TECHNIA

ADDNODE GROUP

# Addressing the challenges of multi-physics at multi-scales

EXPERIENCE MATTERS

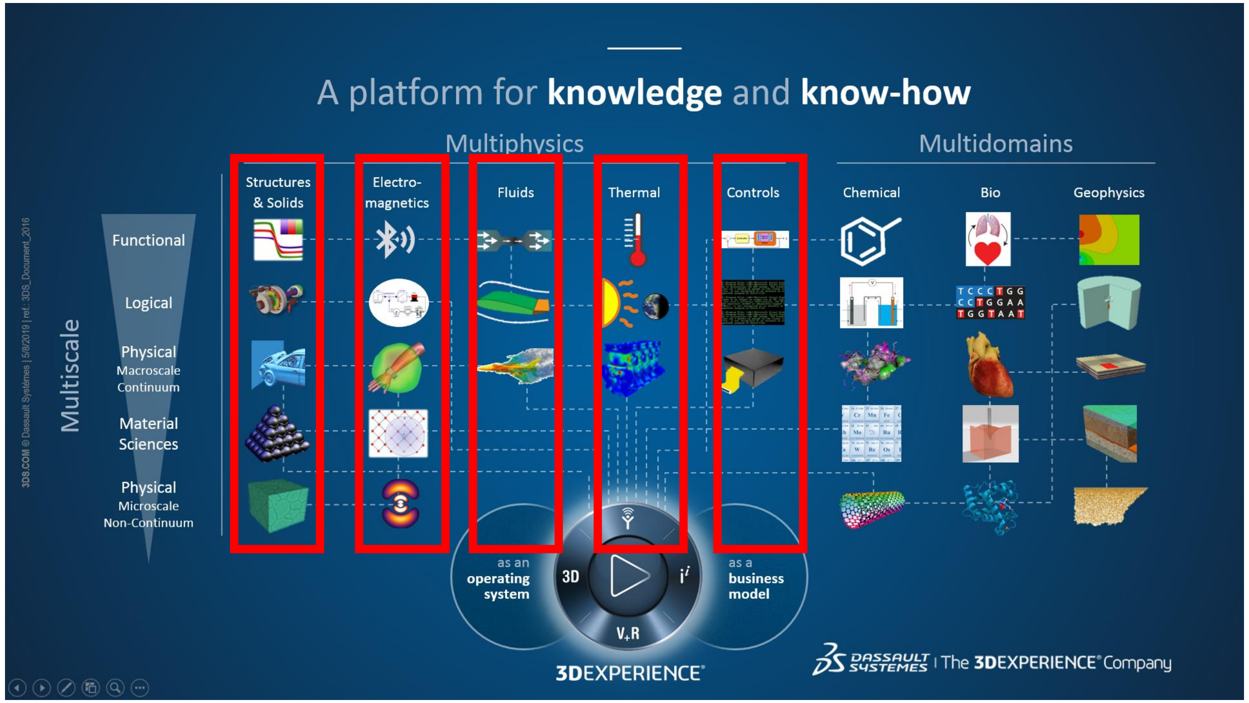
# Finding the pattern

# The challenge of multi-physics across multi-scales..

- Multiple single physics
- Coupled physics problems
- Working across the length scales

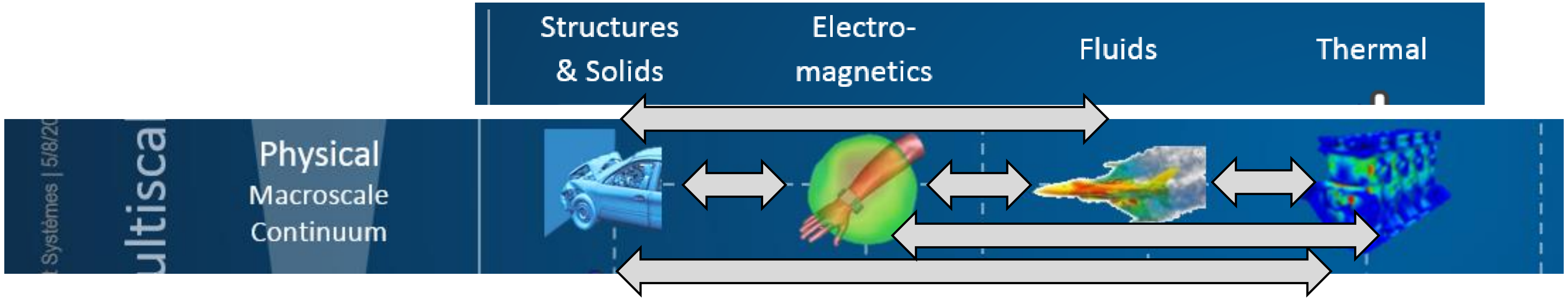
# Multiple single physics

- Most simulation usage is in a single physics domain.



# Coupled physics problems

- Loosely coupled field problems are relatively common
- Closely coupled field problems less so
- Closely coupled true multi-physics problems are thankfully rare

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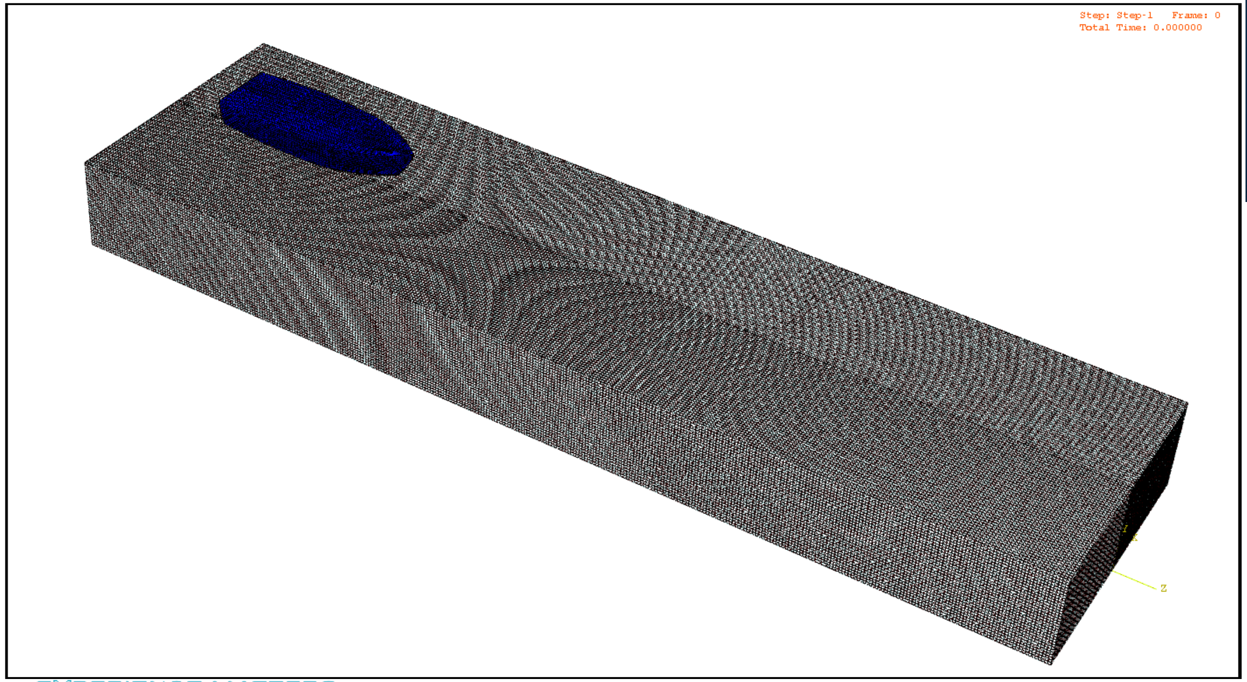
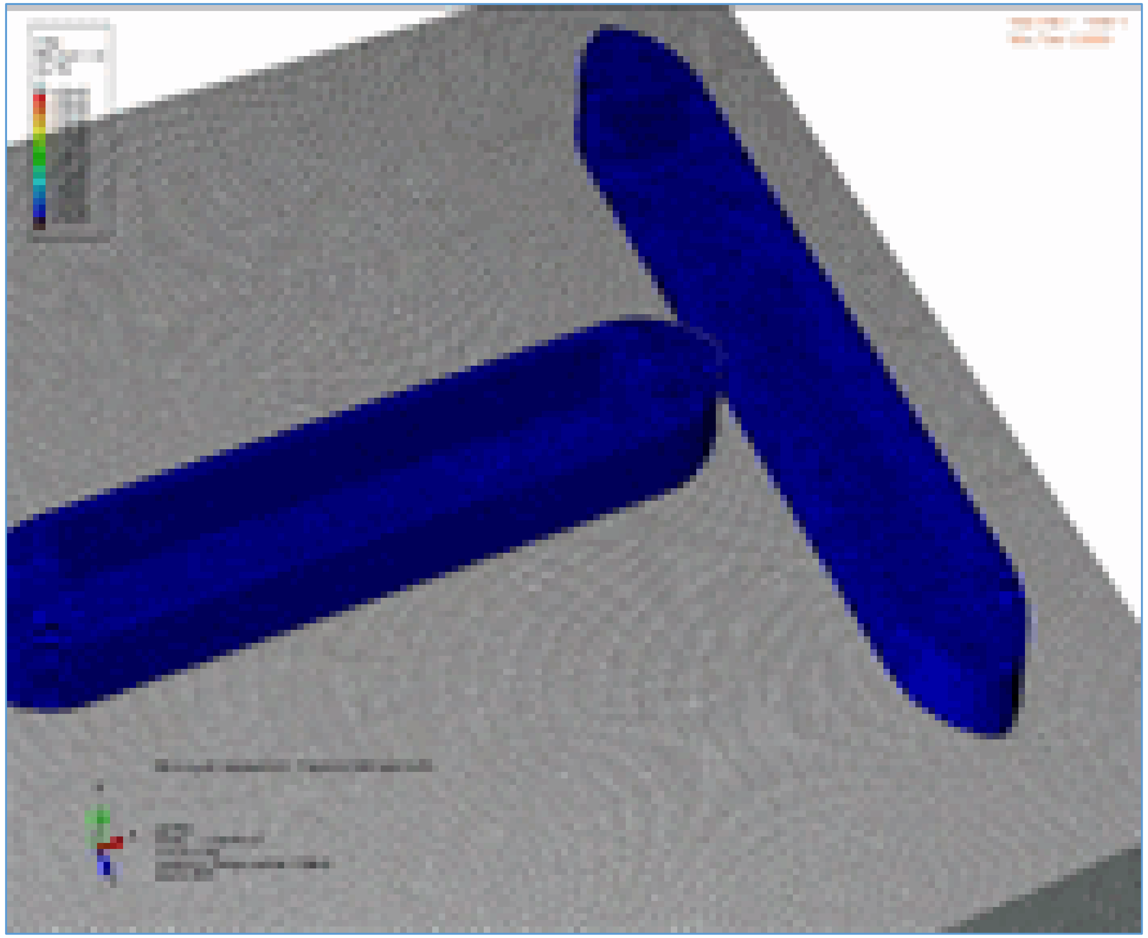



