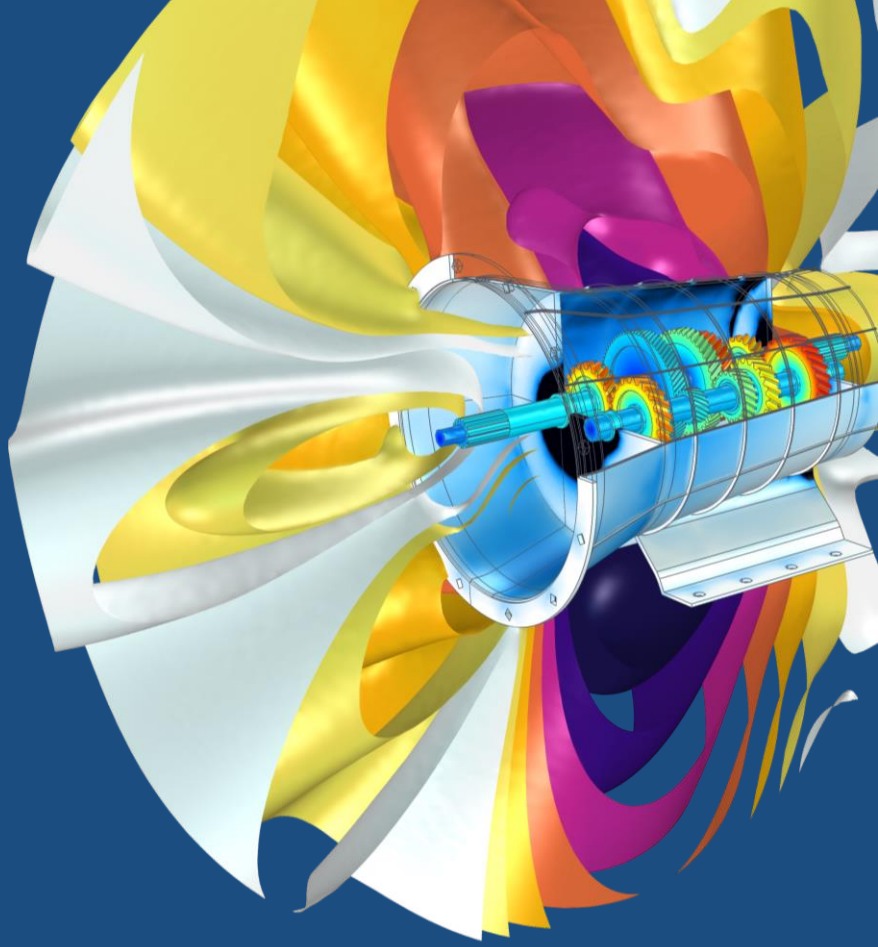
# The Future of Modeling

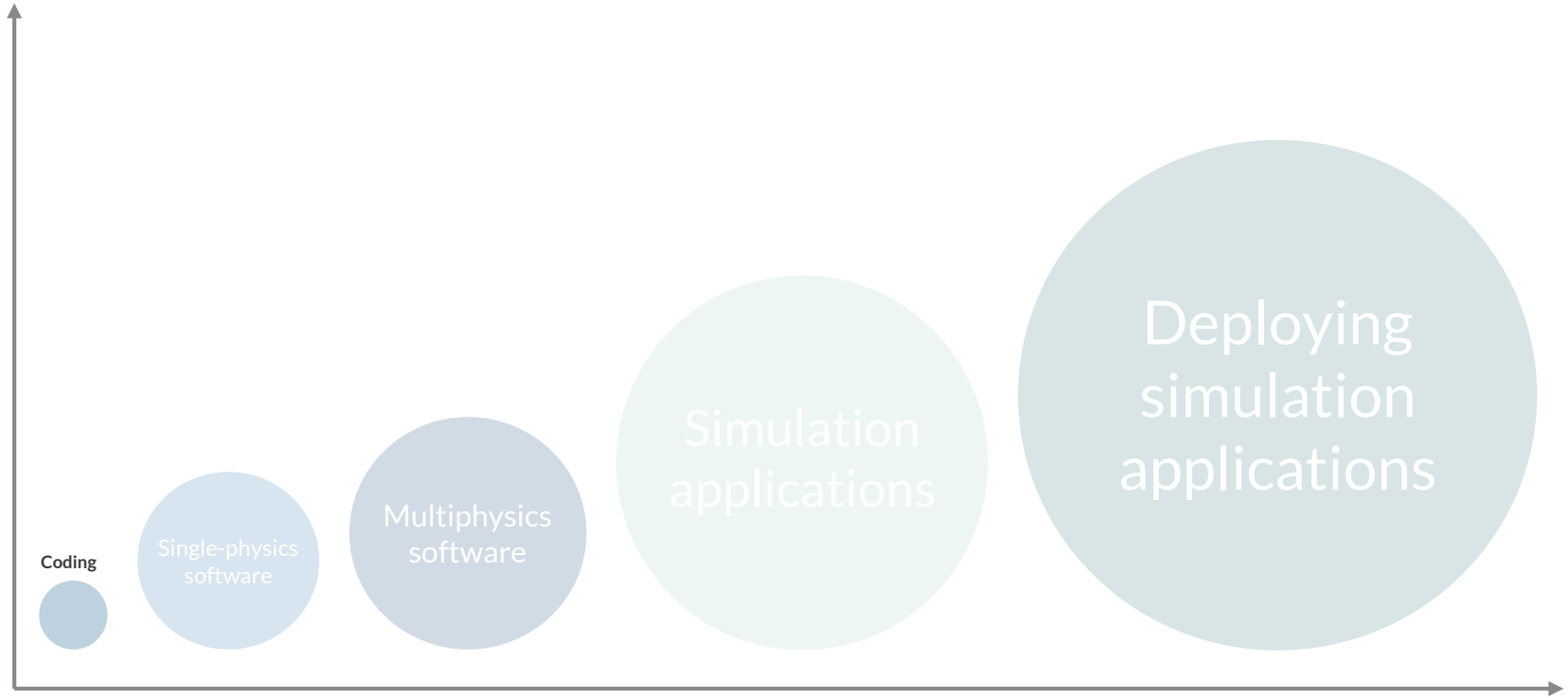
Phil Kinnane, COMSOL, Inc.



# The Future of Modeling

- Democratization of Simulation
  - Transfer the power of simulation from the expert to the person actually using the results
  - Simplify models and design them to a specific audience
  - Efficiently deploy these models to this audience

