Multiphysics Modeling and Digital Twins

Model or Digital Twin?

- Model:
  - Often validated by comparing to experimental data during the design and development of a product, device, or process
  - May be connected to a real device during operation for control and system identification purposes, but often using a limited set of data
- Digital twin (DT)
  - Tightly connected to the real device
  - Follows a device or process throughout its lifetime, from development to disposal
  - May contain and process a vast amount of data, not only for modeling
  - Is specific for that unit; i.e., not only for that make and model of the product

Early Adopters: Aerospace and Defense Industry

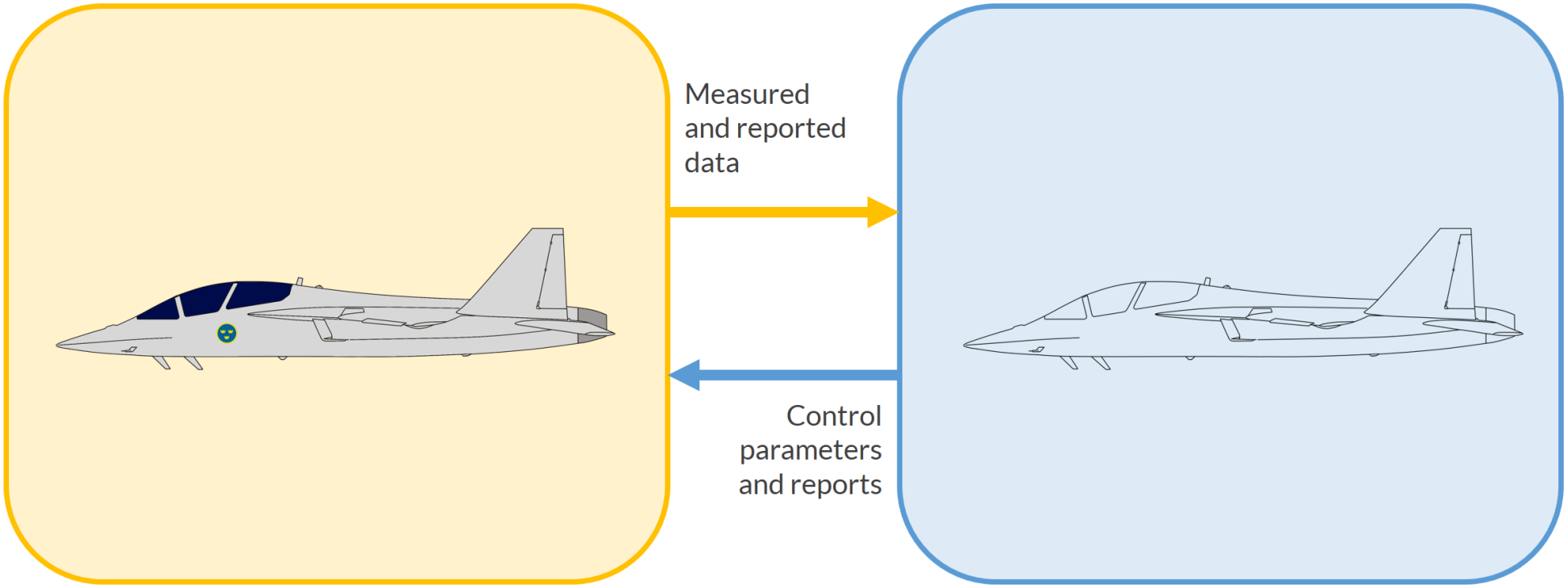
- “A digital twin is an integrated multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physics models, sensor updates, fleet history, etc., to mirror the life of the corresponding flying twin.”

  Glaessgen (NASA) and Stargel (US Airforce), 2012

Fighter jets are expensive devices that require safe operation and detailed control, and at the same time are subjected to very high demands on performance.

