

# Introduction to COMSOL Multiphysics®

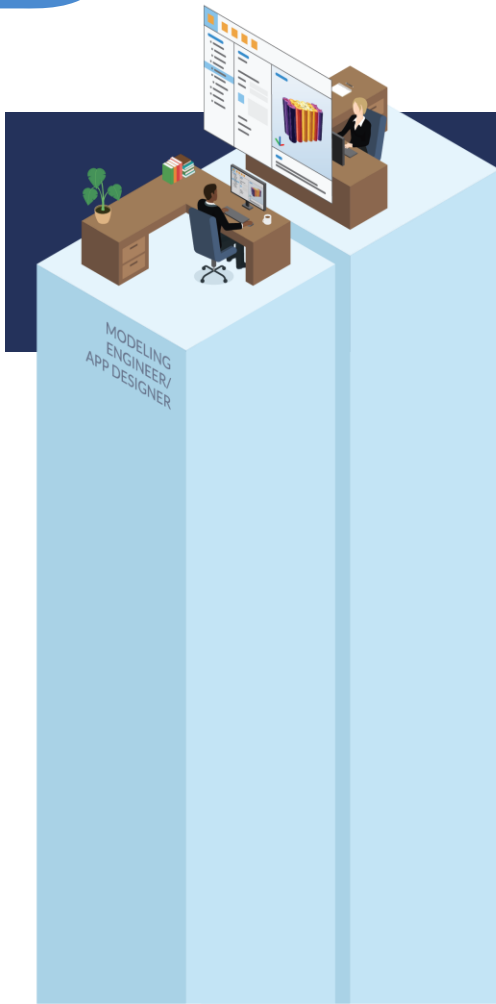
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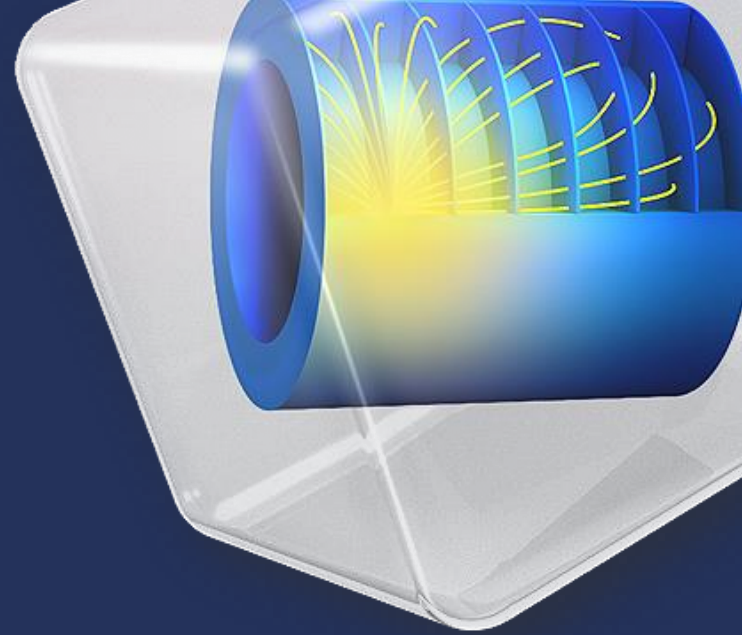
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# Agenda

- Introduction to COMSOL Multiphysics
- Introduction to COMSOL Server
- Introduction to COMSOL Compiler
- Application areas



# COMSOL Multiphysics<sup>®</sup>, COMSOL Server<sup>™</sup> and COMSOL Compiler<sup>™</sup>

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# Real-world physics example

Engineering catastrophe

- Ferrybridge (UK) powerplant
  - demolition in 2019
  - cooling tower blowdown in 1965
- Calculations didn't take into account all towers, just one.

