

Fremtidens Matematik

COMSOL
MULTIPHYSICS®

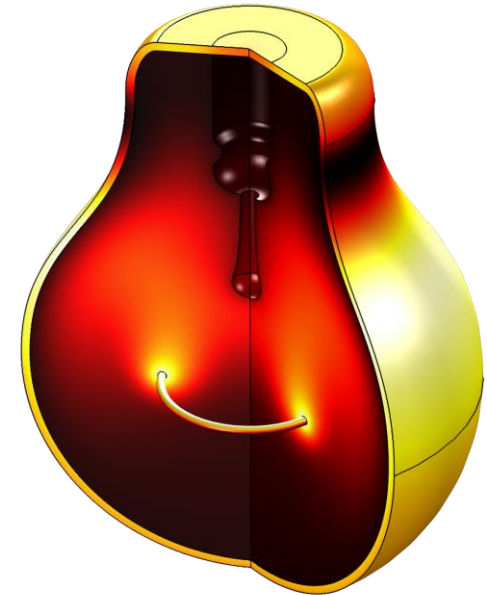


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Agenda

- Baggrund
 - COMSOL og IDA Matematik
- COMSOL Multiphysics
 - Udvikling
 - Anvendelse
- Matematisk software
 - Hvad kan vi lære af historien

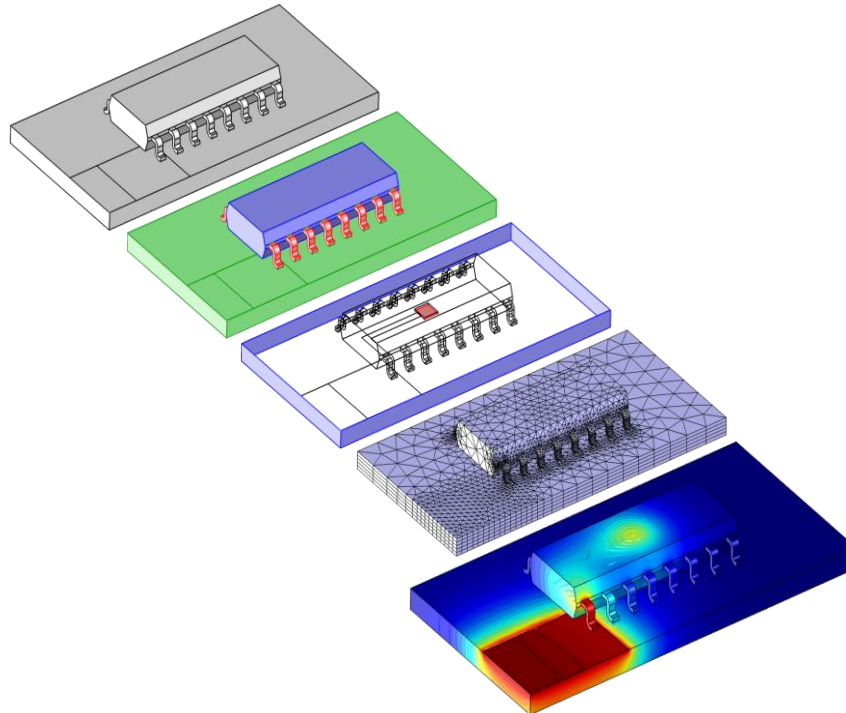


Baggrund

- Kemiingeniør.
- ErhvervsPHD fra Novo Nordisk og Institut for Kemiteknik, DTU.
- Områder
 - Matematisk modellering, regulering, multivariabel statistik, neurale netværk, optimering, parameterestimering.
- Arbejder for COMSOL (Lyngby)
 - Marketing, salg, udvikling, konsulent
- Formand for IDA Matematik.

COMSOL

- Mission
 - To develop easy-to-use **software** for modeling and simulation of real world multiphysics systems.
 - To assist **our users** in getting the most out of our products.



Worldwide Sales Offices

- 18 offices in Europe, India and USA, Distributor network
- +400 employees.
- More than 90.000 users.

- 10 ansatte i Danmark
(9 mastergrad, 2 Ph.D.)

● COMSOL OFFICES
● COMSOL DISTRIBUTORS

IDA Matematik



- Fagteknisk selskab under IDA
 - Ca. 1200 medlemmer fordelt over hele Danmark
- Afholder fortrinsvis gå-hjem-møder:
 - Vind og vejr, økonomi, kryptografi, bitcoin, akustik, farmakokinetik, grafik til spil, topologi-optimering, strømning, statistik, machine learning, ...
- Konference om matematisk software (2012)
 - Maple, Mathematica, MathCad, COMSOL, Mosek, MATLAB.
- Kontakt mellem virksomheder og studerende.

