

# HPC resources in COMSOL<sup>®</sup> from Simulations to Apps

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COMSOL Srl

# Outline

- COMSOL
- Multiphysics Modeling and Simulations
- Choosing the right hardware
- How COMSOL parallelizes
  - shared, distributed and hybrid computing
- Some benchmarks and users cases
- New frontiers in simulations: Apps

# Company Mission

“To Develop Easy-To-Use Software for Modeling and Simulation of Real World Multiphysics Systems”

# COMSOL 2017

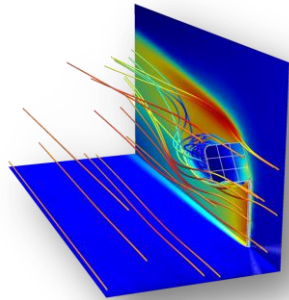
- ~500 Employees in 15 countries
- COMSOL Multiphysics®
  - Modeling and Simulation
    - Ready made physics and math interfaces
    - Built-in CAD tools
    - Add-on modules with specialized physics
    - LiveLink™ products connects with partner software
  - Development tools
    - Model Builder
    - Physics Builder
    - Application Builder
  - Deploying Apps
    - COMSOL Multiphysics®
    - COMSOL Server™



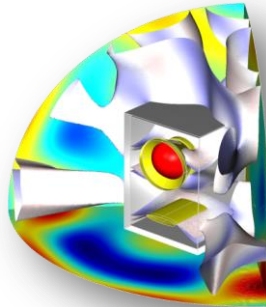
# Multiphysics Modeling and Simulations

# Multiphysics and Single-Physics Simulation Platform

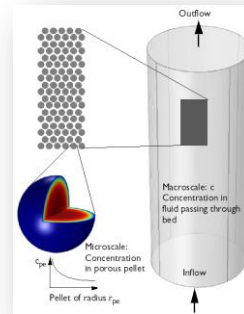
- Mechanical, Fluid, Electrical, and Chemical Simulations
- Two or more physics phenomena that affect each other with *no limitation* on which combinations or how many



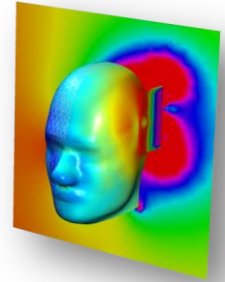
*Fluid & Mechanical:  
Fluid-Structure Interaction of a Solar Panel*



