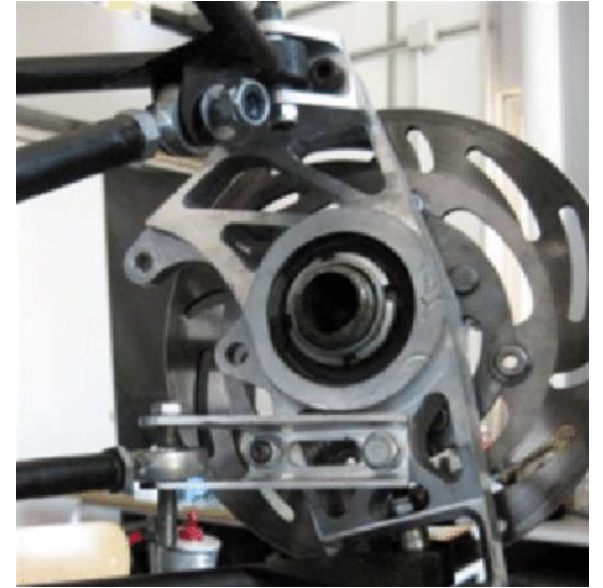


Design Exploration via Topology Optimization

Ethan Thompson, Team Lead – Ansys Discovery

/ Traditional Method of Design and Manufacturing

- Traditional way of manufacture has influenced the way products are designed
- Experience drives design (a good thing)
- Traditional design made from Boolean operations such as subtraction, considers the tooling needs and processes
- Leads to limitations in design and optimization benefits



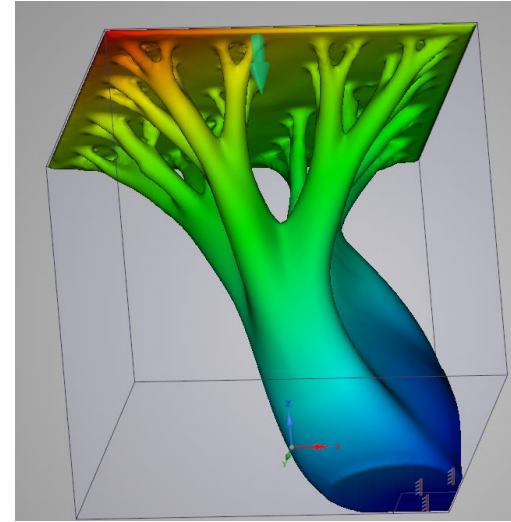
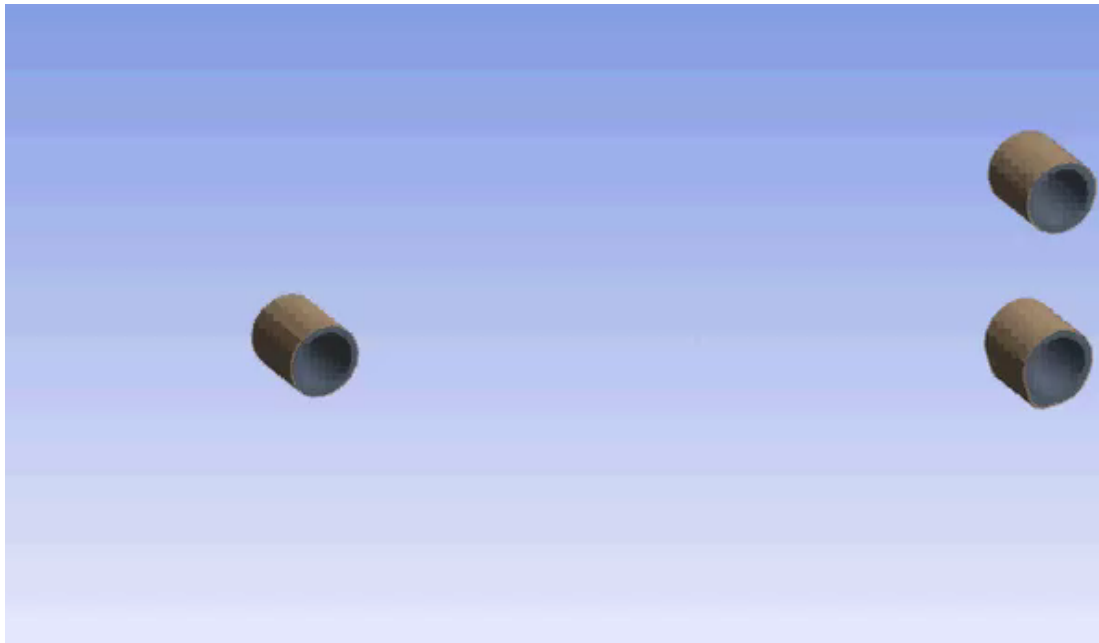
[1] Vehicle upright – manufactured via CNC Milling



