Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
ROME TECHNOPOLE INNOVATION ECOSYSTEM

Seminario Online
25 Giugno 2024 ore 10:30

Introduzione al Digital Twin: Obiettivi e soluzioni

Digital Twins and Biomedical Technologies

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Digital Twins and Biomedical Technologies

ROME TECHNOPOLE INNOVATION ECOSYSTEM

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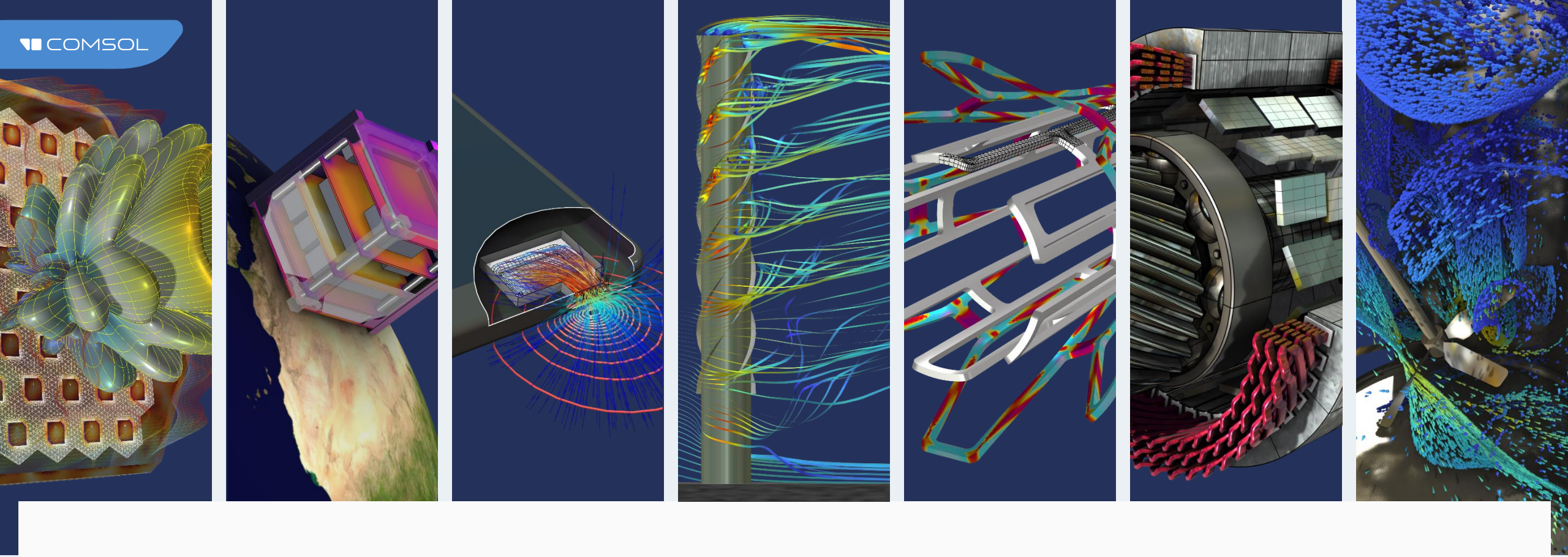

About COMSOL

17 offices world wide & 450+ employees

We develop modeling and simulation software that drives new breakthroughs in physics and engineering.

1986
Stockholm, Sweden
COMSOL was founded.

1998
Version 1.0
First platform product release.

2010
Version 4.0
New graphical user interface.

2014
Version 5.0
New feature: Application Builder
New product: COMSOL Server™

2018
Version 5.4
New product: COMSOL Compiler™

2021
Version 6.0
New feature: Model Manager

COMSOL

What Is Multiphysics?

The world is multiphysics in nature.

Multiphysics mul·ti·phys·ics

- Coupled physical phenomena in computer simulation.
- The study of multiple interacting physical properties.

The ability to fully couple physics phenomena in a model enables highly accurate numerical simulations that closely mimic real-world performance.

Make smarter design decisions, generate new ideas, reduce costs for physical prototypes and experiments, and speed up product development with multiphysics.