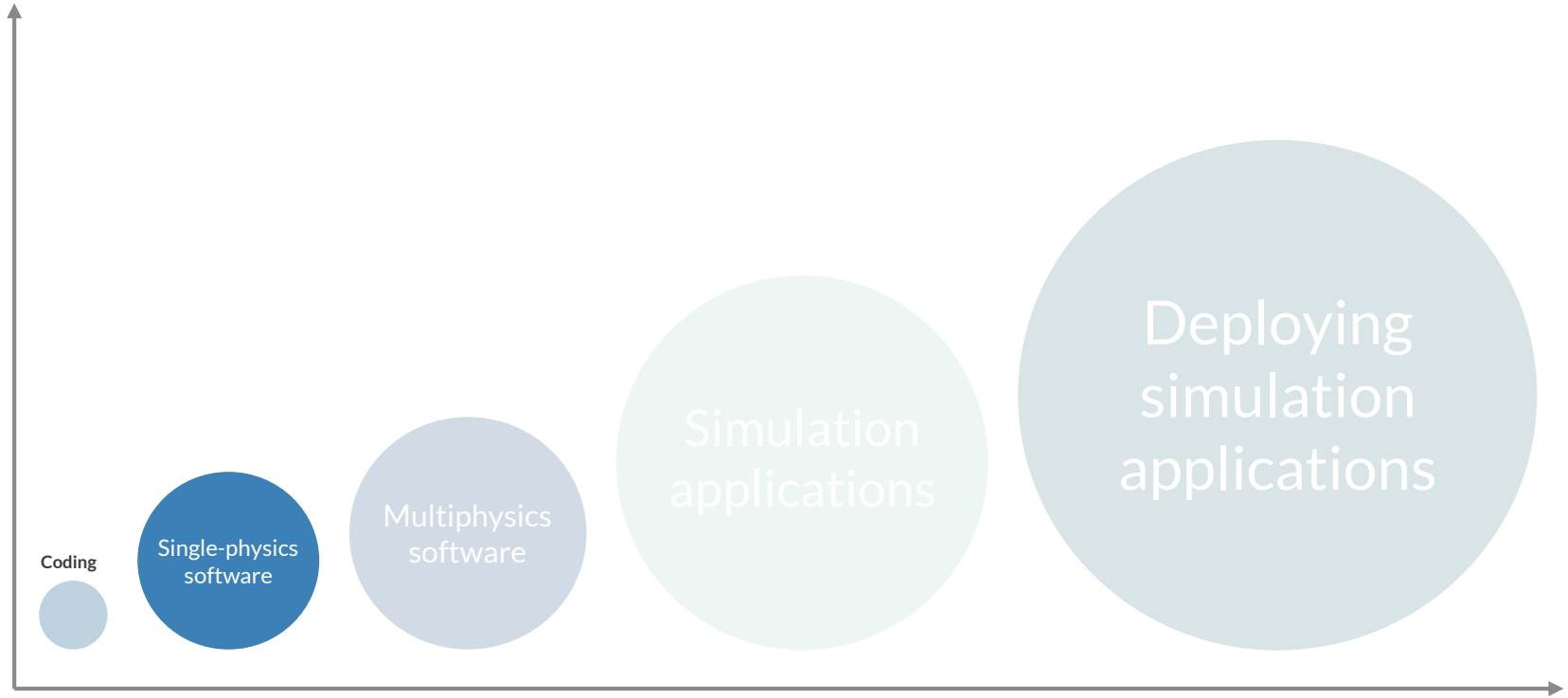
# Origins of Modeling: Coding



# Coding

- Benefits:
  - Predict the behavior of a physical process or object to the surrounding environment
- Barriers:
  - Expertise in physics, numerical methods, and coding
  - Time and effort
  - Which method? Which language?
  - Understanding other peoples' code
  - Which hardware and operating system?

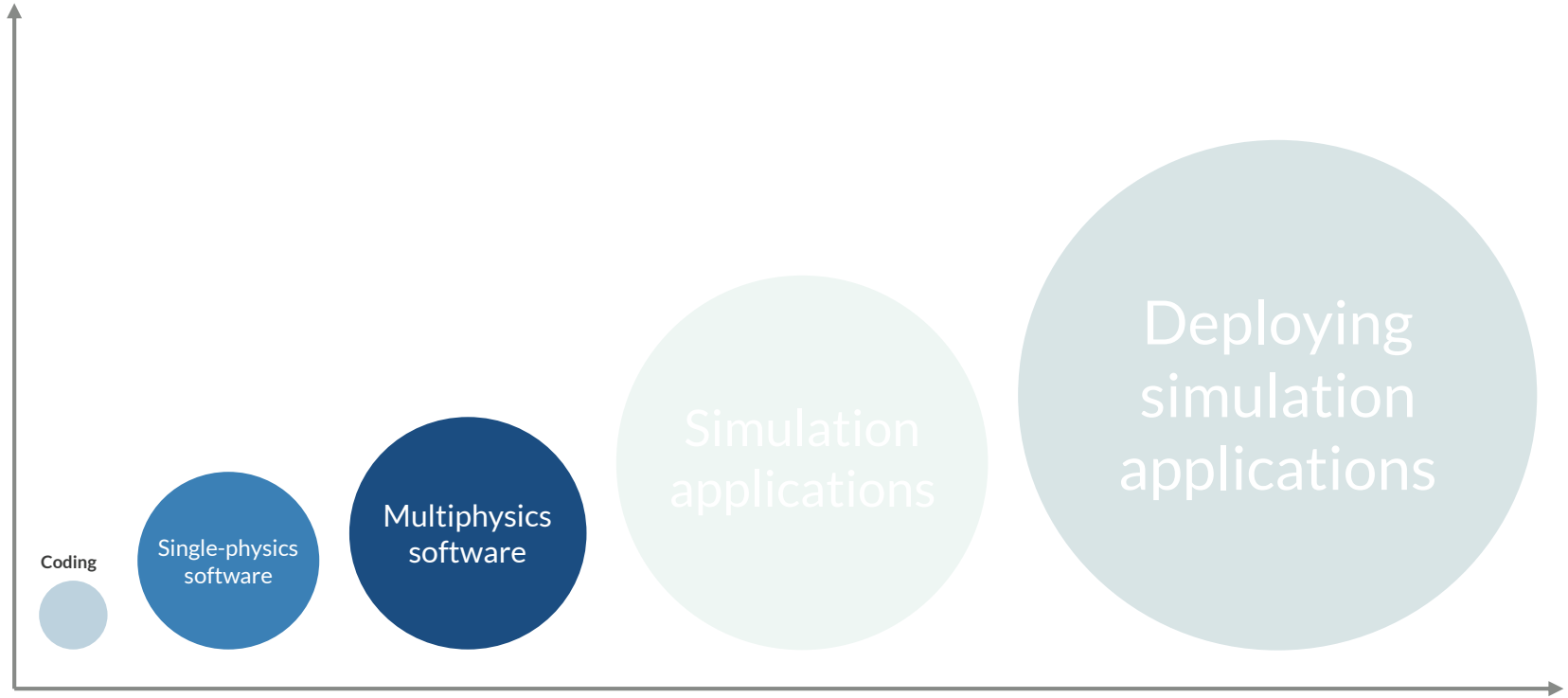
# Commercialization: Single-Physics Software



# Single Physics (Built-In Multiphysics) Software

- Benefits:
  - Less time and effort to set up models
  - No coding required
  - Standardized hardware and operating system(s)
- Barriers:
  - Different numerical methods: FEM, FVM, FDTD, MoM
  - Expertise in the physics, numerical methods, and the software
  - Different user interfaces, model-building workflows, and syntax
  - Different model formats
  - Different vendors