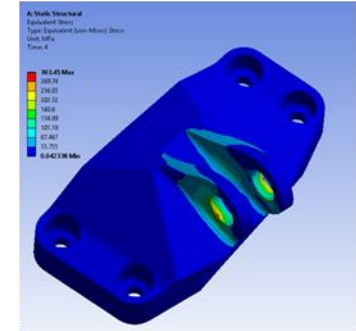
[1] Muzzupappa, Maurizio & Barbieri, Loris & Bruno, Fabio. (2011). Integration of topology optimization tools and knowledge management into the virtual Product Development Process of automotive components. Int. J. of Product Development. 14. 14 - 33. 10.1504/IJPD.2011.042291.

What is Topology optimization?

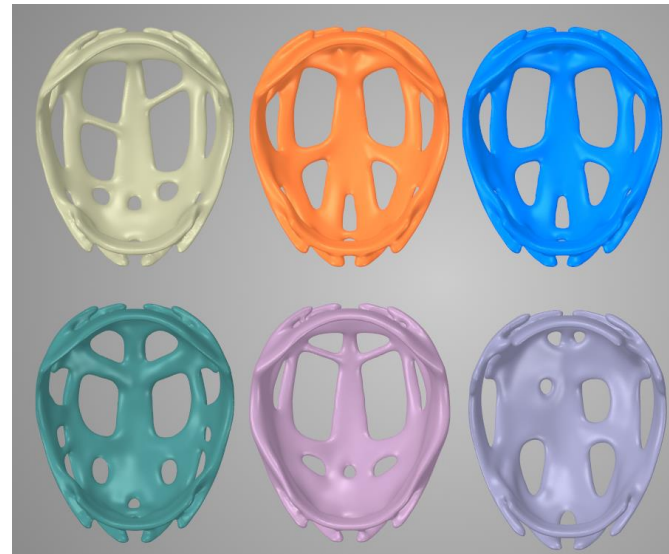
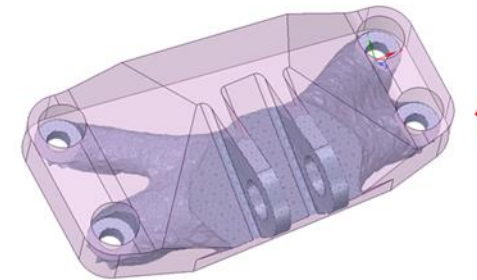
Topology optimization is a physics driven approach to identify what the optimal material distribution is based on certain constraints and loads.



Human intuition drives the geometry



ANSYS physics drives the geometry



Why do it?

- Improved product performance and design
- Light-weighting
- Reduced material waste and part consolidation (+AM)
- New material properties (+AM)
- Guide product design