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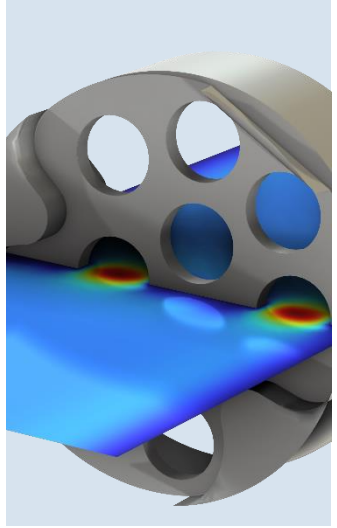
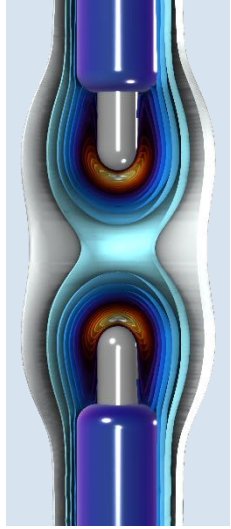
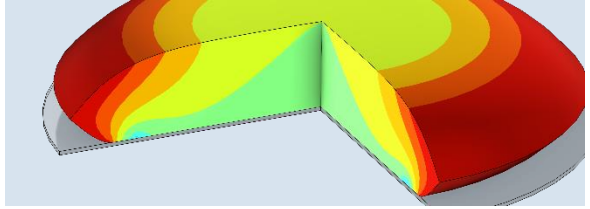
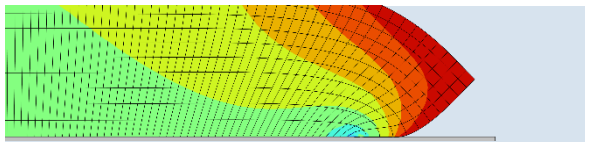
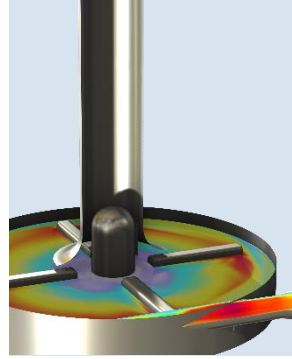
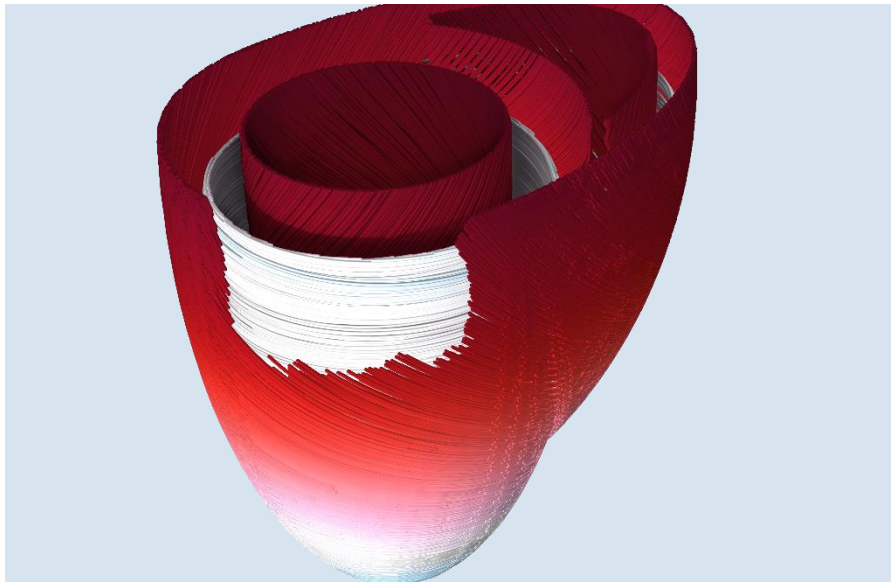
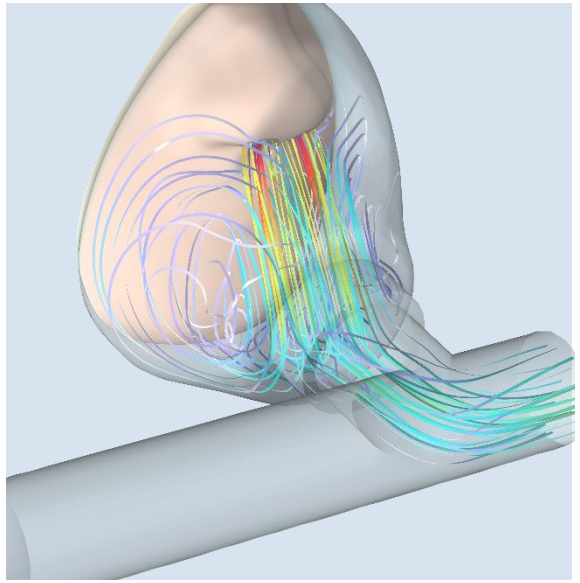
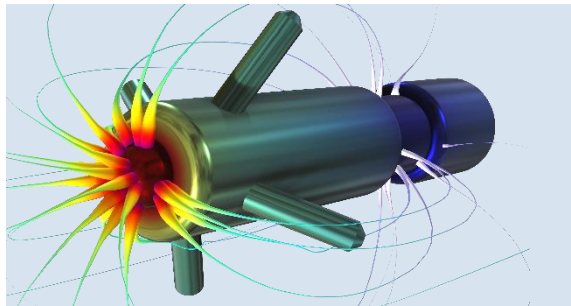
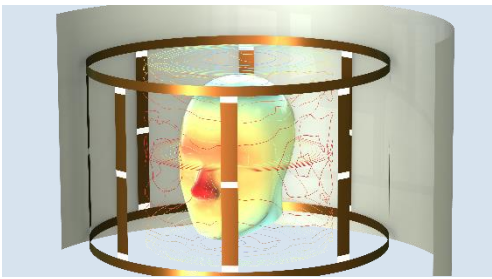
Simulation Accelerates the R&D Process