Closely coupled fluid structural interaction problem

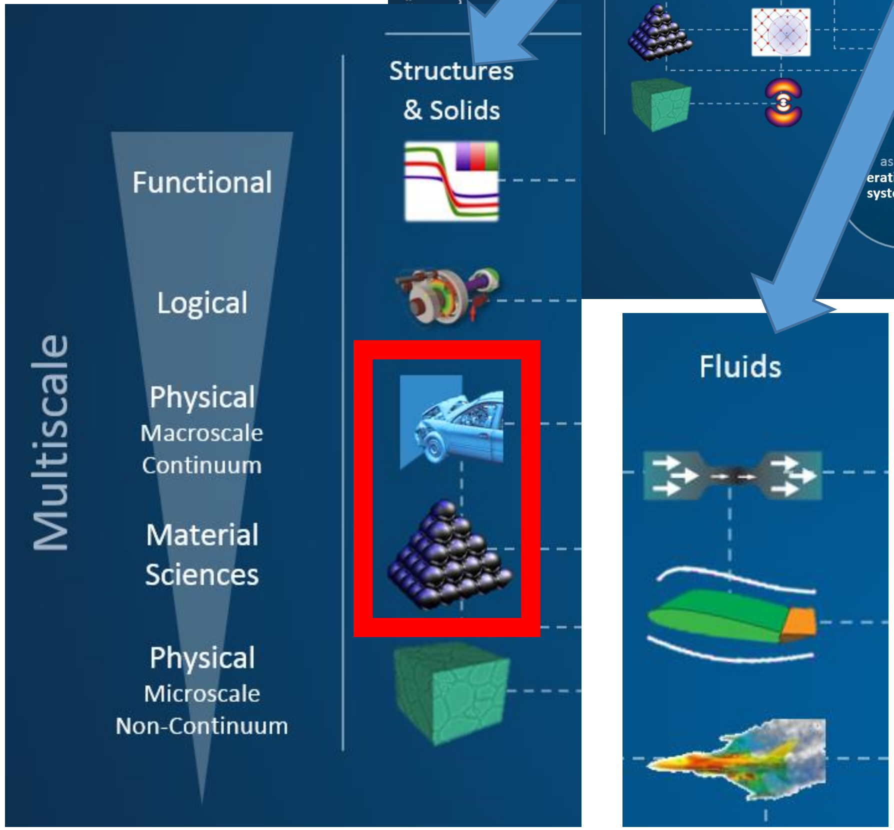
# Coupled physics problems




This model highlights a problem with big results sets..

# Multi-scale analysis

- Analysing systems, assemblies, components and is routinely carried out
- Simulations where the various length scales are considered together are less common *


*unless you are talking about CFD when you've never really had any choice because of turbulence.