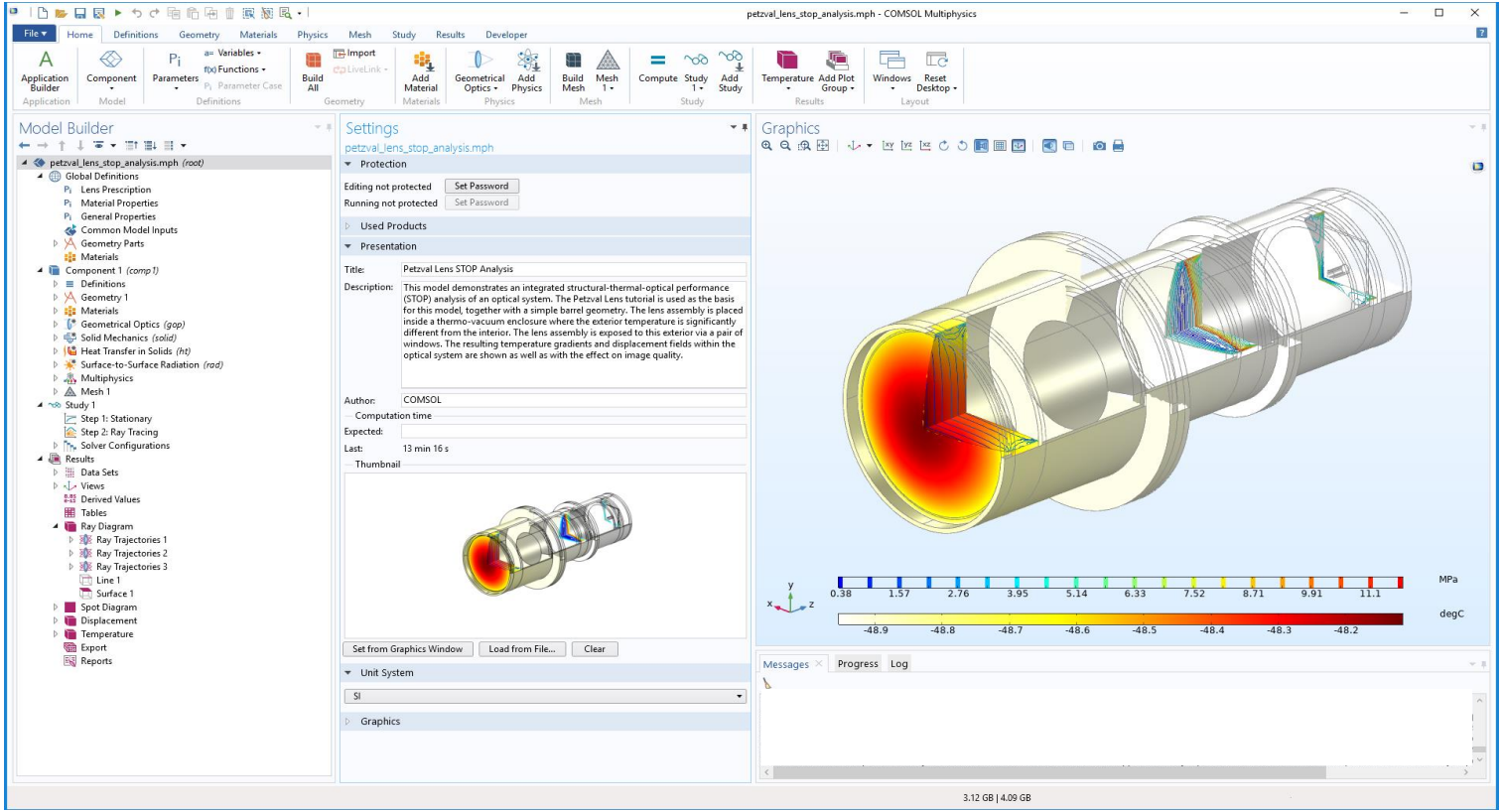
# Unification: Multiphysics Software



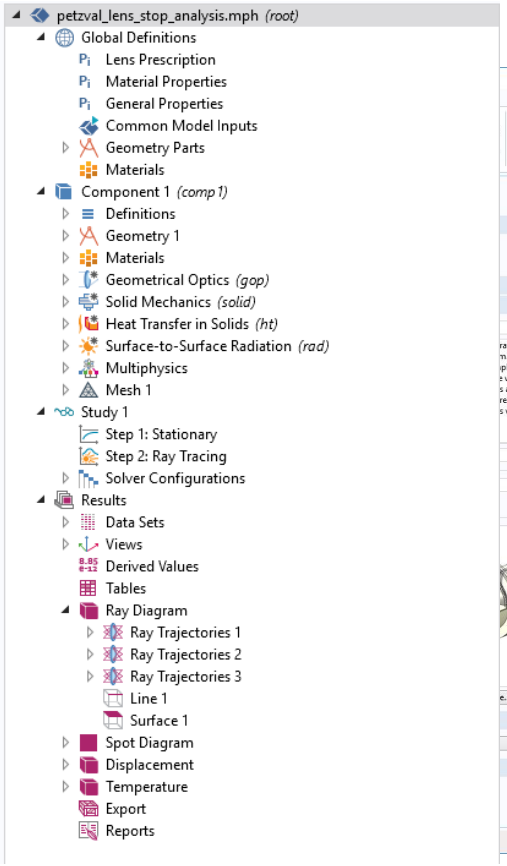
# Multiphysics Software

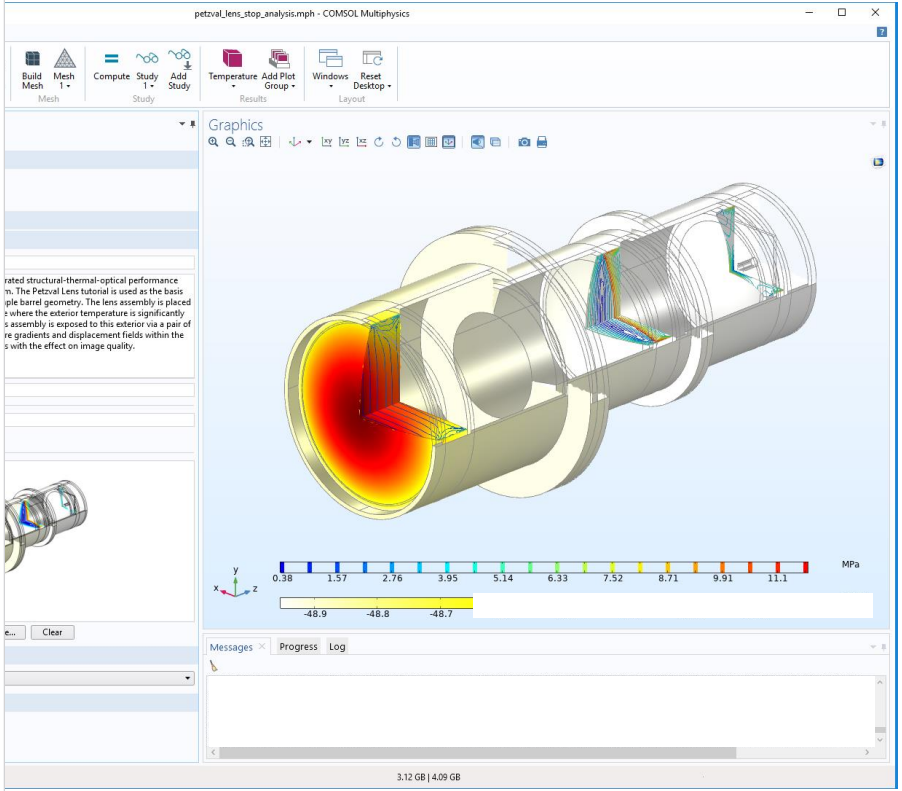
- Benefits:
  - Same user interface, model-building workflow, and syntax in multiphysics