Medical devices and Biomedical applications:

- Biomaterials & Tissue Biomechanics
- Pacemakers
- Hydrogels
- Blood pumps
- Oxygen masks
- Rapid tests
- MRI technology

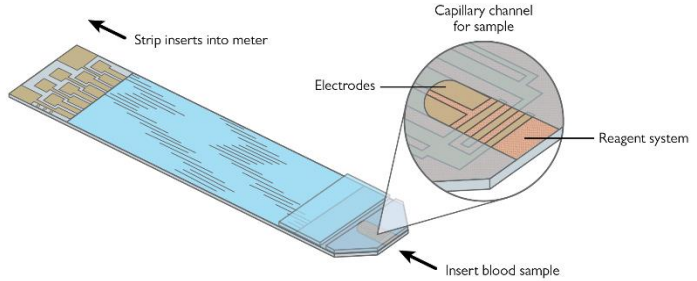


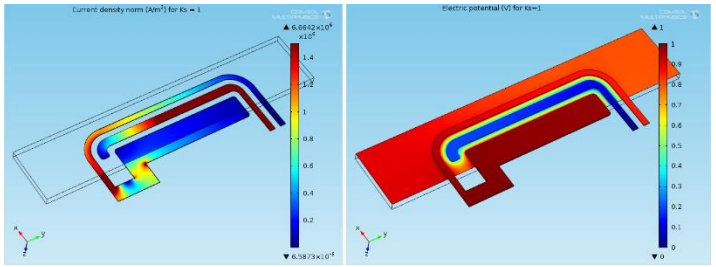

INNOVATION AT Roche Diagnostics

Glucose Sensor Development

Diabetes care relies on accurately monitoring glucose levels using sensing strips. Improper storage of these glucose sensors can lead to inaccurate results, posing direct risks to the person using the device. Roche takes real-world conditions into account when developing glucose monitor designs.

During blood sample analysis, a DC voltage is applied at the electrodes in the monitor, yielding a current response that predicts the glucose concentration in the sample to be displayed to the user. Configuration and manufacturing of the test strip affect the response accuracy, and the chemical reactions are sensitive to environmental conditions.



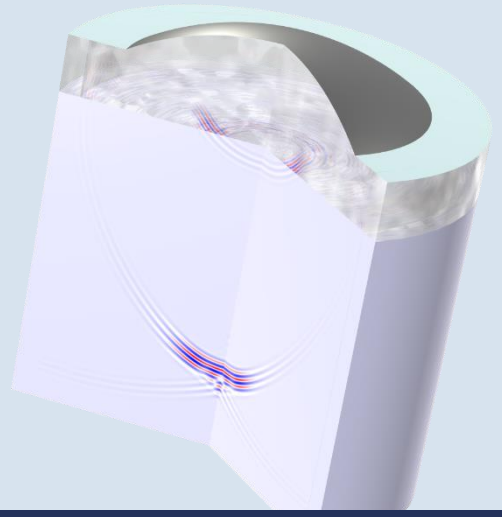


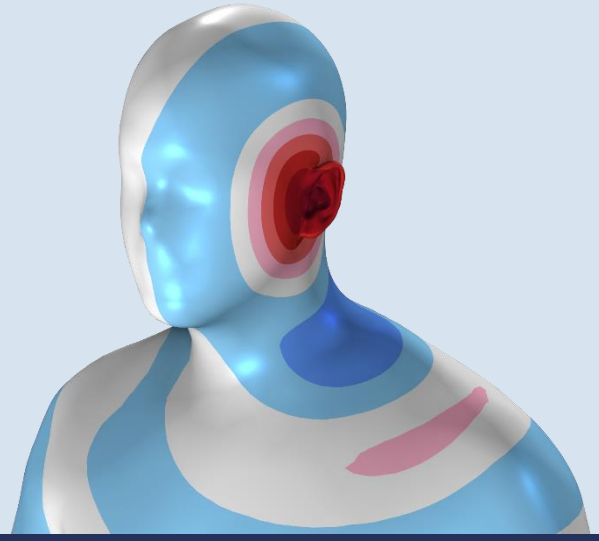
It is impossible to measure the potential drop across the electrodes or within the electrolyte in the measurement cell without physically disturbing the system. Modeling enabled the Roche team to isolate the chemical reactions from the electrical, mechanical, and temperature conditions so that they could analyze the voltage response.