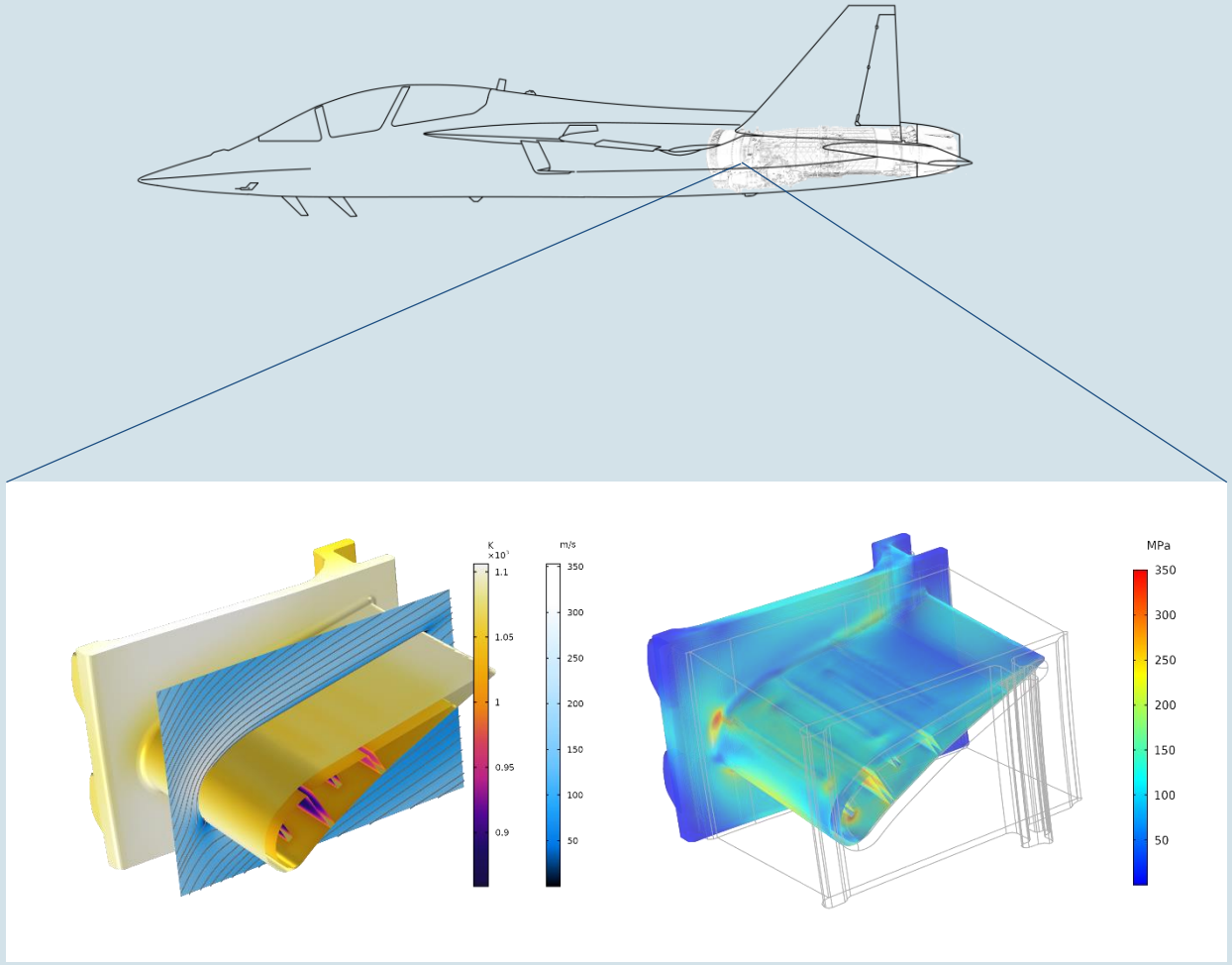
NASA Photo / Jim Ross

The Digital Twin Concept



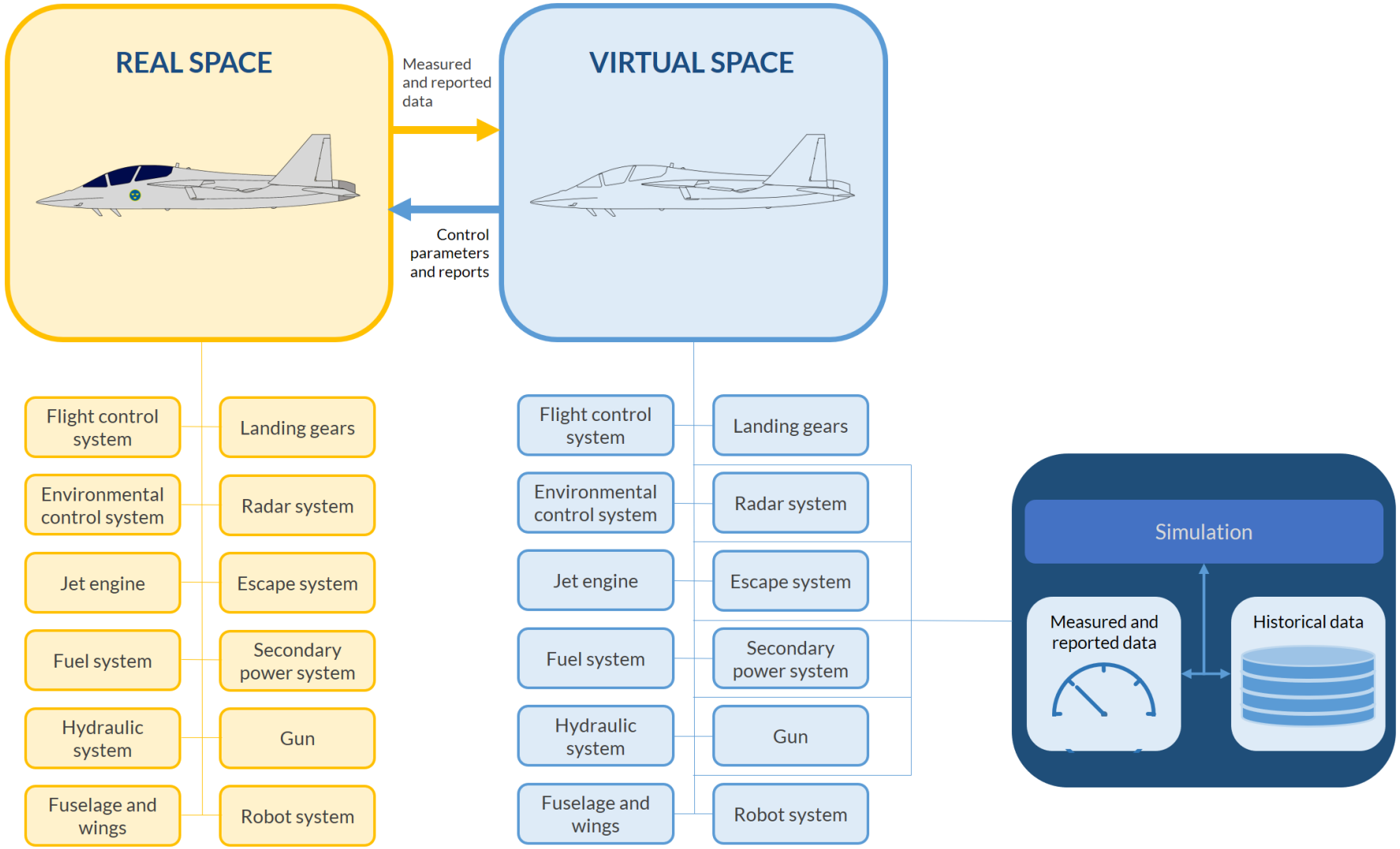
Multiphysics Models in Digital Twins

- Thousands of critical parts may require high-fidelity multiphysics models
- Each critical part is in turn part of a larger subsystem
- Each subsystem may require its own DT

