# Survey Preamble

This survey is being administered and distributed by the American Institute of Aeronautics and Astronautics Digital Engineering Integration Committee Subcommittee on Computational Design and Analysis for Digital Engineering (AIAA DEIC-CoDADE). The objective of the DEIC-CoDADE is to bridge the gap between digital engineering infrastructure development and their end-users: engineers and other individuals who perform computational design and analysis. As part of this effort, this survey serves as a query to determine whether the digital twin and thread positions held by the DEIC support maximizing interoperability and responsible use of non-deterministic methods for computational design and analysis (e.g., AI). The population queried include individual engineers conducting aerospace-driven computational design and analysis across industry, government, and academia.

Responsible use of AI and other non-deterministic methods can be best summarized by the DoD Defense Innovation Board [1]. Per the DoD, “the first layer of responsibility lies with those persons with authorities for and over the design, requirements definition, development, acquisition, testing, evaluation, and training for any DoD system, even AI ones.” In the context of digital engineering, responsible use would require ensuring that the engineers have a full-scale, life cycle-oriented view of where their data comes from, how their models are being used, and what sorts of decisions are being made using said models. These would seek to answer two questions: (1) Are the models, data, and decision-making process appropriate for the desired application? (2) Are the models, data, and decision-making process sufficiently mature for quantification of uncertainty and establishing trust?

According to DoD Instruction 8330.01 [1], interoperability is defined as the ability of systems, units, or forces to provide data, information, materiel, and services to, and accept the same from, other systems, units, or forces, and to use the data, information, materiel, and services exchanged to enable them to effectively operate together. In the context of non-deterministic methods (e.g., AI), the goal is to emphasize how interoperability of these methods with other digital infrastructure can supported in a responsible manner. Considering the described requirements for responsible use of AI, the notion of interoperability of infrastructure required for using AI is central to ensuring responsible use.

With DEIC-CoDADE’s positions on what constitutes “responsible use” and interoperability, the following includes definitions and implementation details for digital twins and threads. For a summary of the definitions and the implementation details, refer to the table below.

**Digital twin** - A set of virtual information constructs that mimics the structure, context and behavior of an individual / unique physical asset, or a group of physical assets, is dynamically updated with data from its physical twin throughout its life cycle and informs decisions that realize value (AIAA Digital Twin Position Paper).

Separating this definition into individual components, the digital twin is a virtual construct (e.g., a mathematical model, CAD model) that is routinely updated with data measured or collected from an individual physical system to update the virtual construct to best represent the current state of the physical model to inform prescriptive decision-making with respect to the physical asset. This decision-making can incorporate assessment of current physical asset state, monitoring of upcoming physical asset state, or prediction of future physical asset state. Note that a digital twin only represents an individual instance of a product or system and should not be used to represent a whole fleet of systems. However, the model used by the virtual construct that is part of a digital twin can be a model of a fleet of systems that is instantiated to represent a single system (e.g., inputting individual values into a parametrized model).

**Digital thread**: A collection of linked authoritative digital information pertaining to a process, product, or system, whose consistency is actively managed throughout the life cycle. This enables accessibility, traceability, currency, applicability, and credibility of information, thus facilitating the capture, communication, and use and reuse of knowledge to efficiently inform decisions that realize value (AIAA Digital Thread Position Paper).

Ultimately, the goal of the digital thread is providing data for the digital twin to use to set generate prescriptive recommendations and decision-making. The digital thread is composed of a comprehensive linkage of models, data sources, and information across the entire life cycle, including customers, suppliers, partners, and configuration management. This also implies that various kinds of data would also need to be sufficiently linked and readily available to digital twins through their different digital threads. Considering the requirements for the digital twin, the data would need to be as current as possible and delivered as quickly as possible to support decision-making as well. As a result, though not absolutely required, it is preferable to receive data automatically from the physical systems upon data collection.

|  |  |
| --- | --- |
| **Digital Constructs** | **Summary of Definition and Implementation Details** |
| Digital Twin  ( [1], [2]) | * Includes a virtual construct of an individual physical system (only one system, not a fleet of systems) * Best to use a parametrized model in the virtual construct so you can create instantiations of the virtual construct that would capture idiosyncrasies of the individual physical system * Dynamically updated with data (preferably automatically delivered upon data collection) * Digital twin can use assessments of system behavior, monitoring of upcoming system behavior, and prediction of future system behavior to conduct decision making and generate prescriptive recommendations. |
| Digital Thread  ( [3]) | * Models, data sources, and information across system lifecycle and entities (e.g., customers, suppliers, partners) need to be linked and readily available for digital twin to query. * Data needs to be delivered as quickly as possible upon data collection to ensure most up-to-date digital twin decision making (ideally automatically delivered) |

For further information about the survey or DEIC-CoDADE, please email Abhishek Ram ([aram@draper.com](mailto:aram@draper.com)). All of us in DEIC-CoDADE would like to thank you for the time and effort taken to respond to the survey questions and for your consideration of our positions on digital engineering.