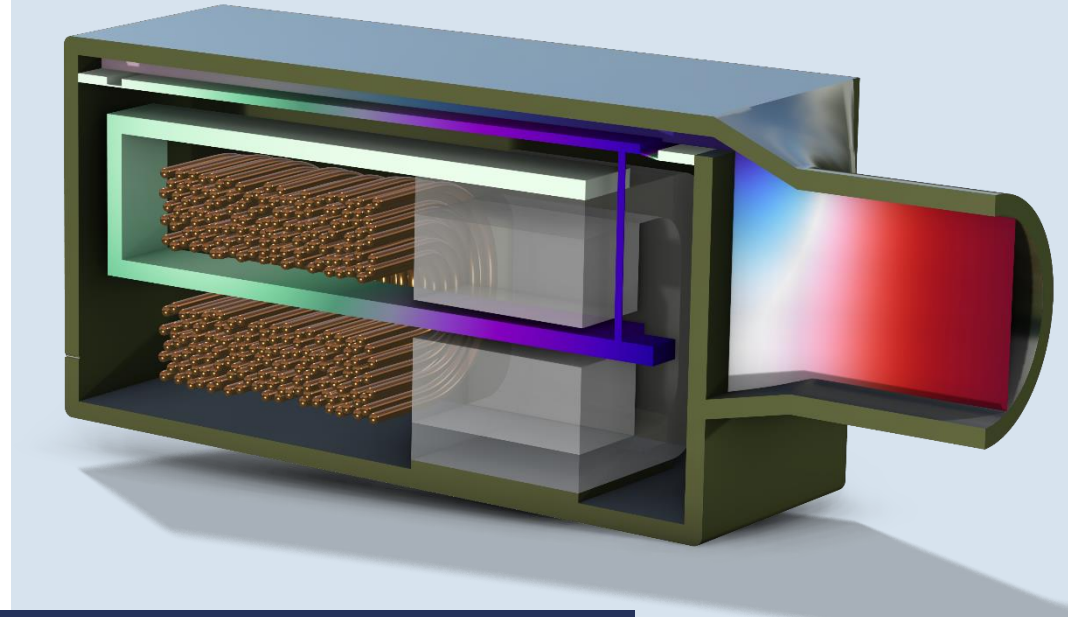
Using multiphysics simulation alongside experiments and calculations, the team optimized its test strip design and measurement methods to develop a device that survives various environments, delivers accurate results, and detects conditions that would cause errors.

The Roche team's innovative system sets a new standard for biosensing devices, and its work is leading to the production of these new sensors, ultimately bringing better care to people with diabetes.

Bringing Glucose Monitoring to New Levels Through Integrated Sensor Design







Acoustics Examples for Biomedical Applications

Treatments

- High-intensity focused ultrasound (HIFU)
- Ultrasound-induced heating

Devices

- Hearing aids
- Sensors & piezoelectric transducers

Measurements

- Head-related transfer function (HRTF)
- Telephonometry

Purposes of M&S[1]

- Understand, design, and optimize
- Estimate risks
- Simulation before clinical tests
- Assist in the registration and approval process

[1] M&S = modeling and simulation

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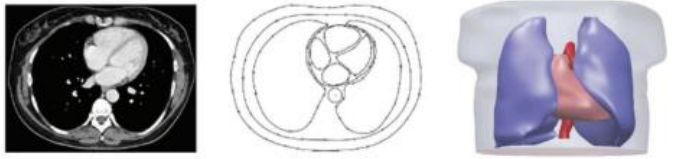
INNOVATION AT
STMicroelectronics

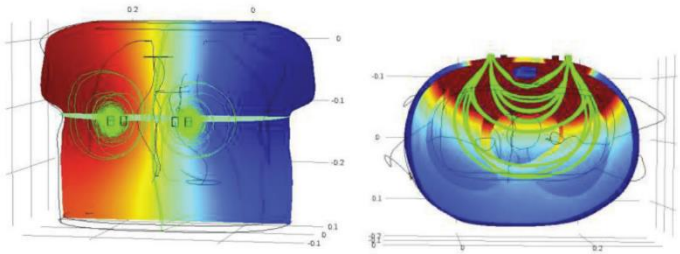
Wearable Medical Monitoring

Wearable technology provides real-time monitoring of patients' cardiac activity. Engineers at STMicroelectronics use numerical simulation to optimize their semiconductor solutions for a wide range of applications, including medical uses.