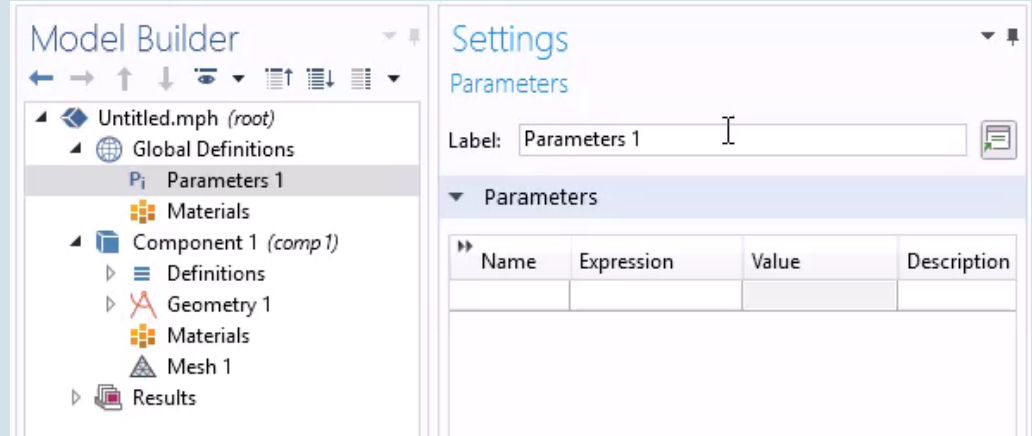
Left: Youtube video of demolition in 2019

Right: Wikipedia images.



# COMSOL Multiphysics

- Parameters definitions



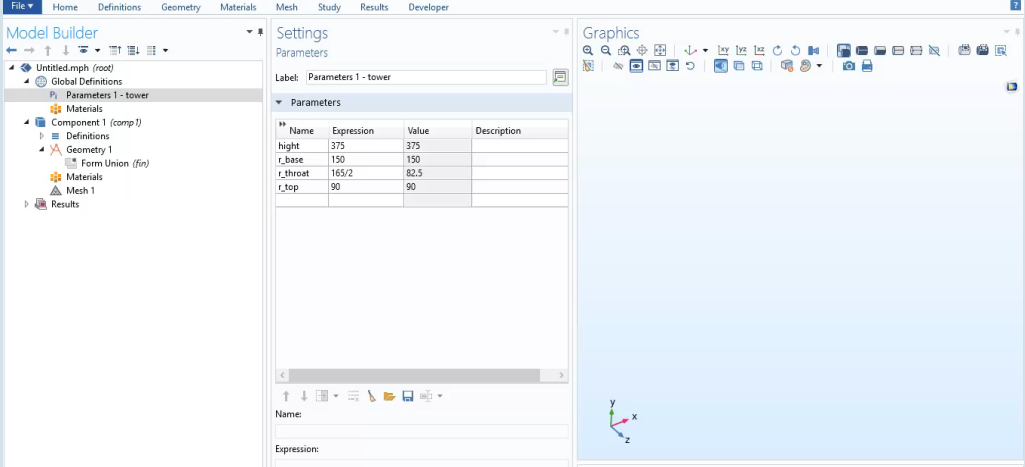
The screenshot displays the COMSOL Multiphysics software interface. On the left, the **Model Builder** panel shows a hierarchical tree structure for a model named "Untitled.mph (root)". The tree includes "Global Definitions" (containing "Parameters 1"), "Materials", "Component 1 (comp1)" (containing "Definitions", "Geometry 1", "Materials", and "Mesh 1"), and "Results".

On the right, the **Settings** panel is open for "Parameters 1". It features a "Label" field containing the text "Parameters 1". Below this, a table titled "Parameters" is visible, with the following structure:

Name	Expression	Value	Description

# COMSOL Multiphysics

- Parameters definitions
- Import / Building of geometry



The screenshot displays the COMSOL Multiphysics software interface. The top menu bar includes File, Home, Definitions, Geometry, Materials, Mesh, Study, Results, and Developer. The Model Builder window on the left shows a tree view with the following structure:

- Untitled.mph (root)
  - Global Definitions
    - Parameters 1 - tower
  - Materials
  - Component 1 (comp 1)
    - Definitions
    - Geometry 1
      - Form Union (fir)
    - Materials
    - Mesh 1
  - Results

## Settings

### Parameters

Label: Parameters 1 - tower

#### Parameters

Name	Expression	Value	Description
height	375	375	
r_base	150	150	
r_throat	165/2	82.5	
r_top	90	90	

Name:

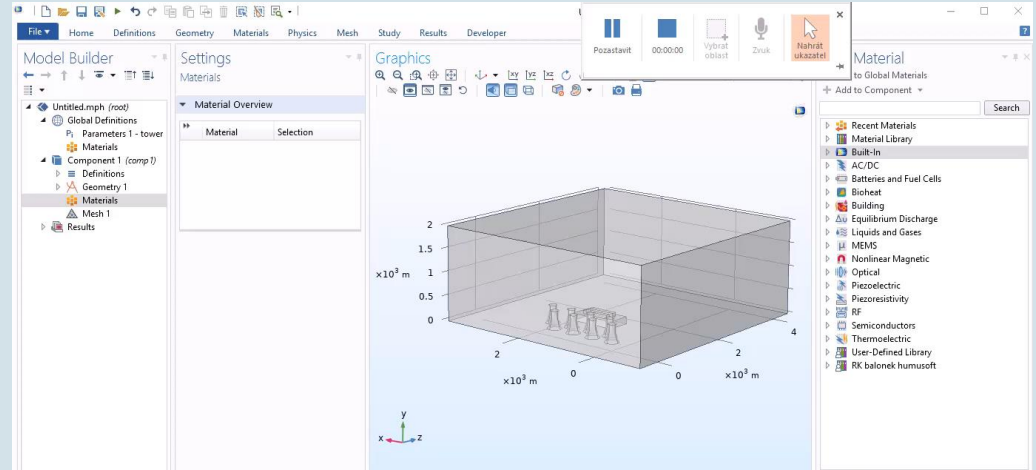
Expression:

## Graphics



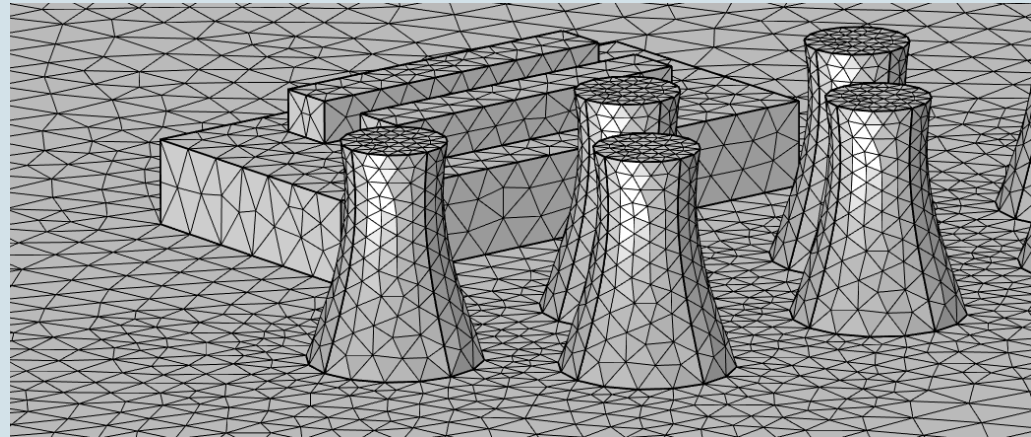
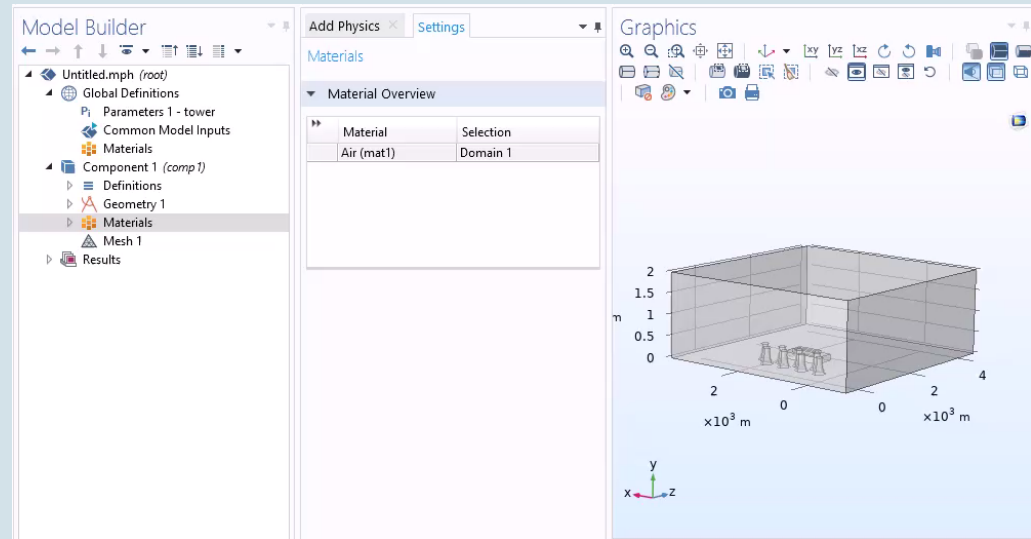
# COMSOL Multiphysics