*Mechanical & Electrical:  
Acoustics Speaker Systems*

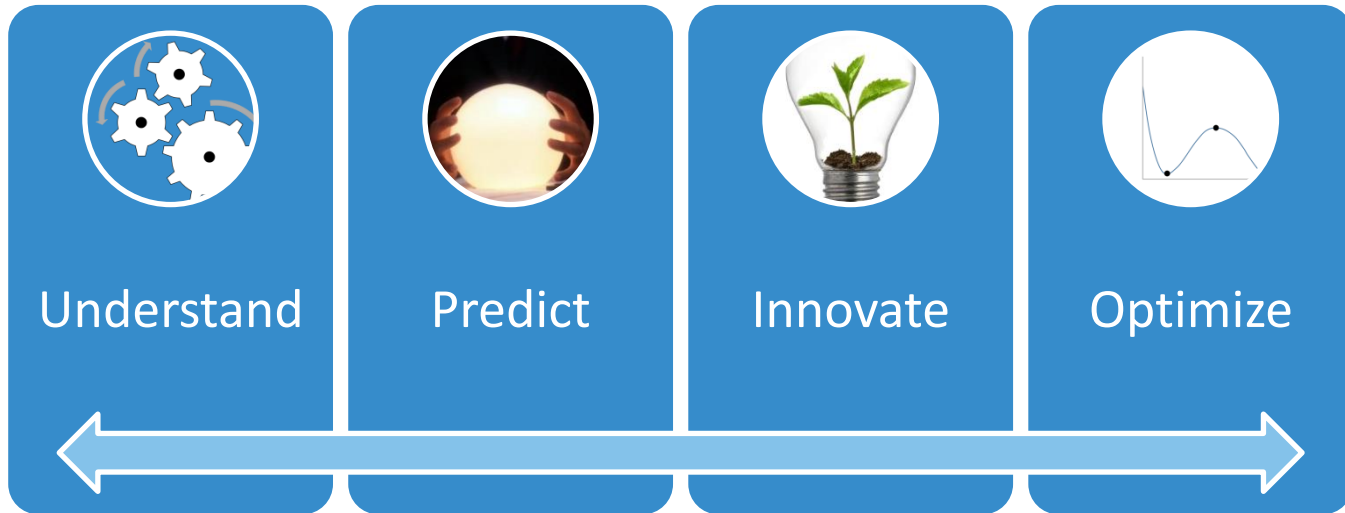


*Chemical with extra dimensions:  
Packed bed reactor*



*Electrical & Mechanical:  
Cell Phone Radiation*

# How Our Customers Use COMSOL

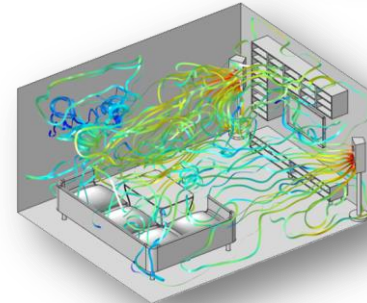
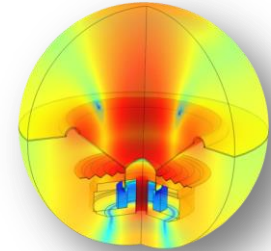
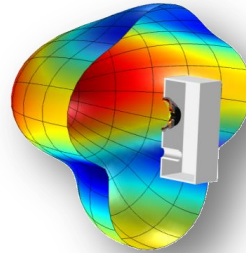


# The Right Hardware Choice

Increasing hardware requirements



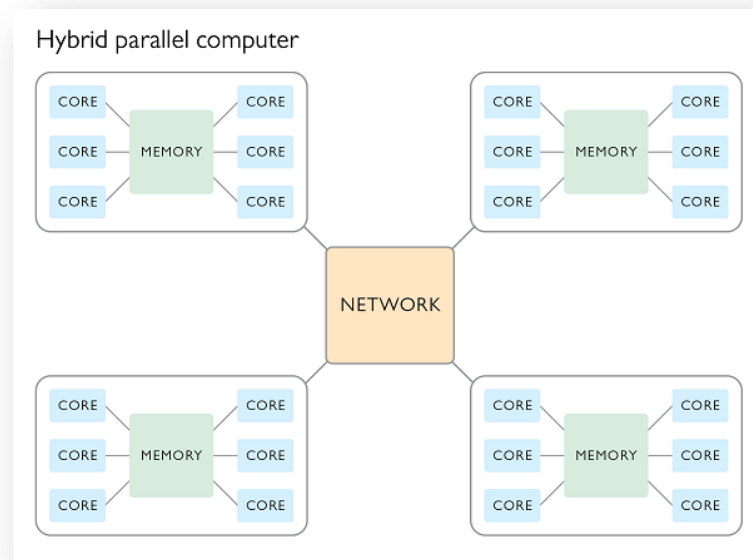
- Conception and understanding
  - Mathematical model (PDEs and ODEs)
  - Innovation: small but advanced model
- Design and optimization
  - Virtual experiments
  - Parameterization/optimization
- Testing and verification
  - Virtual prototyping: Faster than real prototyping
  - Big comprehensive models





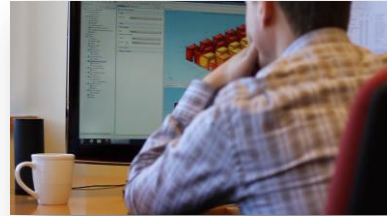
# Parallel computing

- Today multicore processors are standard
- Each node is multicore
- Traditionally two different realms
  - Shared Memory
  - Distributed Memory
- Approach for hybrid parallel computing



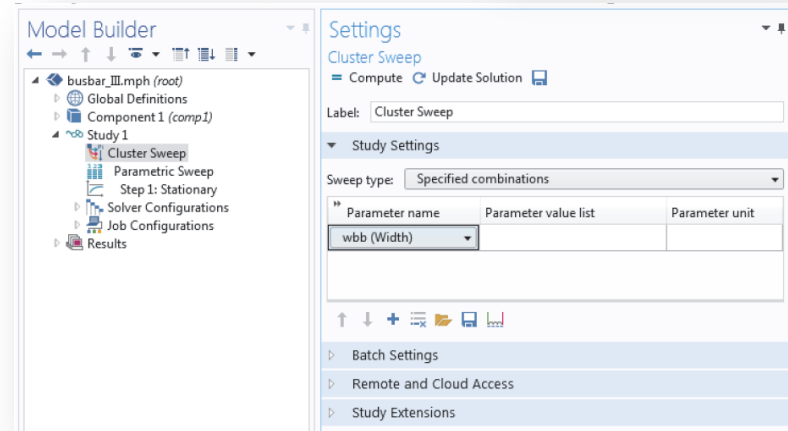
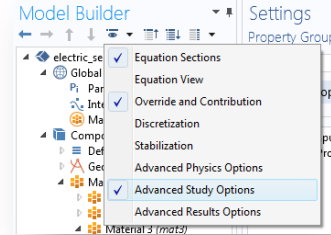
# COMSOL in HPC

- Intuitive solutions
- Effective solutions
  - Licensing
  - Scalability
  - Usability