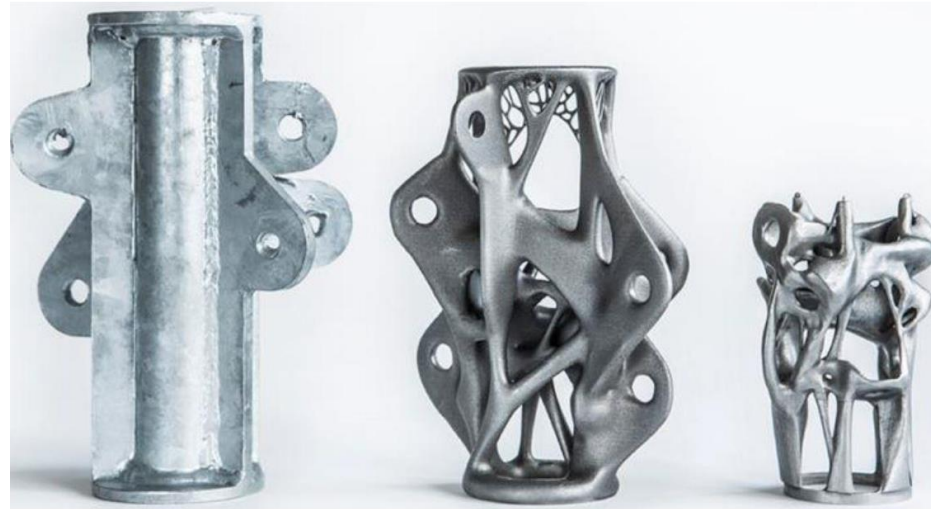
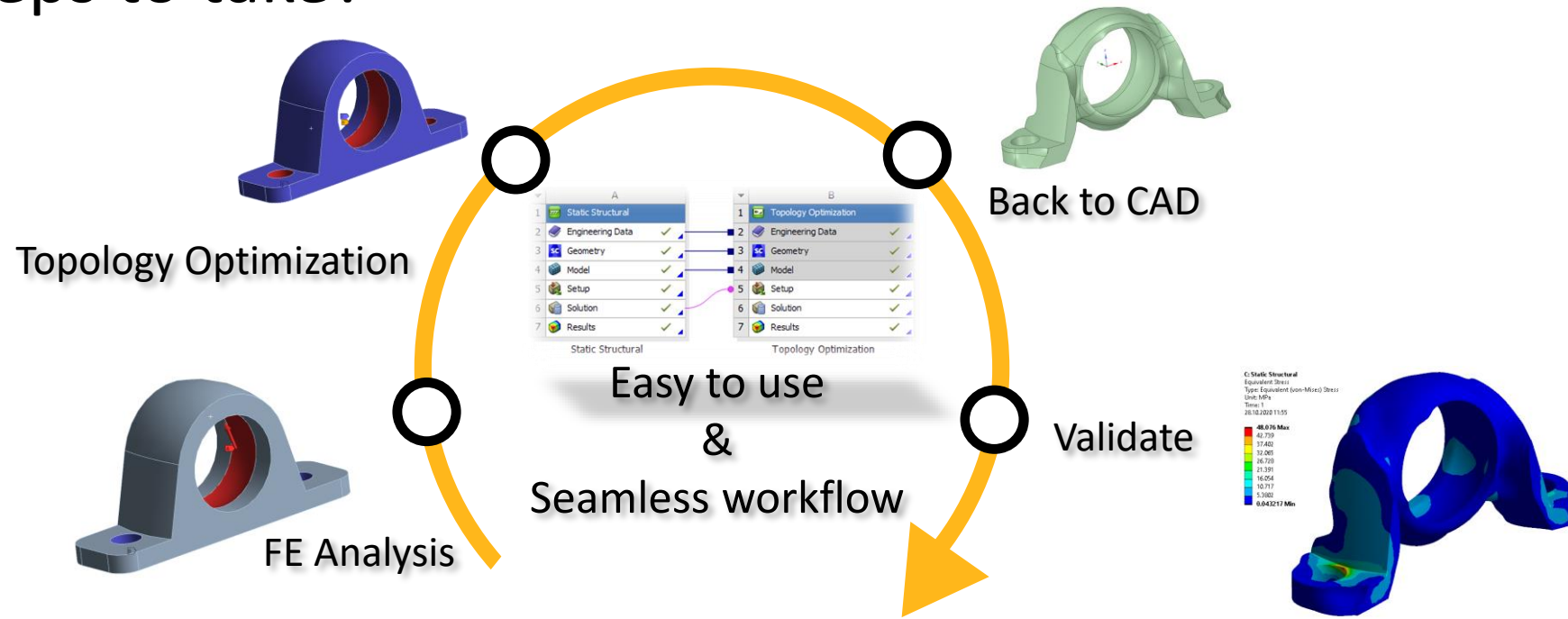


Figure 1.1—Organic optimised shapes produced by topology optimisation. From (Galjaard et al. 2015)



What steps to take?