# Multi-scale analysis

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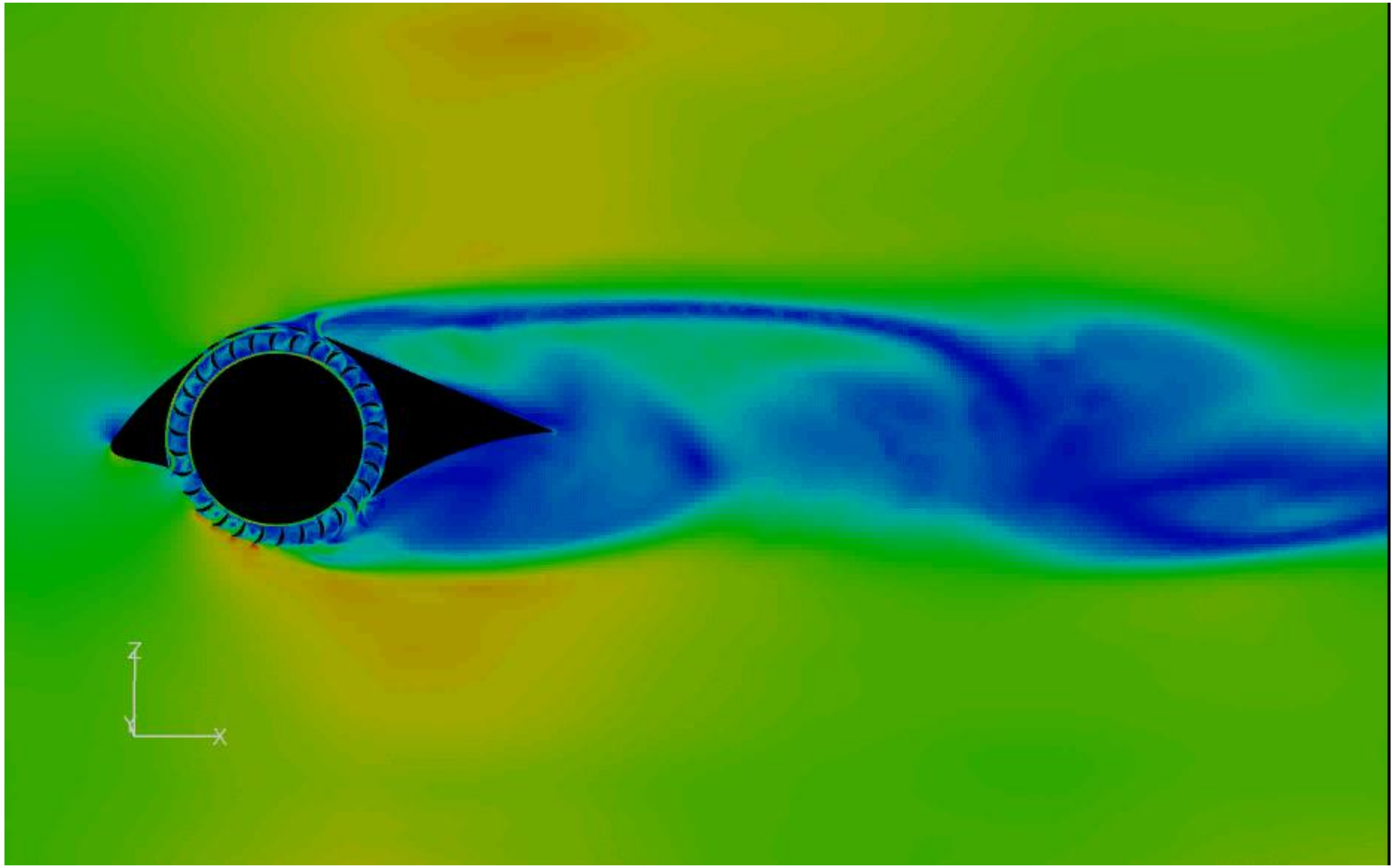
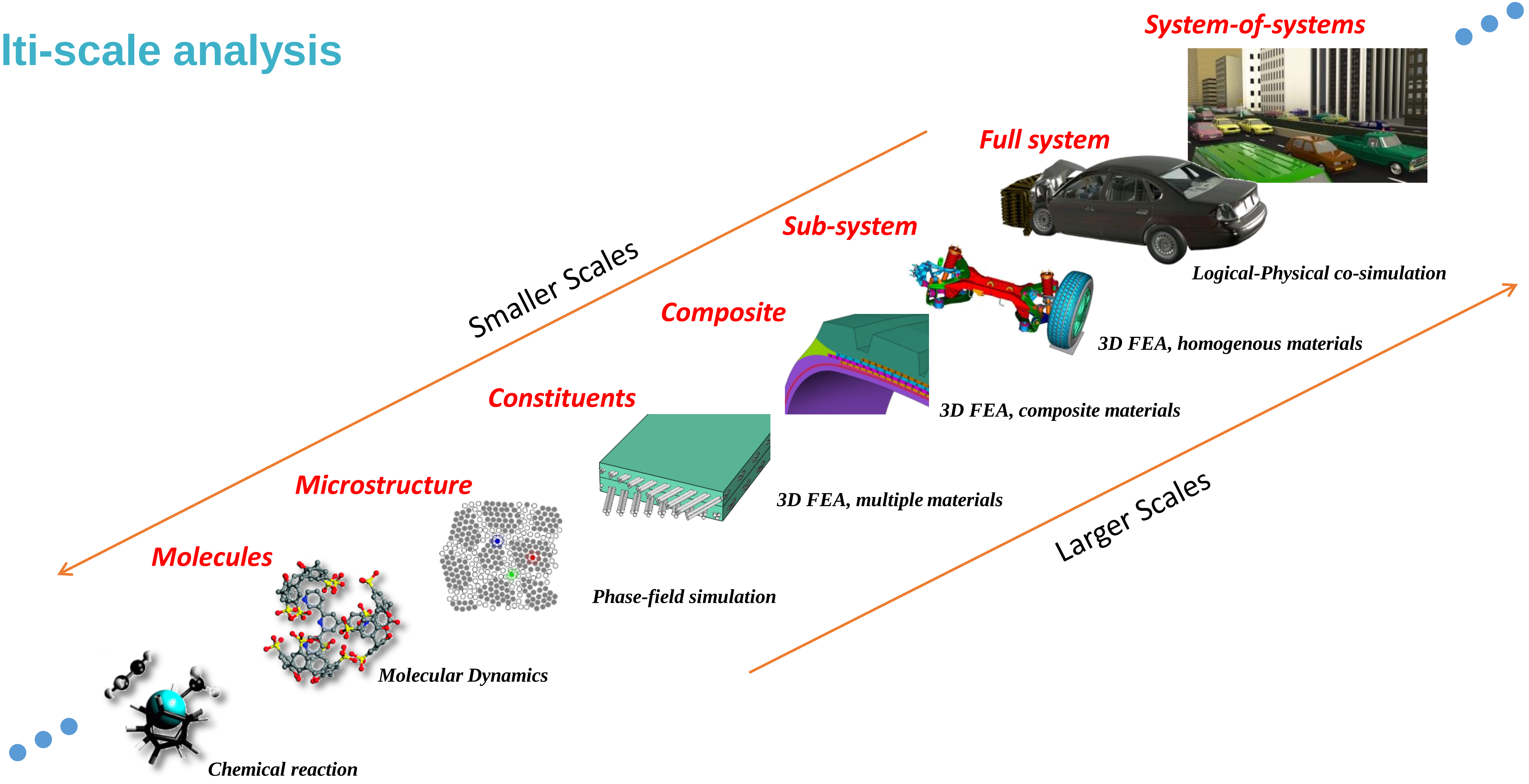
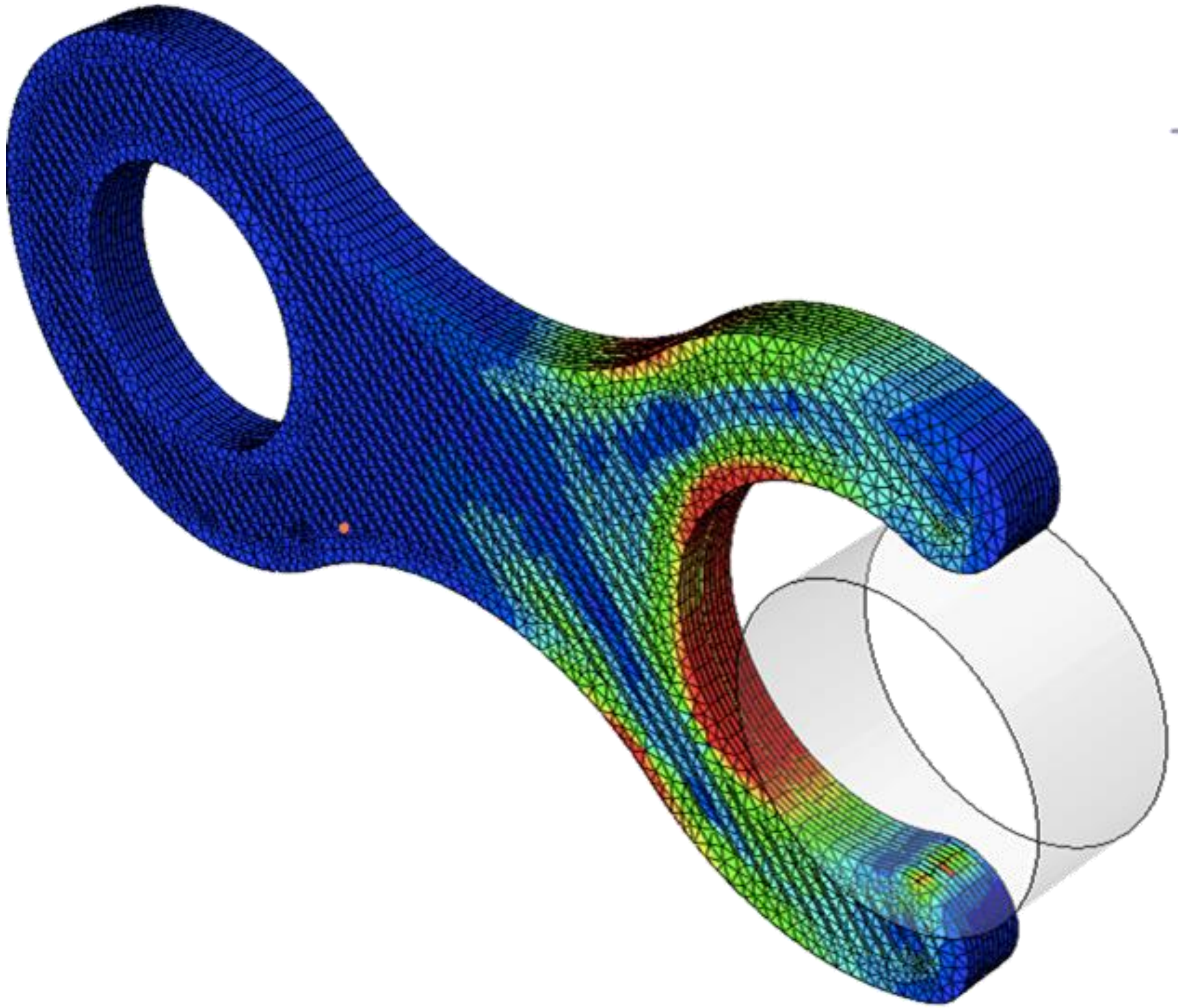


# Multi-scale analysis



# Multi-scale analysis

- We can assume that components are made of uniform single materials
- We can model the actual internal material structure
- Or we can model the material as a mixture of different materials which interact with each other and the component which is made from them.