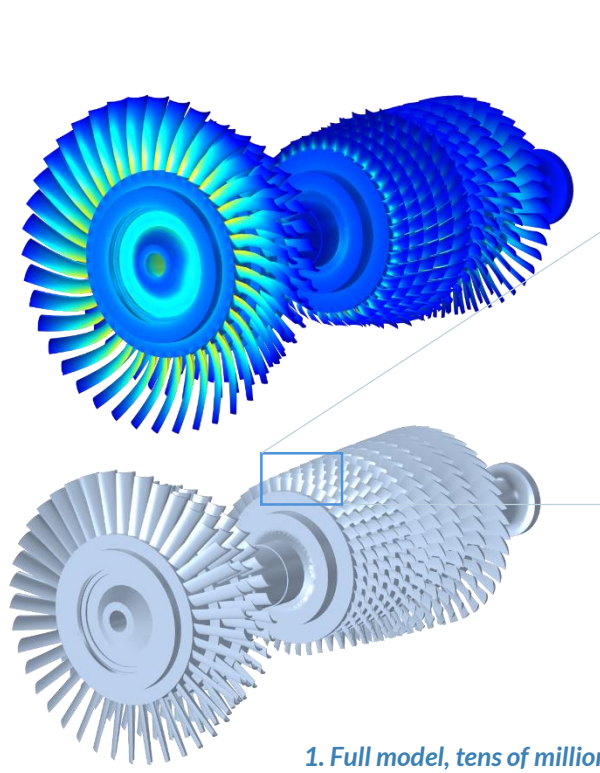


A turbine stator is just a small component in a turbine engine, which in turn is a subsystem of the fighter jet.

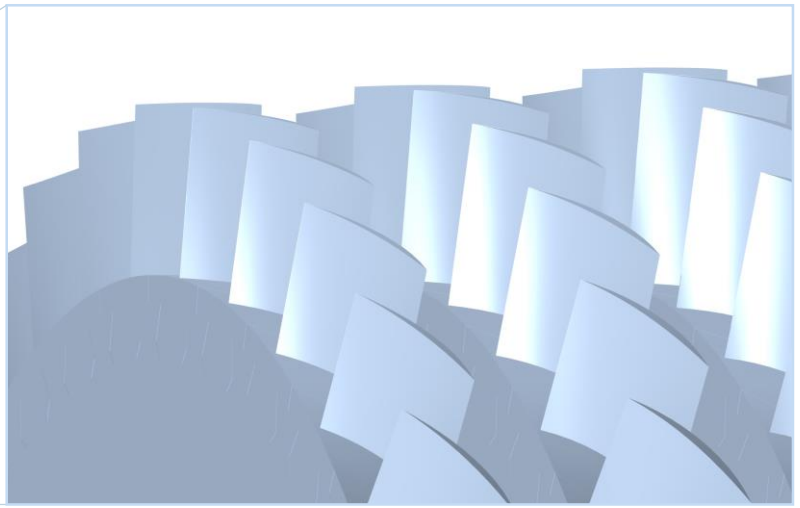
Digital Twin Aggregates



Lightweight Models and Reduced-Order Models (ROM)



1. Full model, tens of millions of degrees of freedom (DOFs)



2. Sector model, 50 kDOFs

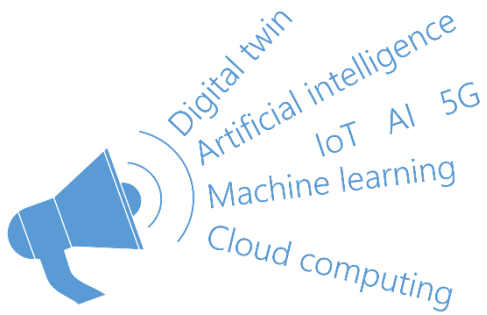
$$\mathbf{M}\ddot{\mathbf{X}}(t) + \mathbf{D}\dot{\mathbf{X}}(t) + \mathbf{K}(\Omega)\mathbf{X}(t) + \mathbf{F}(\mathbf{X}(t)) = \mathbf{F}_a(t)$$