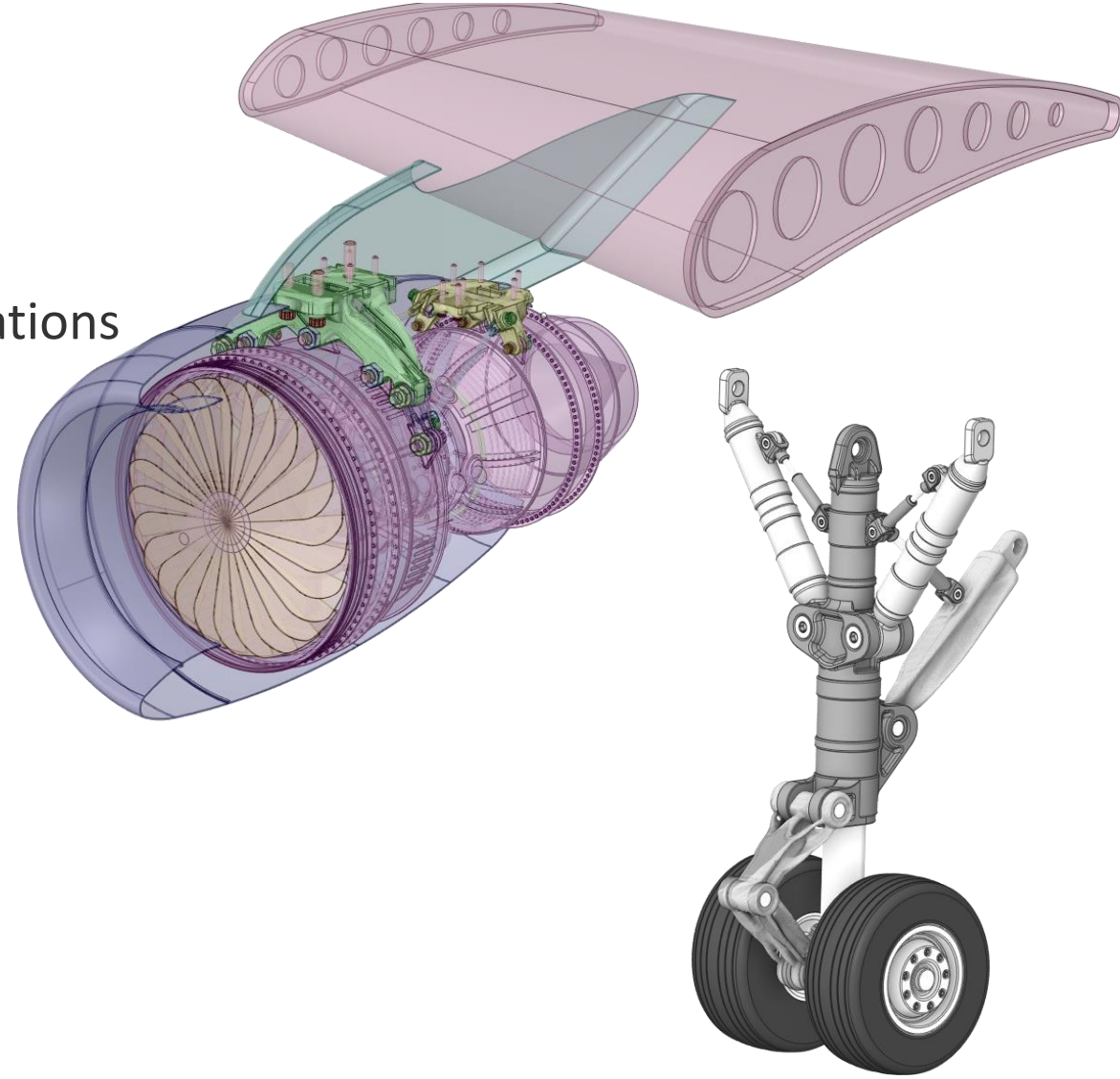


Topology optimization helps you create new, innovative or improved designs.