# Questions About Your Organization

1. My organization most aligns with:
   1. Government
   2. Military / Defense
   3. Commercial / Industrial
   4. Academia
   5. Other
2. What is your impact on digital twins (select all that apply)
   1. As a vendor of supporting technology
   2. As a developer / product manager of twins or twinned products
   3. As a consumer of twins / user of twinned products
3. How large is your organization?
   1. N/A: Independent contractor / government / academic
   2. Small business (<100 people)
   3. Medium-sized business (100 – 1500 people)
   4. Large business (>1500 people)
4. How would you describe the career ages of your workforce?

**[Select All That Apply]**

* 1. 0 to 4 years
  2. 5 to 9 years
  3. 10 to 19 years
  4. 20 to 29 years
  5. 30 years or more

1. How much progress into digital twin and digital thread development has your organization achieved?
   1. Conceptual stage (designed, but no implementation at all)
   2. Minimum viable product (basic implementation, meeting design requirements)
   3. Operational on a team-wide scale (fully implemented in a limited setting)
   4. Operational on an enterprise scale (fully implemented and “fielded” to relevant teams/efforts)

# Questions About Your Experience

1. How long have you been in the science & engineering workforce?
   1. 0 to 4 years
   2. 5 to 9 years
   3. 10 to 19 years
   4. 20 to 29 years
   5. 30 years or more
2. Your age is \_\_\_\_ years old. (reasoning in parentheses – would not include those in survey 😊)
   1. less than 25 (entering workforce)
   2. 25 to 34 (becoming established)
   3. 35 to 44 (core career)
   4. 45 to 59 (established and mentoring)
   5. 60 to 65 (thinking about retirement)
   6. more than 65 (retired/no plan in retiring)
3. Do you agree with the DEIC’s definitions of a digital twin and digital thread?
   1. Yes
   2. No
   3. Other [Request Short Answers]
4. How would you classify your experience and expertise in these subject areas?

**[List of Subject Areas with Options to Choose Levels of Expertise Next To Them]**

e.g., Subject Area \_\_\_\_\_\_ {Dropdown Box With List of Levels of Expertise}

1. Regarding which subject areas would you feel comfortable answering survey questions?

**[Select All That Apply]**

1. Computational Design and Analysis Framework Development
2. Impacts of Computational Design and Analysis on Enterprise Data and Software Architecture
3. Hardware and Software Infrastructure Co-Design
4. Impacts of Socio-Technical Interactions on Computational Design and Analysis Strategy
5. If you would like to see the survey results, please provide your email. Note: this will not be shared to anyone without your permission.

**[Request Short Answer}**

# Computational Design and Analysis Framework Development

1. Select appropriate level of *personal* professional experience and expertise in:  
   **[None / Dabbled / Learning / Occasional / Commonplace]**
   1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
   2. Coupled Multiphysics Mod/Sim
   3. Multiscale Mod/Sim (single or multi-physics/discipline)
   4. Multifidelity Mod/Sim (single or multi-physics/discipline)
   5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
   6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
   7. AI/ML applied to sophisticated automation, data analysis, etc.
   8. Hybrid AI/ML + traditional modeling/simulation integrated methods
   9. Other: [Request Short Answers]
2. Select your best estimate of your *enterprise*/collaborators’ best experience and expertise in:  
   **[None / Dabbled / Learning / Occasional / Commonplace]**
   1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
   2. Coupled Multiphysics Mod/Sim
   3. Multiscale Mod/Sim (single or multi-physics/discipline)
   4. Multifidelity Mod/Sim (single or multi-physics/discipline)
   5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
   6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
   7. AI/ML applied to sophisticated automation, data analysis, etc.
   8. Hybrid AI/ML + traditional modeling/simulation integrated methods
   9. Other: [Request Short Answers]
3. In which research areas do you believe digital engineering would find the most interoperability?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. In which research areas do you believe digital engineering would find the least interoperability?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. Which research areas do you think DEIC-CoDADE should invest the most time in investigating interoperability?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. In which research areas do you think DEIC-CoDADE should suggest guidelines for maximizing interoperability?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. In which research areas do you think DEIC-CoDADE should suggest guidelines for responsible use of models in these research areas?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. In which research areas do you think DEIC-CoDADE should suggest guidelines for maximizing responsible use?