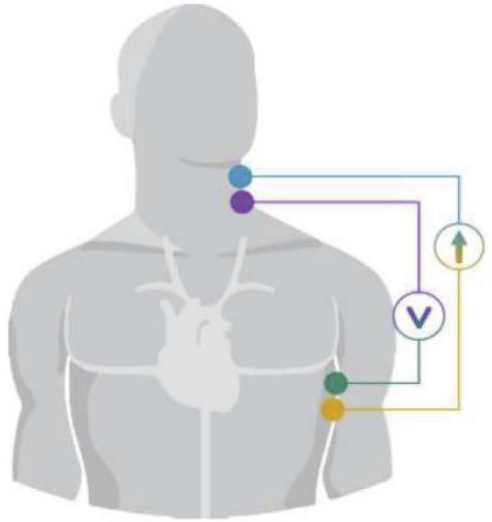
In one prototype project, a patch was designed to measure the bioimpedance of an organ, such as the heart, inside the human body.

Working from medical imaging of human organs, researchers created a 3D low-frequency electromagnetics model to assess the effect of the electrode shape and position on the measured physiological parameters.





"Compared to physical testing, we can implement new solutions and verify them at zero cost. Simulation is one of the key tools that drives innovation." — *Lucia Zullino, technology R&D engineer at STMicroelectronics*



The simulation results correlated closely to real-life measurements and enabled the development of a wearable configurable patch capable of indicating physiological changes. These sensors will enable doctors monitoring various heart conditions to get real-time data to provide patients with the best possible care.

Reliable Structures and Wearable Systems Call for Multiphysics Simulation

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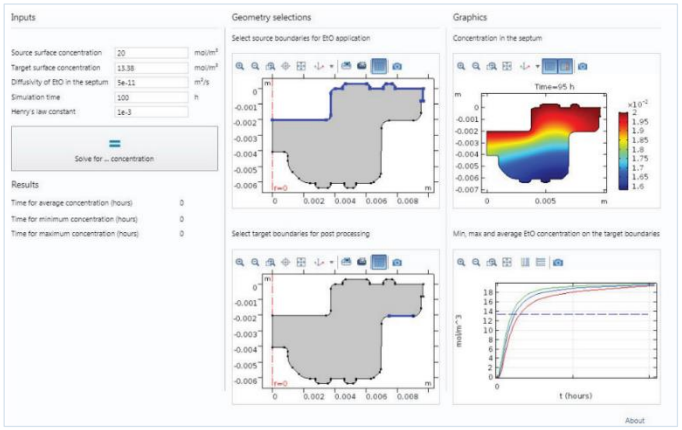
INNOVATION AT Amgen

Modeling in Biopharma

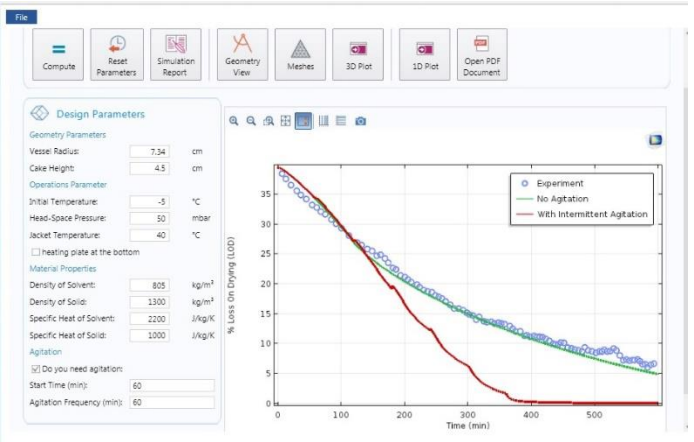
Amgen produces various drug products that have treated serious illnesses in millions of people around the world. To enhance its workflow, Amgen employs a diverse portfolio of process models and builds custom simulation apps.

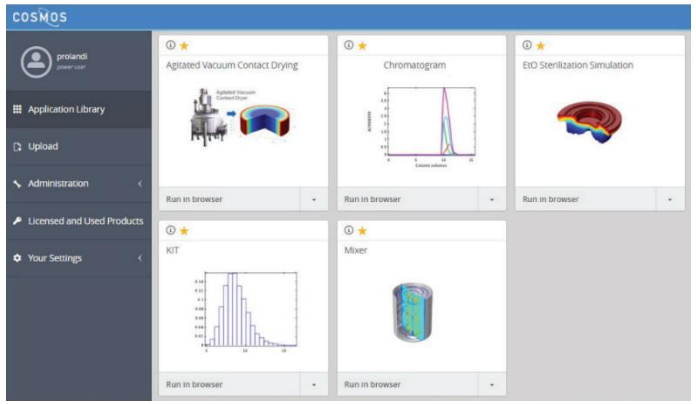
As various problems in the development phase arise, the Amgen team turns to multiphysics modeling for solutions. In many cases, these solutions are also accompanied by custom simulation apps.