3. ROM, 100 DOFs

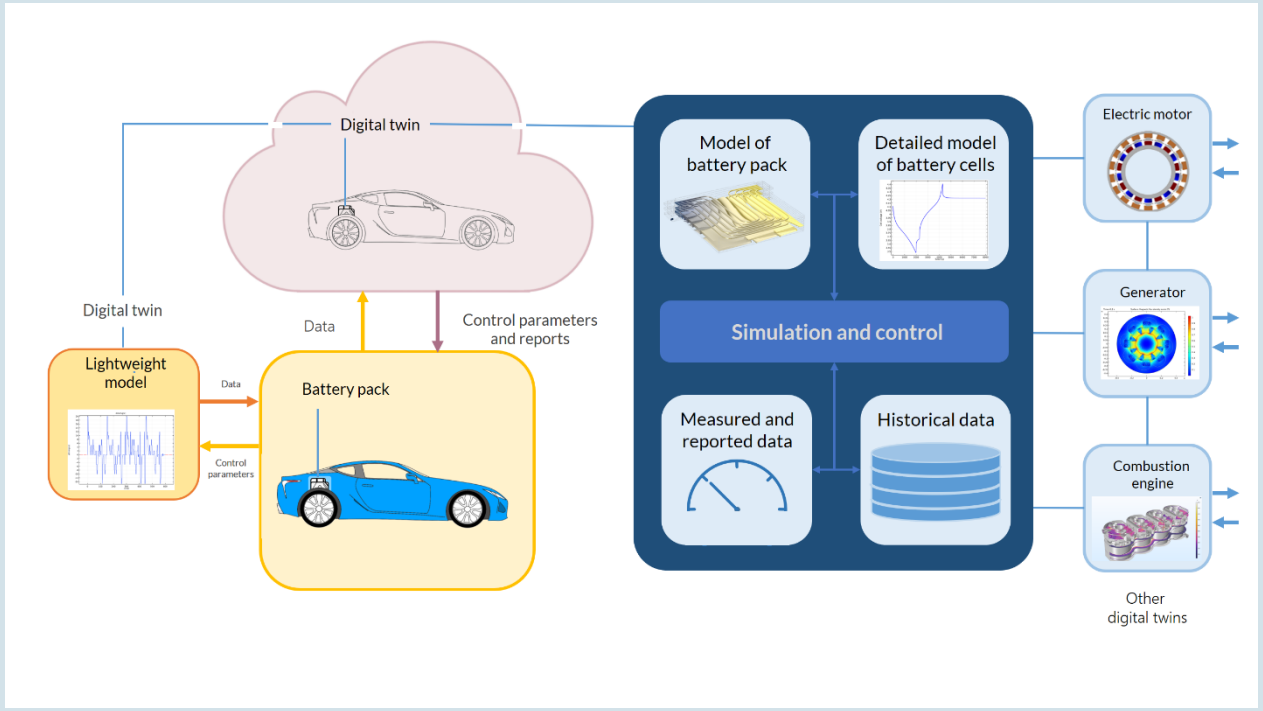
https://hal.archives-ouvertes.fr/hal-01130542/document

Civil Applications Rely on New Technology

- Cloud computing
- Machine learning (AI)
- 5G
- Internet of things (IoT)



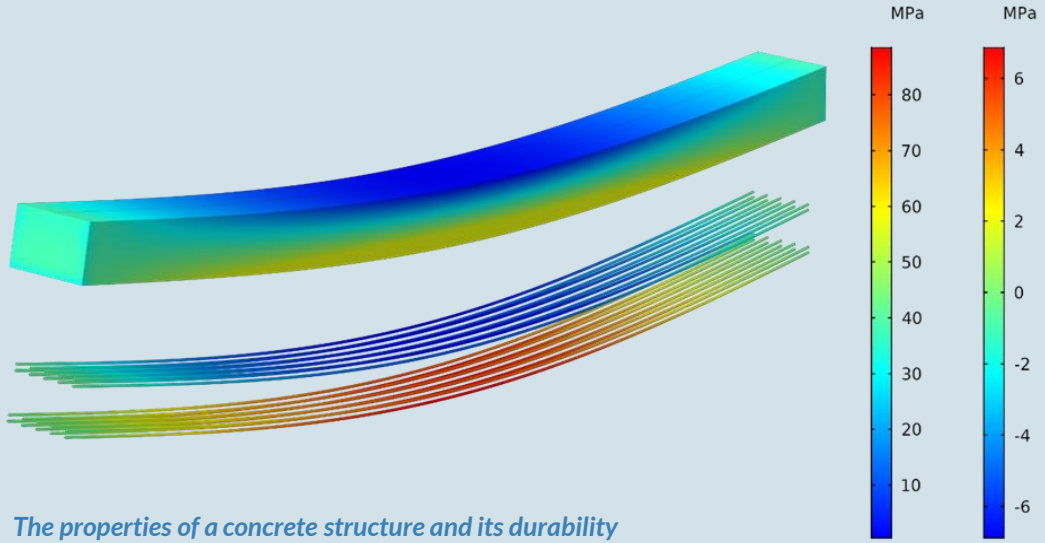
Not just hype!