- Parameters definitions
- Import / Building of geometry
- Material Library



# COMSOL Multiphysics

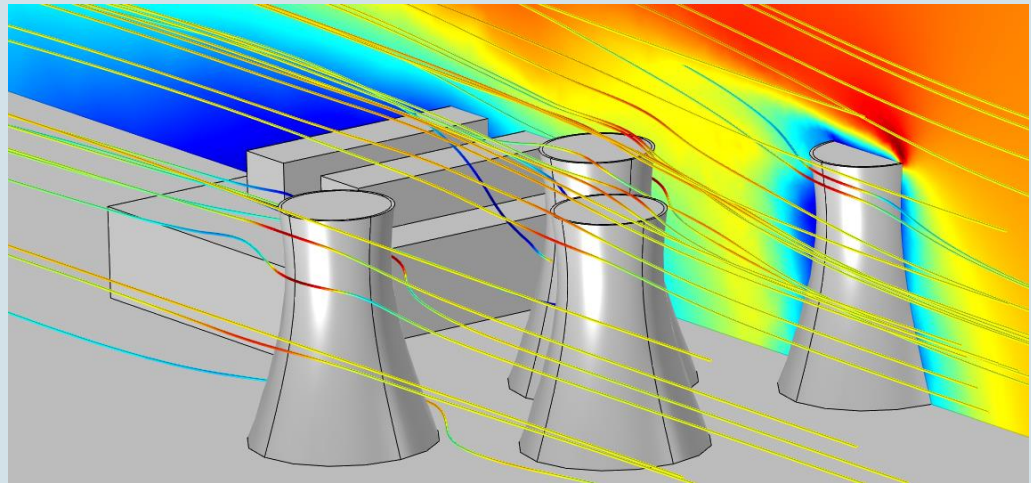
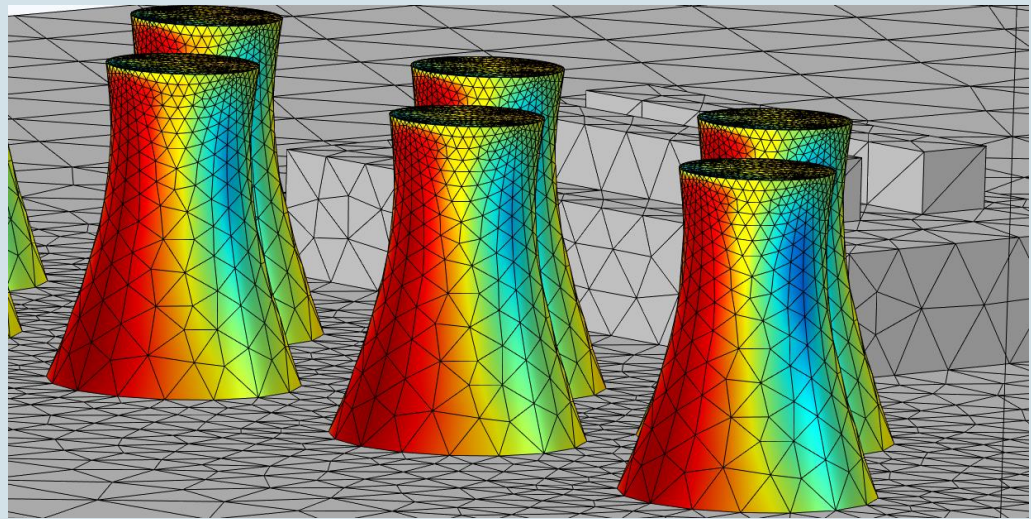
- Parameters definitions
- Import / Building of geometry
- Material Library
- Boundary / Initial conditions
- Meshing