# Unification: User Interface

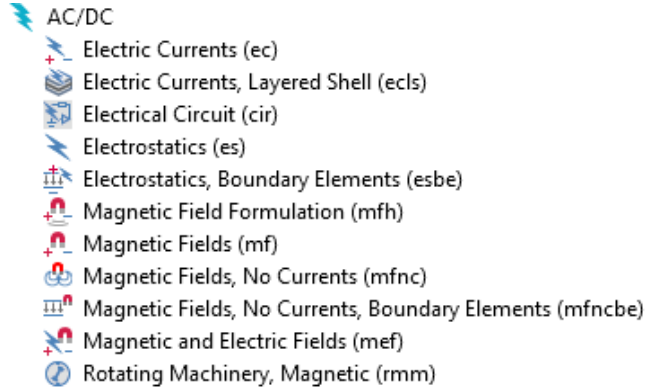


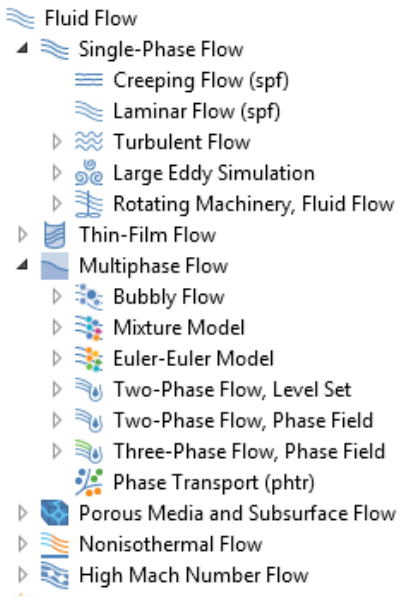
# Unification: User Interface



# Unification: Multiphysics

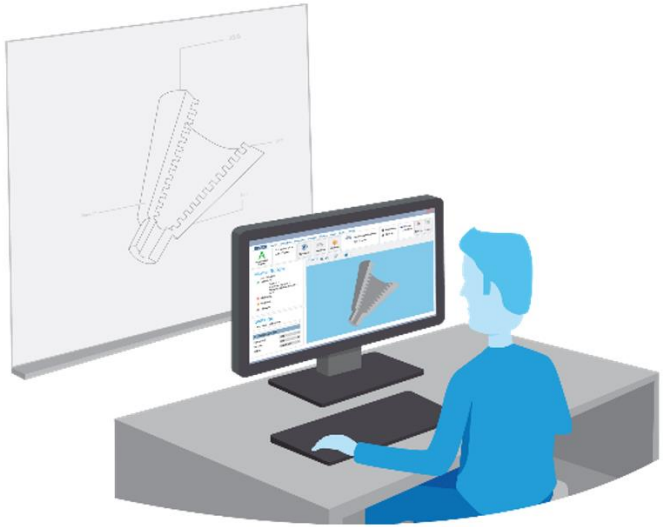


# Multiphysics Software

- Benefits:
  - Same user interface, model-building workflow, and syntax
  - Same model format
  - Same vendor
  - Streamlined numerical methods
  - Greater accuracy
- Barriers:
  - Expertise in the physics and the software

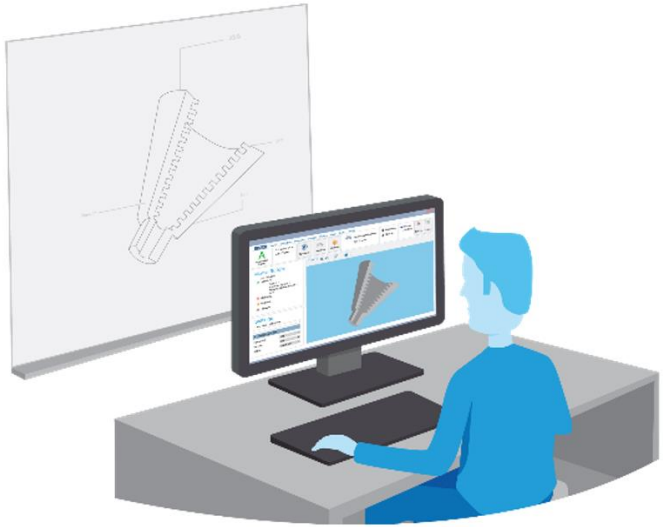
# The Modeling Expert



**MODEL**

*Reports and data*
*Operating conditions*
*Design parameters*
*Complex understanding*

# The Model User



**MODEL**

*Reports and data*
*Operating conditions*
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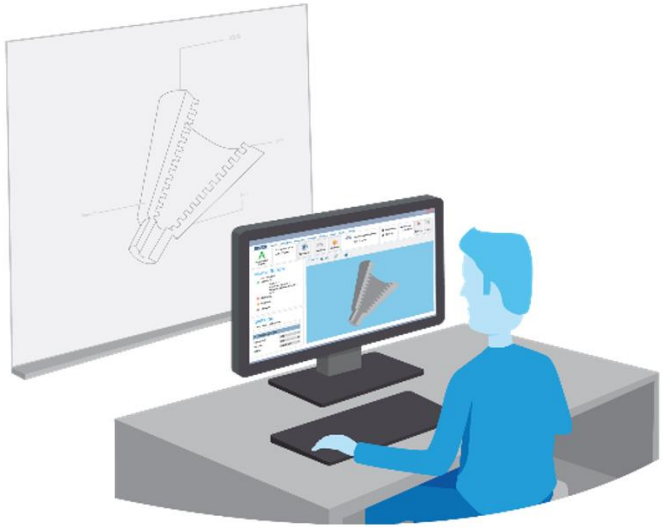
*Complex understanding*

**MODEL USE**

*Project feasibility and QA*
*Process decisions*
*Optimized designs*
*Complex understanding*

# The Feedback



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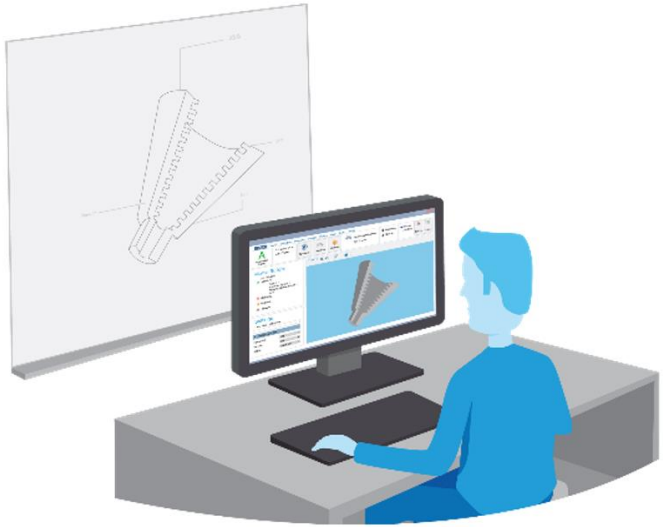
# The Bottleneck



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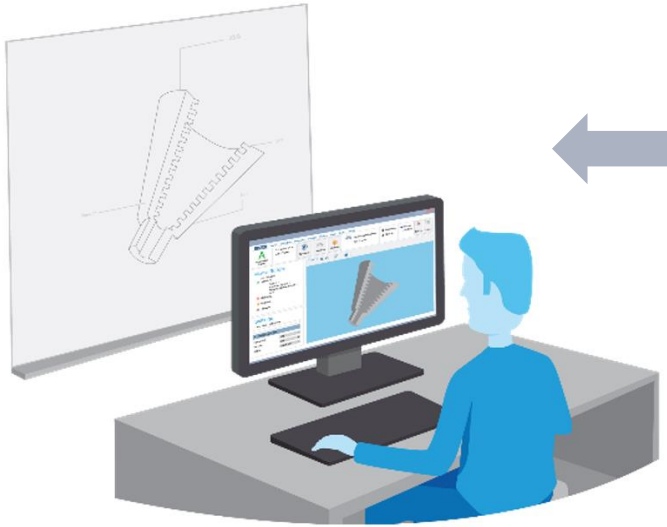
# The Model Expert, Model User, and Feedback



