Grand Challenges

Towards a CCP in Data-driven Computational Mechanics (CCP-DCM)

Over the next decade, digital twins will become central to engineering, healthcare, climate modelling, and manufacturing. Their role will expand from isolated simulations to adaptive, data-driven systems capable of real-time prediction, optimisation, and decision support. However, widespread use demands robust, scalable computational models accessible beyond elite HPC centres. Here, CCP-DCM will be crucial: by advancing open, efficient, and user-friendly numerical methods for solving partial differential equations—the backbone of digital twin physics—it will democratize access to high-fidelity modelling. Through CoSeC's community-driven software, training, and cross-domain collaboration, CCP-DCM will help ensure digital twins evolve from specialised research tools into everyday enablers of innovation across UK academia and industry.

The Community

Add Logo!

ccp-dcm.github.io

CCP-DCM is a CCP centred around the FEniCS and Firedrake software frameworks for the numerical solution of partial differential equations (PDEs). These numerical simulations are essential for advancing science and engineering across a very broad range of disciplines. FEniCS and Firedrake are used to develop solvers in the geosciences (ocean, atmosphere, cryosphere, geodynamics), nuclear fusion (plasma, tritium transport, breeding blankets), physiology and medicine (brain, heart), and many more besides.

The Challenge

Widespread adoption of faithful digital twins across computational science and engineering

The grand challenge of the CCP-DCM is to enable the widespread adoption of faithful digital twins across computational science and engineering. A digital twin is a high-fidelity, multiphysics simulation that integrates real-time or historical data from a physical system. Its purpose is to replicate the behaviour of the system with sufficient accuracy to support design decisions, operational insights, and scientific discovery. A well-known example is numerical weather prediction, which combines complex physical models with rapid assimilation of observational data to produce accurate forecasts.

Grand Challenges

Extending this paradigm to other engineered and natural systems opens the door to value-driven science, where costly and time-consuming physical experiments can be replaced—or augmented—by efficient, predictive simulations.

The Solution

Democratising digital twin technology to be available to all with modest computational resources

The core challenge lies in democratising digital twin technology: making it accessible to engineering firms and research groups with modest computational resources, rather than requiring the infrastructure of national laboratories or weather centres. The CCP-DCM community is uniquely positioned to address this challenge through its expertise in composable and modular modelling frameworks, automated code generation, and differentiable programming—enabling flexible, scalable, and optimisable simulations that integrate seamlessly with data-driven workflows.

The Outcome

Supporting the core simulation toolchain with digital twin technology fully integrated across computational science and engineering

CCP-DCM will be actively supporting and developing the core simulation toolchain to enable current and new users to continue pushing the limits in simulation scale. Digital twin technology will have been fully developed and integrated across organizations and research groups across compuational science and engineering.

More Information

CoSeC
www.CoSeC.ac.uk
CoSeC@stfc.ac.uk

CCP-DCM
ccp-dcm.github.io