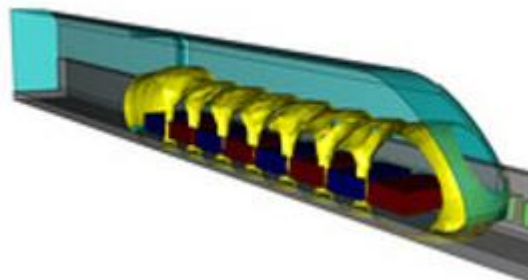
IDA Matematik

$$\blacksquare = \text{D} + \wedge$$



- Gå-hjem-møder

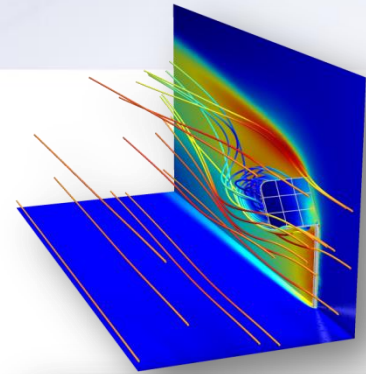
- Som regel nemt at få folk til at snakke om det de laver
- Få personer definerer sig som matematikere
- Vi vil gerne se ligninger
- ...og også gerne praktiske resultater
- Send gerne forslag til mig ...



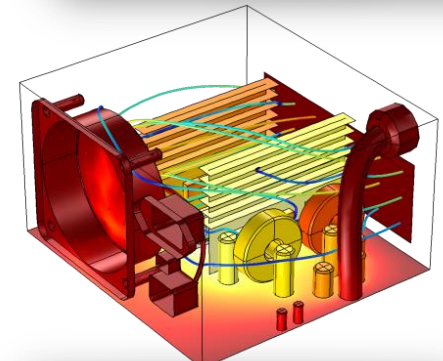
$$\begin{aligned}\nabla \times \mathbf{E} &= -\frac{\partial \mathbf{B}}{\partial t} \\ \nabla \times \mathbf{H} &= \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t} \\ \nabla \cdot \mathbf{D} &= \rho \\ \nabla \cdot \mathbf{B} &= 0\end{aligned}$$

What is COMSOL Multiphysics?

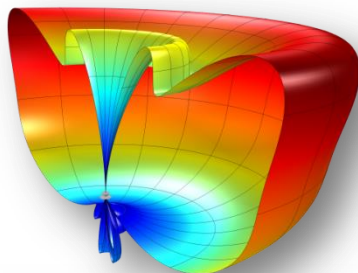
- More than one physics acting at the same time
 - Coupling between physics
- Multiple single physics problems
 - No coupling between physics



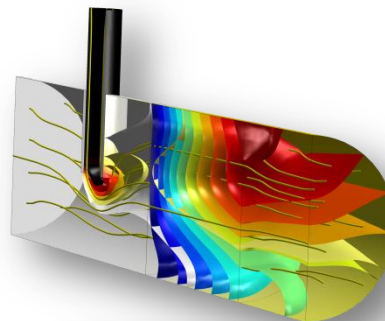
Fluid-Structure Interaction of a Solar Panel