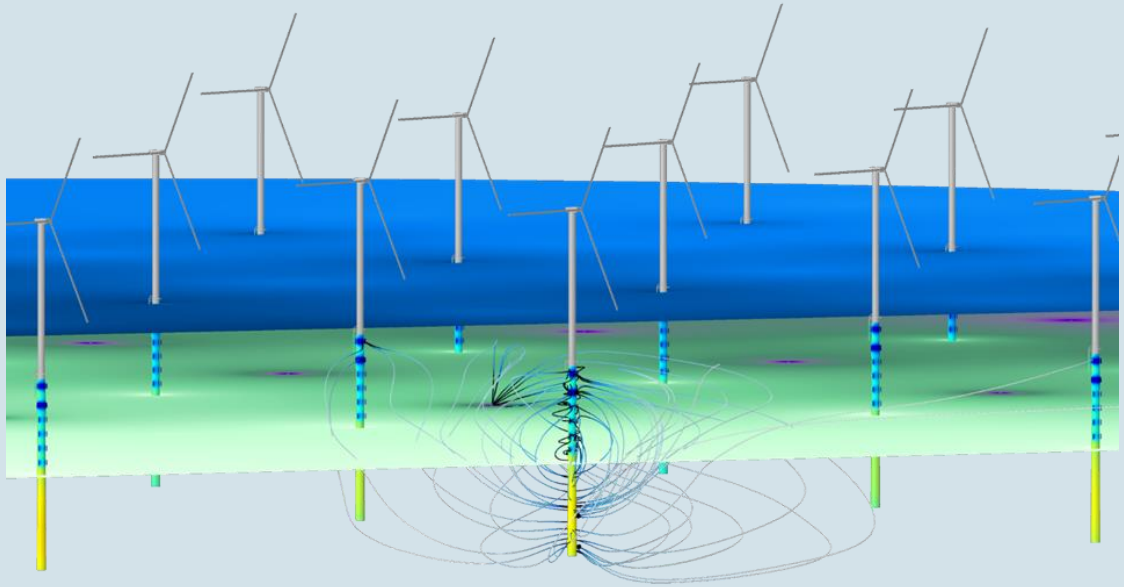
The implementation of a DTA in civil applications, such as for the battery system in a hybrid car, may rely on emerging technologies such as machine learning and IoT.

Mundane Earthbound Applications

- Design of concrete structures
- Monitor and control the construction and curing process
- Monitor the status and structural integrity of the structure
- Control and maintain corrosion protection systems
- Schedule maintenance
- Predict life of the structure



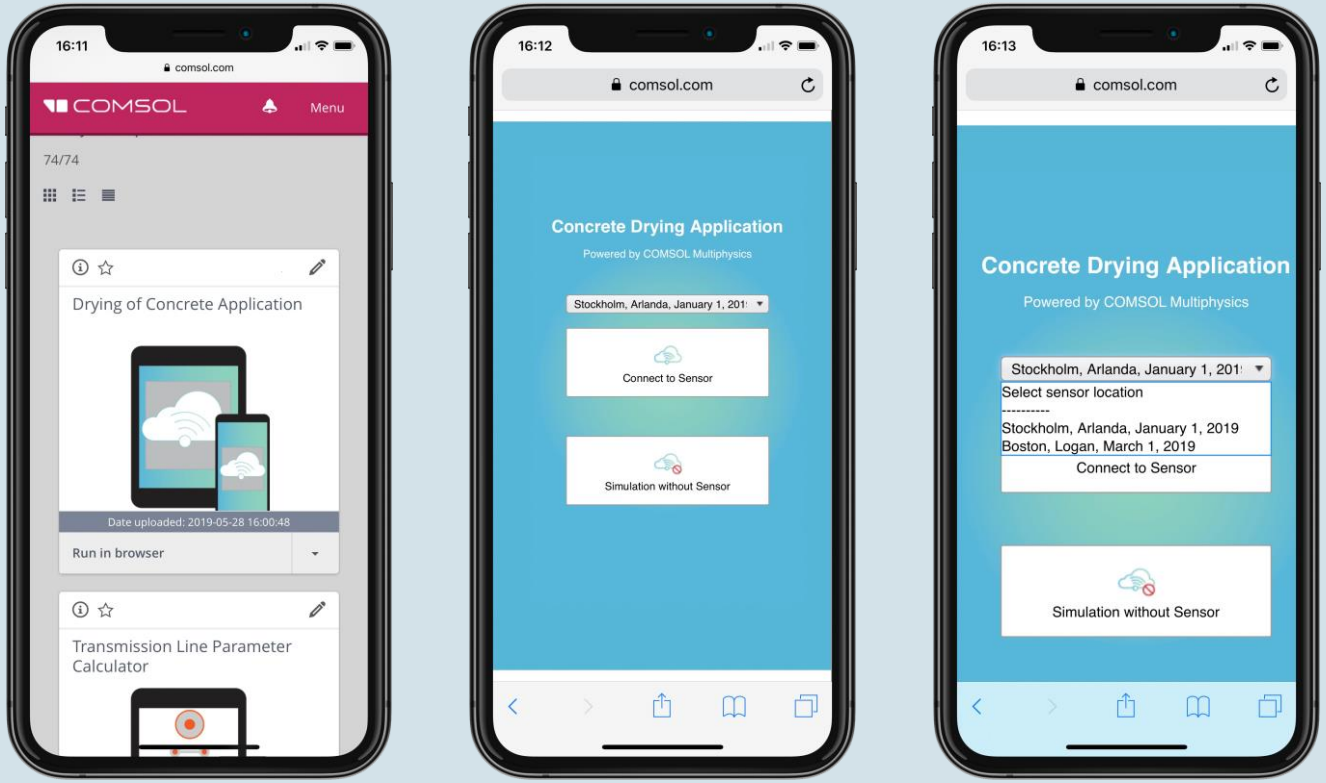
The properties of a concrete structure and its durability can be evaluated and followed with a DT.



These structures can be very complex and include corrosion protection systems for offshore applications.

