



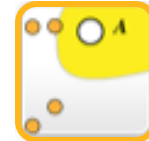
The Synthesizer Tool:

hybrids and other models

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Cellular structures



Composites



Sandwich structures



Multi-layers



Part cost estimator



Battery Designer

Learning objectives for this lecture unit

Ansys software mentioned

- Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes

Knowledge and Understanding	Understanding of the potential of hybrid materials
Skills and Abilities	Ability to use the synthesizer to explore material combinations
Values and Attitudes	Inspiration to combine properties to create new materials

Resources

- Text: *“Materials Selection in Mechanical Design”*, 5th edition by M.F. Ashby, Butterworth Heinemann, Oxford, 2016, Chapters 12 - 13.
- [Ansys Granta EduPack software synthesizer tool](#), available in advanced subject databases
- [The Synthesizer Tool Model Writes Guide](#), available from the Ansys Education Resources Website

Outline of lecture unit



Cellular structures



Composites



Sandwich structures



Multi-layers



Part cost estimator



Battery Designer

- **Holes** in material-property space
- **Hybrids materials** – expanding the filled space
- Example 1 – **cellular materials**
- Example 2 – **sandwich structures**
- New developments – **Part cost estimator**
- Add your own **Synthesizer model**

Advanced systems use hybrid materials



*Sails – Kevlar + Nylon mixed weave
With thermally bonded PET skin*

*Mast and boom –
CFRP, filament wound*

*Hull – sandwich construction,
carbon fibre/PMAA foam core*

Accelerating new material development

Current internationally:

ICME - *Integrated Computational Materials Engineering*

MGI - *The Materials Genome Initiative*

AMD - *Accelerated Material Development..... more*

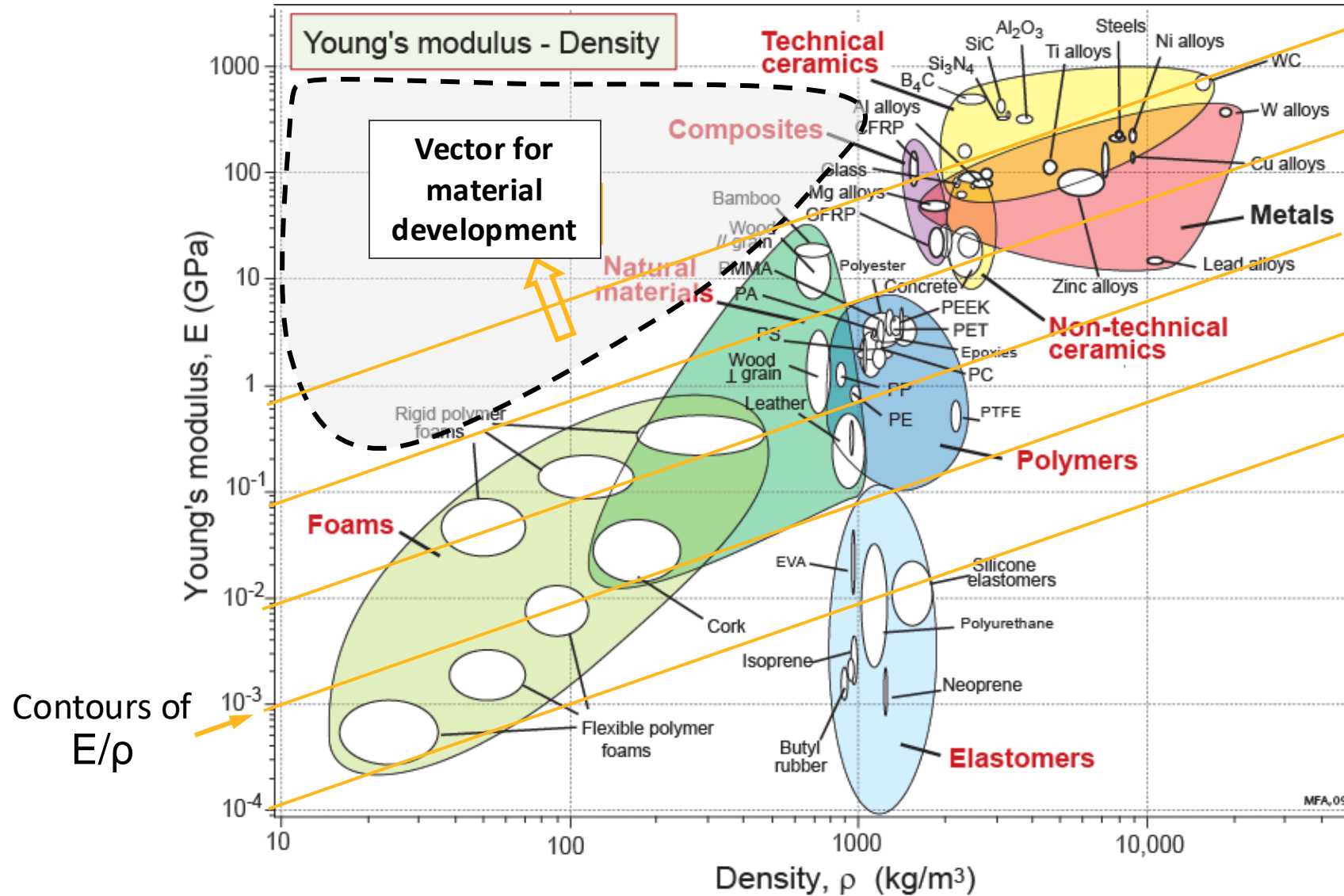
Vision: Materials Informatics

*Use today's ability to store, process and retrieve information
to accelerate material development*