# Multi-scale analysis

- Representative volume elements
- Mean field homogenisation
- Model a small section of the material and use this instead of saying “steel” or “aluminium”
- FE$^2$ approaches

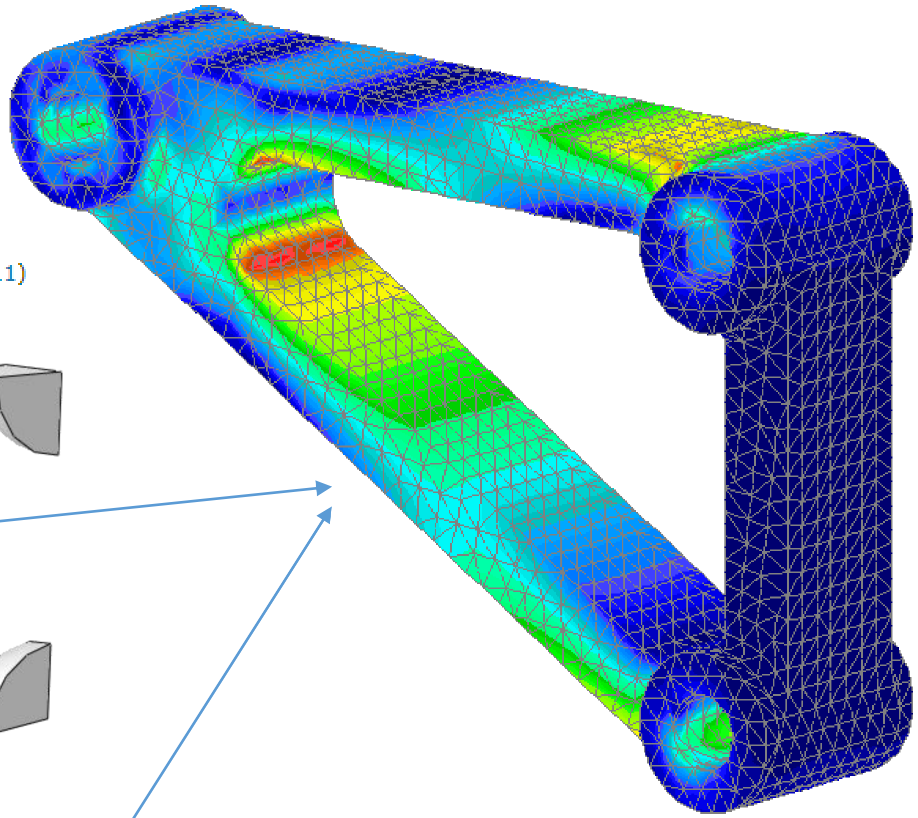
$$H_1 = \left[E : (C_M^{-1} C_I - I) + I\right]^{-1},$$

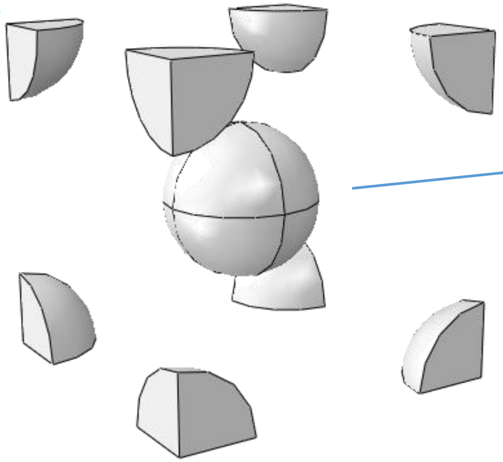
$$H_2 = \left[E : (C_I^{-1} C_M - I) + I\right]^{-1},$$

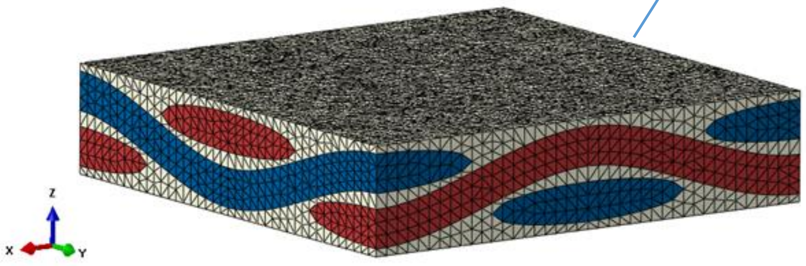
$$A = \left[(1-\varphi) H_1^{-1} + \varphi H_2^{-1}\right]^{-1},$$

where $\varphi$ is the smooth interpolation function proposed by Lielens (11)

$$\varphi = \frac{1}{2} v_f^I \left(1 + v_f^I\right).$$








Composite
**Crystal structure**
Biomaterial

# Multi-scale analysis

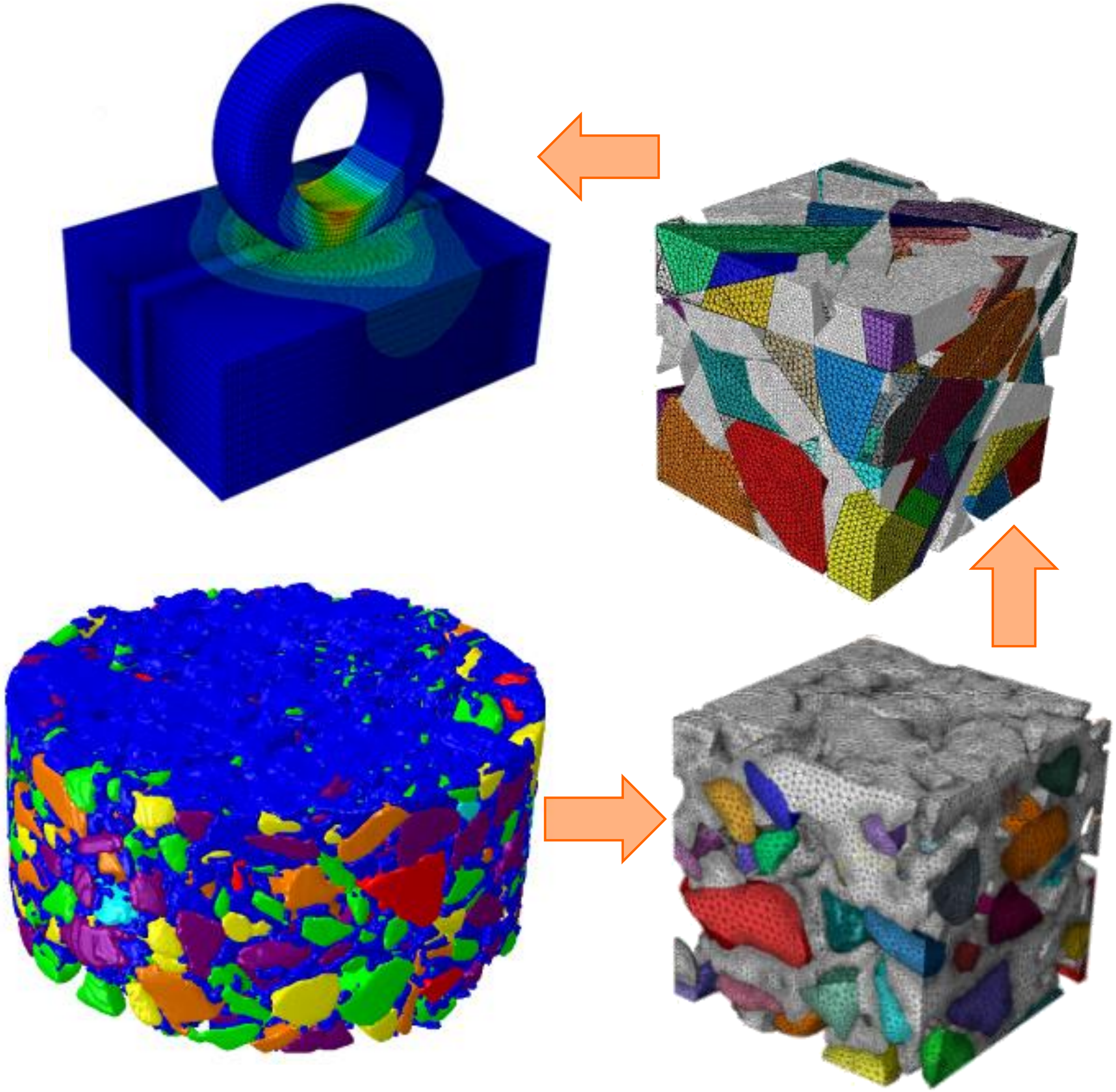
## Life optimisation tool for asphalt mixture using multiscale modelling

Stephanie Miot[1], Natascha Poeran[2] and Dolf Broekaart[3]

[1]Strategic Simulation and Analysis Ltd, [2]Boskalis Nederland B.V., [3]Simuleon B.V.