MODEL
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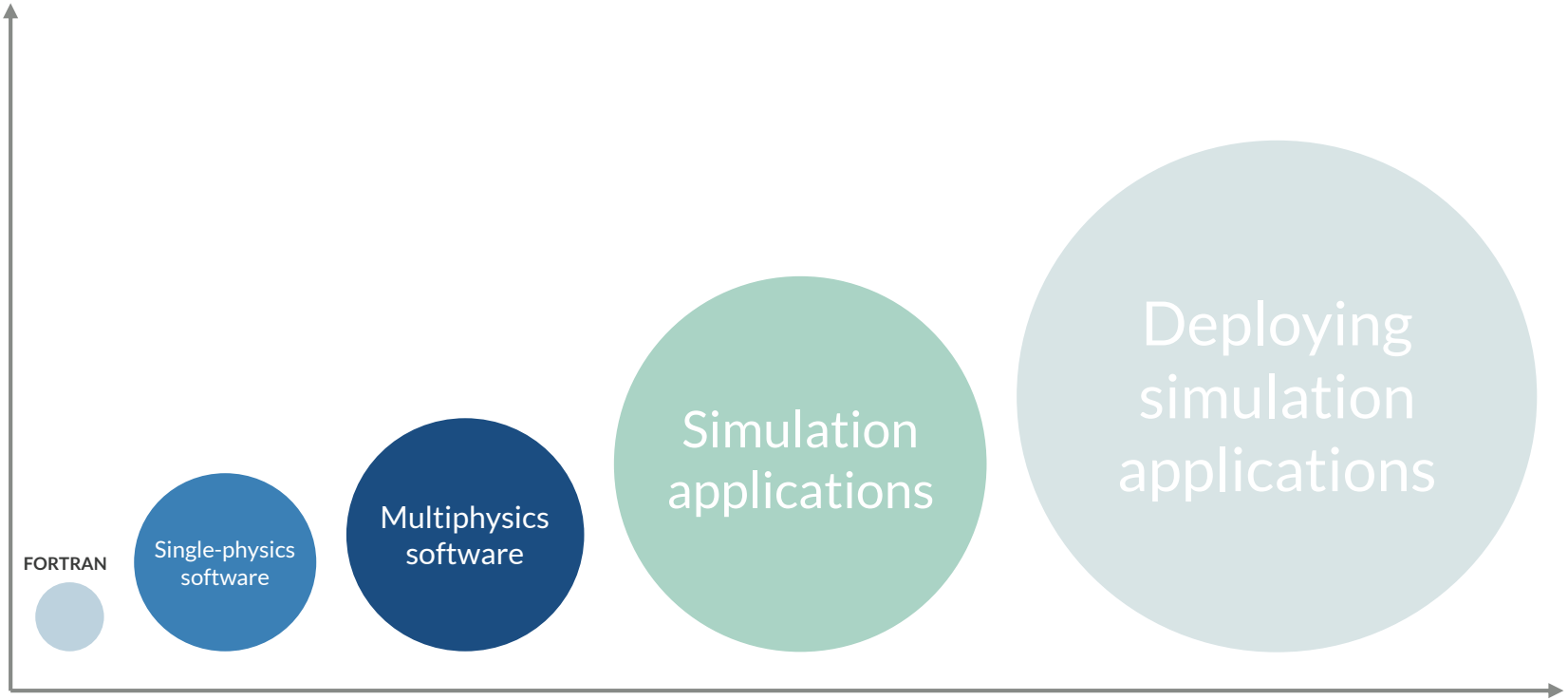
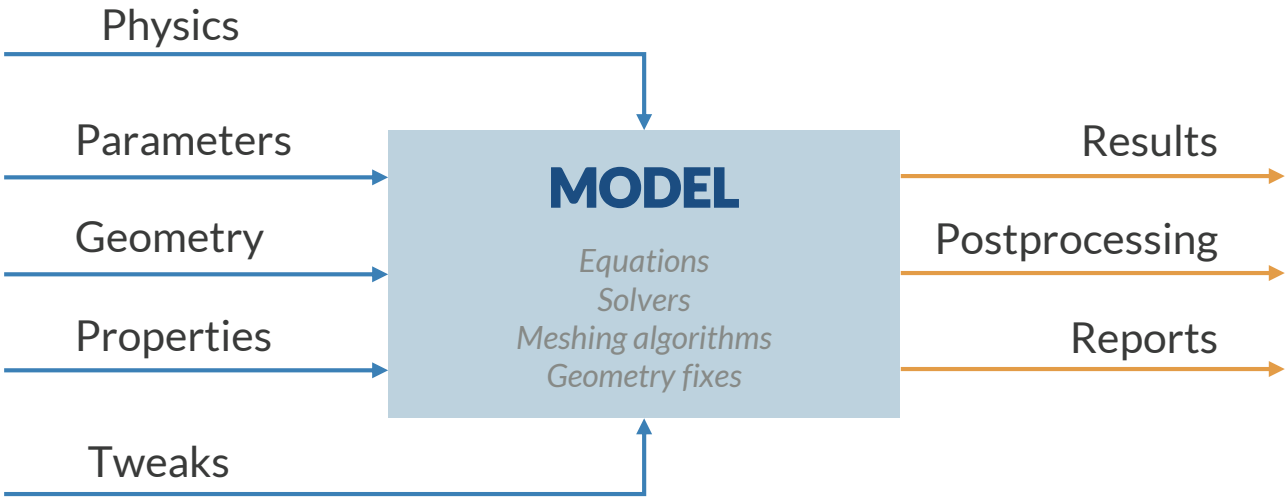
MODEL

