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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Digital Twins and Game Technology

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1 Terminology

This RFI (https://www.federalregister.gov/documents/2024/06/18/2024-13379/networking-and-information-technology-research-and-development-request-for-information-on-digital) defines via The National Academies report, "Foundational Research Gaps and Future Directions for Digital Twins:"

> *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 bidirectional interaction between the virtual and the physical is central to the digital twin.*

We refer readers to a recent explanation via RIT faculty: https://theconversation.com/what-are-digital-twins-a-pair-of-computer-modeling-experts-explain-181829.

Given that the RFI welcomes alternate definitions from various fields, we suggest supplementing (not replacing) the definition of a digital twin via https://www.unrealengine.com/en-US/digital-twins:

> *A digital twin is a 3D model of a physical entity like a building or city, but with live, continuous data updating its functions and processes in real-time, providing a means for analyzing and optimizing a structure. When live data from the physical system is fed to the digital replica, it moves and functions just like the real thing, giving you instant visual feedback on your processes. The collected data can be used to calculate metrics like speed, trajectory, and energy usage, and to analyze and predict efficiencies.*

2 Game Engines

Please refer to resources like Schwartz's Game Design Primer for those unfamiliar with games and game design.

Game Engines are a cohesive collection of software development environments for creating interactive multimedia experiences that incorporate digital models, audio, user interaction, display (or rendering), physics (simulated or imaginary), parallelism, AI, and other critical aspects of games. The Unreal Engine (Section 1) is especially popular, e.g., the "power" behind Fortnite.

Readers may need to realize that popular game engines like Unreal and Unity have expanded multimedia and enterprise divisions. When we meet prospective students at RIT and ask if they've enjoyed *The Mandalorian* or *Star Trek*, we note that they've also witnessed Unreal. A search on Google Scholar for *Virtual Production* will show research from various sectors.

The enterprise divisions of Unreal and Unity offer opportunities in simulation, architecture, construction, and more:

- https://unity.com/industry
- https://www.unrealengine.com/en-US/uses/automotive
- https://www.unrealengine.com/en-US/uses/simulation

The authors research and teach in games, animation, and multimedia development, especially in applications extending beyond the entertainment industry:

- https://theivytree.com/category/portfolio/current-projects/
- https://www.rit.edu/news/rit-researchers-create-serious-video-game-infrastructure-resilience-cyberattacks

We note that *serious games*, *gamification*, *game-based learning*, and related concepts rename simulation and attempt to distill how games, interactive development and design, and multimedia applications have developed over time. Digital twins allow games to impact scientific research and educational processes.

A quick search for "game design" via NSF and NIH yields multiple projects and results:

- https://search.nsf.gov/search?query=game+design&affiliate=nsf&search=
- https://search.nih.gov/search?utf8=%E2%9C%93&affiliate=nih&query=game+design&commit=Search

We refer readers to additional resources for recent research:

- https://seriousplayconf.com

- https://www.iitsec.org
- https://chiplay.acm.org/2024
- https://www.gamesforchange.org

Despite the role, popularity, and success of games in STEAM (STEM with the Arts), we note the lack of a top-level division in NSF and NIH that is devoted to the study of game design and development. This issue will significantly affect the advancement of digital twins research, as discussed in Sections 3 and 4.

3 Connecting Digital Twins and Game Technology

Even without our supplements to the supplied definition of digital twins, we suggest that readers search for the terms *interaction*, *visualization(s)*, and *game* (or *game engine*) in the National Academies report.

Among the 18 references to the visualization of digital twin data, this passage is significant:

> *Effective visualization and communication of digital twin data, assumptions, and uncertainty are critical to ensure that the human user understands the content, context, and limitations that need to be considered in the resulting decisions. While opportunities for data visualization have expanded considerably over recent years, including the integration of GUIs and virtual reality capabilities, the understanding and visualization of the content in context, including the related uncertainties, remains difficult to capture; effective methods for communicating uncertainties necessitate further exploration.*

"Interaction(s)" appears 109 times, further stressing connecting components. We highlight the report's involvement of people in the connectivity via Figure S-1. While graphics, interaction, and visualization tend to combine conceptually regarding virtual reality, a search for the primary technology for doing this work—game engines—has zero mentions in this report. When searching for just "game," we also find no mention.