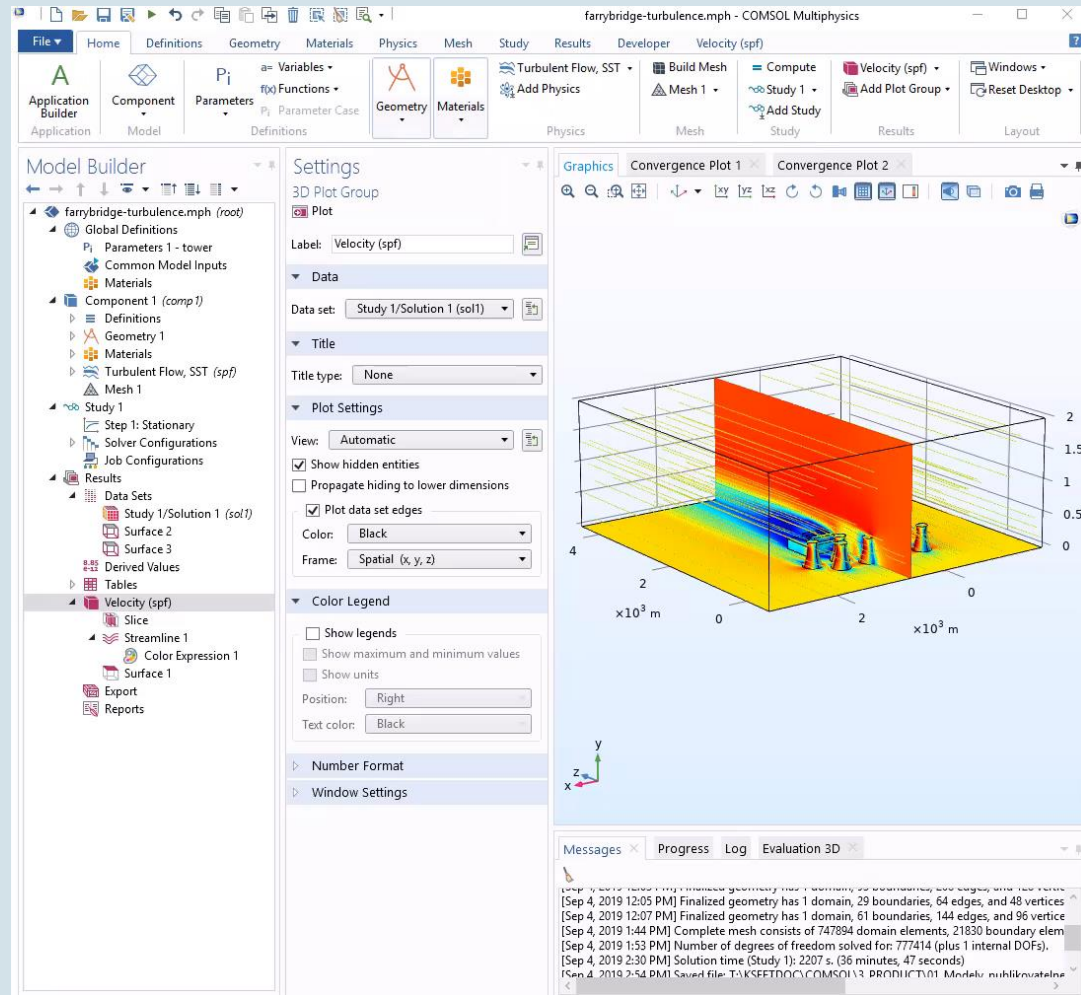
# COMSOL Multiphysics

- Parameters definitions
- Import / Building of geometry
- Material Library
- Boundary / Initial conditions
- Meshing
- Calculation
- Postprocessing of results
- Add another physics