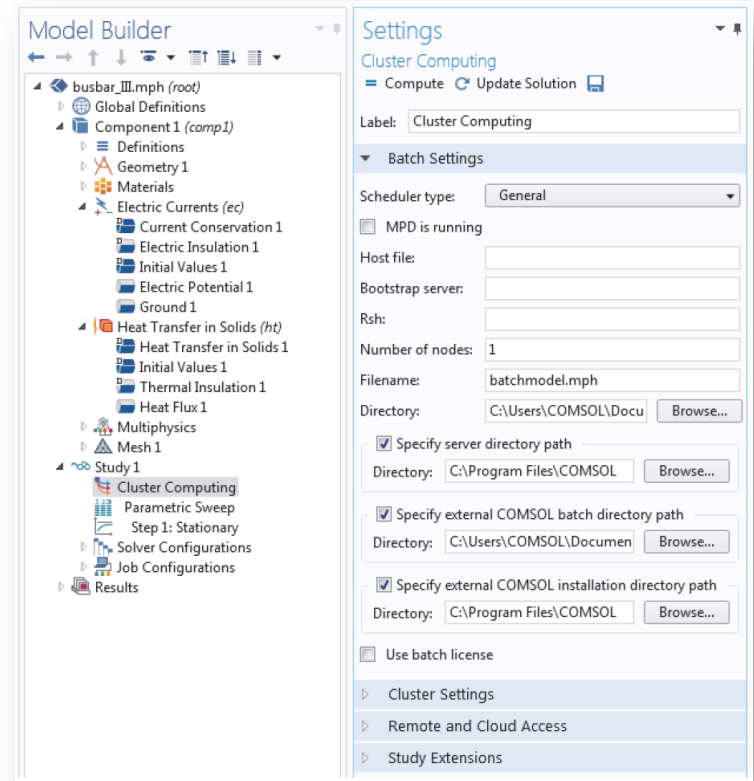
# Cluster Sweep

- Option in the Model Builder under Study
- You need to enable Advanced Study Option to see this option
- Available for Floating Network License
- For distributing a parametric sweep across a cluster
- Sweep functionality similar to regular Parametric Sweep
- Also sometimes known as “Embarrassingly Parallel” computation

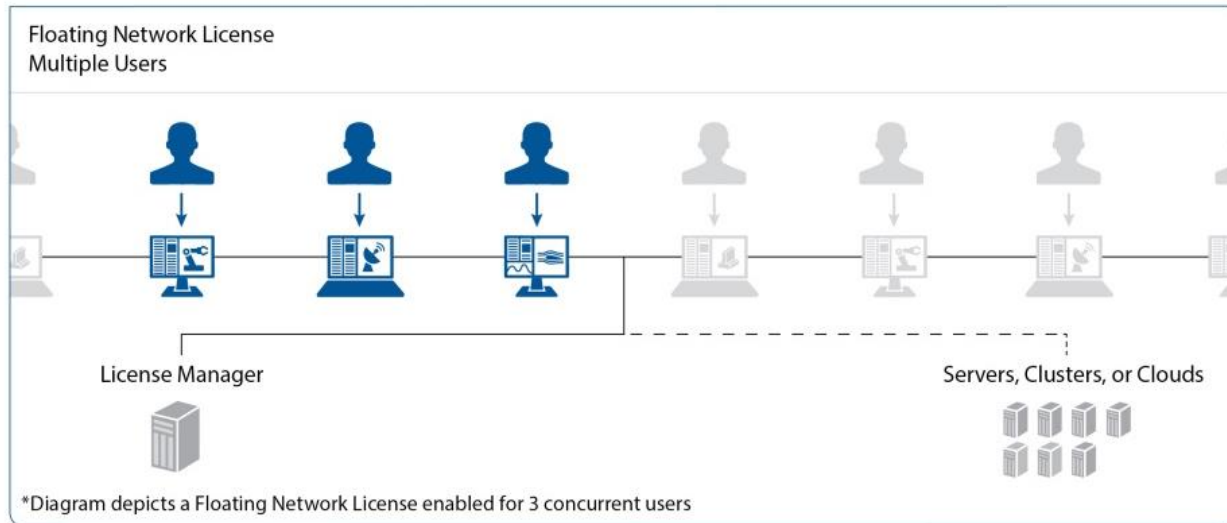


# Cluster Computing

- Option in the Model Builder under Study
- You need to enable Advanced Study Option to see this option
- Available for Floating Network License
- For distributing one large job over a cluster
- Cluster configuration controlled from the Cluster Computing Settings window (same is true for Cluster Sweep)



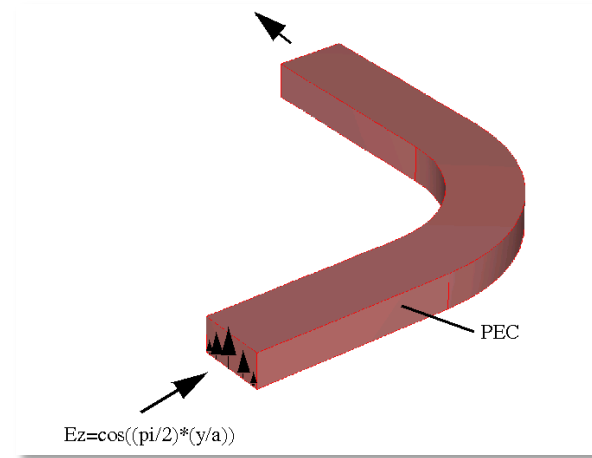
# The Floating Network License



COMSOL Multiphysics® is compatible with the Windows®, OS X, and Linux® operating systems.