Ansys makes it easy to use for every engineer

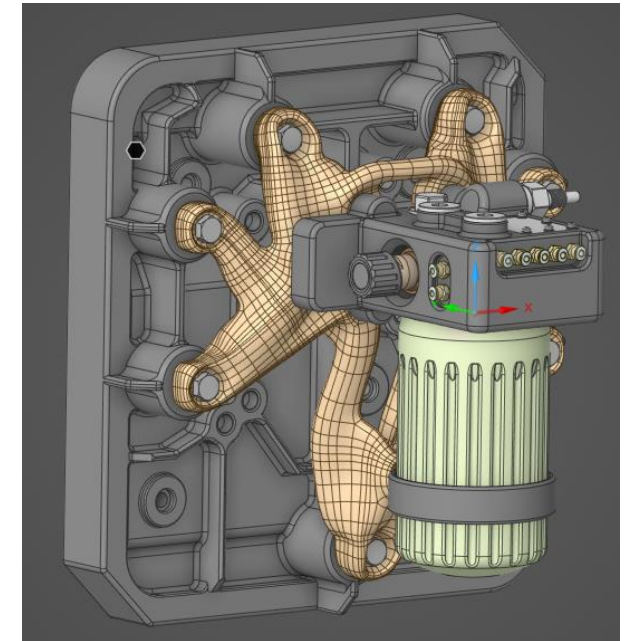
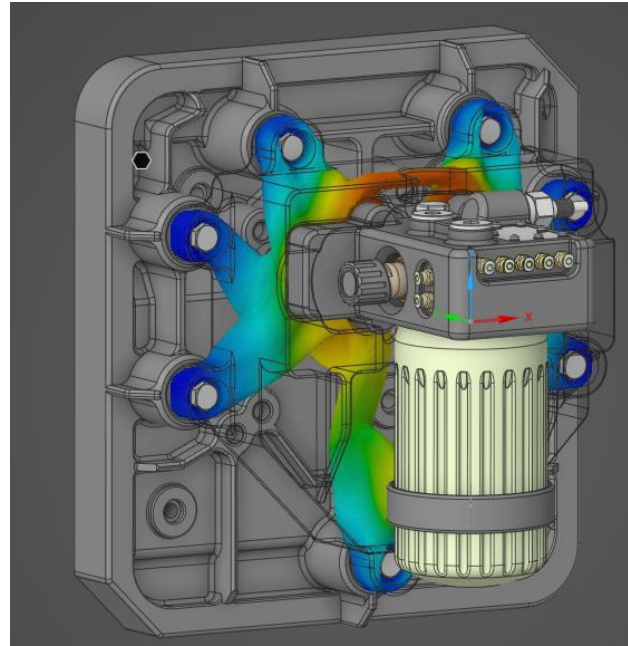
ANSYS Topology Optimization Solutions

- Ansys Discovery
 - GPU powered topology optimization
 - Structural simulation only
 - Integrated geometry operations for further operations
- Ansys Mechanical
 - Higher fidelity capability
 - Advanced options
 - Solver options, controls, meshing, responses, etc.
- LS-Dyna
 - LS-Opt and LS-TaSC
- Ansys Fluent
 - Adjoint Solver

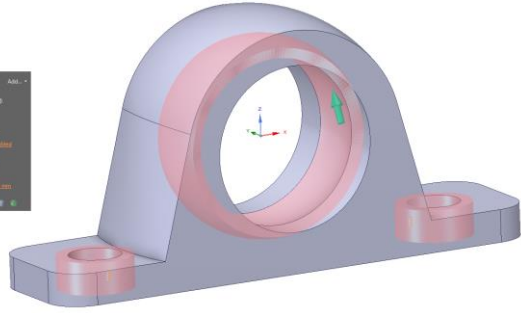
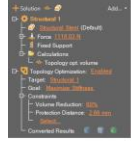


ANSYS Discovery – Upfront Simulation and Geometry Tool

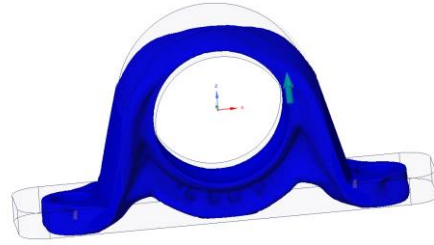
- GPU powered solver
 - Robust voxel-based meshing
 - “Live” physics
- Structural optimization only
- Integrated geometry modeling
 - Facets/STL toolkit
 - Reverse engineering capabilities
 - Subdivisional modeling
- Connection with Ansys Mechanical