**[Select All That Apply]**

* 1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
  2. Coupled Multiphysics Mod/Sim
  3. Multiscale Mod/Sim (single or multi-physics/discipline)
  4. Multifidelity Mod/Sim (single or multi-physics/discipline)
  5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
  6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
  7. AI/ML applied to sophisticated automation, data analysis, etc.
  8. Hybrid AI/ML + traditional modeling/simulation integrated methods
  9. Other: [Request Short Answers]

1. Are you most interested in developing one-off digital twins or repeated-use digital twins?
   1. One-off digital twins
   2. Few-repeated-use digital twins (used a finite number of times and shelved)
   3. Continuously used and operated digital twins
   4. Other: [Request Short Answers]

# Impacts of Computational Design and Analysis on Enterprise Data and Software Architecture

1. Which kinds of data do you mostly utilize in your work?

**[Select All That Apply]**

* 1. Unstructured text data
  2. Structured data
  3. Boundary conditions
  4. Geometric data
  5. Tolerances
  6. Photographs
  7. Other: [Request Short Answers]

1. Is the data you work with:
   1. Measured
   2. Simulated
   3. Fusion (mixed simulated and measured data)
   4. Other: [Request Short Answers]
2. Which types of data would you expect to be the least challenging to manage with respect to digital twin development?

**[Select All That Apply]**

1. Unstructured text data
2. Structured data
3. Boundary conditions
4. Geometric data
5. Tolerances
6. Photographs
7. Other: [Request Short Answers]
8. Which types of data would you expect to be the most challenging to manage with respect to digital twin development?

**[Select All That Apply]**

1. Unstructured text data
2. Structured data
3. Boundary conditions
4. Geometric data
5. Tolerances
6. Photographs
7. Other: [Request Short Answers]
8. What data management do you think DEIC-CoDADE should investigate how to maximize interoperability with digital twin development?
   1. Unstructured text data
   2. Structured data
   3. Boundary conditions
   4. Geometric data
   5. Tolerances
   6. Photographs
   7. Other: [Request Short Answers]
9. What types of data do you think DEIC-CoDADE should investigate how to utilize responsibly in digital twin development?
   1. Unstructured text data
   2. Structured data
   3. Boundary conditions
   4. Geometric data
   5. Tolerances
   6. Photographs
   7. Other: [Request Short Answers]
10. With what types of data do you think DEIC-CoDADE should suggest guidelines for maximizing responsible use?

**[Select All That Apply]**

* 1. Unstructured text data
  2. Structured data
  3. Boundary conditions
  4. Geometric data
  5. Tolerances
  6. Photographs
  7. Other: [Request Short Answers]

# Hardware and Software Infrastructure Co-Design

1. What research areas do you use high performance computing for? **[Select All That Apply]**
   1. Co-simulated (uncoupled) Multiphysics (e.g., aeroacoustics, CHT, FSI, etc.)
   2. Coupled Multiphysics Mod/Sim
   3. Multiscale Mod/Sim (single or multi-physics/discipline)
   4. Multifidelity Mod/Sim (single or multi-physics/discipline)
   5. Multidisciplinary Trade-off Analyses (integrated design/manufacturing, performance/lifing, etc.)
   6. Automation for labor-intensive tasks (meshing, post-processing, etc.)
   7. AI/ML applied to sophisticated automation, data analysis, etc.
   8. Hybrid AI/ML + traditional modeling/simulation integrated methods
   9. Other: [Request Short Answers]
2. What types of data do you utilize in your research areas that use high performance computing? **[Select All That Apply]**
   1. Unstructured text data
   2. Structured data
   3. Boundary conditions
   4. Geometric data
   5. Tolerances
   6. Photographs
   7. Other: [Request Short Answers]
3. Approximately what percentage of your cyber-physical infrastructure is dedicated to computational design and analysis?

**[Choose One Option]**

* 1. <10%
  2. 10-20%
  3. 20-30%
  4. 30-40%
  5. 50-60%
  6. >60%

1. What types of scaling do you anticipate your enterprise having to undergo in the future?

**[Select All That Apply]**

1. Strong scaling – Incorporate more hardware to reduce the time-to-solution for a given problem.
2. Weak scaling – Incorporate more hardware to solve larger problems than before.
3. User scaling – Add ability to support growth in concurrent users with minimal efforts.
4. Functional scaling – Add new functionality/interoperability with minimal effort.
5. Horizontal scaling – Add more nodes/racks/data centers.
6. Vertical scaling – Upgrading nodes (e.g., processor, memory, interconnect)
7. Which research areas would benefit the most from which kind of scaling?