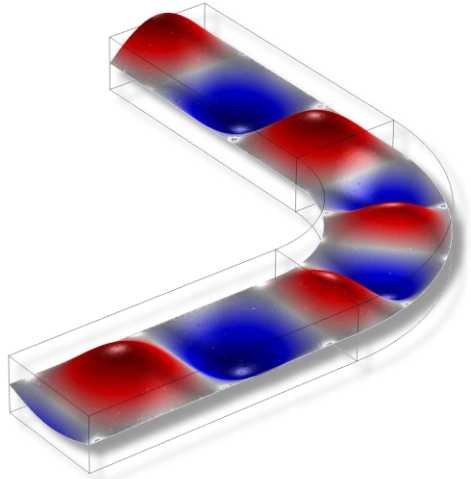
# Electrical Application: H-Bend Waveguide

- An H Bend waveguide is used to bend microwaves, typically by 45 or 90 degrees
- An H bend can be designed to have very low losses
- Frequency Sweep over 128 frequencies

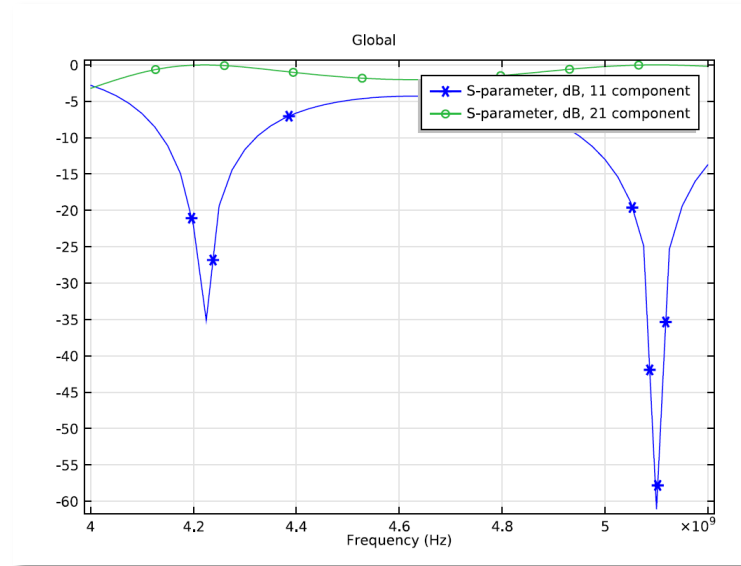


*Model Set-up*

# Electrical Application: H-Bend Waveguide



*Electric field in the z direction*

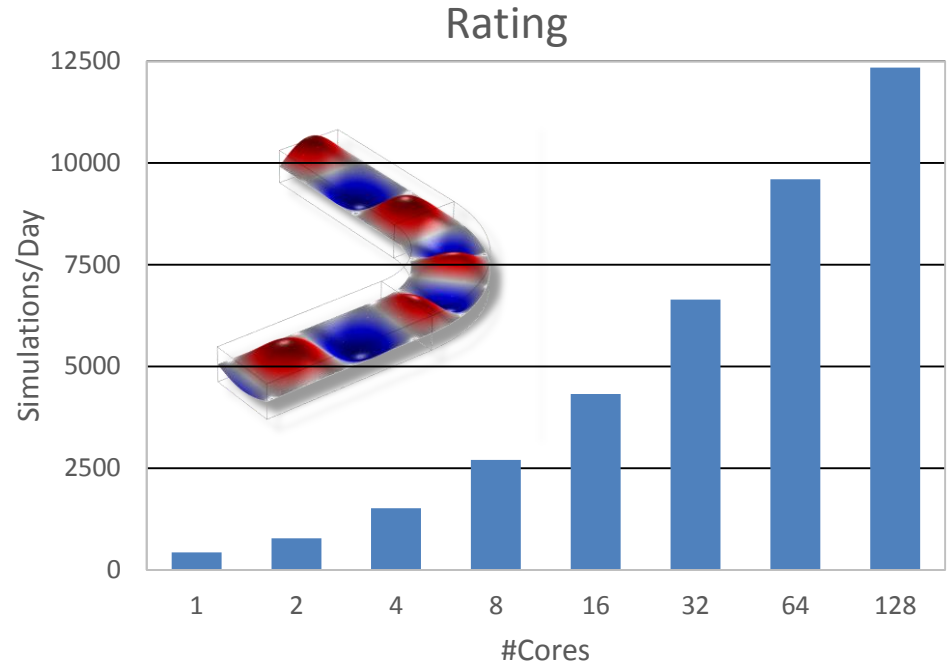


*Parametric sweep from 4.3 to 6 GHz*

# Results (Distributed Parametric Sweep)

## RF Waveguide

Comsol version	5.3
Model Size	26kDOF / 6GB RAM
Solver type	Multigrid, BiCGStab
Distribution type	Dist. parametric sweep
No. Parameters	128
Server type	Fujitsu 10-blade cluster
Processor type	Intel® Xeon® CPU E5-2650 v2
Clock Frequency	2.60 GHz