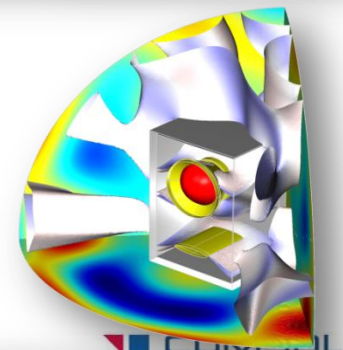
Cooling of electronic components



Radiation Pattern of a Broadband Conical Antenna

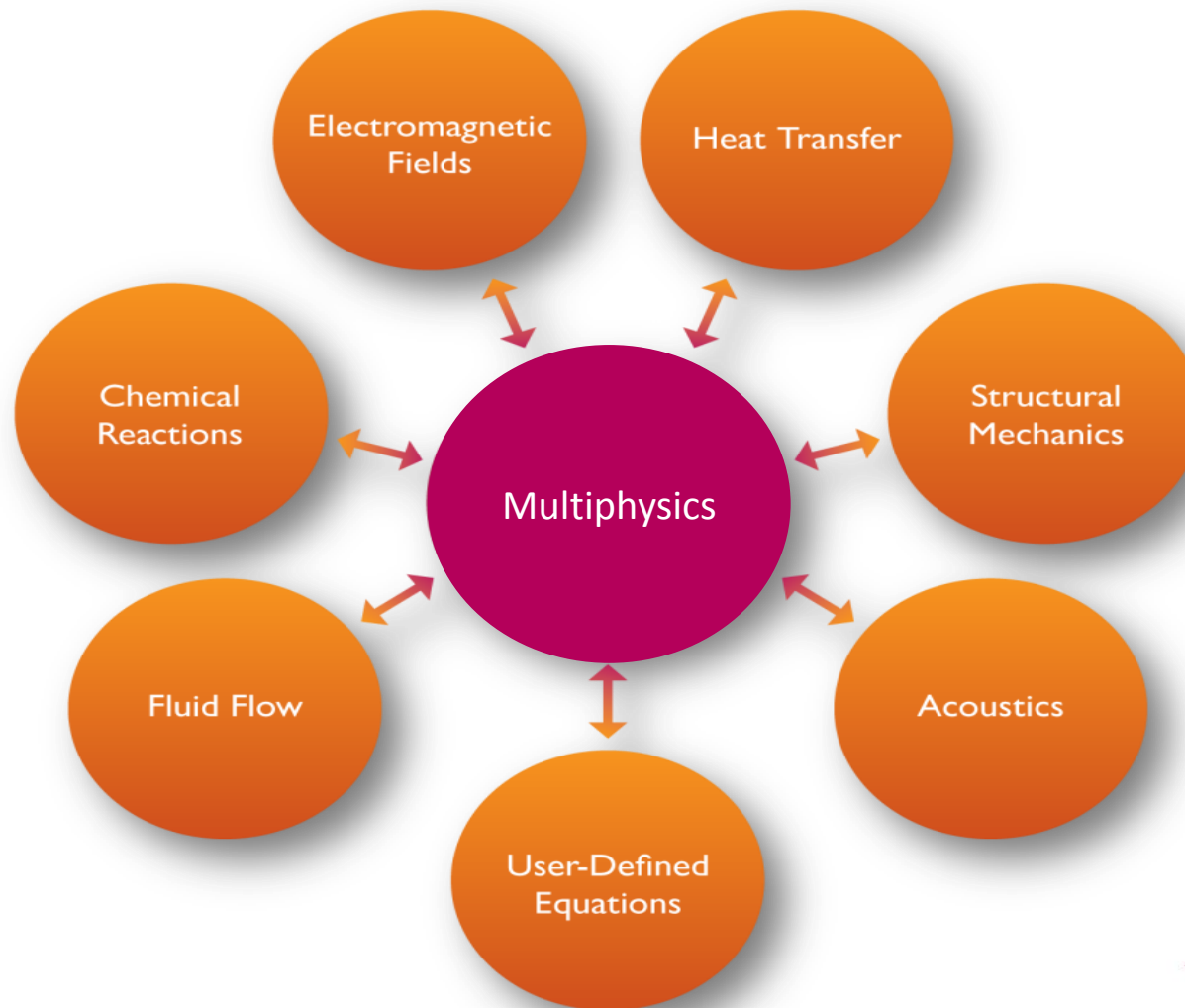


Porous Reactor



Acoustics Speaker Systems

Real Systems are Multiphysics Systems



Interactive Modeling Environment

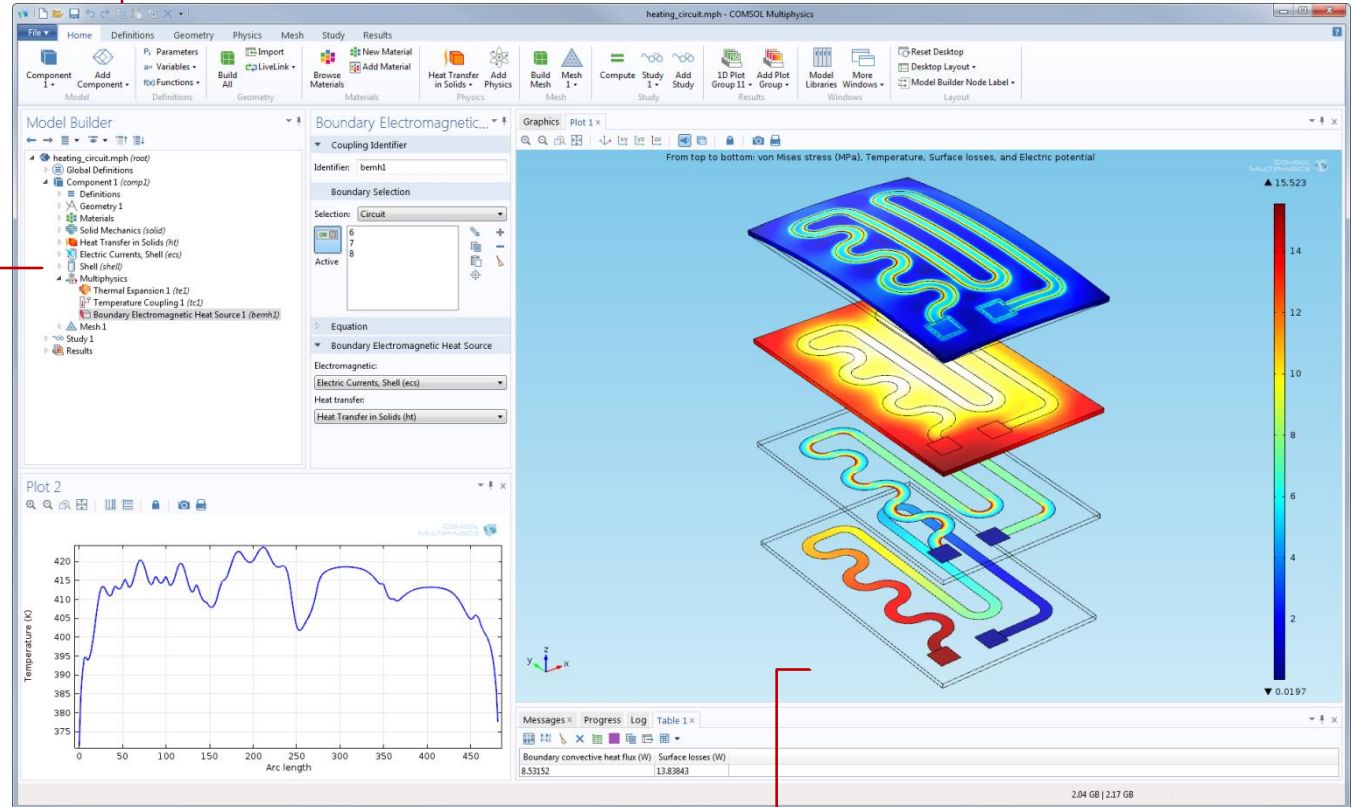
COMSOL Desktop®

Straightforward to use, it gives full insight and control over the modeling process