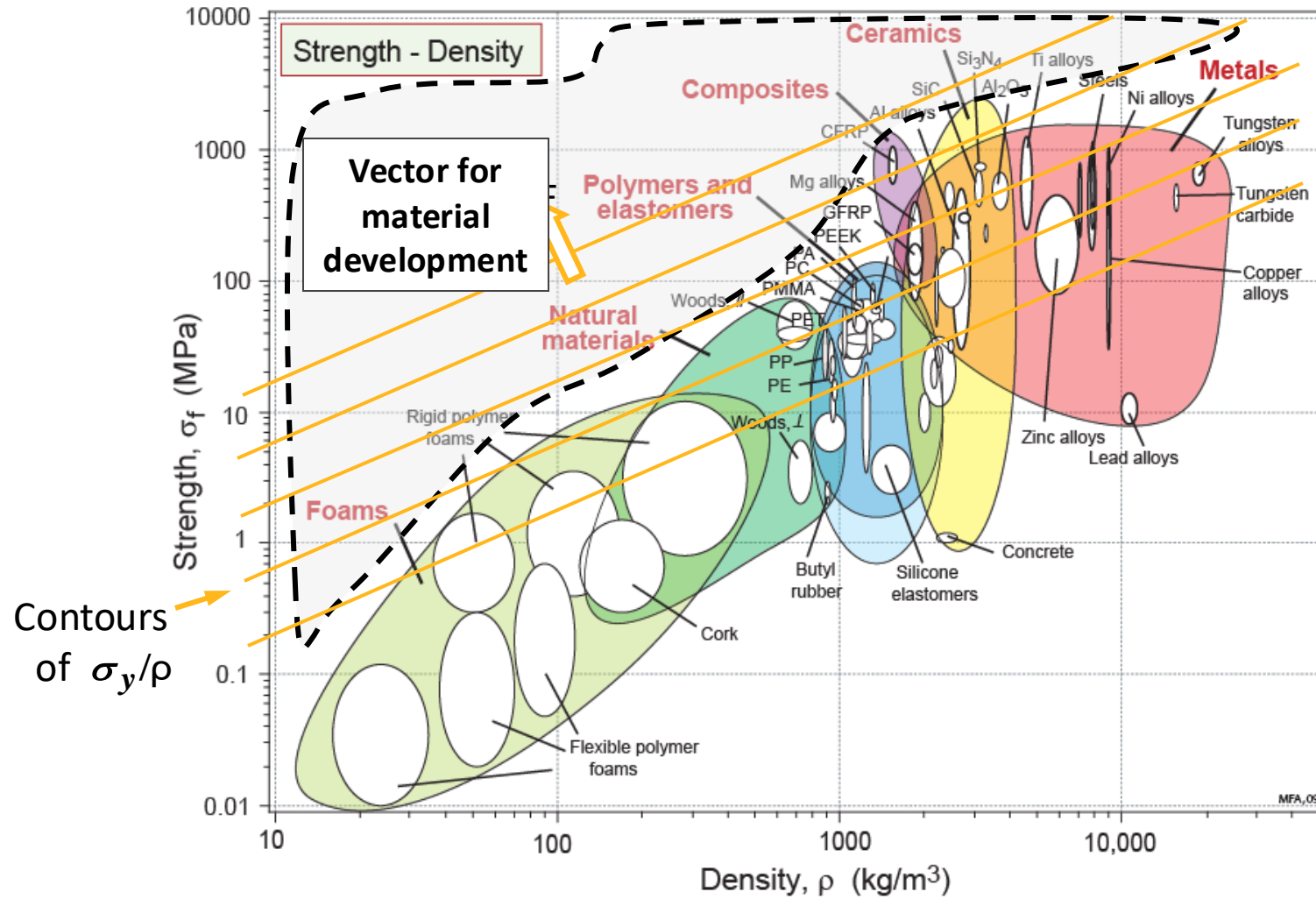
Almost all “bottom-up”: *sub-atomic → nano → micron → mm scale*

Can envisage “top-down”: *Design requirements → Architecture?*

Modulus and density






Strength - Density



Criteria of excellence: material indices

- **Material index** = combination of material properties that limit performance

Objective minimise mass	Constraints	
	Stiffness	Strength
Tension (tie) 	E/ρ	σ_y/ρ
Bending (beam) 	$E^{1/2}/\rho$	$\sigma_y^{2/3}/\rho$
Bending (panel) 	$E^{1/3}/\rho$	$\sigma_y^{1/2}/\rho$