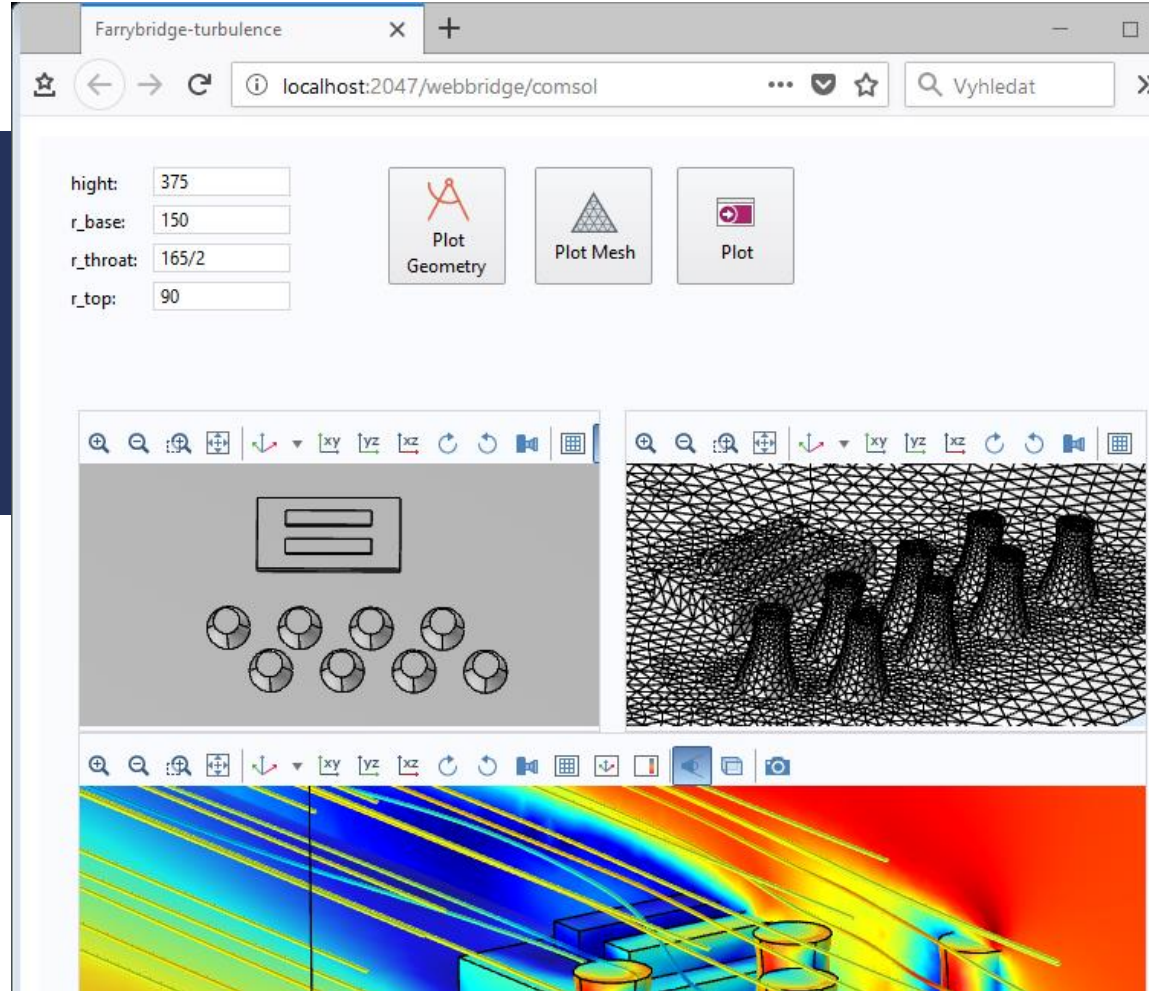
# COMSOL Multiphysics

- Parameters definitions
- Import / Building of geometry
- Material Library
- Boundary / Initial conditions
- Meshing
- Calculation
- Postprocessing of results
- Add another physics
- Create an application



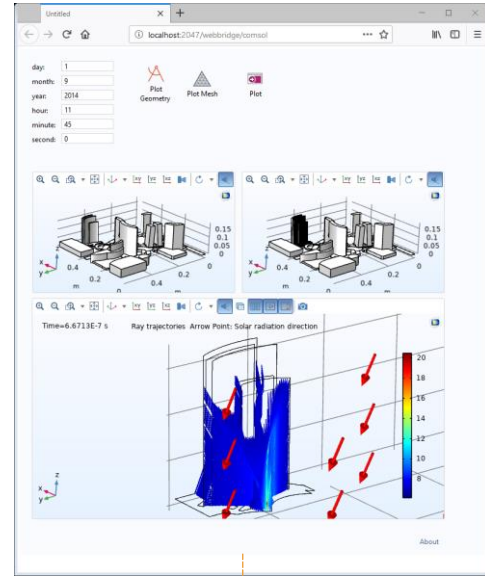
# COMSOL Server

- Access applications through a web browser
  - Passwords and user accounts
  - Only web browser needed
- Install COMSOL Server™ where you want:
  - Own server (inside your company)
  - Cloud using a cloud service



# COMSOL Compiler

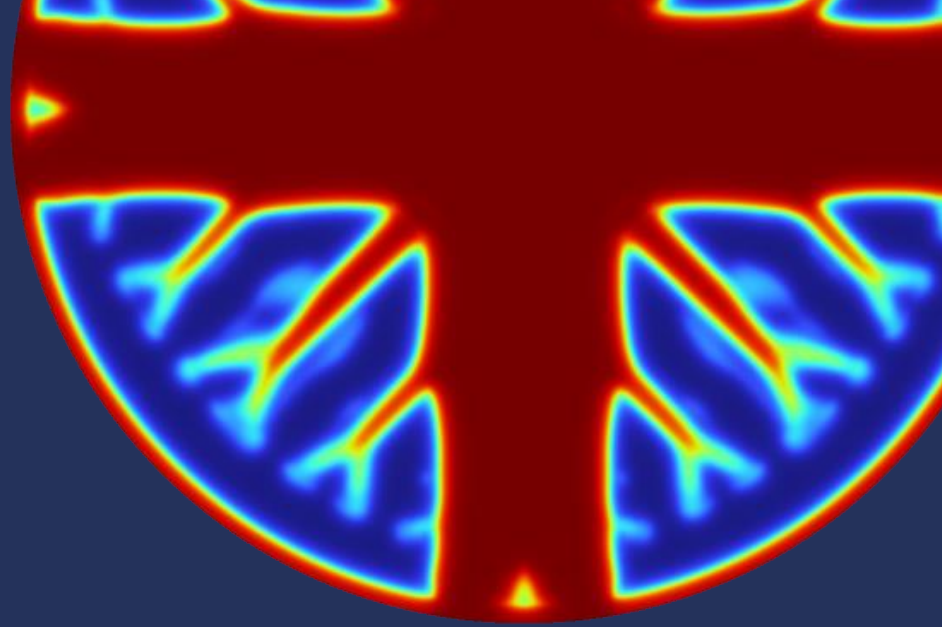
- Creates standalone executable program which does not require COMSOL Multiphysics to run
- License files for compiled apps