In one situation, to meet sterilization standards for classification of vials as novel containers, modeling ethylene oxide diffusion throughout the vials made it possible to adjust the required sterilization process without costly iterations.

A simulation app created from the model made it possible for process engineers to determine if concentration levels were high enough to warrant sufficient sterilization.



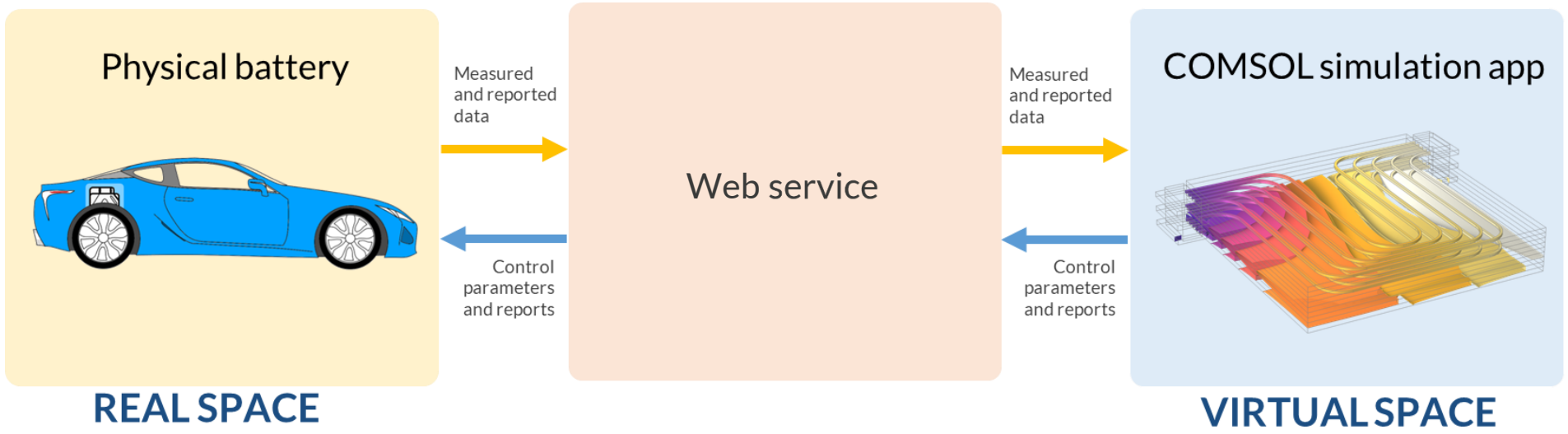


By working with models and simulation apps, Amgen is able to eliminate bottlenecks in production, ensure sterilization standards are met, and integrate uncertainty in operating conditions into drug time-of-delivery calculations.

Multiphysics Modeling in the Biopharma Industry.

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 life cycle, from development to disposal
  - May contain and process a vast amount of data, not only for modeling
  - Is specific to a certain unit of a product, i.e., not to all units of the make and model



Example: Digital Twin Implementation in COMSOL®

- The simulation app is created in the Application Builder.
- The simulation app can use *Timer* events to trigger the execution of methods, for example, to download sensor data, run simulations, and send data to an external server.
- The COMSOL API* can be used from a web service.

*API = application programming interface

SIMULATION APP

HETT^{22}

A leading global cement supplier provides its customers with a standalone simulation app that predicts curing times for concrete casting at construction sites. Since launch, it has been downloaded 1500 times!

SIMULATION APP

HETT^{22}

- The app user chooses the concrete and cement mixture based on weather and construction structure
- Uses data from weather stations to determine the conditions for the curing process in real time
- The output from the simulation app:
  - Predicts temperature, degree of curing, and structural properties
  - Warns if the structural integrity of the structure is at risk

Developed by Deflexional AB
(COMSOL Certified Consultant)

deflexional

COMSOL

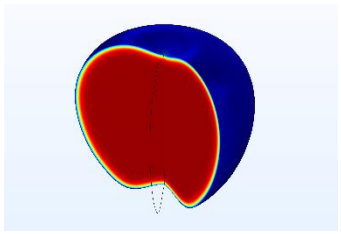
INNOVATION AT Empa

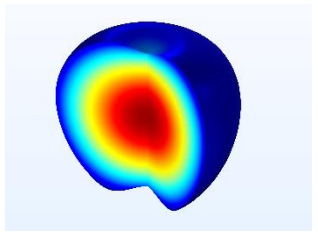
Forecasting Produce Shelf Life

Each year, approximately one-third of the food produced for human consumption worldwide is lost or wasted. To optimize the use of refrigerated food storage in developing countries, farmers and traders need to be able to predict the shelf life of fresh fruits and vegetables.