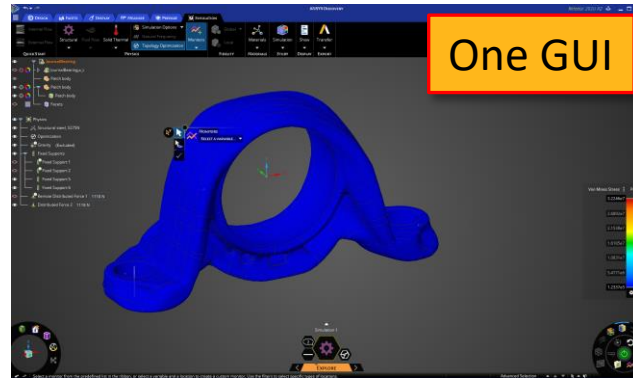
Journal Bearing - Overview Discovery



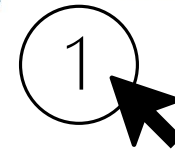
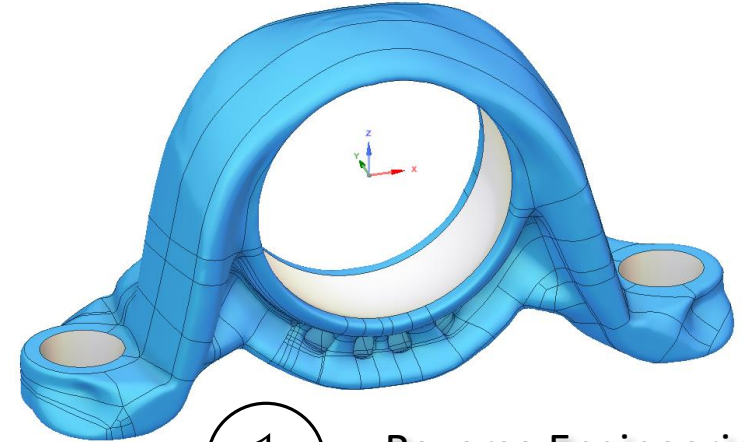
Topology Optimization:
Objective & Constraints



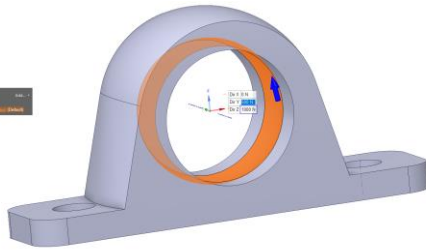
No Meshing
Run on GPU



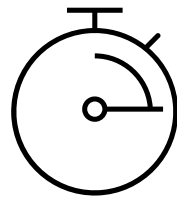
One GUI



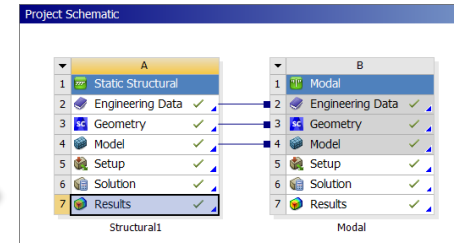
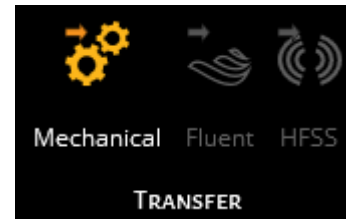
Reverse Engineering



Structural setup:
BCs & Load



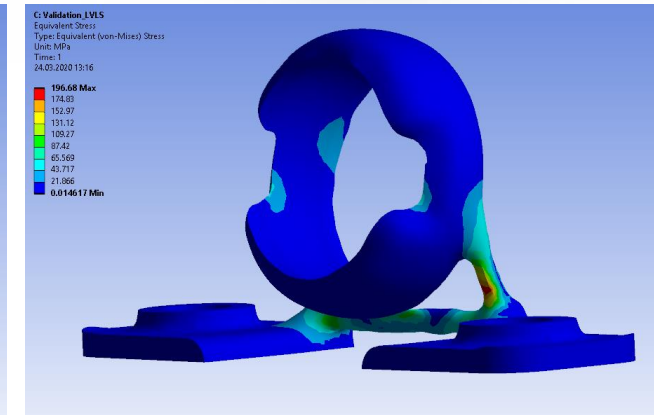
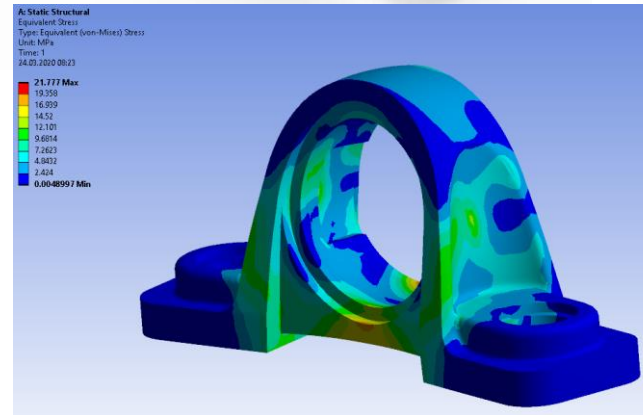
Overall < 5 min