Hybrid materials



Cellular structures



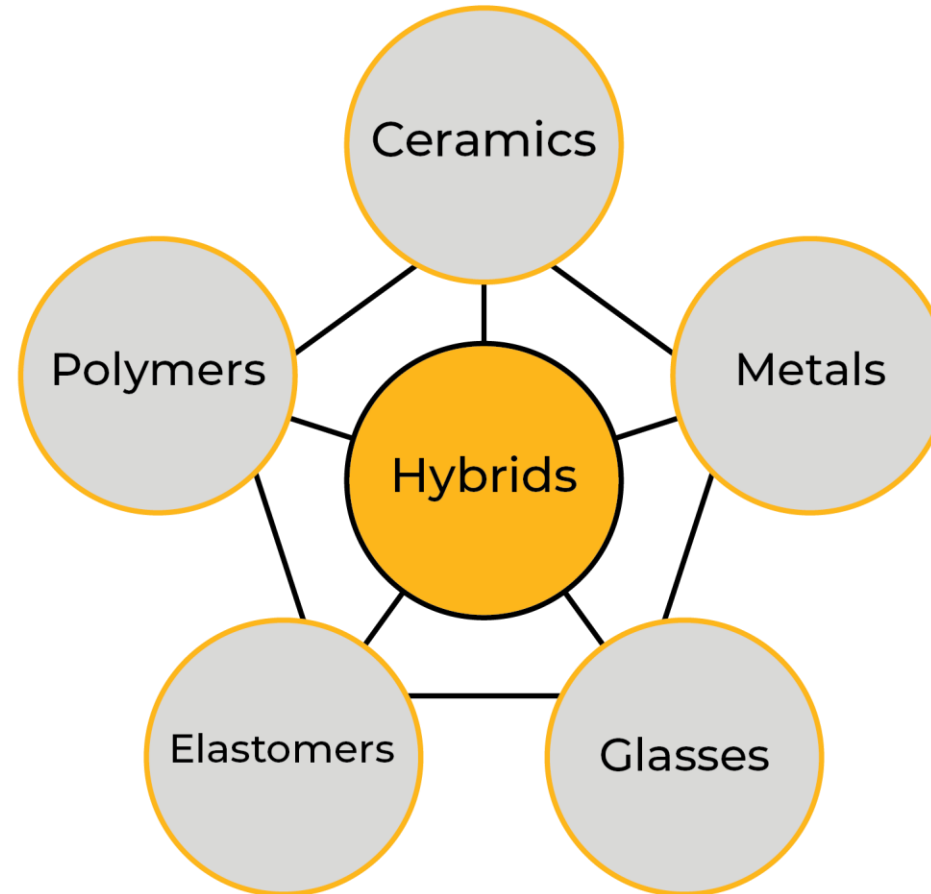
Composites



Sandwich structures



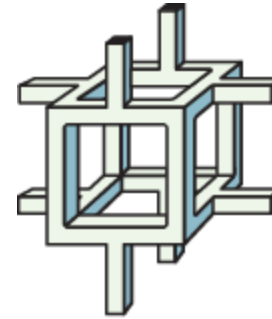
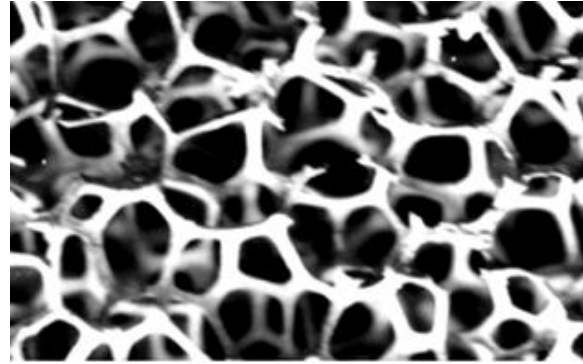
Multi-layers



Design variables:

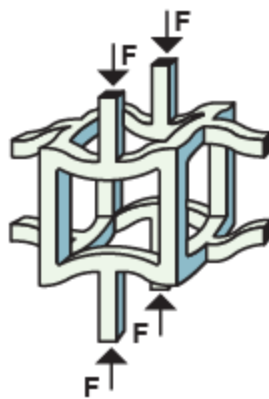
- Choice of materials
- Volume fractions
- Configuration
- Connectivity
- Scale

Configuration: Foam – property models

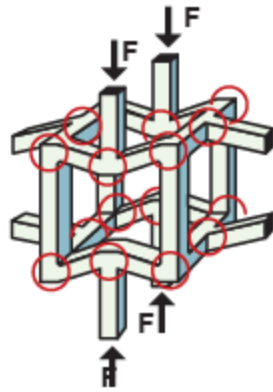


Foam cell

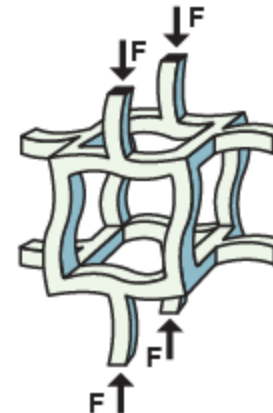
Mechanical response



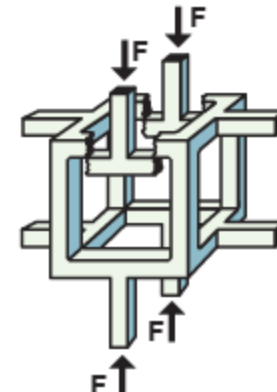
Elastic deformation



Plastic collapse



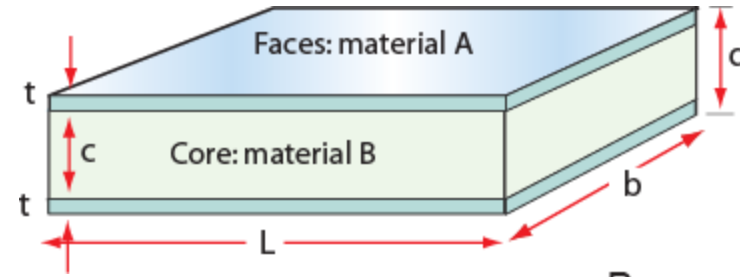
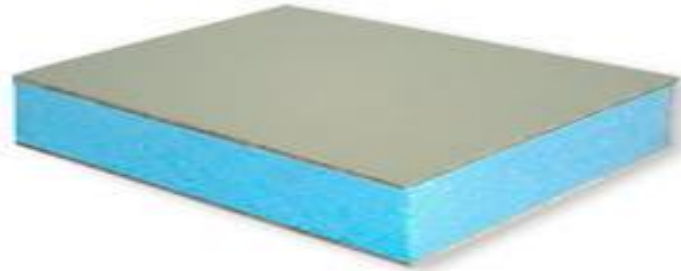
Cell edge buckling