MODEL USE
MODEL USE
MODEL USE
MODEL USE

# Democratization: Simplification



# Inputs/Outputs in a Model

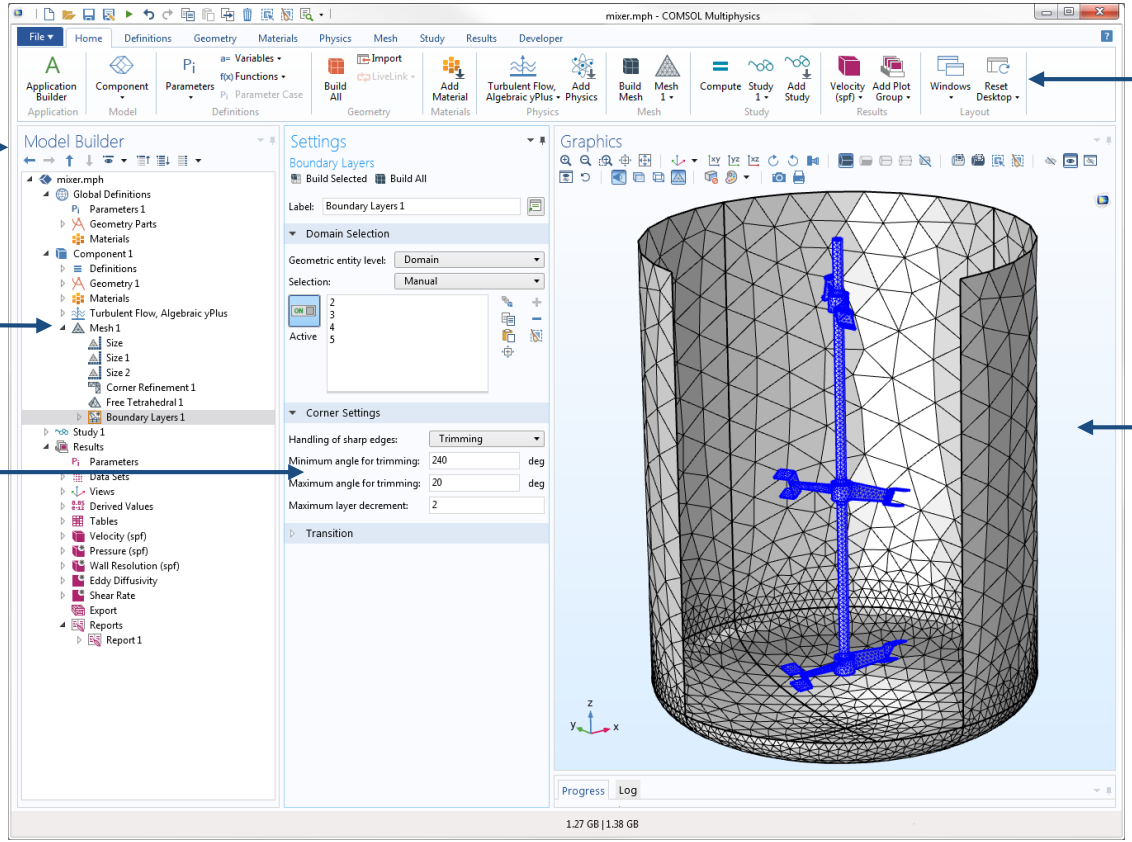


# Inputs/Outputs in a Model

Model Builder

Nodes & subnodes

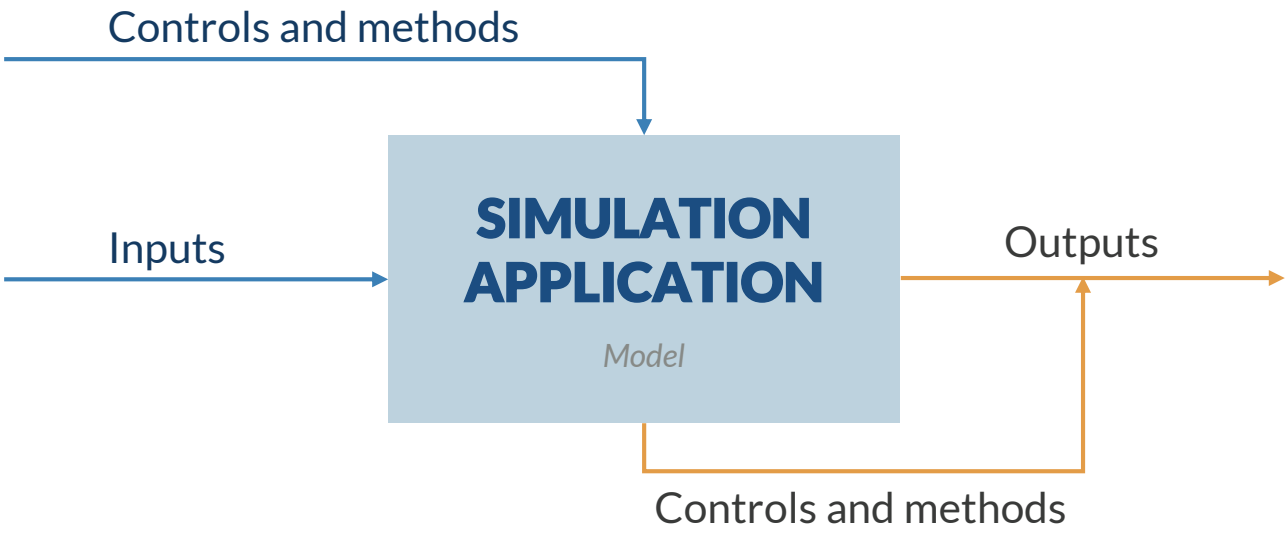
Settings fields



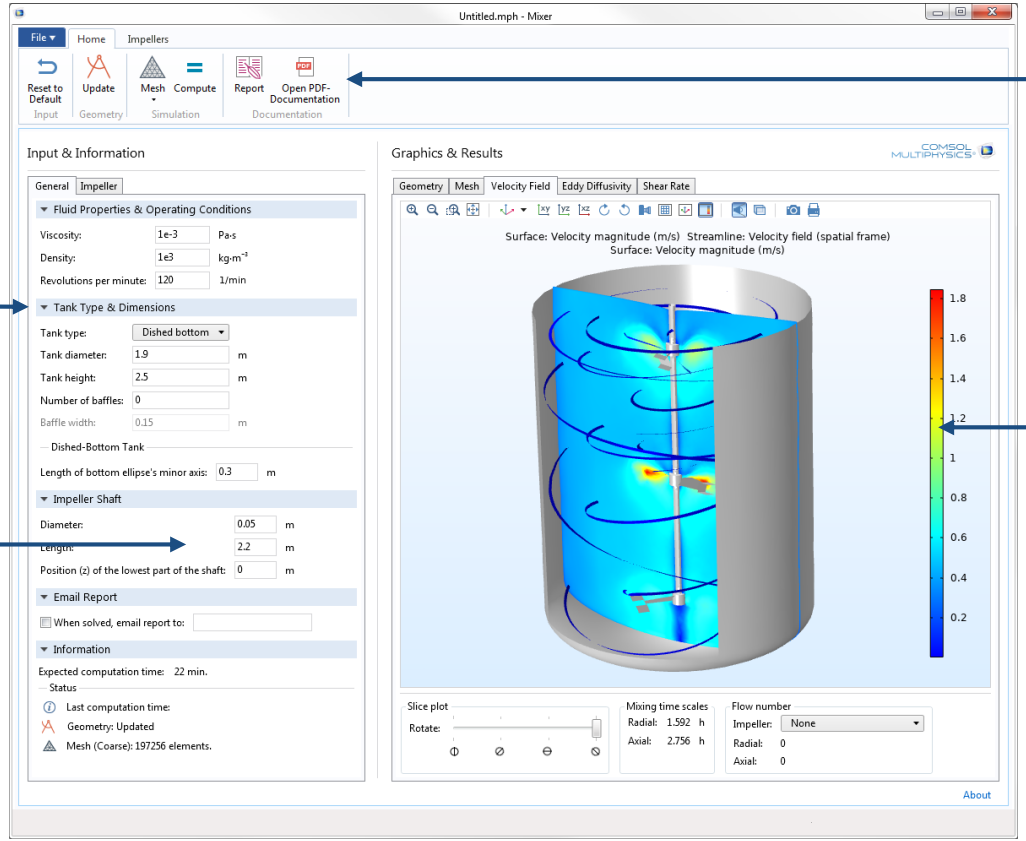

Menu items

Model graphics

# Inputs/Outputs in a Simulation Application



# Inputs/Outputs in a Simulation Application




Menu items

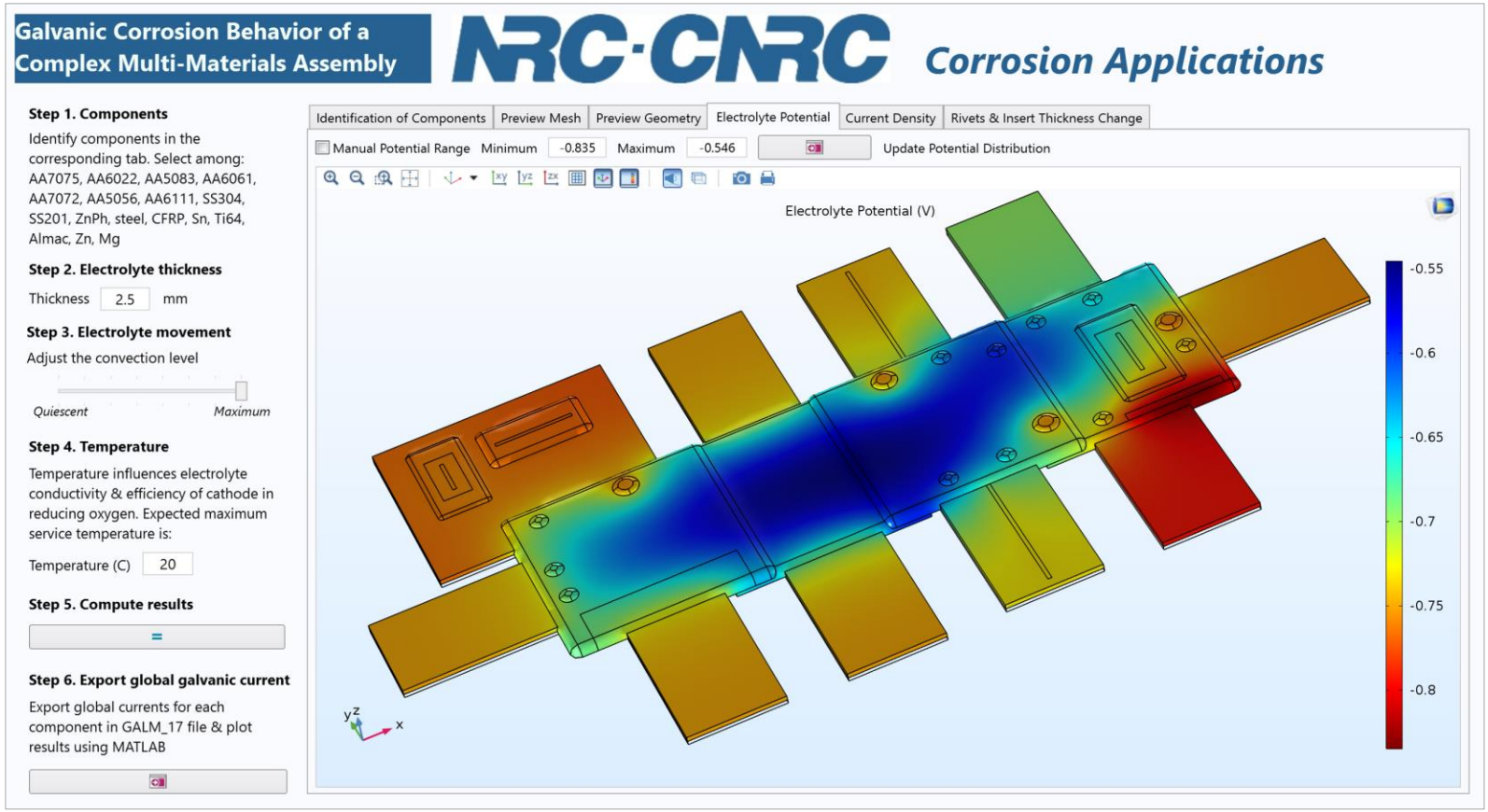
Nodes & subnodes

Model graphics

Settings fields

# Example of a Simulation Application

- Lightweighting with aluminum: corrosion applications
  - Advance aluminum adoption in automotive lightweighting by designing galvanic, corrosion-resistant multimaterial assemblies
  - Optimized multimaterial assemblies for resistance to galvanic corrosion
  - Utilize simulation applications to deploy to NRC colleagues and ALTec members
  - *COMSOL News 2018: Danick Gallant, NRC, Canada.*