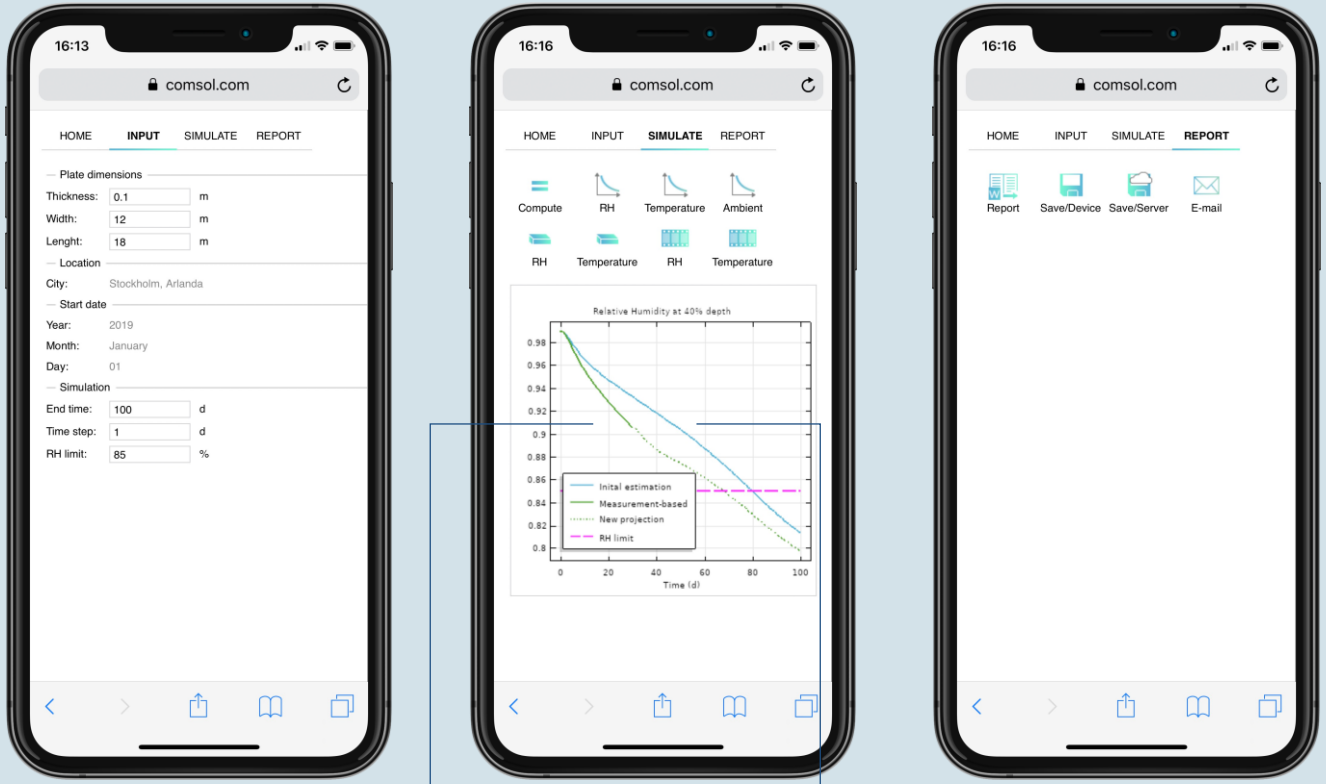
DT Tutorial

- DT for concrete curing
- Typically part of a DTA
- Reads sensor data for moisture and temperature
- Loads weather data, including relative humidity and temperature
- Predicts and keeps track of concrete curing process
- Tutorial for using the Application Builder to set up DTs



DT Tutorial

- DT for concrete curing
- Typically part of a DTA
- Reads sensor data for moisture and temperature
- Loads weather data, including relative humidity and temperature
- Predicts and keeps track of concrete curing process
- Tutorial for using the Application Builder to set up DTs