Model Builder

Provides instant access to any part of the model settings

- CAD/Geometry
- Materials
- Physics
- Mesh
- Solve
- Results



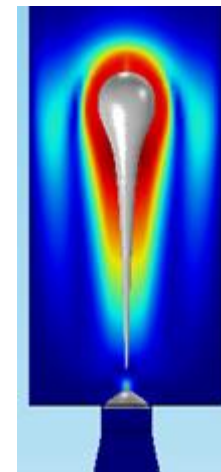
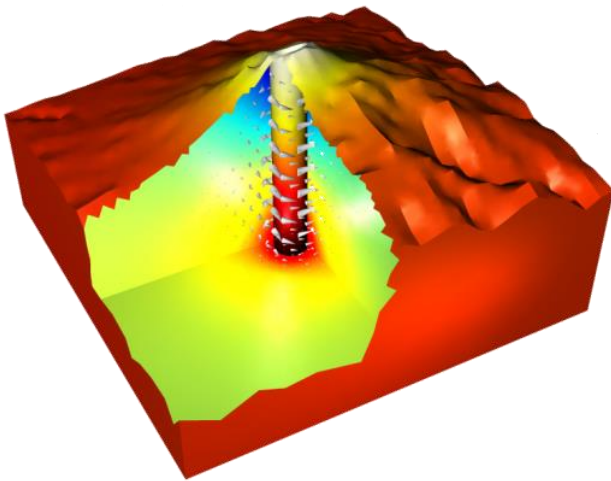
Graphics

Ultrafast graphic presentation, stunning visualization, and multiple plots

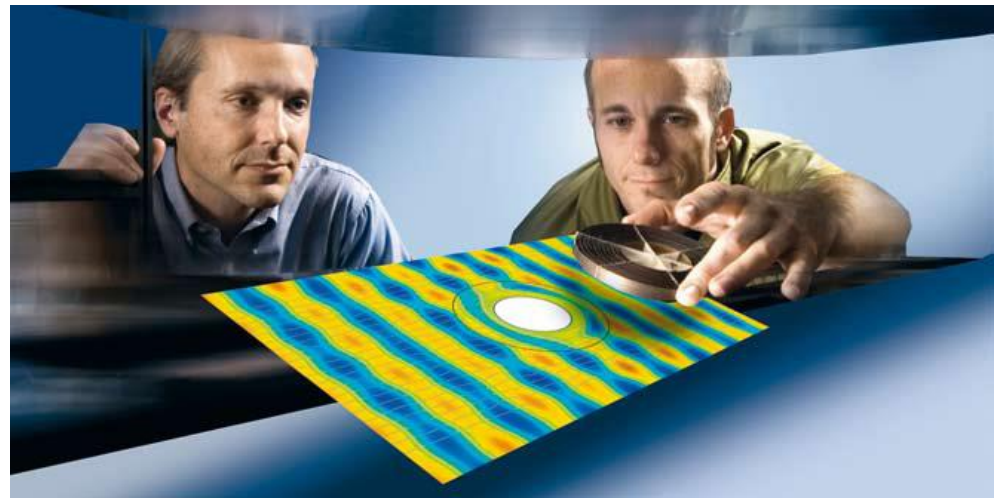
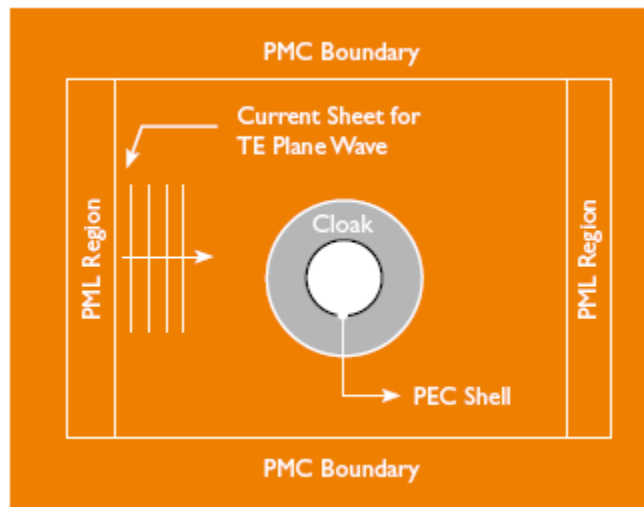
Equations (coef. Form)

$$d_a \frac{\partial u}{\partial t} - \nabla \cdot (c \nabla u + \alpha u - \gamma) + \beta \nabla u + au = f \quad \text{inside subdomain}$$

$$\left. \begin{aligned} n \cdot (c \nabla u + \alpha u - \gamma) + qu &= g + h' \mu \\ hu &= r \end{aligned} \right\} \quad \text{on subdomain boundary}$$



Modelling metamaterials



Steve Cummer (left) and David Schurig both from Duke University, Durham, NC.