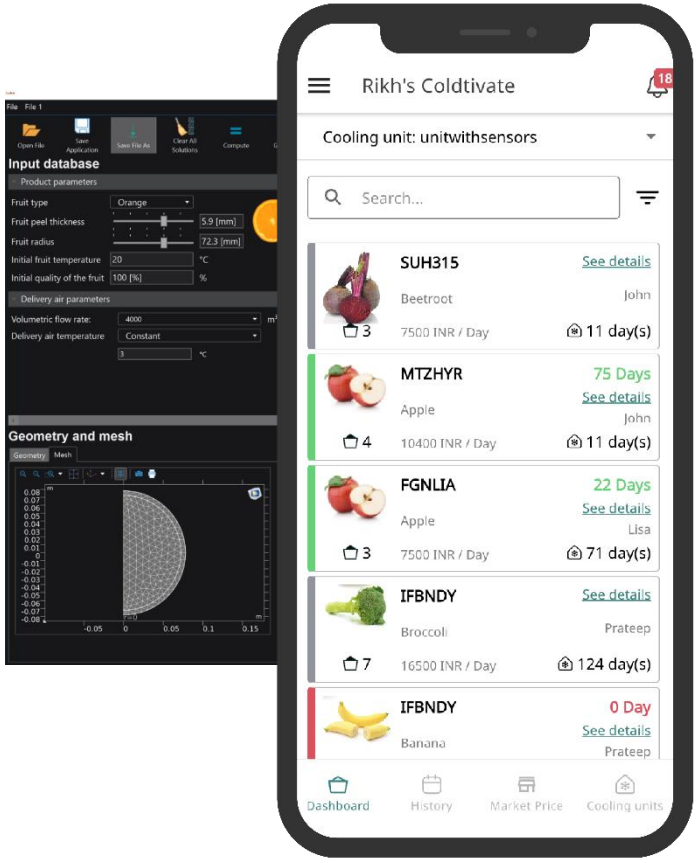
Minimizing post-harvest losses with limited refrigerated space available requires insight into how ambient temperatures directly influence the shelf life of fresh produce.

The EMPA team compiled a simulation app from their multiphysics models to provide data-driven forecasts on the freshness of produce in a cold room. Results from the simulation app are fed into a smartphone app.





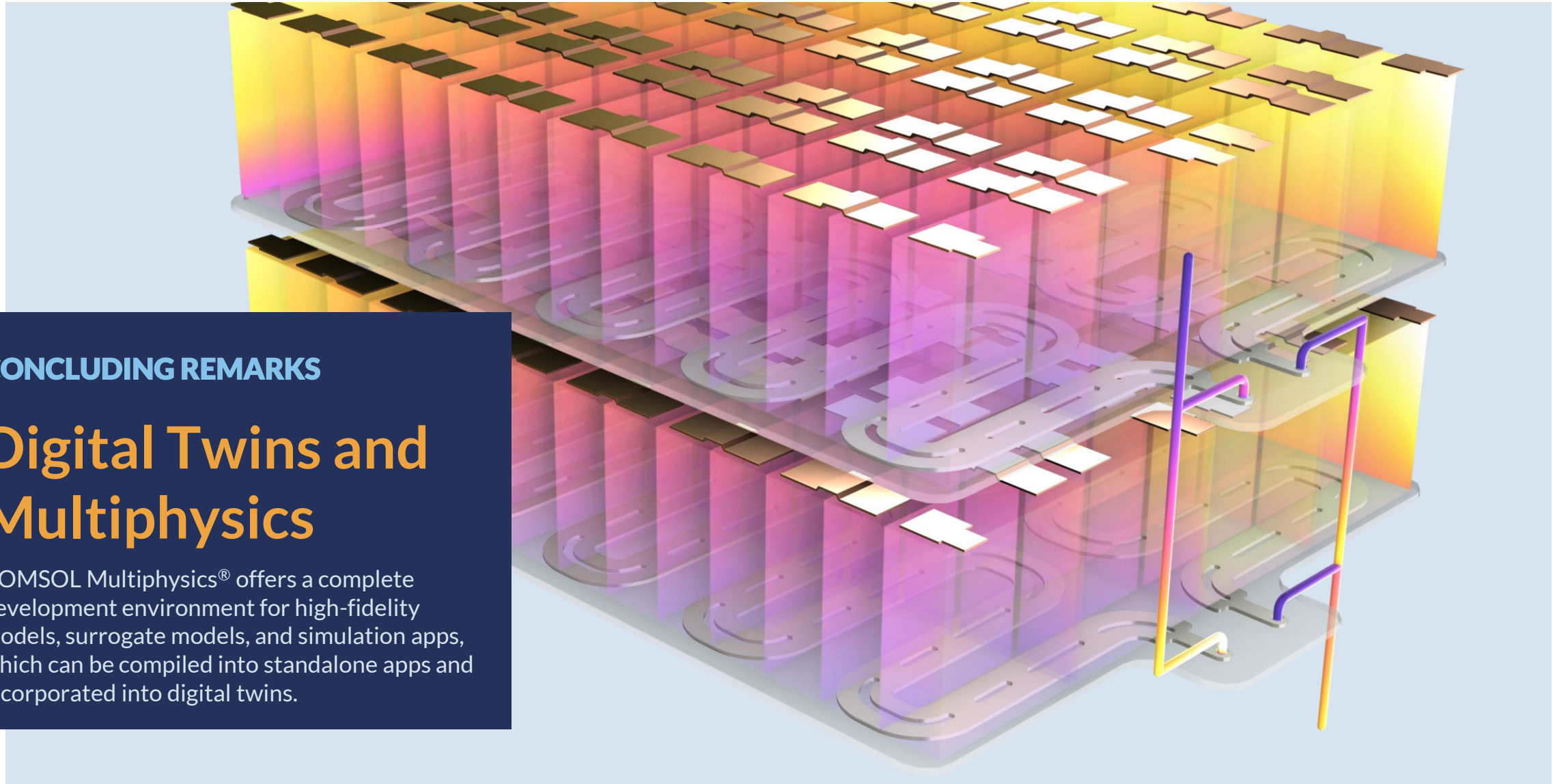
The Coldtivate mobile app informs farmers and cold storage operators of the cooling and decay process of different types of produce in real time. The values shown in the app are recalculated every 6 hours based on the latest cold room temperature data.