Memory	64GB DDR3, 1600 MHz
Network	IB Mellanox QDR



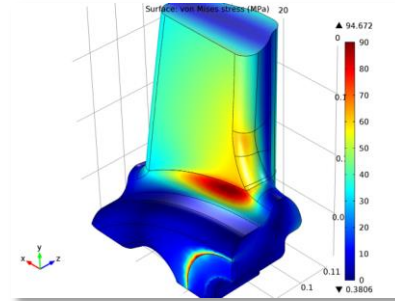


# Structural Mechanics: Wheel Rim

- Resolve the stress concentrations in a wheel rim.
- A global model is solved to obtain displacements
  - These are then used as boundary conditions in a local model of the region where the stress concentrations occur.



*Global model*

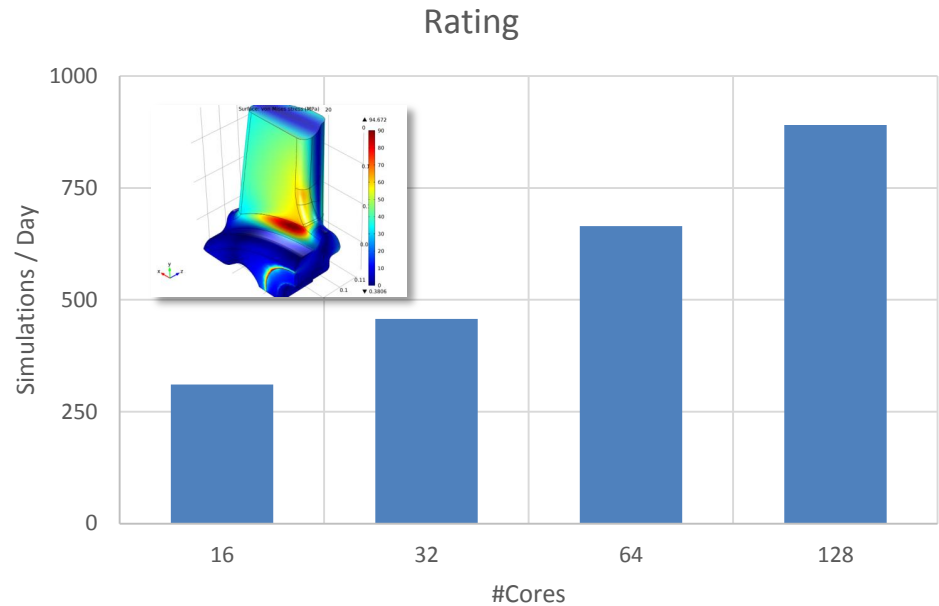


*Stresses in the submodel*

# Results with MUMPS

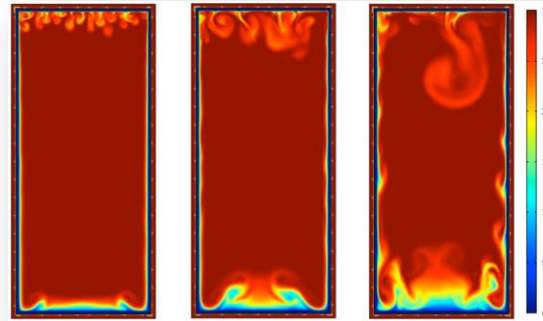
## Wheel Rim

Comsol version	5.3
Model Size	1.6 MDOF / 23GB RAM
Solver type	Direct
Preconditioner	MUMPS
Distribution type	Distributed
Server type	Fujitsu 10-blade cluster
Processor type	Intel® Xeon® CPU E5-2650 v2
Clock Frequency	2.60 GHz
Memory	64GB DDR3, 1600 MHz
Network	IB Mellanox QDR