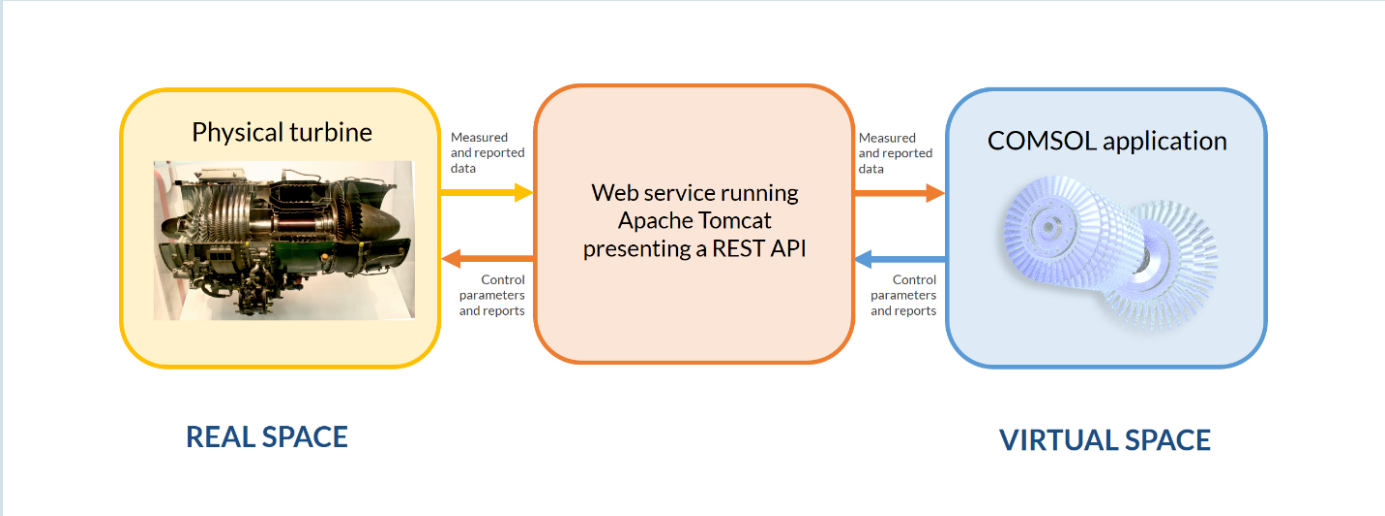


Updated prediction of moisture content

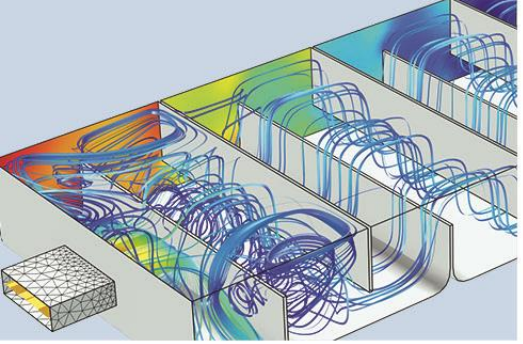
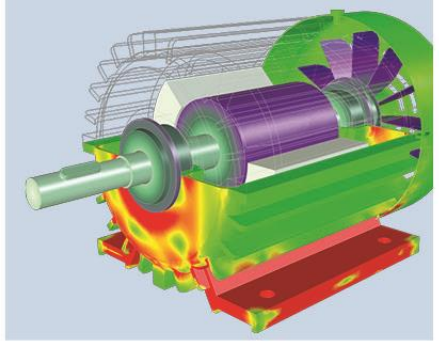
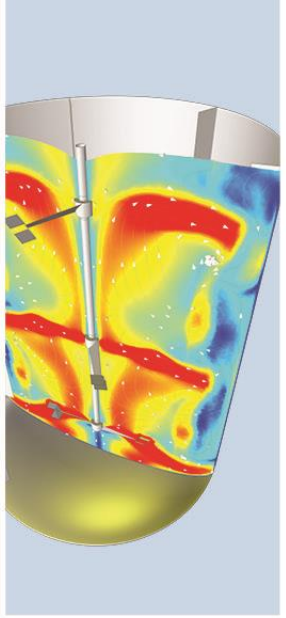
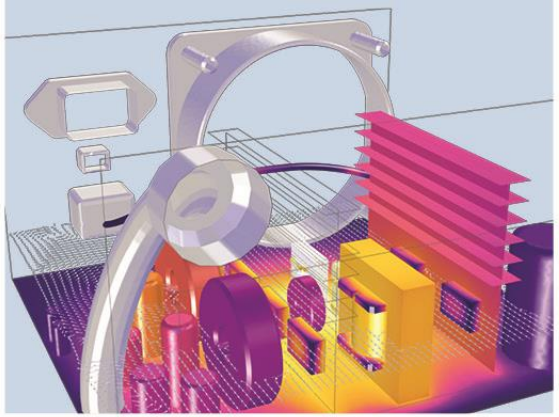
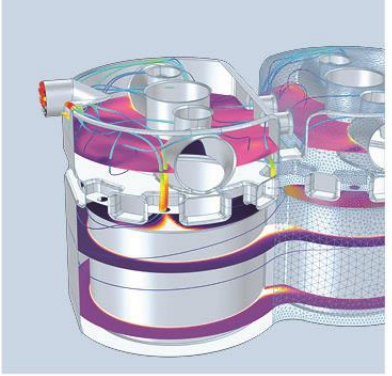
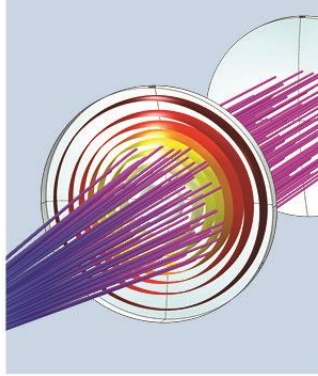
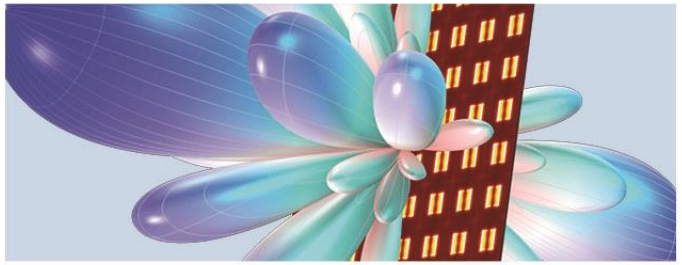
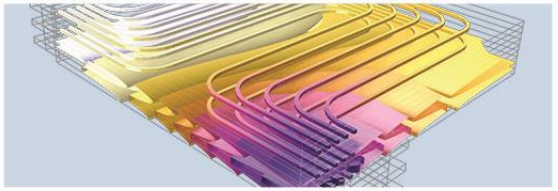
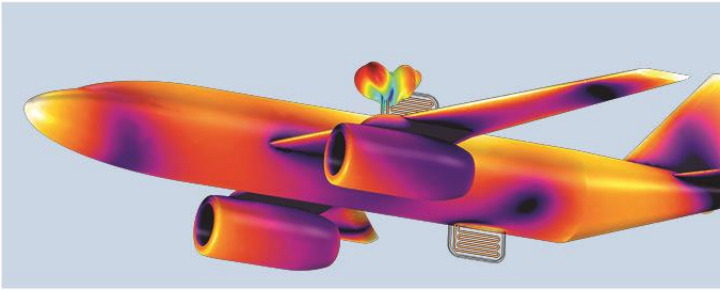
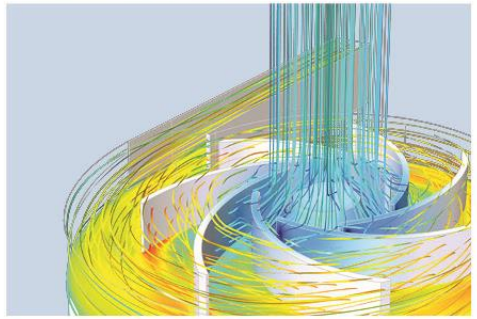
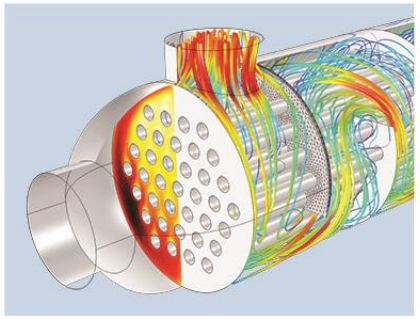