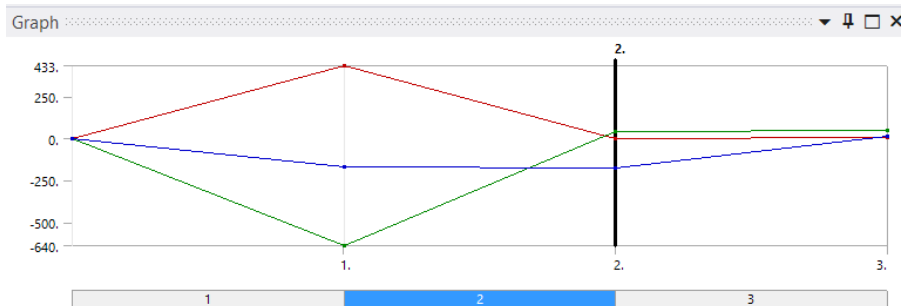
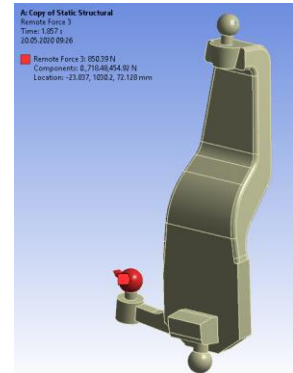
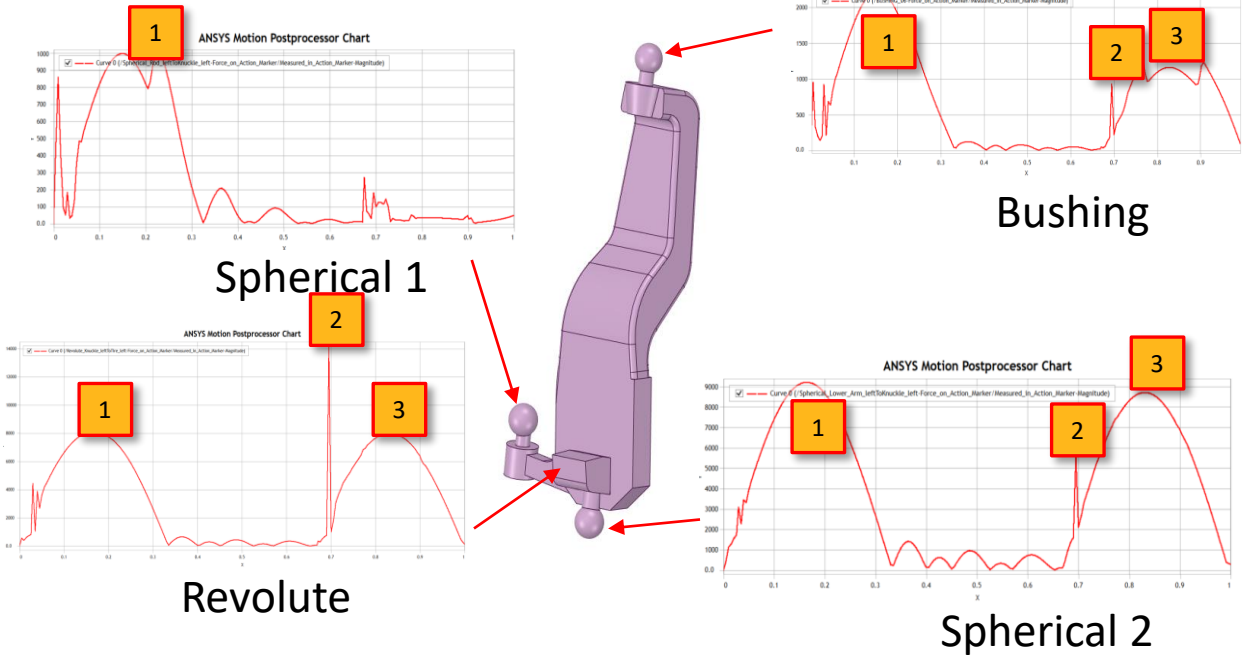
Validate & Compare → WB