COMPILE applications  
with COMSOL Compiler™

INSTALL & RUN applications  
locally on Windows®, macOS, or Linux®

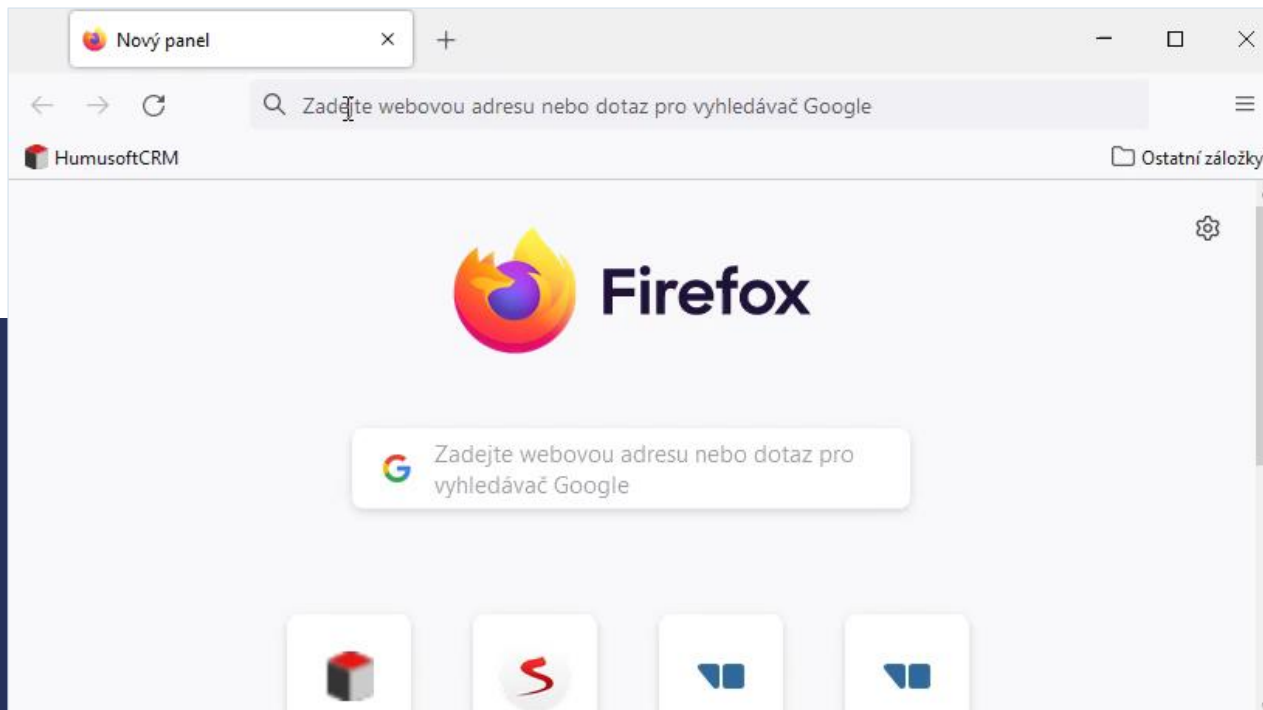





# Showcase: Topology Optimization of 3D-printed Heat Sink

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# Inspiration: COMSOL Conference 2018