We chose COMSOL because it is likely the only commercial simulation tool that enables the user to specify the shell's unusual electromagnetic properties.

The Ginzburg-Landau Equation Solved by the Finite Element Method

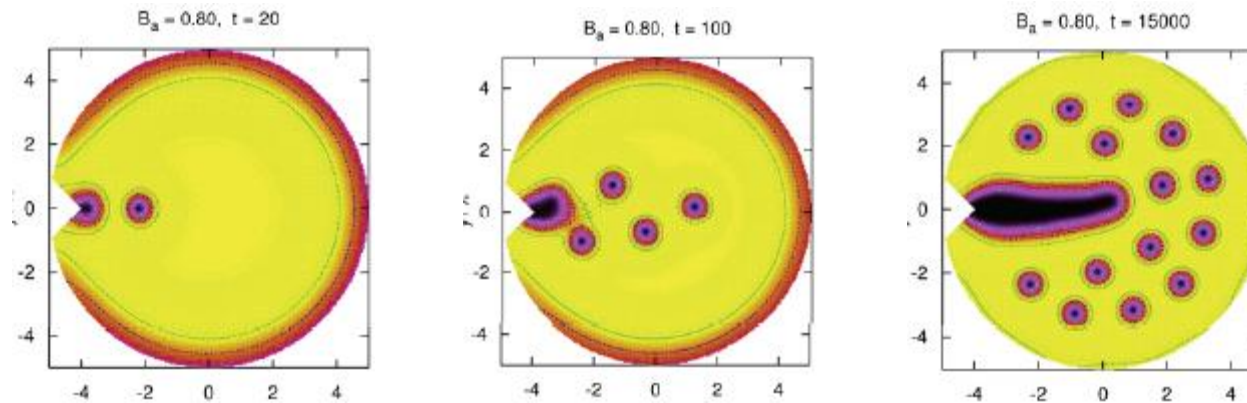
- **Mads Peter Sørensen**, Tommy S. Larsen, MAT, DTU. Niels Falsig Pedersen and Søren Madsen, Ørsted, DTU

- The Ginzburg-Landau equation coupled to a magnetic field:

$$\frac{\hbar^2}{2mD} \left(\frac{\partial}{\partial t} + i \frac{q}{\hbar} \Phi \right) \Psi = - \frac{1}{2m} \left(\frac{\hbar}{i} \nabla - qA \right)^2 \Psi + \alpha \Psi - \beta |\Psi|^2 \Psi$$

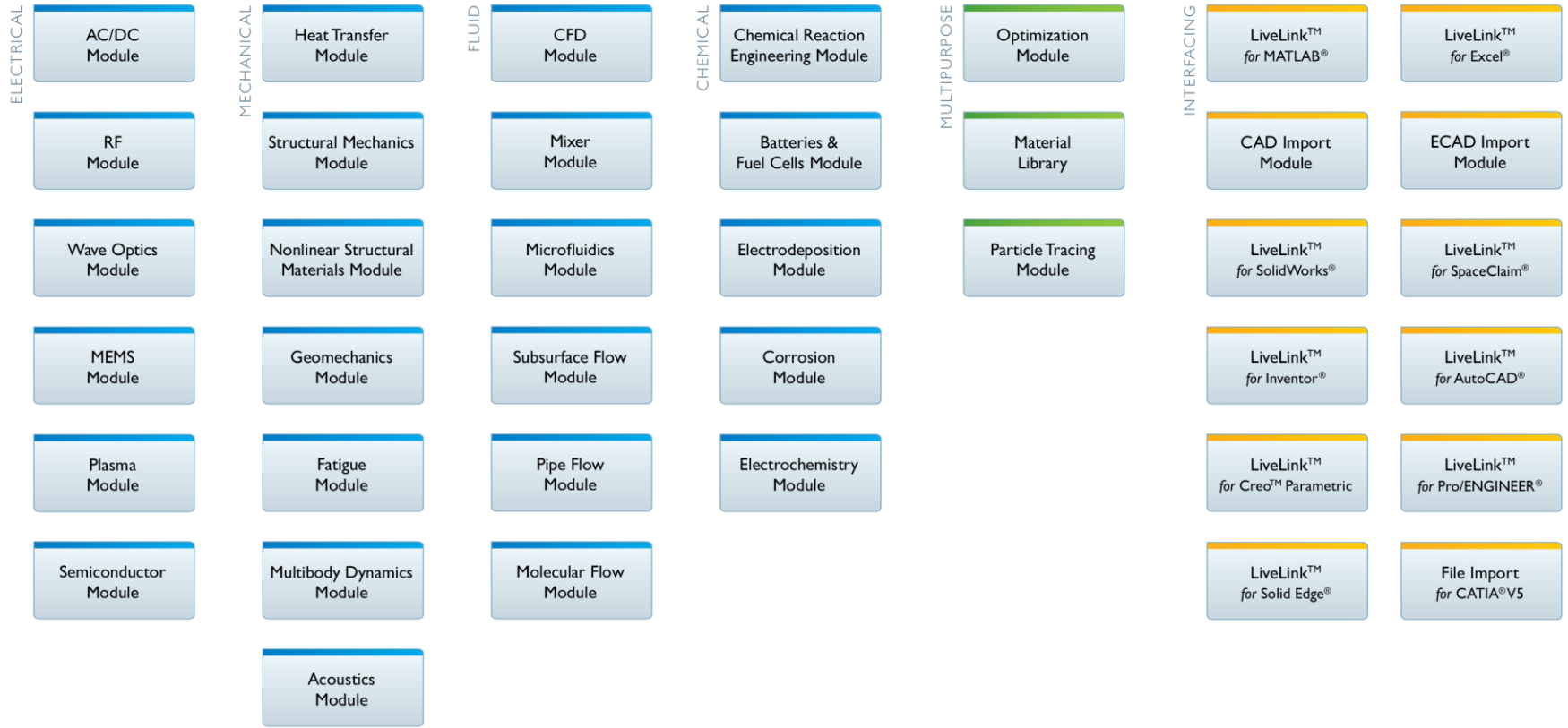
- The equation for the magnetic vector potential A:

$$\sigma \left(\frac{\partial A}{\partial t} + \nabla \Phi \right) = \frac{q\hbar}{2mi} (\Psi^* \nabla \Psi - \Psi \nabla \Psi^*) - \frac{q^2}{m} |\Psi|^2 A - \frac{1}{\mu_0} \nabla \times \nabla \times A$$



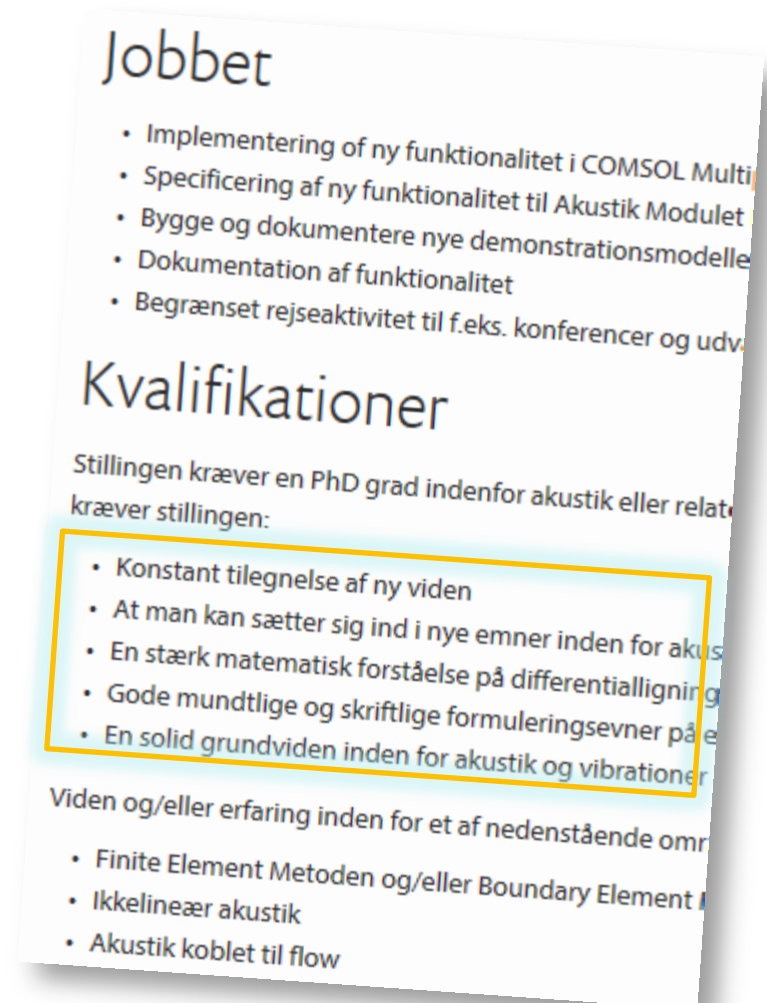
Product Suite – COMSOL 4.4

COMSOL Multiphysics®



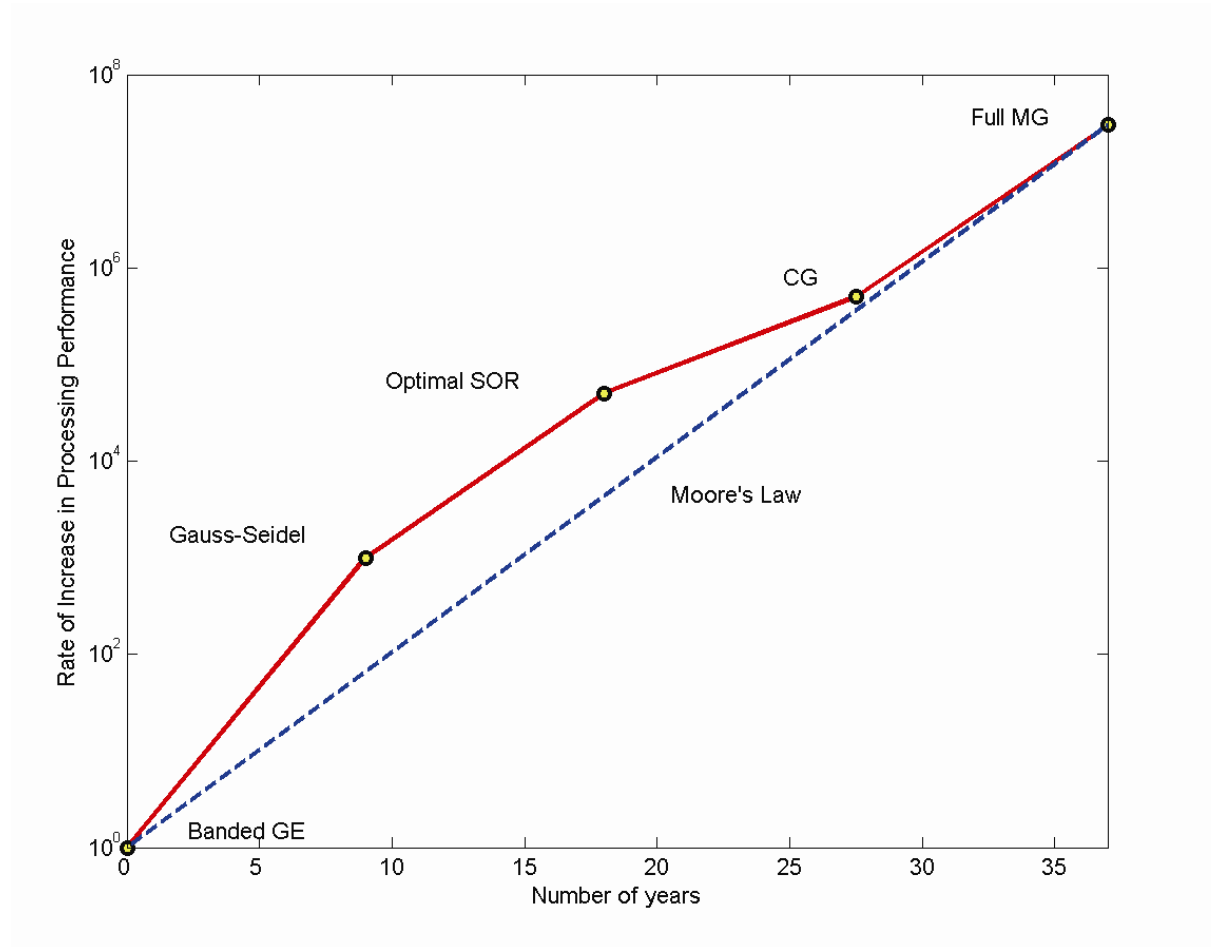
Udviklere