# Cluster Simulation of Refrigeration Systems

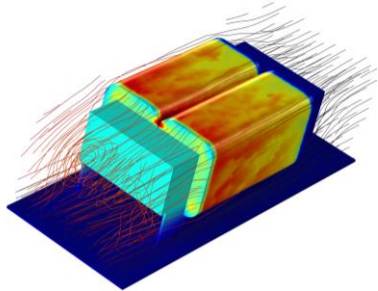
- The food industry produces 20% of total greenhouse gases and food transport is highly inefficient. A variable-state ice slurry, called Deepchill™, is highly efficient for cooling food produce in trucks.
- COMSOL was utilized to investigate specific design criteria, modeling the coupling of heat transfer and fluid flow using an HPC cluster.
- COMSOL News 2012: Codyer and Raessi, *UMass Dartmouth, MA, USA*; Currie and Goldstein, *Sunwell Technologies, ON, Canada*



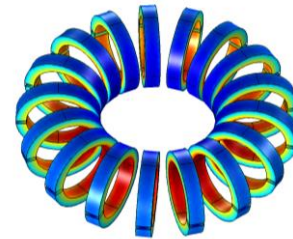
*Natural convection and temperature distribution during cooling of a refrigeration unit by using the Deepchill™ thermo batteries (left to right:  $t = 5, 8$  and  $12$  s).*

# HPC-Enabled Simulation Aids in the Design of Customized High-Power Electrical Devices

- The goal is to reduce the number of prototypes necessary before finalizing a coiled product design, such as in the design of transformers, power supplies, EMC filters, and reactors.
- Engineers used multiphysics simulation to characterize a line reactor used to filter out spikes of current from the power supply, the temperature distribution throughout an air-cooled DC choke, and the magnetic flux density in a toroidal choke.
- IEEE Spectrum Multiphysics Simulation Insert: *M. Siatkowski, Block Transformatoren-Elektronik, Germany*



*Simulation of an air-cooled DC choke where temperature distribution and velocity streamlines are shown.*



*Magnetic flux density in a toroidal choke. Its inductance is numerically determined as a function of inner and outer radius and wire thickness.*

# Running in the Cloud

## ACCESS THE CLOUD, NO IT SKILLS REQUIRED

Our partners are here to help you get up and running on your preferred cloud vendor quickly and easily. Take your first step toward faster computations by contacting them today.

CONTACT NIMBIX



CONTACT RESCALE



CONTACT NOR-TECH



CONTACT CPU 24/7



CONTACT UBER CLOUD



CONTACT TOTALCAE

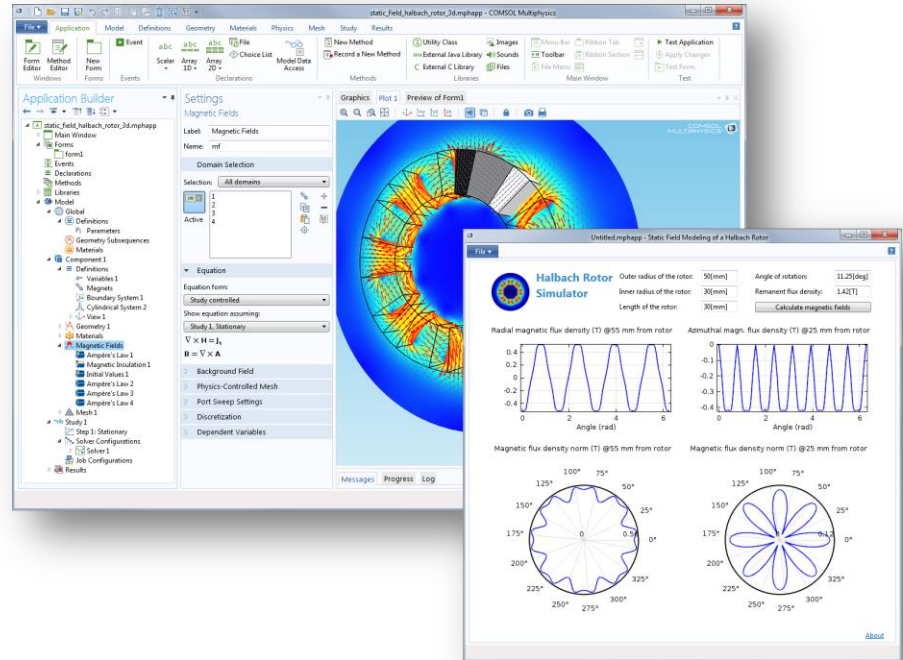




What's the future?

