A New Paradigm

Contact

Universität Stuttgart
Cluster of Excellence EXC 2075

Gefördert durch
DFG Deutsche Forschungsgemeinschaft

SimTech Cluster of Excellence

"Data-Integrated Simulation Science"

A New Paradigm

Data-Integrated Simulation Science

> We are reaching the limits of our traditional approaches, when it comes to simulating highly complex phenomena and we can only overcome these issues by integrating all the data which is available. We are convinced that the new methods emerging out of SimTech will fundamentally change research and development in many scientific disciplines.
>
> **PROF. DR. THOMAS ERTL**
> **EXECUTIVE DIRECTOR AND SPOKESPERSON**

Simulations have become an indispensable part of research and development in many different areas, and they make key contributions towards technological progress. Since 2007, the Cluster of Excellence EXC 310 „Simulation Technology" (SimTech) at the University of Stuttgart has advanced simulation science in great depth and breadth based on models, methods and computing aspects from an engineering perspective. With its interdisciplinary and methodical profile, it has established itself as an internationally visible research focus. The University of Stuttgart can now advance these findings and successes of its research into a new direction.

The long-term research objective of the new **Cluster of Excellence EXC 2075 „Data-Integrated Simulation Science"** is to systematically integrate information derived from various types of data into the modeling-simulation-analysis cycle. This will give us a deeper understanding, let us obtain more precise predictions, and help us make reliable decisions. SimTech aims to develop a new class of jointly simulation- and data-driven approaches that will boost the applicability and accuracy of simulations and fundamentally transform the way in which we do science and engineering.

The resulting methodological innovations are expected to meet the great challenges facing contemporary engineering and natural sciences and, eventually to profoundly impact many aspects of human life.

Our Visionary Examples

We forsee data-integrated simulation science growing into a challenging and influential research area in all fields of engineering and sciences that promises to have an enormous impact on may aspects of life. SimTech addresses three **Visions**:
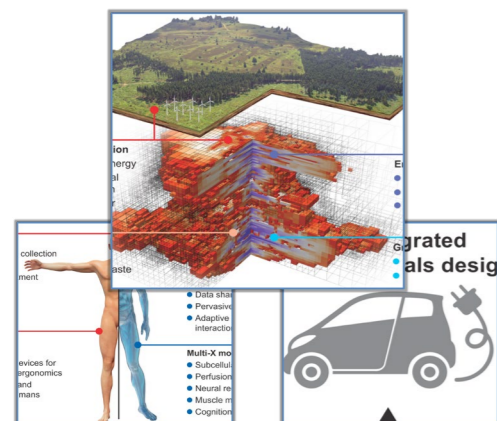

Our vision **Engineered Geosystems** provides a showcase for data-integrated simulation science involving multiphase flow and porous media. It will address pressing environmental issues in engery storage, energy generation, and groundwater preservation.

Our vision **Digital Human Model** will inspire data-integrated simulation science at the interplay between biomechanics and systems biology, addressing future personalized healthcare, novel therapies for rare diseases, and neuro-protheses.

Our vision **Next-Generation Virtual Materials Design** will establish a new paradigm in computational engineering by combining first principles and experimental observations into a holistic development cycle for innovative materials and products.

Our Focus Challenges
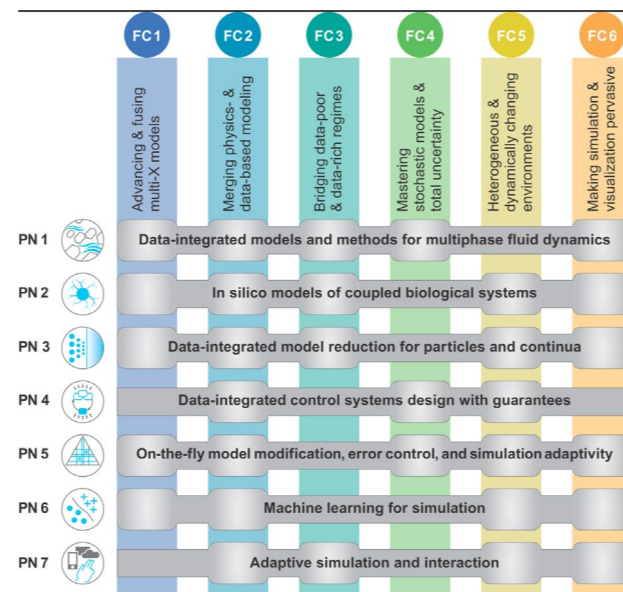
We have identified six **Focus Challenges** that will drive the research during the first funding period:

1. **Advancing and Fusing Multi X-Models**
2. **Merging Physics- and Data-Based Modeling**
3. **Bridging Data-Poor and Data-Rich Regimes**
4. **Mastering Stochastic Models and Total Uncertainty**
5. **Heterogeneous and Dynamically Changing Environments**
6. **Making Simulation and Visualization Pervasive**

These Focus Challenges are chosen to tackle the enormous complexity that will result from data integration and how simulation will actually be done in the coming decade.
Eventually, as new methods are mainstreamed or different requirements arise, SimTech will adjust these Focus Challenges.

Our Project Networks

PN 1: Data-integrated models and methods for multiphase fluid dynamics will advance models and simulation methods for multiphase processes in turbulent free and porous media flow. **PN 2: In silico models of coupled biological systems** focuses on holistic yet person-specific computational models of, for example, the neuromusculuar system. **PN 3: Data-integrated model reduction for particles and continua** will develop new techniques for data integration into models of materials and biological matter. The predictive power of reduced or coarse-grained models will be enhanced by incorporating data from different sources. **PN 4: Data-integrated control systems design with guarantees** will develop novel methods to control individual systems or networks of systems. It will exploit the benefit of data and learning strategies on top of classical first-principles models while still providing rigorous guarantees for the overall system behavior in all steps of the systems and control design cycles. **PN 5: On-the-fly model modification, error control, and simulation adaptivity** will balance systematic errors and stochastic variations against resource limitations in computing power and available data. **PN 6: Machine learning for simulation** will integrate the so far separated fields of classical simulations and machine learning, paving the way to joint model-based and data-driven predictions. Assisted by novel visualization techniques, it also explores how physical models and simulations can improve machine learning and vice versa. **PN 7: Adaptive simulation and interaction** is key to pervasive simulations in dynamically changing heterogeneous communication and computing infrastructures. It focusses on modeling and real-time adaption of systems, traceability and provenance, adaptive user interaction, and visualization.

Early Career Researchers

Scientific progress relies significantly on the fresh impetus and dedicated work by early career researchers. We view their promotion as one of our main responsibilities as well as strategic investments in the future. SimTech provides young researchers with continuity, interdisciplinarity as well as international networking opportunities. We foster them by the following means:

- A **junior academy** for high school seniors
- An **elite study programme** on Bachelor's and Master's level
- A **graduate school** with more than 150 doctoral students
- **PostDoc positions** for intensified pursuit of our visions
- **Junior professorships** for highly-qualified young scientists
- A **mentoring programme** for women in science
- **Child care** arrangements
- Frequent **seminars and workshops**

Furthermore, SimTech provides its young researchers with a lively research environment, international and interdisciplinary exchanges, and a tailored educational experience supported by an outstanding mentoring concept.

Collaboration is the key to fostering young scientists.