*Abstract: With the objective of extending the life of asphalt mixture, an FE modelling approach was developed to predict the mechanical response of the mixture at the mesoscale, the scale of the aggregates, calculate the homogenous properties then evaluate the performance of the asphalt under a cyclic loading. This project is divided into 3 phases and this paper presents the results of the second phase. In the first phase, samples of asphalt mixture were scanned and a 3D realistic model was created. The model accounts for the visco-elastic response of the mortar, the adhesive zone between the aggregates and the mortar and the detailed geometry of the aggregates. The realistic model was used to characterise the asphalt mixture and identify the relevant parameters to include in the predictive model. In the second phase, a new model based on a representative volume element (RVE) has been developed. The model idealises the asphalt mixture but still accounts for the geometrical characteristics of the aggregates and the mortar. A Python script was written to automatically create the geometry and generate the mesh. The FE-RVE plug-in can then be used to calculate the homogenised properties. This allows for multiple iterations over various types of mixture in order to design a specific asphalt for each application. Finally, in the last phase of the project, a macromodel of the asphalt with multiple layers will be created using the properties obtained from the RVE model. The life of the asphalt under a representative cyclic load will be estimated using an energy based approach.*

*Keywords: Asphalt, Multiscale Model, Optimisation, Fatigue Life, Scripting, Viscoelasticity*



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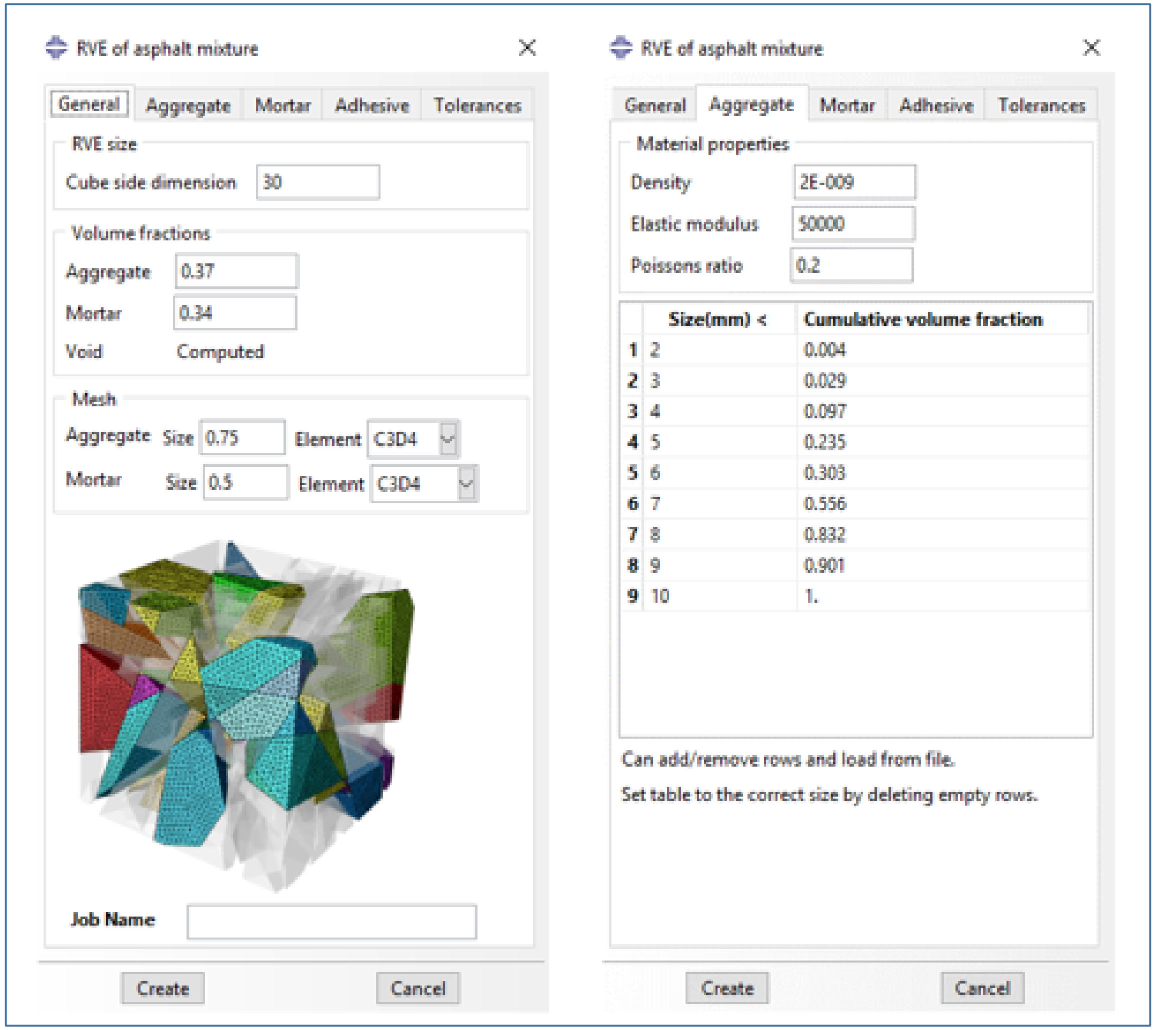
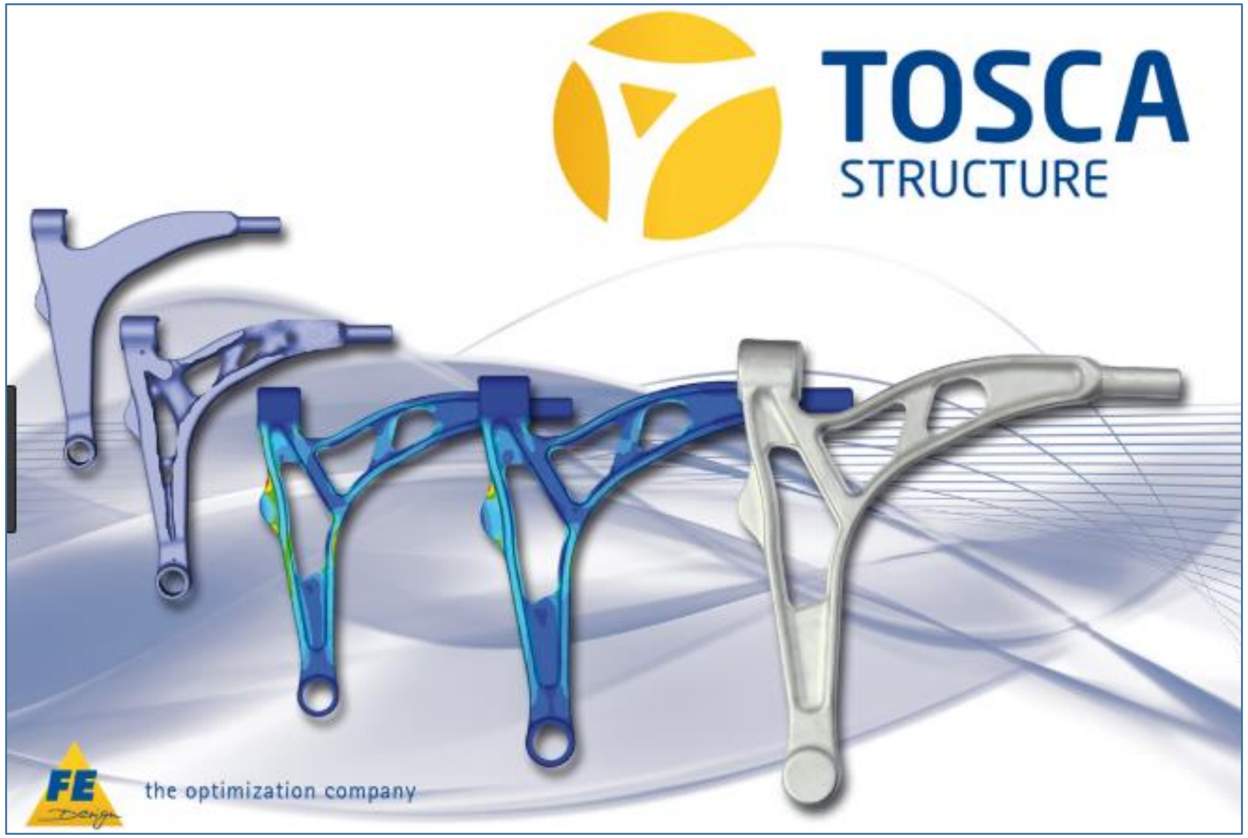
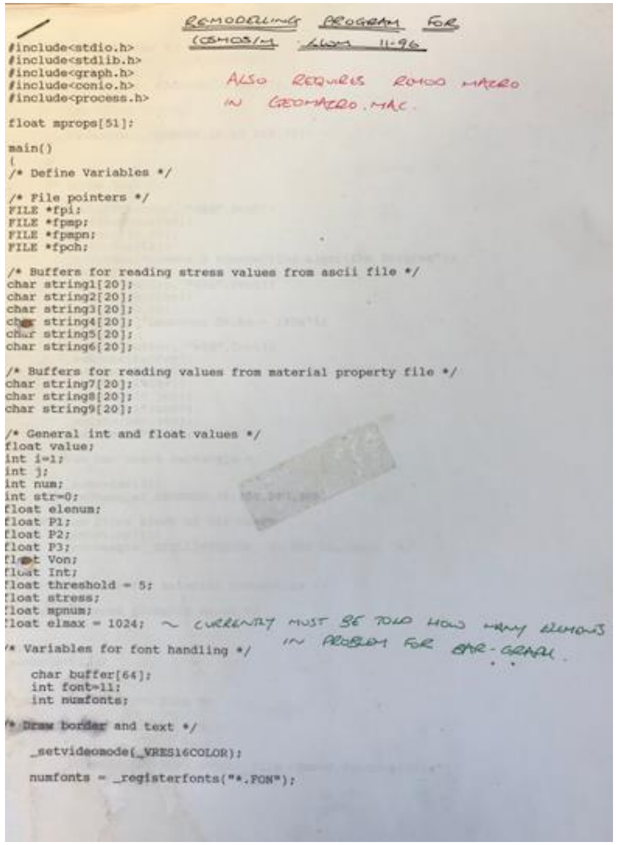