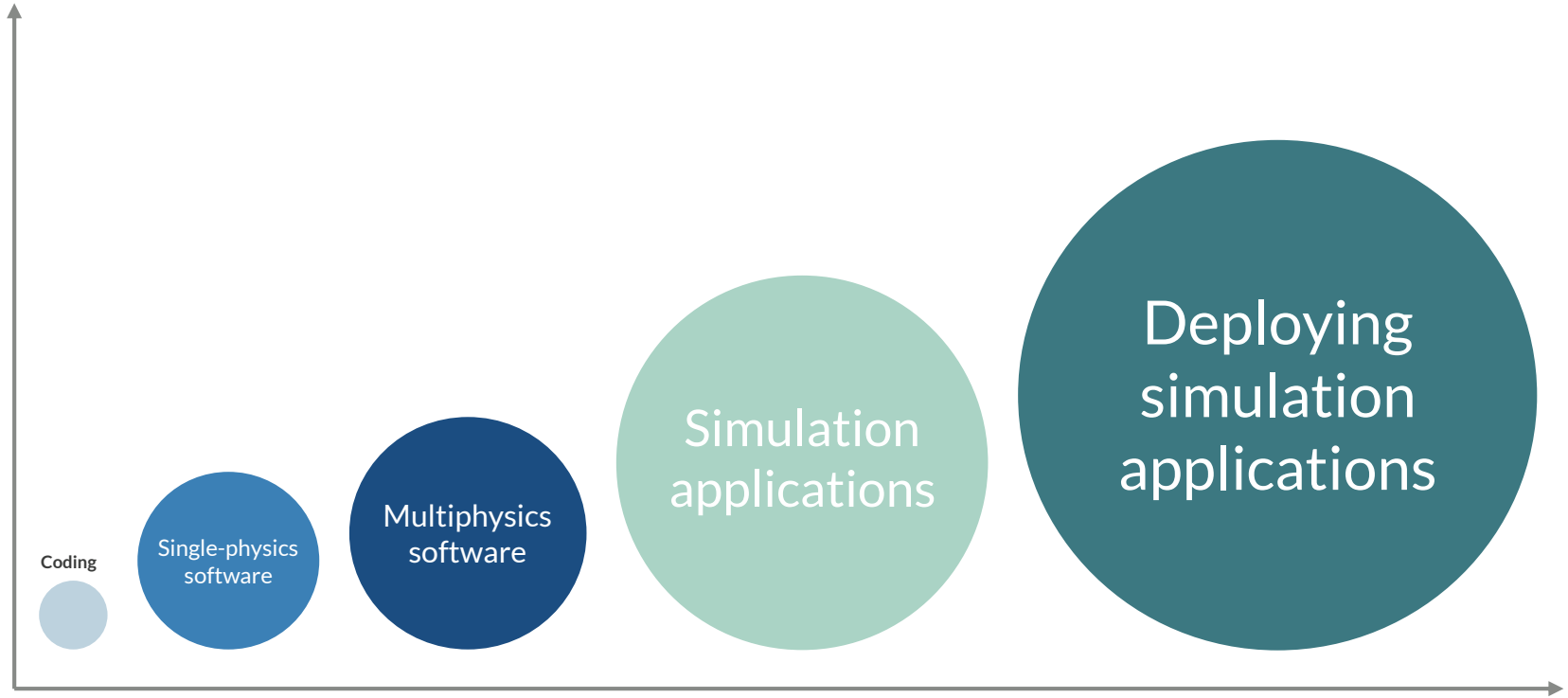



*A simulation application for determining the electrolyte potential across the assembly.*

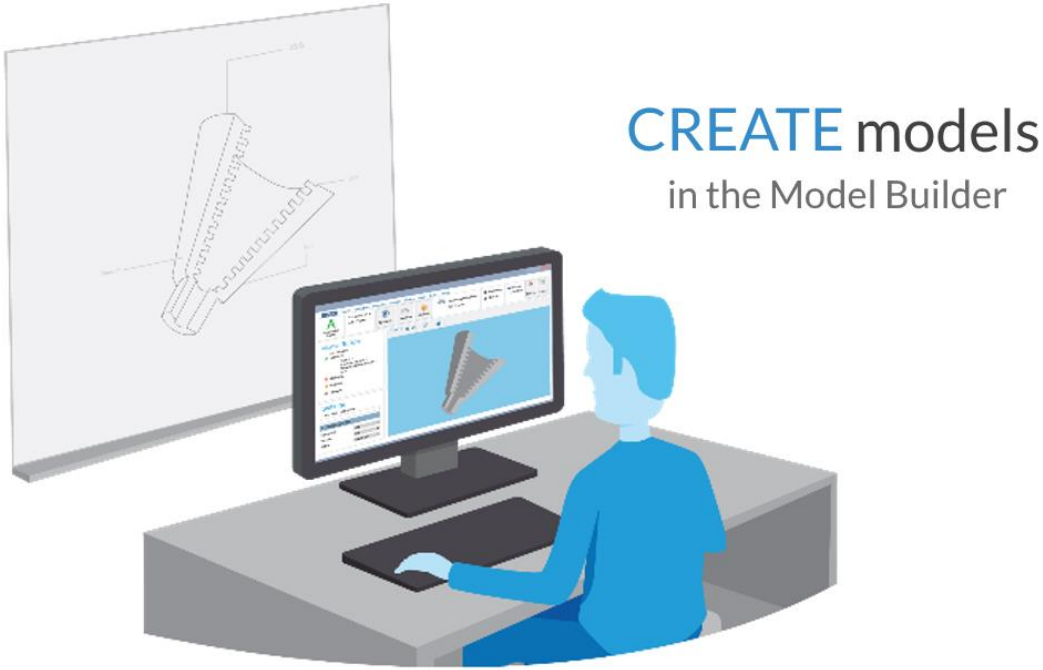
# Simulation Applications

- Benefits:
  - Specialized user interfaces applicable to the audience and application
  - No simulation experience required
  - No long-term need for a sophisticated software
  - Build understanding of product, process, or application behavior
  - Feedback from users create more accurate simulations
  - Provide a service to customers, clients, vendors, and colleagues
- Barriers:
  - Deployment?