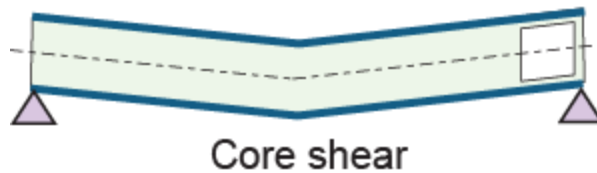
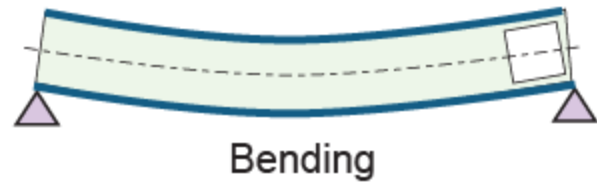
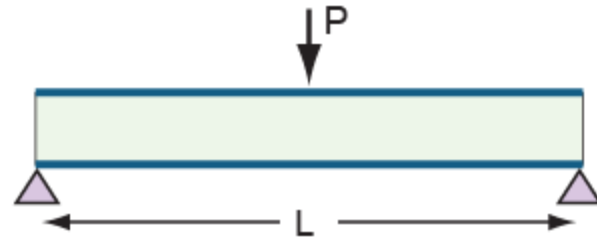
Cell edge fracture

Plus **thermal and electrical properties**

Configuration: Sandwich panel – property models

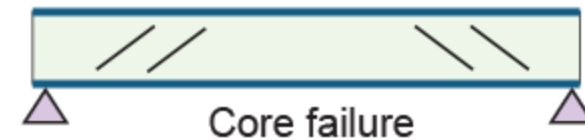
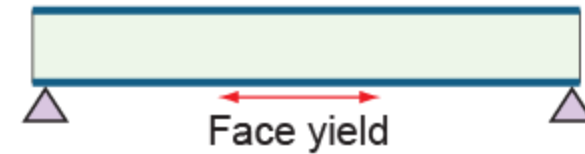
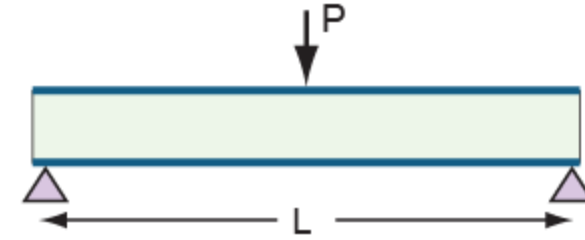


Elastic response

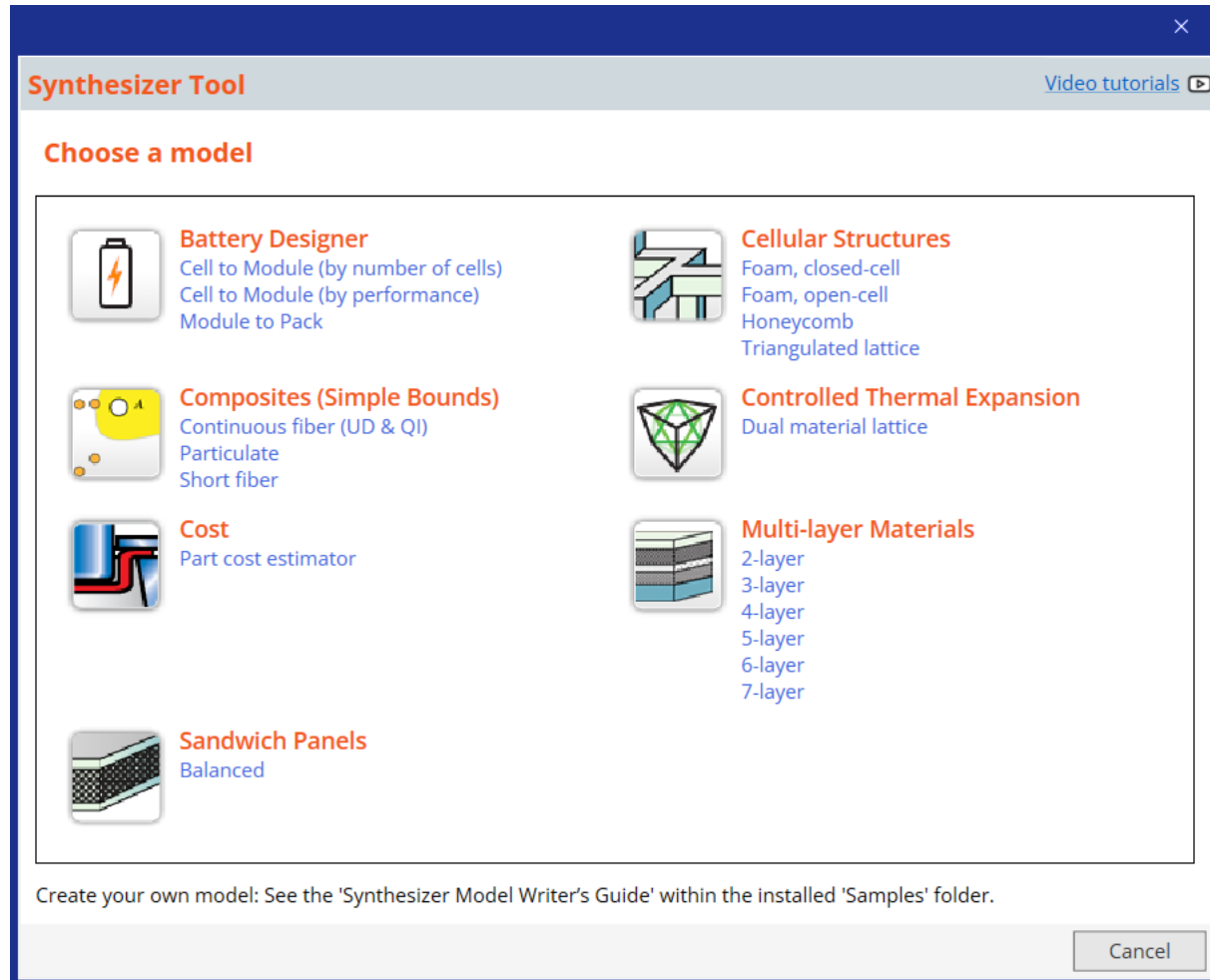
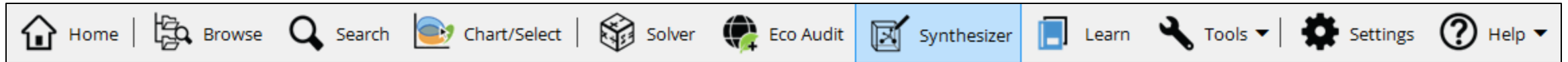