# Application Builder

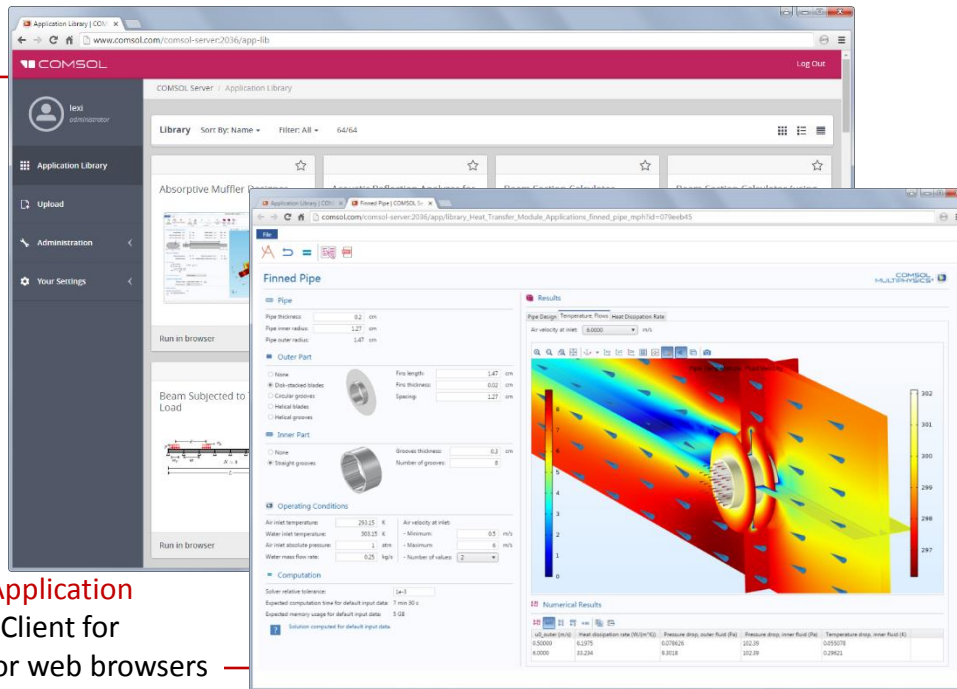
- Hide the static settings
- Encapsulate the model
- Simplify for colleagues without simulation experience



# Run Custom Applications

## COMSOL Server™

The engine for running COMSOL apps and the hub for controlling their deployment, distribution, and use