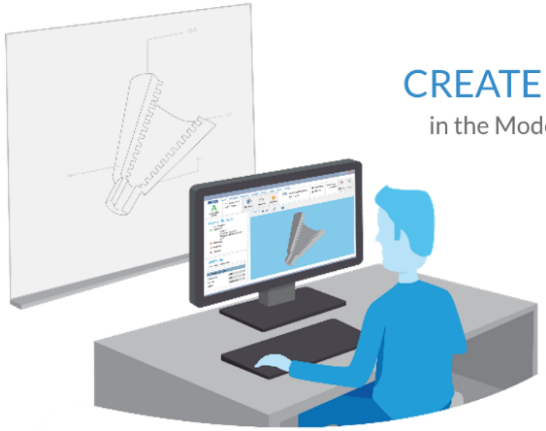
# Democratization: Deployment



# The Model Builder



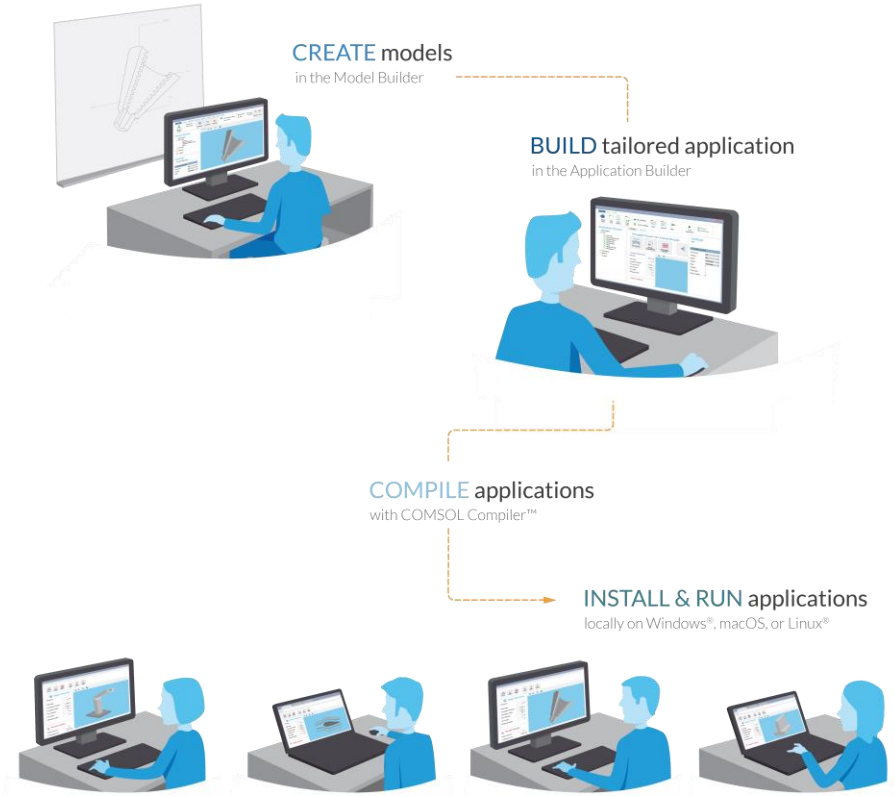
# The Application Builder



**CREATE** models
in the Model Builder

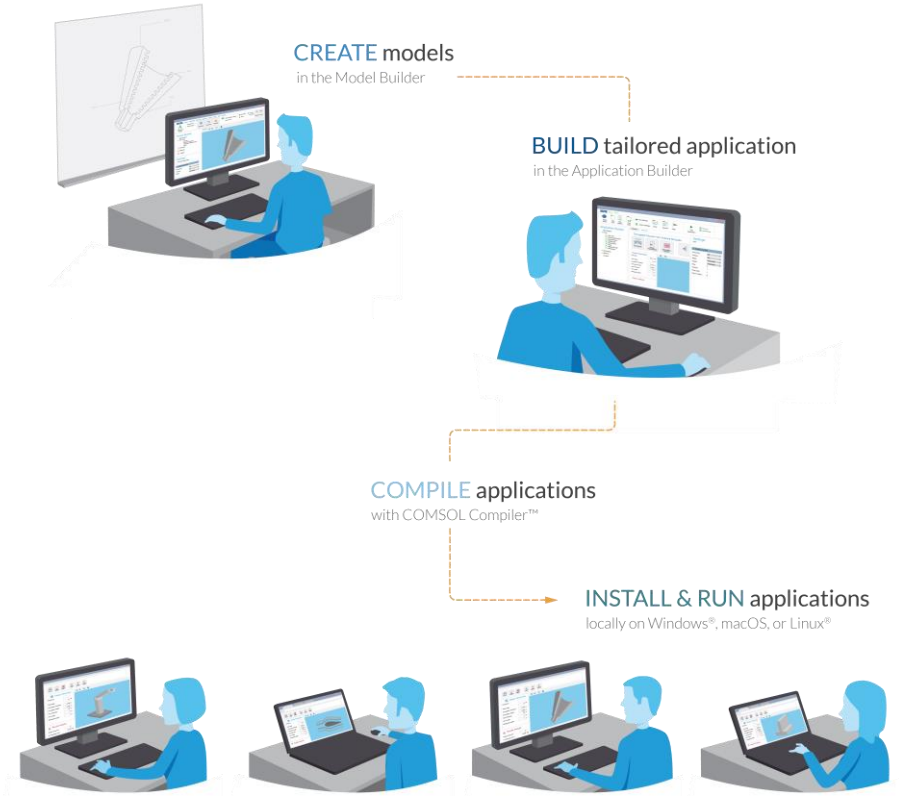
**BUILD** tailored applications
in the Application Builder

# The Deployent of Simulation Applications



# Deploying Simulation Applications

- Simulation applications can be run by anyone that is anywhere in the world
  - No restrictions on deployment
  - No license required
  - Use your own branding
  - Sell them or rent them out
- Create your own simulation software!



File ▾ | Home | Definitions | Geometry | Materials | Physics | Mesh | Study | Results | Developer | Current Density

Application Builder | Component | Parameters | Variables | Functions | Parameter Case | Build All | Import | LiveLink | Add Material | Electric Currents | Add Physics | Build Mesh | Mesh 1 | Compute | Study 1 | Add Study | Current Density | Add Plot Group | Windows | Reset Desktop

Application | Model | Definitions | Geometry | Materials | Physics | Mesh | Study | Results | Layout

## Model Builder

- busbar.mph
  - Global Definitions
    - Parameters 1
    - Common Model Inputs
    - Materials
  - Component 1
    - Definitions
    - Geometry 1
    - Materials
    - Electric Currents
    - Heat Transfer in Solids
    - Multiphysics
      - Electromagnetic Heating 1
    - Mesh 1
  - Study 1
  - Results
    - Data Sets
    - Derived Values
    - Tables
    - Electric Potential (ec)
    - Temperature (ht)
    - Isothermal Contours (ht)
    - Current Density
    - Export
    - Reports

## Settings

3D Plot Group

Plot

Label: Current Density

**Data**

Data set: Study 1/Solution 1

**Title**

**Plot Settings**

View: Automatic

- ☐ Show hidden entities
- ☐ Propagate hiding to lower dimensions
- ☑ Plot data set edges

Color: Black

Frame: Material (X, Y, Z)

**Color Legend**

- ☑ Show legends
- ☐ Show maximum and minimum values
- ☐ Show units

Position: Right

Text color: Black

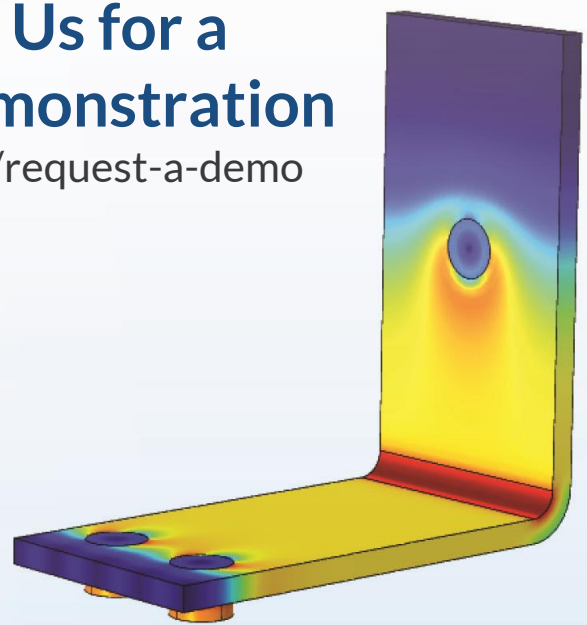
**Number Format**

**Window Settings**

## Graphics

Surface: Current density norm (A/m²)






Messages | Progress | Log | Table