Plus thermal and electrical properties

Collapse response



The Synthesizer tool and its models

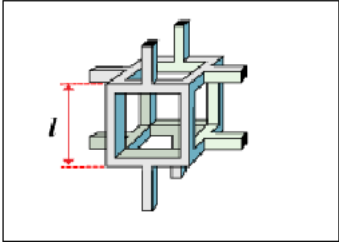


Select:

- Configuration
- Materials
- Control parameters
- Click "Create"

Exploring metal foams - inputs

Foam, open-cell



Predicts the performance of open-cell foams, based on relative density

Assumptions:

- Cell size and structure is uniform
- Cell geometry is isotropic
- All cells are interconnected and filled with air

Relative density = (density of cellular structure) / (density of solid from which it is made)

Source Records

Bulk Material

Model Variables

Enter values or range of values. For example, 1; 3; 8 or 1-8.

Relative Density % Number of values:

Model Parameters

Relative flaw size (l/a)

Record Naming

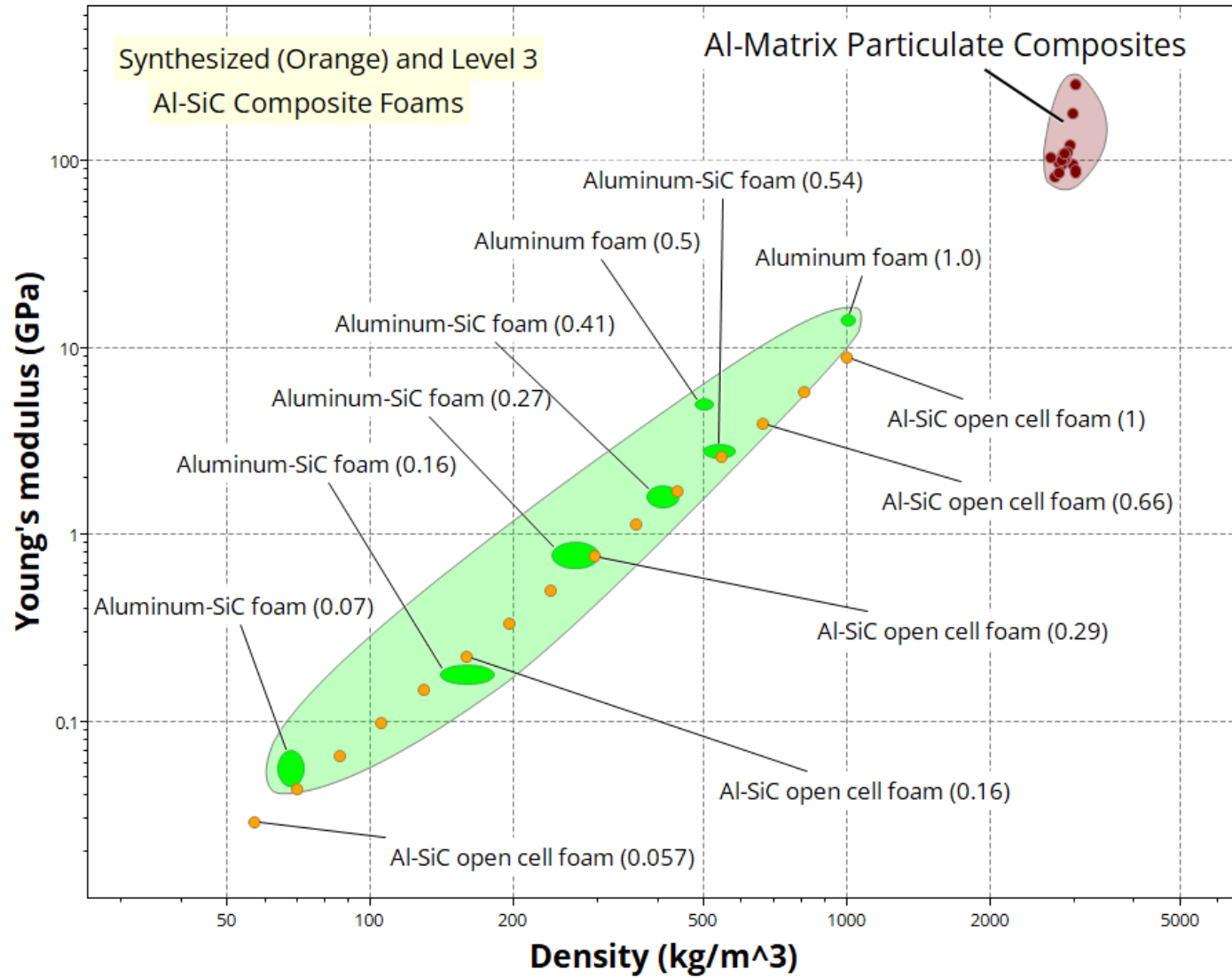
Bulk Material

This model will generate 15 records

Browse

- MaterialUniverse
 - Ceramics and glasses
 - Fibers and particulates
 - Hybrids: composites, foams, honeycombs, natura
 - Composites
 - Ceramic matrix
 - Metal matrix
 - Aluminum matrix
 - Alumina
 - Aluminum nitride
 - Aramid
 - Boron
 - Carbon
 - Iron
 - Silicon carbide
 - Fiber reinforced
 - Particulate reinforced
 - Al(2009)-20%SiC(p)
 - Al(2024)-30%SiC(p)
 - Al(2124)-20%SiC(p)
 - Al(2618)-12%SiC(p)
 - Al(6061)-25%SiC(p)
 - Al(6061)-55%SiC(p)
 - Al(6061)-70%SiC(p)
 - Al(6091)-25%SiC(p)
 - Al(9009)-11%SiC(p)