## Example of a Running Application

Can be run in COMSOL Client for Windows® OS and major web browsers



# COMSOL Server™

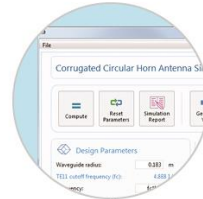
Application Library



Browser client



Windows® client



User management

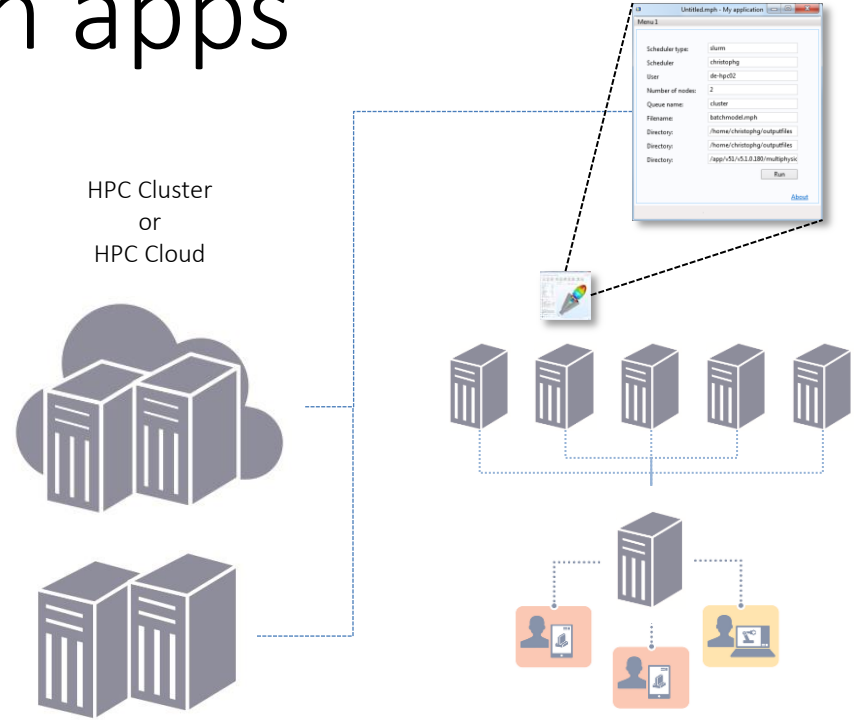


Branding



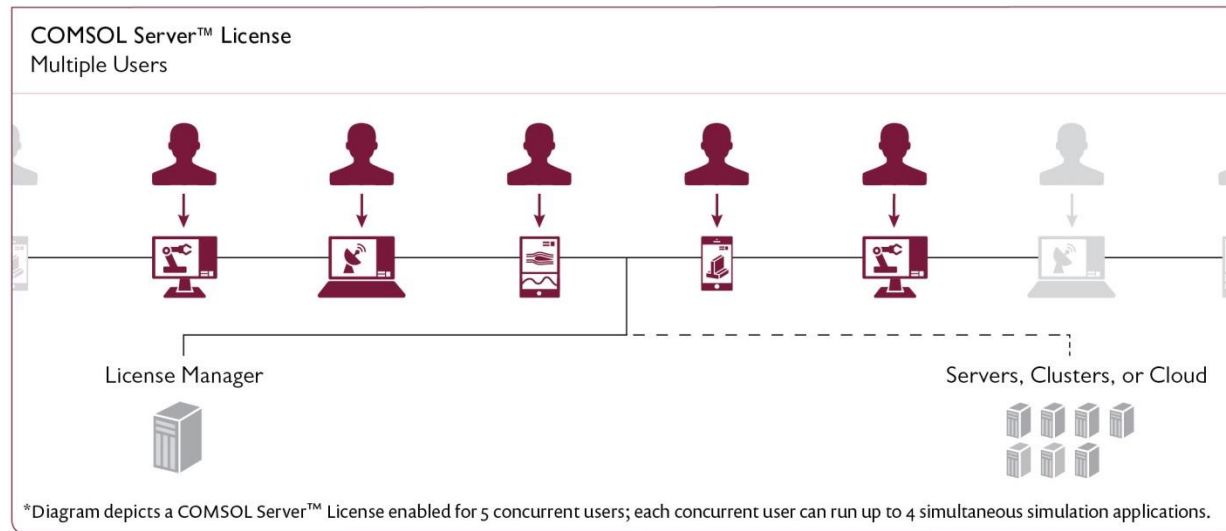
# HPC with apps

- Apps handled as in single and multiple instance COMSOL Server
- App created with an FNL can send job to HPC cluster or HPC cloud from within the app
  - Cluster Computing settings in App
  - Sent per SSH or other remote access means
  - *The computation on the HPC cluster or HPC cloud can use shared memory and/or distributed memory*
    - *Same requirements as on other HPC Clusters!*
    - *HPC network recommended in the cluster*



# License Options – COMSOL Server™

## WORLDWIDE LICENSE



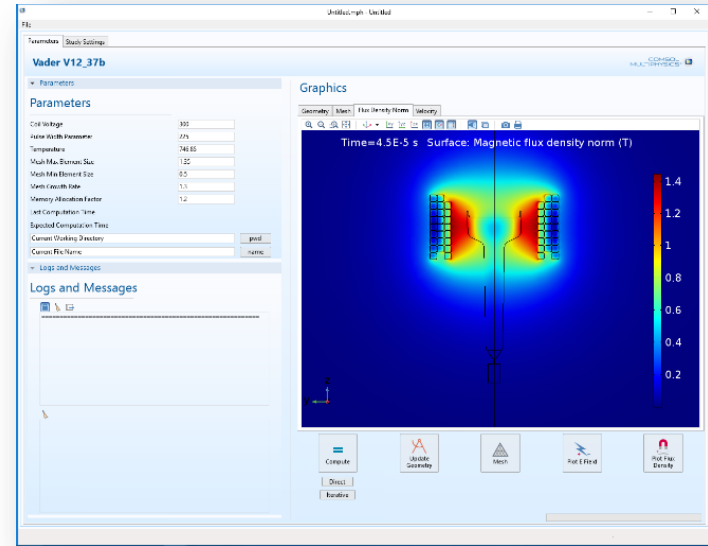
COMSOL Server™ is compatible with the Windows®, OS X, and Linux® operating systems.  
An application can be run in many major web browsers on platforms such as Windows®, OS X, iOS, Linux®, and Android™.

# Custom Simulation Apps

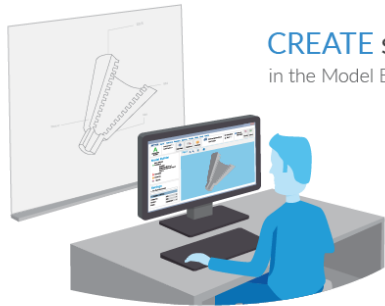
## Accelerate Product Development

*“The deployment of simulation apps via COMSOL Server is especially attractive to companies that have a critical need for modeling to accelerate the development cycle, but cannot justify recruiting a full-time resident expert.”*

Professor Ed Furlani  
University at Buffalo SUNY

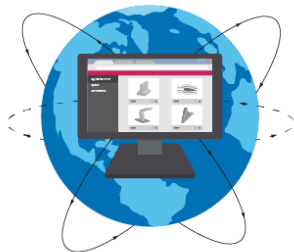


Simulation app for a liquid metal drop ejector.



**CREATE** simulations  
in the Model Builder

**BUILD** specialized apps  
in the Application Builder



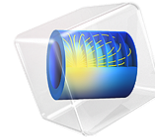
**DISTRIBUTE** multiple apps  
with COMSOL Server

**RUN** simulation apps  
in COMSOL Multiphysics or in a browser

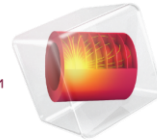


# Thank you

COMSOL  
MULTIPHYSICS®



COMSOL  
SERVER™



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