- Konkurrence fra hele verden
 - Udvikling i Sverige, USA, Danmark, Frankrig, Indien ...
 - Ansøgere fra hele verden.
- Skaber ny viden og metoder
 - Gode kontakter til betydende universiteter over hele jorden.
 - God indsigt i hvad virksomheder gerne vil have.
- Internationalt miljø

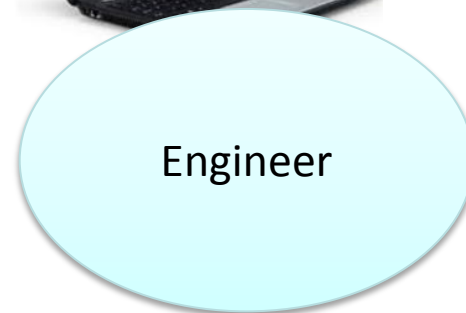
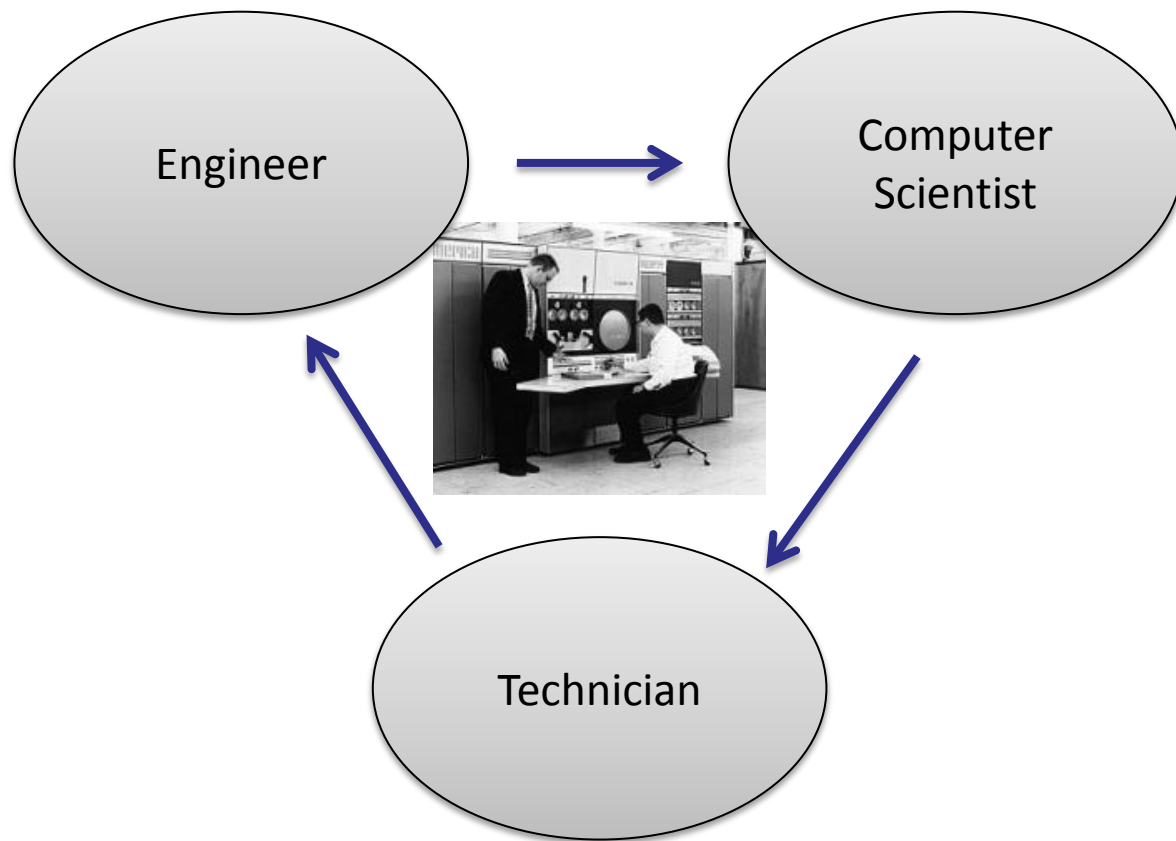