# Structural Optimisation




```
#include<stdio.h>
#include<stdlib.h>
#include<graph.h>
#include<conio.h>
#include<process.h>

float mprops[51];

main()
{
/* Define Variables */

/* File pointers */
FILE *fpi;
FILE *fpmp;
FILE *fpmpn;
FILE *fpch;

/* Buffers for reading stress values from ascii file */
char string1[20];
char string2[20];
char string3[20];
char string4[20];
char string5[20];
char string6[20];

/* Buffers for reading values from material property file */
char string7[20];
char string8[20];
char string9[20];

/* General int and float values */
float value;
int i=1;
int j;
int num;
int str=0;
float elenum;
float P1;
float P2;
float P3;
float Von;
float Int;
float threshold = 5;
float stress;
float mpnum;
float elmax = 1024;

/* Variables for font handling */

   char buffer[64];
   int font=11;
   int numfonts;

/* Draw border and text */

   _setvideomode(_VRES16COLOR);

   numfonts = _registerfonts("*.FON");
```

# Topology Optimisation

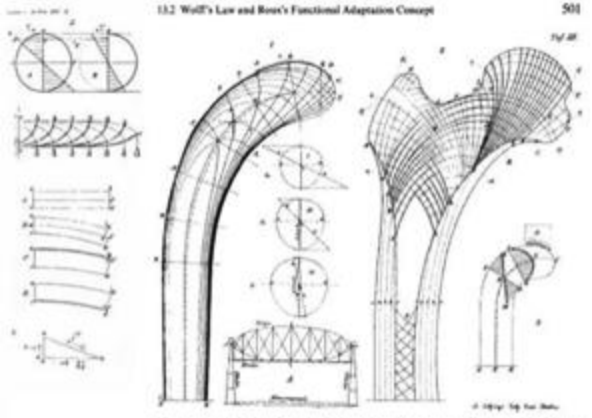


FIGURE 13.21 Culmann's crane presented by Wolff in his 1870 paper in Virchow's Archiv.

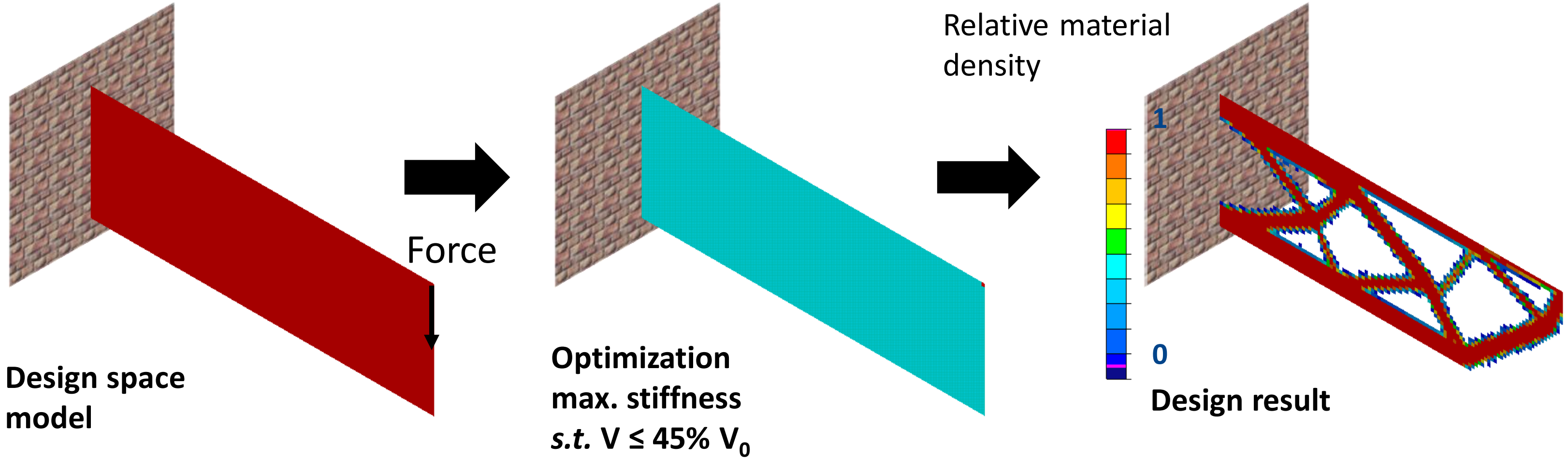
- Change density of elements within design space (“design variables / DV”) considering:

**Objective function**
Minimize/maximize quantity

**Constraints**
Physical bounds

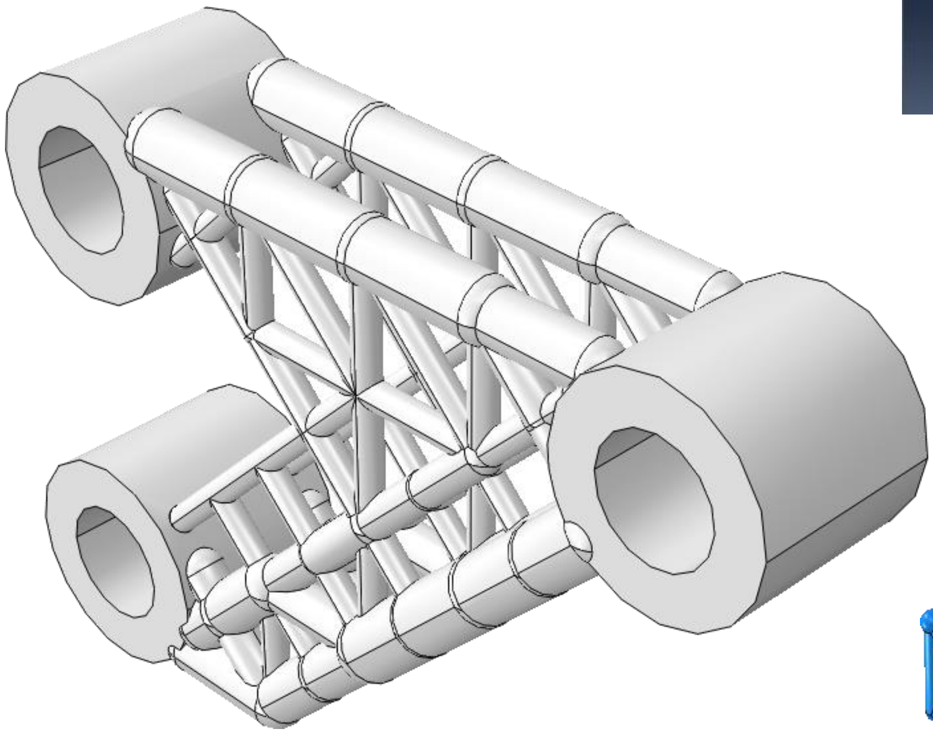
**DV constraints**
Manufacturing, symmetry

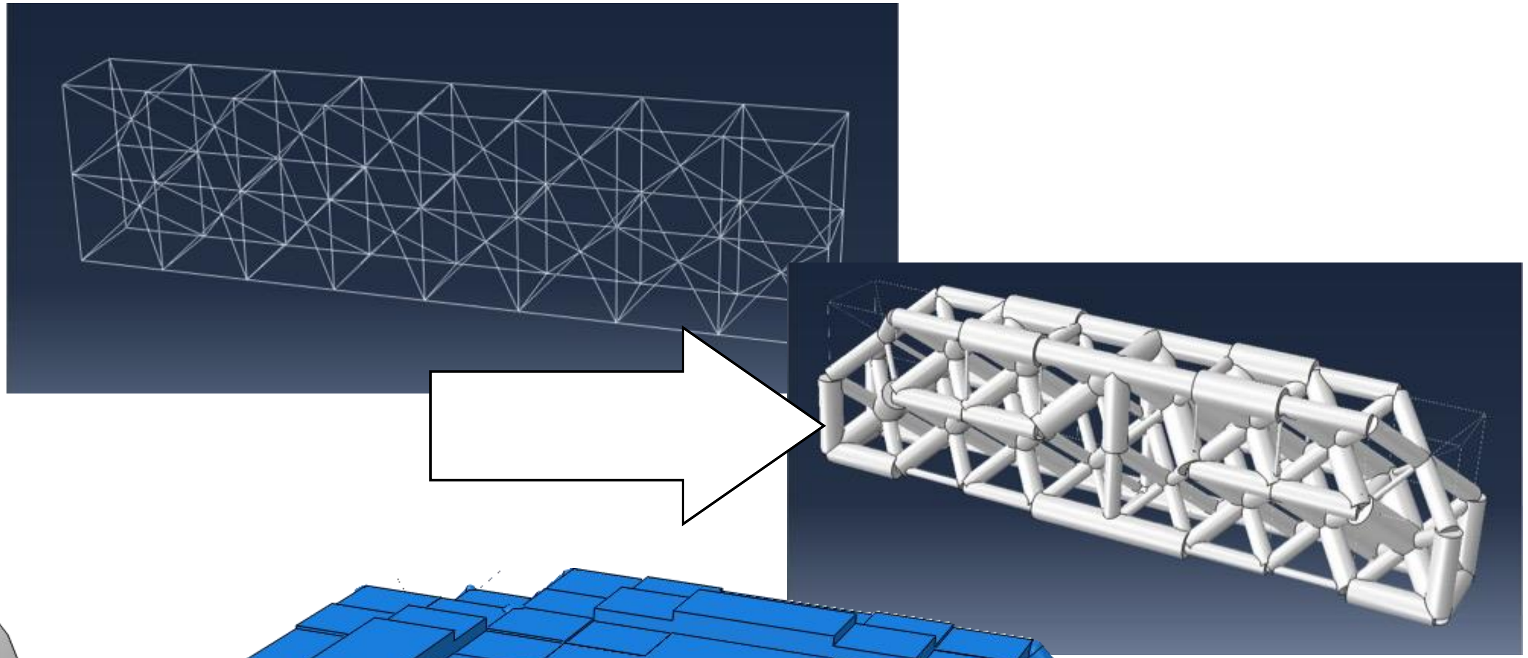
- Best material distribution for given optimization problem

