager and city inhabitants, and additional research funding in this area is recommended. Vision for smart cities start with smart manufacturing and smart supply chains, and a couple of key pointers are detailed below:

2.A – Smart Supply Chains

Effective city planning is a critical matter that impacts the life of residents in meaningful ways – not the least of which is the efficient movement of people and products across the city. IBM has been involved in the design and development of a new purpose-built urban area in Saudi Arabia which is a state-of-the-art model for digitally enabled smart supply chain. The total planned area of the city is 26,500 km^2 and IBM is helping with the smart supply chain strategy as well as building Digital Twins.

IBM **created a Digital Twin simulation platform by utilizing scanned point-cloud images** and fusing together using AI based mesh generation and segmentation. The GenAI based model and texture generation, and environment interaction reduces the simulation to real gap with visually and physically accurate replicas of the real-world environment. The client was able to use the **Digital Twin environment to train a hybrid fleet of autonomous robots for various use cases including last mile delivery**. In typical scenarios, the training of robots in a new environment takes 3-6 months without trustworthy GPS data, but the use of the powerful Digital Twins of the environment to train robots fast-tracked the training time significantly. The faster training of the autonomous robots in the Digital Twin environment was made possible through the richer 3D experience and seamless execution of testing and training scenarios. Cities such as the City of Singapore, and the City of Madrid are some other examples of cities across the world that have invested heavily in creating the Digital Twin of the city for improved services and decisions across their operations.

2.B - Smart Manufacturing

IBM created an Assembly Digital Twin for a leading aircraft manufacturer to help significantly optimize assembly line operations through reduction in cycle time. The Original Equipment Manufacturers for doors and fuselages manufacture the parts with a considerable tolerance to maintain economic viability of their process, and these parts are never perfectly identical causing delays on the final assembly line at the aircraft manufacturer. Final assembly is one of the most important steps in the aircraft building process, and its quality determines reliability and service life of the aircraft directly.

IBM made **Digital Twins of aircraft doors and fuselages consisting of 3D geometry models** (as-designed) **and 3D laser measurement data** (as-manufactured) and these twins are processed in a digital world to match best fitting components together. The analysis output is automatically communicated to the assembly line for optimum mix and match of the components to ensure near perfect assembly of these components with the rest of the aircraft body resulting in significant reducing in re-work and cycle time of operations.

Additionally, IBM has our own manufacturing facility in the United States producing mainframe servers that power the most mission critical processes for key industries globally. IBM Consulting has created an **immersive Digital Twin of the IBM Server manufacturing facility to model, simulate and test innovations** across the manufacturing environment. IBM scanned and built 3D models of the assets as the site did not have existing models to use in the Digital Twin. IBM then created the Digital Twin environment bringing data from various sources and integrating operations data as well. To further **enhance the usability of the Twin, IBM infused AI based simulations to enable faster decision making** that is supported by real-time data and effective visualizations.

Manufacturing critical products such as aircrafts and servers within the borders of the United States is of national importance, especially given the rising challenges with supply chain security. This becomes even more pronounced with the ever-increasing scrutiny from

the public on civil aviation safety – use of the Digital Twin technology has shown improvements in the assembly of such products as it enables the manufacturer to enhance system/subsystem reliability and useable lifespans.

3. AI, Trust, and Responsible use of Digital Twins

IBM is a leader in trustworthy AI and our flagship product, WatsonX.governance is a full lifecycle governance methodology to manage, monitor and govern AI models. IBM champions responsible use of technology and prioritizes compliance as well as "do not harm" approach to technology implementations in Digital Twins and beyond. IBM recognizes the compounding power of bringing together exponential technologies but realizes the importance of responsible use of technology as detailed in below examples:

3. A – AI integrations with Digital Twins

A Digital Twin that is powered by an intelligent agent can compound the impact of the technology, especially when it is used in use cases where direct human intervention is dangerous/slow/ineffective. As an example, IBM collaborated in creating the Digital Twin of a ship powered by an AI captain, which converted the ship into an autonomous research vessel for real-time **monitoring of the ocean**; this has shown improvements in data collection across the waters, and **improved decision-making efficiency "on-board",** leading to reduced carbon emissions as well.

Covering 71% of the Earth's surface, the ocean generates more than half of the world's oxygen, regulates global climate and provides a heat sink to reduce the effects of global warming. However, despite the ocean's enormity, it is not immune to human activity and today, the ocean is more polluted, warmer, more acidic and stormier than ever. Nevertheless, gathering data about a system as vast and complicated as the ocean is enormously expensive. Conducting research in an environment as unforgiving as the ocean also puts ships and crews at high risk. The practical impact of this cost and risk is that vast

areas of the ocean's surface remain unexplored. Huge gaps in knowledge persist about climate change, plastics pollution, habitat degradation, marine life conservation and other important topics. Autonomous research vessels — integrated with other shore-based, ship and satellite networks — can collect data about the ocean at a scale and cost-effectiveness far beyond what is possible with today's relatively small fleet of crewed research vessels. While the autonomous shipping market is set to grow from USD 90 billion today to over USD 130 billion by 2030, many of today's autonomous ships are just automated robots which do not dynamically adapt to new situations and rely heavily on operator override.[3]

IBM partnered with a marine research and exploration organization to develop a **research-first, true autonomous ship** that has no human captain or onboard crew **and uses AI** and the energy from the sun to travel across the Atlantic collecting data and revealing more about the ocean. Using the integrated **set of IBM's Digital Twin of the vessel, AI, cloud and edge technologies**, the autonomous research vessel set a new course for ocean research by operating independently in some of the most challenging conditions on the planet.

IBM understands the importance of the blue economy, and of securing United States vessels and personnel while on the sea, and investment in research for expanded usage of Digital Twin in these domains is recommended.

3.B – Digital Twins for Serious Gaming

Serious games can be defined as any piece of software that merges a non-entertaining purpose (serious) with an immersive video game structure (game). The purpose of the game could be message-broadcasting, designed to broadcast educative, informative, persuasive, and/or subjective messages. **Serious gaming is a form of advanced simulation (Digital Twin)**, but it differs from traditional simulation in that player decisions could guide the

[3] https://www.ibm.com/case-studies/mayflower

progression of the simulation, and is powered by Digital Twins, AI/ML/Decision Optimization to assist the player to make more effective decisions, providing recommendations and/or real-time impact assessment of choices.

There are several use cases for using an immersive Digital Twin environment including:

1. Citizenry outreach to support civic learning and engagement to crowdsource solutions

2. Workforce training as it provides a safe environment to practice skills with little risk

3. Operational war planning in defence activities

4. Emergency management, e.g. improve nursing students understanding of COVID-19

For the US government - obviously a very highly regulated industry - finding specialized tech partners that can ensure the model risk management framework meets supervisory standards and that these standards are adopted by procurement offices such that they know exactly what kinds of audits, and features/function they need to see in AI models to meet standards is critical. **Earning trust in serious games (and certainly Digital Twin and AI in general) is important** and further funding for research and collaboration with private organizations (such as IBM) is essential.

Conclusion:

As with other fast-advancing technology, Digital Twins have the capacity to play a pivotal role in driving development and improving outcomes for the United States, across sectors and use cases. IBM's Digital Twin solutions in sustainability, smart operations, and AI and Trust highlight the transformative potential of these technologies.

As we look to the future, sustained investment in research and development in the right areas is crucial for furthering these advancements and maximizing their benefits. IBM remains committed to leading this charge and supporting the strategic initiatives necessary for extending Digital Twin innovation.