www.comsol.dk/company/careers

Udvikling i regnekraft

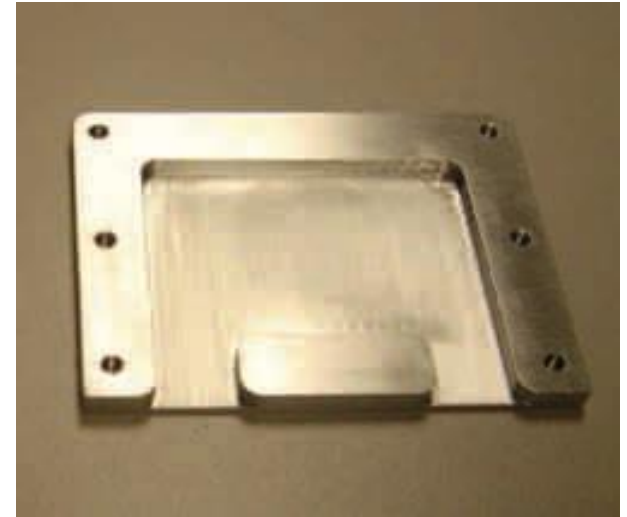


Udvikling i måden at arbejde på



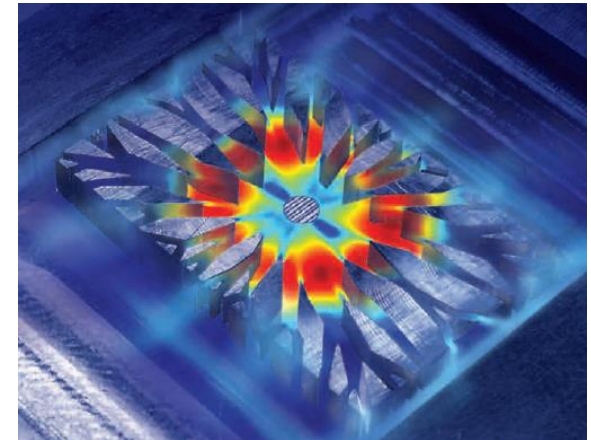
TOYOTA RESEARCH INSTITUTE

- By combining jet impingement with a peripheral channel structure, Toyota was able to create a process to remove the most heat with the least pressure drop
- Modeling showed the optimal cooling channel topology for the cold plate design
 - Using this topology, they designed and evaluated a prototype to verify pressure drop and heat transfer



Matematisk Modellering

- Opnå resultater
 - Forstå den eksisterende process eller idé.
 - Optimere.
 - Spare tid (virtuelle prototyper).
 - Spare penge.
- Dokumentere
 - Modellen er "levende" dokumentation.
 - Kan let overtages af andre.



Konklusion

- Matematik er tæt forbundet til anvendelse og/eller udvikling af software.
- Matematisk software er som regel meget nem at anvende
 - Sparet tid
 - mulighed for bedre forståelse vs. hurtige, nemme resultater.
 - Kræver matematisk og fysisk forståelse.

Mere information

- IDA Matematik
 - www.ida.dk/netvaerk -> It, Tele og Elektroteknik
 - Bitcoin: 26. maj 2014.
- COMSOL Multiphysics
 - www.comsol.dk
 - Workshops: www.comsol.dk/events
 - Konference: www.comsol.dk/conference2014
- Email: larsg@comsol.dk