# Inspiration: Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT



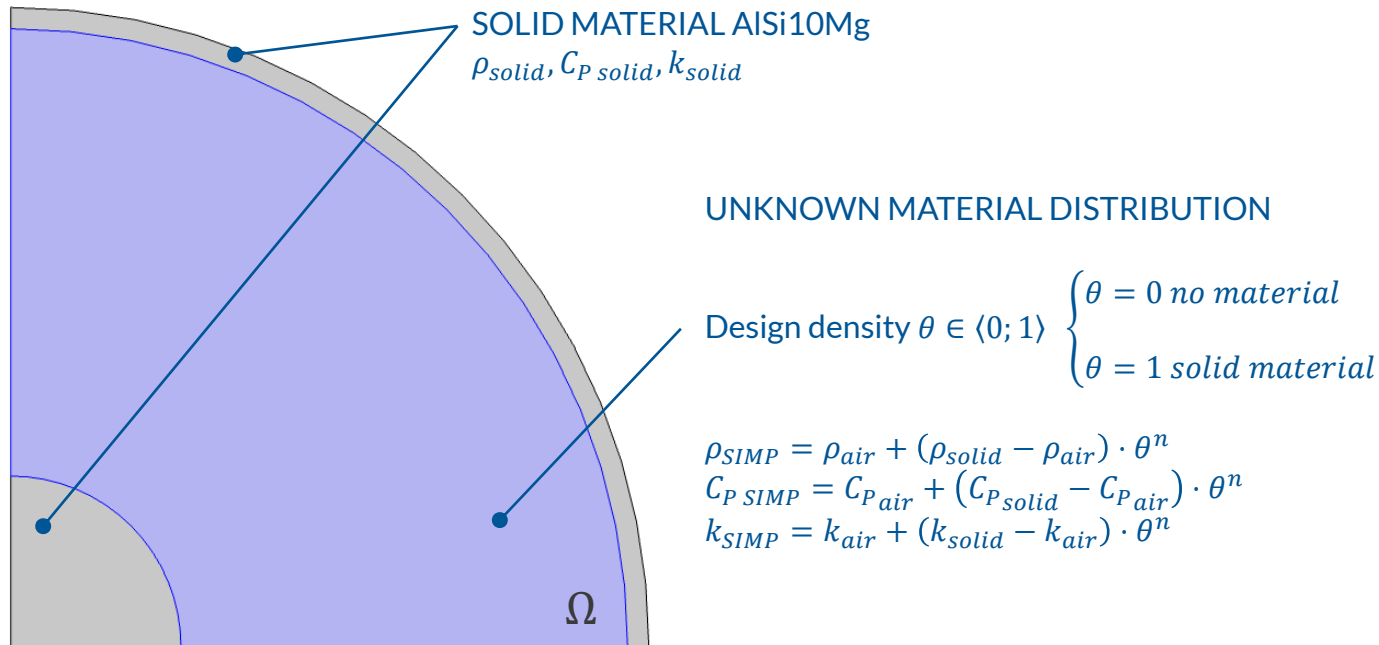
The image shows a YouTube video player interface. At the top left is the YouTube logo with 'c2' next to it. A search bar is located at the top right. The video content area displays the title 'Topology Optimization of AM Heat Sinks' in a large, bold font. To the right of the title is a 3D model of a heat sink with a complex, tree-like internal structure. The Fraunhofer IAPT logo is in the top right corner of the video area. Below the title is a 'future AM' logo with icons for a factory, a bar chart, a network, and a gear. The video player controls at the bottom include a play button, a progress bar showing '0:00 / 2:06', and various settings icons.

Topology Optimization of 3D Printed Heat Sinks

Source: <https://youtu.be/dnsR9bS9Quo>

# Material distribution method

- Penalization scheme SIMP (Solid Isotropic Microstructure with Penalization)





# Governing Equation

- Fourier's Law

$$-\nabla \cdot (k\nabla T) = Q$$

T = Temperature

K = Thermal conductivity

Q = volumetric heat source

# Objective function

- Objective 1: minimizing the total variation of the temperature in the design domain  $\Omega$

$$f_1 = \int k_{SIMP} (\nabla T)^2 d\Omega$$

- Objective 2: mesh independent restriction of a given minimum wall thickness

$$f_2 = \frac{h_0 h_{max}}{A} \int |\nabla \theta(x)|^2 d\Omega$$

- Complete objective function: balance between best thermal conductor and printable design

$$f_{objective} = (1 - q) \cdot \int k_{SIMP} (\nabla T)^2 d\Omega + q \cdot \frac{h_0 h_{max}}{A} \int |\nabla \theta(x)|^2 d\Omega$$

# Constraint

- Limited solid fraction  $\gamma \in (0; 1)$  of the domain area  $A$

$$0 \leq \int \theta(x) d\Omega \leq \gamma A$$

# Let's look at the modeling process

If you want to try it yourself, let me know!

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