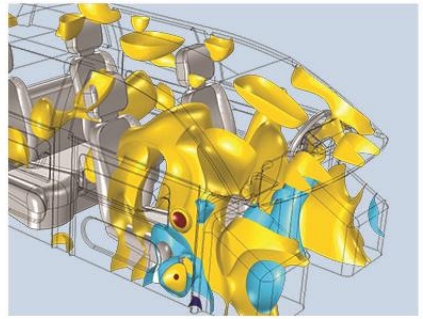
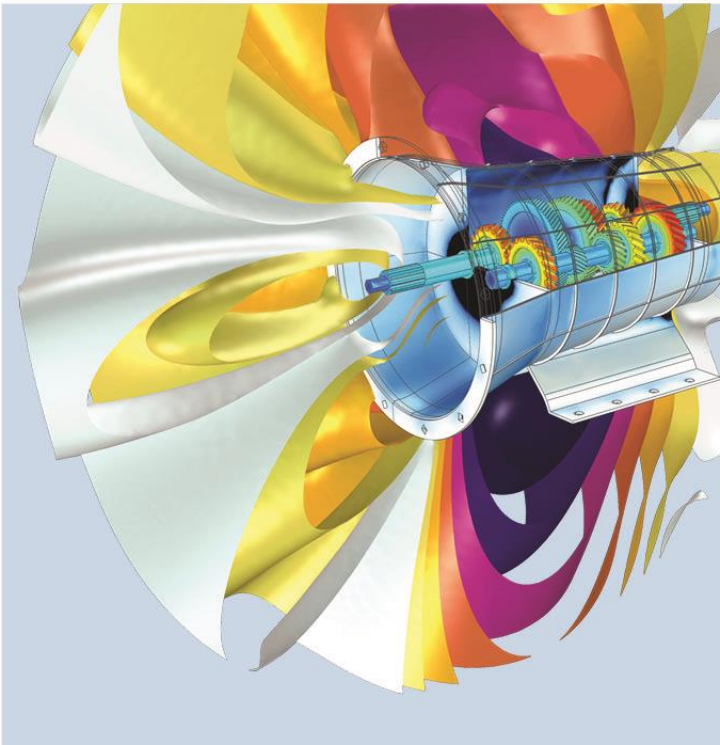
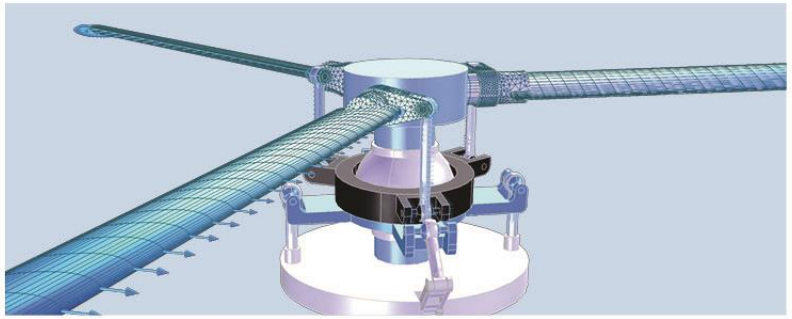
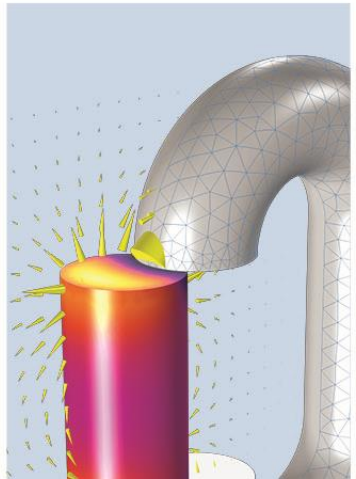
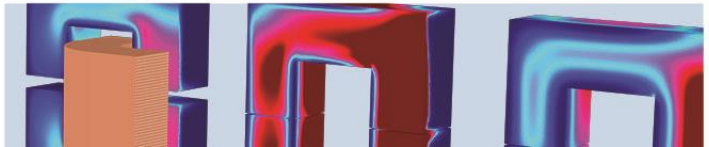
Initial prediction of moisture content

DT Implementation in COMSOL®

- COMSOL® API *for use with* Java® using dynamic link library files*
- Virtual space as a web service running inside Tomcat presenting a representation state transfer API (REST API)



*API = application programming interface

Contact Us

comsol.com/contact