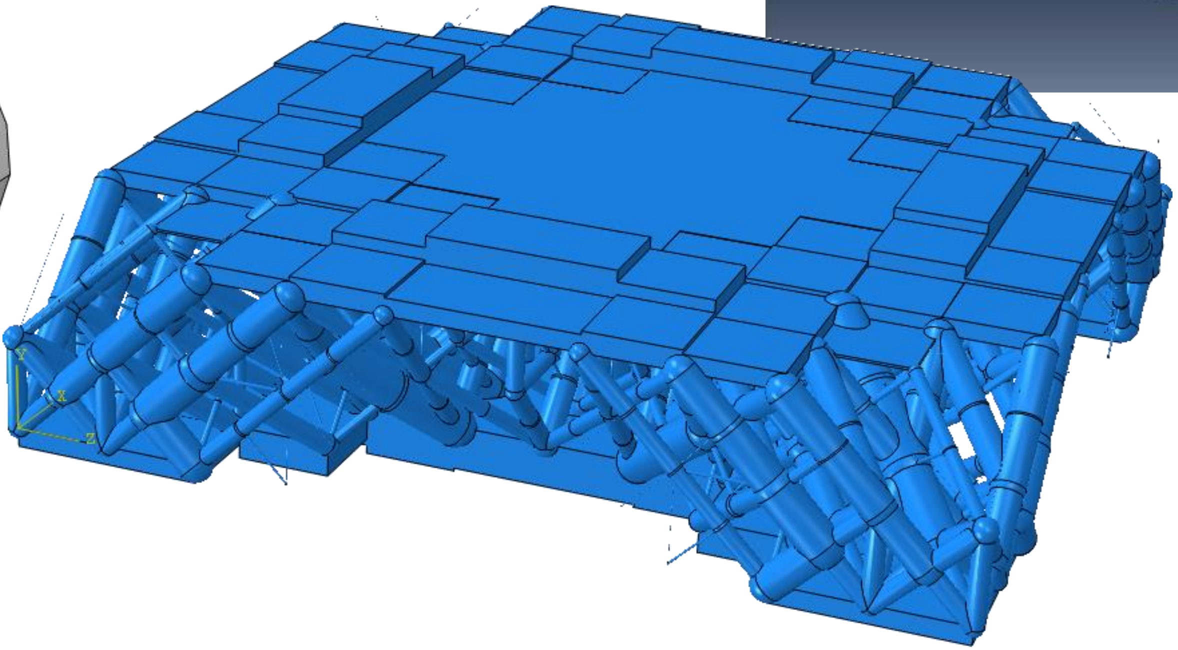


# Topology Optimisation

- Lattices

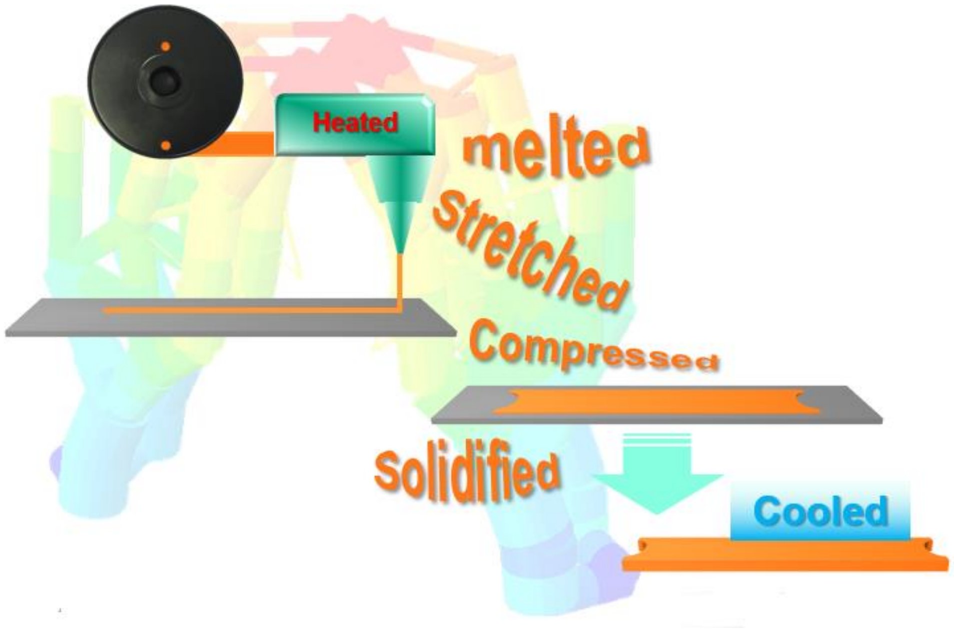


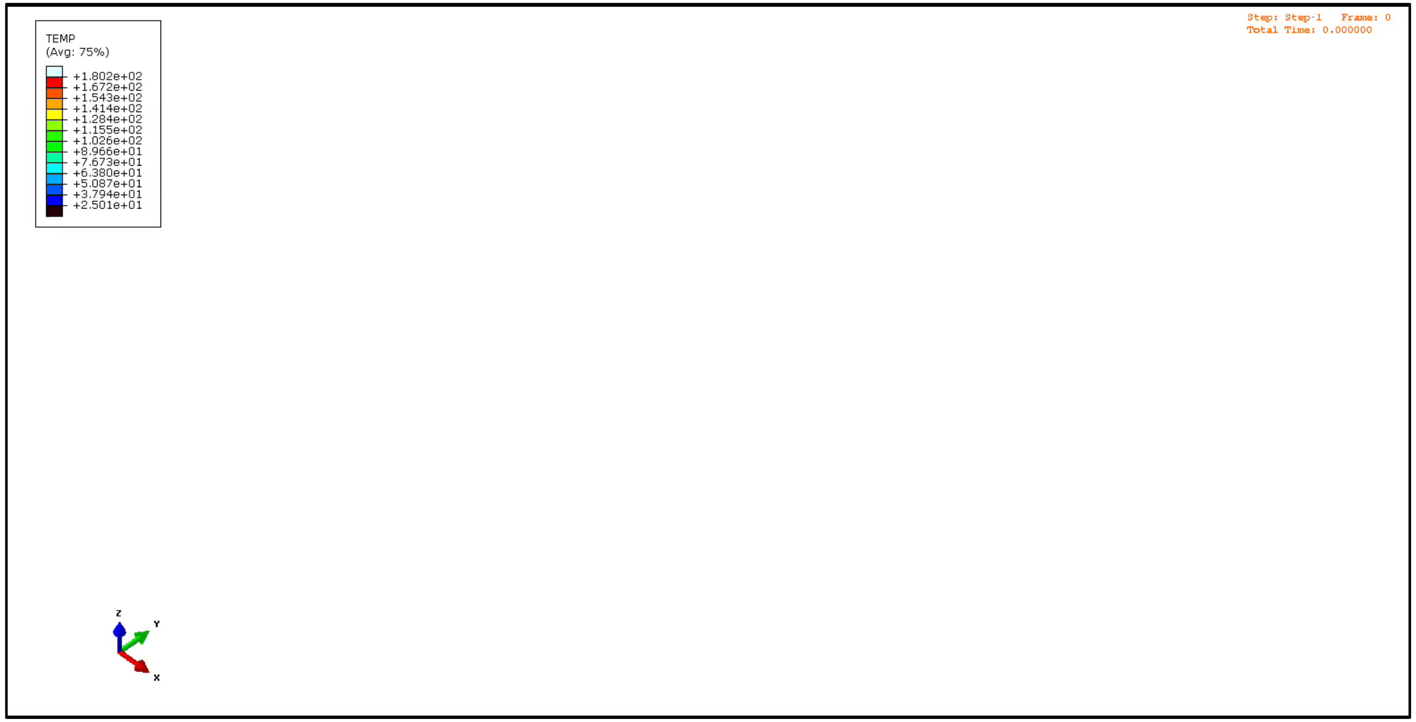




# Additive manufacturing process simulation

- Coupled thermal structural analysis with non-linear material properties and addition of material

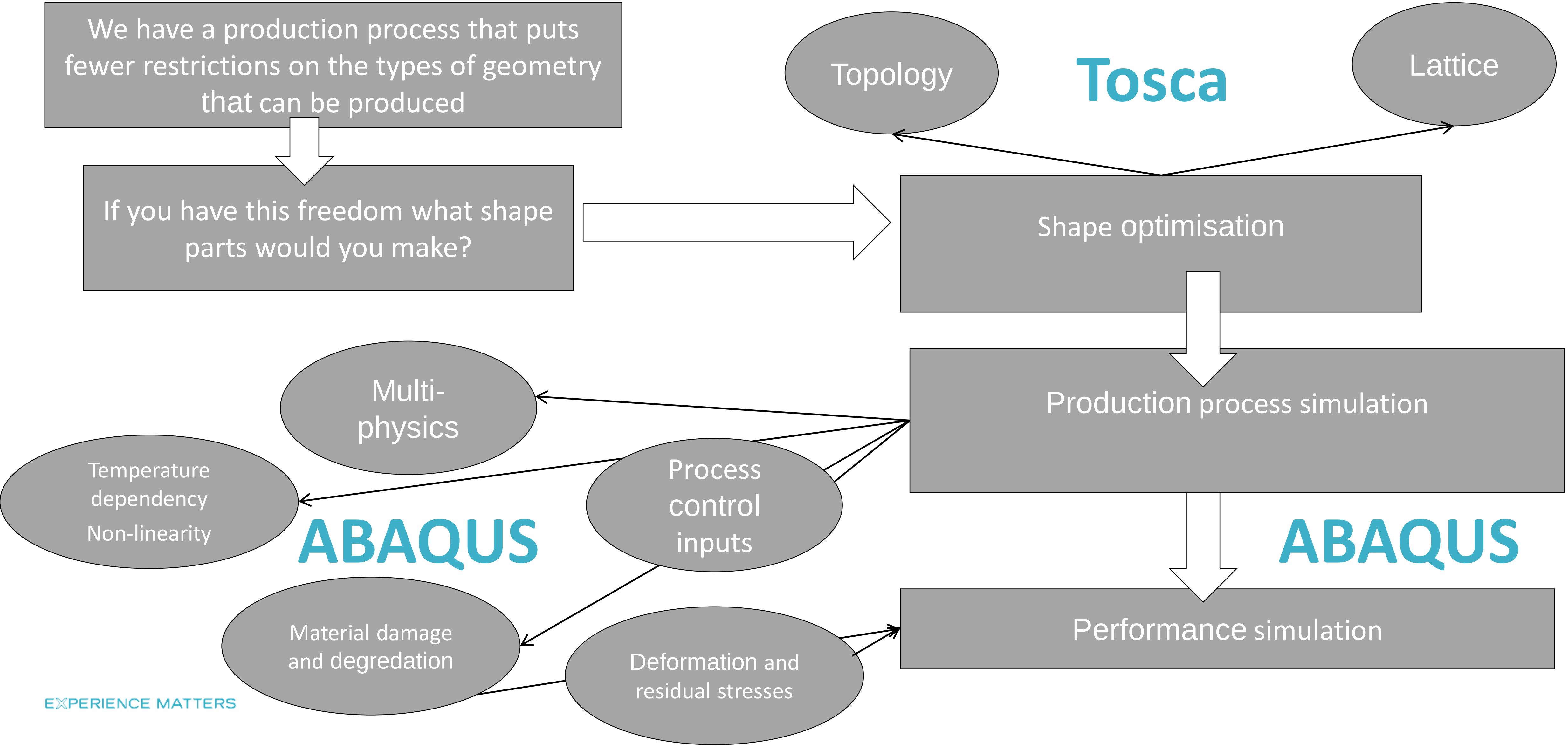



**Which has created a part with a structure that has properties which vary according to position, direction, scale, process, et al..**

## We’ve used a multi-physics process to create a multi-scale part

# A multi-physics multi-scale workflow



## Which begs a few questions

- What is structure?
- What is material?
- What is geometry?
- How are these affected by the physics of production and operation?
- And how do I manage, exploit and retain this knowledge?

**And these are the sorts of challenge that the CSE is there to address..**

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