In August 2022, the simulation-powered app was released to 17 cold rooms, serving more than 300 farmers, who are reporting a 20% increase in their incomes and reduction of their post-harvest food losses.

Empa and its partners are now working to expand Coldtivate's impact.

Forecasting Fruit Freshness with Simulation Apps



CONCLUDING REMARKS

Digital Twins and Multiphysics

COMSOL Multiphysics® offers a complete development environment for high-fidelity models, surrogate models, and simulation apps, which can be compiled into standalone apps and incorporated into digital twins.

Optimize Your Workflow

A simulation-driven R&D workflow is most successful when collaborators across teams, departments, organizations, and enterprises are able to access and contribute to the modeling results.

- Combine physics phenomena in one model and with the Model Builder.
- Create custom simulation apps from models with the Application Builder.
- Collaborate and organize models and apps with the Model Manager.
- Deploy and run apps in digital twins as standalone apps or run them from a web browser UI with COMSOL Server™.

COMSOL

COMSOL MULTIPHYSICS®

The platform product for simulating real-world designs, devices, and processes. One user interface for all engineering applications.

— MODEL BUILDER: Combine physics phenomena in one model

— APPLICATION BUILDER: Build simulation apps from models

— MODEL MANAGER: Collaborate and organize models and apps

COMSOL Compiler™
Compile simulation apps into executable files. Run them freely on any computer.

COMSOL Server™
Host and administrate your simulation apps. Run them through a web interface.

ADD-ON PRODUCTS

ELECTROMAGNETICS

- AC/DC Module
- RF Module
- Wave Optics Module
- Ray Optics Module
- Plasma Module
- Semiconductor Module

FLUID & HEAT

- CFD Module
  - Mixer Module
- Polymer Flow Module
- Microfluidics Module
- Porous Media Flow Module
- Subsurface Flow Module
- Pipe Flow Module
- Molecular Flow Module
- Metal Processing Module
- Heat Transfer Module

STRUCTURAL & ACOUSTICS

- Structural Mechanics Module
  - Nonlinear Structural Materials Module
  - Composite Materials Module
  - Geomechanics Module
  - Fatigue Module
  - Rotordynamics Module
- Multibody Dynamics Module
- MEMS Module
- Acoustics Module

CHEMICAL

- Chemical Reaction Engineering Module
- Battery Design Module
- Fuel Cell & Electrolyzer Module
- Electrodeposition Module
- Corrosion Module
- Electrochemistry Module

MULTIPURPOSE

- Optimization Module
- Uncertainty Quantification Module
- Material Library
- Particle Tracing Module
- Liquid & Gas Properties Module

INTERFACING

- LiveLink™ *for* MATLAB®
- LiveLink™ *for* Simulink®
- LiveLink™ *for* Excel®
- CAD Import Module
- Design Module
- ECAD Import Module
- LiveLink™ *for* SOLIDWORKS®
- LiveLink™ *for* Inventor®
- LiveLink™ *for* AutoCAD®
- LiveLink™ *for* Revit®
- LiveLink™ *for* PTC® Creo® Parametric™
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