Aluminum SiC composite foams



Sandwich panels - inputs

Sandwich Panel

Source material

Face sheet

Aluminum 6061

Core

PVC cross-linked

Model variables

Face-sheet thickness

Core thickness -

Model parameters

Support and load condition

Span 3 m

Model

Balanced

Predicts the performance of balanced sandwich structures

Assumptions:

- Face-sheet to core bonding is perfect
- Face-sheets remain flat under loading (no dimpling on honeycomb cores)

Source Records

Face-sheet: Aluminum, 6061, T4 [Browse...]

Core: PVC cross-linked foam (rigid, closed cell, AC 0.090) [Browse...]

Model Variables

Enter values or range of values. For example, 1; 3; 8 or 1-8.

Face-sheet thickness: 0.1-3 mm Number of values: 5

Core thickness: 10-50 mm Number of values: 3

Model Parameters

Support and load conditions: Built-in ends / Central load

Span: 3 m

Record Naming

Face-sheet: Al 6061

Core: PVC foam

This model will generate 15 records

Previous Create Cancel

Browse

Magnetic

Material Universe

- ceramics and glasses
- fibers and particulates
- hybrids: composites, foams, honeycombs, natural materials
- Composites
- Foams
 - Ceramic
 - Metal
 - Polymer foams, elastomeric
 - Polymer foams, flexible
 - Polymer foams, rigid
 - Phenolic
 - Polycarbonate
 - Polyetherimide
 - Polyethersulfone
 - Polyethylene terephthalate
 - Polymethacrylimide
 - Polystyrene
 - Polyurethane
 - Polyvinylchloride
 - PVC cross-linked foam (rigid, closed cell, AC 0.040)
 - PVC cross-linked foam (rigid, closed cell, AC 0.055)
 - PVC cross-linked foam (rigid, closed cell, AC 0.065)
 - PVC cross-linked foam (rigid, closed cell, AC 0.075)
 - PVC cross-linked foam (rigid, closed cell, AC 0.090)
 - PVC cross-linked foam (rigid, closed cell, DH 0.030)
 - PVC cross-linked foam (rigid, closed cell, DH 0.045)