As discussed in Section 1, game engines have already proliferated and have several industry examples. When we expand to industries that support game engines, modeling, and related technologies, we can generate a significant and critical list of companies already providing digital twin capabilities:

- https://www.unrealengine.com/en-US/digital-twins
- https://www.esri.com/en-us/digital-twin/overview
- https://www.nvidia.com/en-us/omniverse/solutions/digital-twins
- https://unity.com/topics/digital-twin-definition
- https://www.autodesk.com/solutions/digital-twin/architecture-engineering-construction

For those curious about NVIDIA's approach to digital twins, readers from outside of art and animation domains might be surprised about the reliance on Pixar's open-source *Universal Scene Descriptor* (USD) data format:

- https://docs.omniverse.nvidia.com/digital-twins/latest/building-full-fidelity-viz/usd.html
- https://openusd.org/release/index.html

At RIT, we have recent and current grants leveraging game engines, e.g.,

- https://www.rit.edu/news/hanif-rahbari-earns-nsf-career-award-enhance-connected-vehicle-security (Unreal)
- https://www.rit.edu/imagine/exhibits/integration-gamification-and-ideis-enable-crew-health-and-performance-mars (Unity)

And many other academic game programs are doing similar work.

4 Workforce Development and Broader Impacts

In 2022, Game Career Guide (https://www.gamedeveloper.com/gcg-status-update; no longer functional) listed almost 500 academic programs listing games as degrees, minors, or other. For now, we refer readers to https://hevga.org, US News & World, The Princeton Review, and The Animation Career Review for examples of academic programs.

Say 500 schools generate an average of 25 students annually. If we consider the thousands of computer science and art students also applying for the game industry, the estimated 12,500 graduates balloon to potentially tens of thousands more. When narrowed down to a non-enterprise, purely entertainment-based game industry, we cannot place everyone into "just games" jobs. A simple Internet search for "how to break into the game industry" will demonstrate many editorials, advice columns, and more.

However, simply telling prospective students "no" will not work—witness the proliferation of entertainment-based academic programs. Based on a multitude of outreach components in NSF grants, we ask what we believe are critical and related questions to resolve:

- **If we suggest attracting STEM majors and graduates via games, shouldn't we provide more career opportunities, especially if the fields have applications beyond entertainment?**
- **Learning how to make games can be very intense and competitive. Wouldn't we want potential students to apply their skills to interactive, 3-D, real-time applications?**

Solving these questions involves including games, game technology, and faculty in these domains. These driven, talented, multidisciplinary students can forge future generations of skilled problem solvers, especially in real-world applications.

Throughout this RFI, we note the representation and advertising of digital twins via Unreal, Unity, and NVIDIA. We strongly recommend NSF and other funding agencies ensure we incorporate games, game design and development processes, and artists as top-level, critical partners in future digital twins research and development.

5 Potential Research Areas

The Foundation Research Gaps report makes a critical distinction between simulation and digital twin on Page 3, also with Figure S-1:

> *Finding 2-1: A digital twin is more than just simulation and modeling.*
>
> *Conclusion 2-1: The key elements that comprise a digital twin include (1) modeling and simulation to create a virtual representation of a physical counterpart, and (2) a bidirectional interaction between the virtual and the physical. This bidirectional interaction forms a feedback loop that comprises dynamic data-driven model updating (e.g., sensor fusion, inversion, data assimilation) and optimal decision-making (e.g., control, sensor steering).*

We anticipate that modern AI will be essential to processing large amounts of data flowing between twins and their real-world counterparts, but we will still need people in some capacity. From the perspectives of games, art, animation, and related fields, we stress the critical importance of including such researchers in any digital twins project that includes humans-in-the-loop, e.g., **data visualization and communication, significantly to help people understand and operate this technology**.

Considering the visual fidelity and interaction of and with a digital twin, game engines are especially adept at representing large digital models in real-time at varying levels of detail. Every functional, real-time game runs on limited hardware—a typical game developer already works in this capacity. **We must continue studying how to increase simulation and visual fidelity at varying levels, leveraging fields connecting game programming, computer engineering, and interactive computer graphics.**

As game programs tend to focus on entertainment or serious games, many have options for simulations but not digital twins. With the incorporation of real-time interactions between digital and real objects, we need pedagogical research to understand how students can combine and possibly converge engineering, games, and art.

Finally, we suggest a further extension of a digital twin from emergency management and disaster response, especially when considering anthropogenic disasters. For example, say

we wish to study the real-time impact of a hurricane. A real-time digital twin of the environment will improve training environments and mitigation plans, save more lives, and deepen the connection between designers and the designed environment. We suggest **asynchronous digital twins—we seek to understand how a simulated virtual environment can be trained and twinned.**