**[List of Research Areas with Options to Choose Types of Scaling Next To Them]**

e.g., Research Area \_\_\_\_\_\_ {Dropdown Box With List of Scaling Options}

1. The management of which types of data would benefit the most from which kind of scaling?

**[List of Research Areas with Options to Choose Types of Scaling Next To Them]**

e.g., Types of data \_\_\_\_\_\_ {Dropdown Box With List of Scaling Options}

1. Which types of scaling do you think the DEIC’s digital twin framework would be most interoperable with?

**[Select All That Apply]**

* 1. Strong scaling – Incorporate more hardware to reduce the time-to-solution for a given problem.
  2. Weak scaling – Incorporate more hardware to solve larger problems than before.
  3. User scaling – Add ability to support growth in concurrent users with minimal efforts.
  4. Functional scaling – Add new functionality/interoperability with minimal effort.
  5. Horizontal scaling – Add more nodes/racks/data centers.
  6. Vertical scaling – Upgrading nodes (e.g., processor, memory, interconnect)

1. Which types of scaling do you think the DEIC’s digital twin framework would be least interoperable with?

**[Select All That Apply]**

* 1. Strong scaling – Incorporate more hardware to reduce the time-to-solution for a given problem.
  2. Weak scaling – Incorporate more hardware to solve larger problems than before.
  3. User scaling – Add ability to support growth in concurrent users with minimal efforts.
  4. Functional scaling – Add new functionality/interoperability with minimal effort.
  5. Horizontal scaling – Add more nodes/racks/data centers.
  6. Vertical scaling – Upgrading nodes (e.g., processor, memory, interconnect)

1. In which types of scaling do you think DEIC-CoDADE should suggest guidelines for maximizing interoperability?

**[Select All That Apply]**

* 1. Strong scaling – Incorporate more hardware to reduce the time-to-solution for a given problem.
  2. Weak scaling – Incorporate more hardware to solve larger problems than before.
  3. User scaling – Add ability to support growth in concurrent users with minimal efforts.
  4. Functional scaling – Add new functionality/interoperability with minimal effort.
  5. Horizontal scaling – Add more nodes/racks/data centers.
  6. Vertical scaling – Upgrading nodes (e.g., processor, memory, interconnect)

# Impacts of Socio-Technical Interactions on Computational Design and Analysis Strategy

1. Who are currently considered to be stakeholders to your digital engineering efforts?

**[Select All That Apply]**

* 1. Other computational design and analysis teams
  2. Program management
  3. Direct customers
  4. End-product users
  5. Community around end-product users
  6. Tool vendors
  7. Other: [Request Short Answers]

1. Who do you believe should be considered as stakeholders to your digital engineering efforts?

**[Select All That Apply]**

* 1. Other computational design and analysis teams
  2. Program management
  3. Direct customers
  4. End-product customers
  5. Community around end-product users
  6. Tool vendors
  7. Other: [Request Short Answers]

1. Who currently has the most influence over your digital engineering efforts?

**[Select All That Apply]**

* 1. Other computational design and analysis teams
  2. Program management
  3. Direct customers
  4. End-product customers
  5. Community around end-product users
  6. Tool vendors
  7. Other: [Request Short Answers]

1. Have you experienced any recent cost-cutting in your digital engineering efforts? What has been the impact on your enterprise as a whole?

**[Choose One Option]**

* 1. Significant impact
  2. Minor impact
  3. No impact
  4. Other: [Request Short Answers]

1. Has the size of your organization impacted your ability to implement digital engineering? If so, what has been the impact?

**[Choose One Option]**

* 1. Significant impact
  2. Minor impact
  3. No impact
  4. Other: [Request Short Answers]

1. Has the career age of your workforce impacted your ability to implement digital engineering? If so, what has been the impact?

**[Choose One Option]**

* 1. Significant impact
  2. Minor impact
  3. No impact
  4. Other: [Request Short Answers]

1. Has your digital engineering implementation been impacted by having to integrate various tools? If so, what has been the impact?

**[Choose One Option]**

* 1. Significant impact
  2. Minor impact
  3. No impact
  4. Other: [Request Short Answers]

1. Has the alignment of your organization (e.g., government, defense, commercial, academia) had an impact on your implementation of digital engineering? If so, what has been the impact?

**[Choose One Option]**

* 1. Significant impact
  2. Minor impact
  3. No impact
  4. Other: [Request Short Answers]

# Short Answer Questions

1. What are the fundamental challenges / major barriers to utilizing digital engineering in this context?

**[Short Answer: No More Than 500 Words]**

1. What are the major tools/technologies/methods we would need to meet any previously identified gaps?

**[Short Answer: No More Than 500 Words]**

1. Would you like to identify yourself to the surveyors? Note: this is independent of the previous question asking for emails.

**[Short Answer: No More Than 500 Words]**