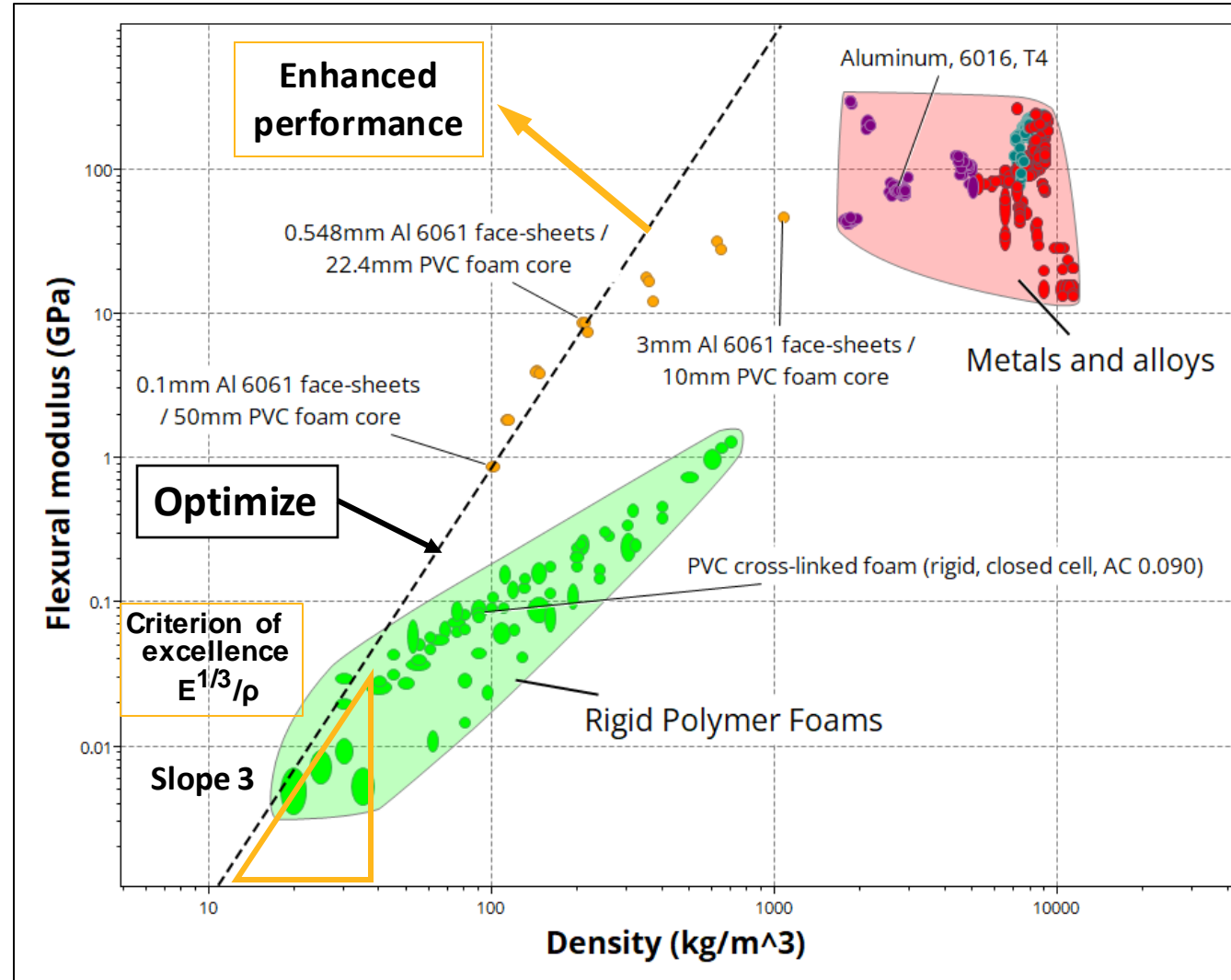
OK Cancel

PVC cross-linked foam (rigid, closed cell, AC 0.075)

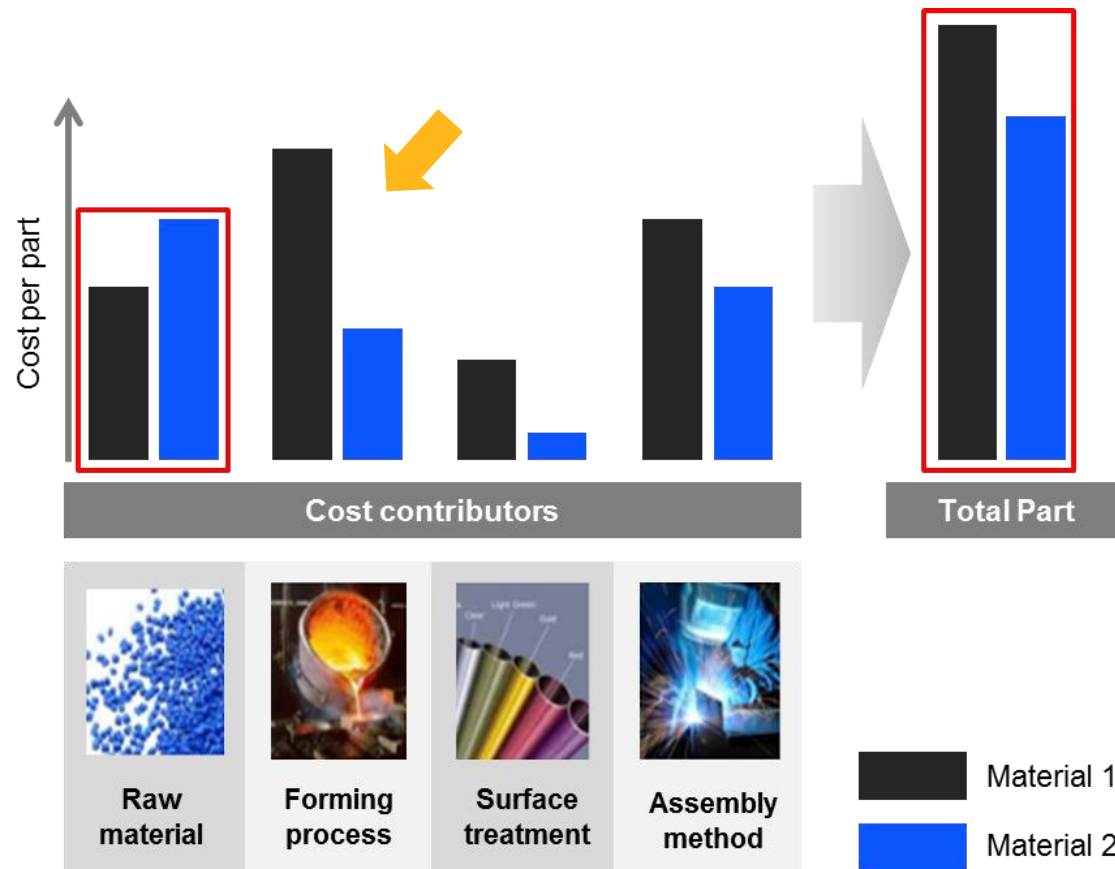
PVC cross-linked foam (rigid, closed cell, AC 0.090)

OK Cancel

Stiff sandwich panels



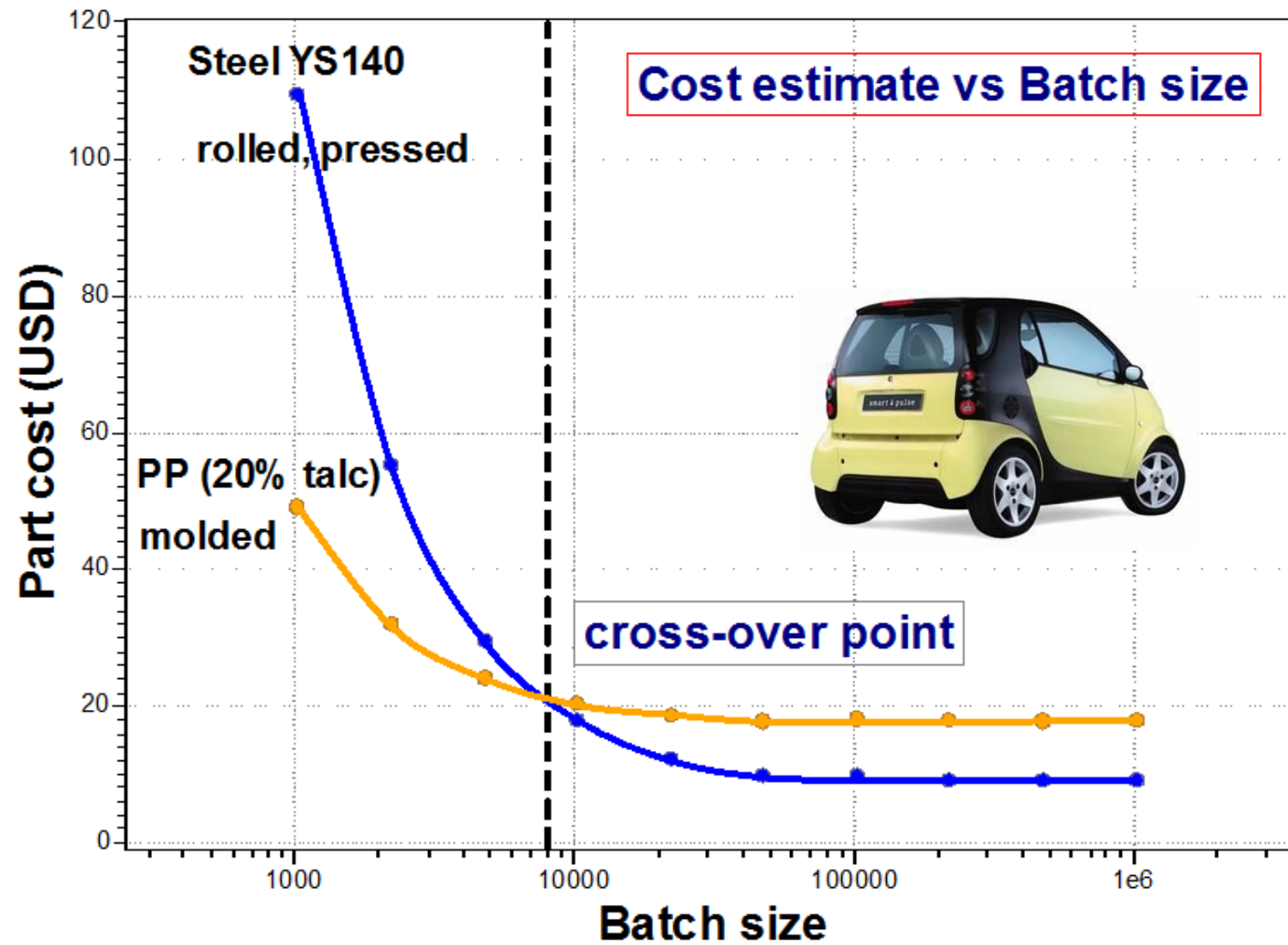
Synthesizer model for part cost



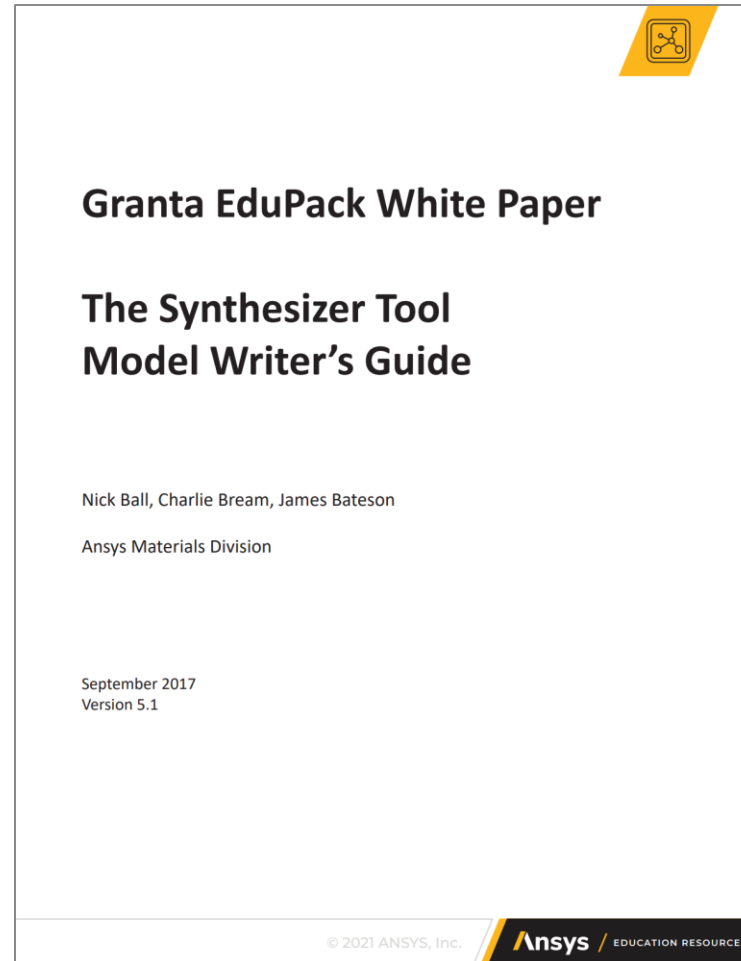
*PP-20% mineral filled door panel
15% saving in door weight, but what
about cost?*

- Quickly estimate the **cost to manufacture a component**
- **Compare different classes of materials** *and* processing routes

Part cost comparison: Door panel



Enter your own models



Outline of a model in code (C#)

- You need: Microsoft Visual Studio (the community edition is free)
- Administrator rights on your PC in order to copy your model
- Details of your model calculations.

```
[Export("Granta.HybridModel")]
```

```
[BindableDisplay(Name = "Simple Model (C#)",  
                 Description = "A simple example model.",  
                 GroupName = "Examples")]
```

```
public class ExampleModel  
{  
  
}
```

Summary

The synthesizer stimulates

- Imaginative exploration of novel material combinations
- Interest in materials modelling
- Direct comparison of hybrids with the standard materials of engineering
- Exploration of structured-structures
- Does **not** advise on manufacture of hybrids, but...
- Can be used to estimate part manufacturing costs
- Enables you to enter your own materials-based models

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