Ansys Mechanical

- Thermal optimization
 - Thermal compliance
- Structural optimization
 - Compliance, Stress, Mass, etc.
- Lattice Optimization
- Optimization Approaches
 - SIMP and Level Set
- Topography Optimization (new in 2023R1)
 - Fabricated structures



Overview: Knuckle – Topology Optimization



Level Set



Level Set Based

- New, 10-year technology
- Boundary is parameter and moved to optimal shape
- Complex load scenarios possible
- Available in Discovery – powered by GPU & Workbench driven by CPU

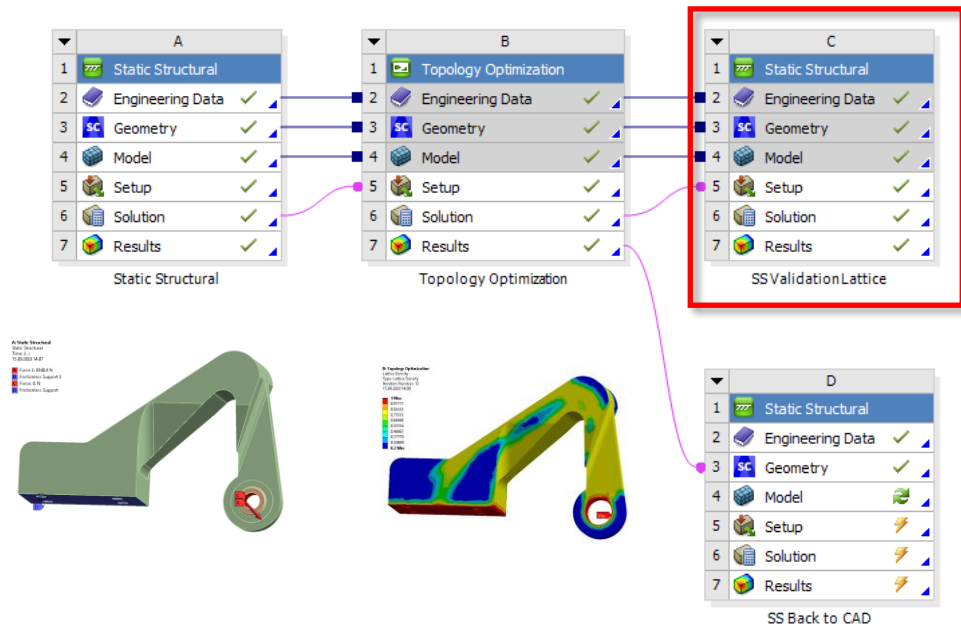
SIMP



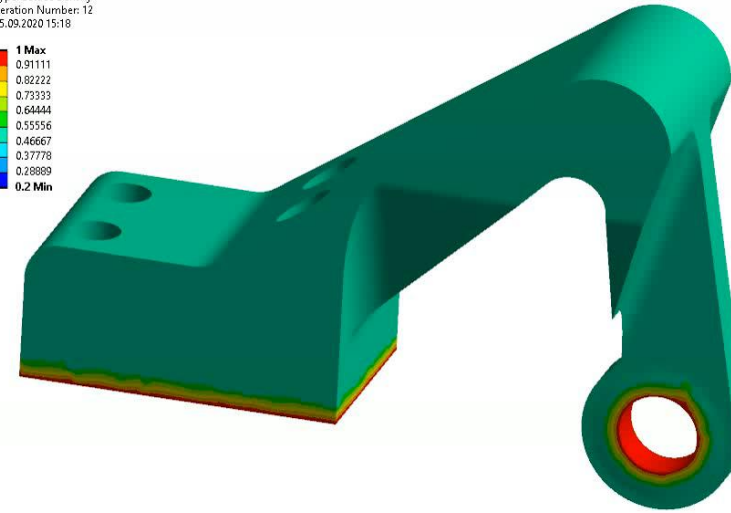
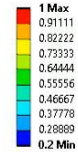
Density based - SIMP

- Matured, 30-year technology
- Density between 0 and 1 applied on mesh elements
- Densities are calculated for each element
- "Power law" filter is applied, and most needed elements are kept.

Overview: Alcoa Bracket – Lattice Optimization



B: Topology Optimization
Lattice Density
Type: Lattice Density
Iteration Number: 12
15.09.2020 15:16



- Easy & fast validation
- Automatic generated & applied variables on initial geometry

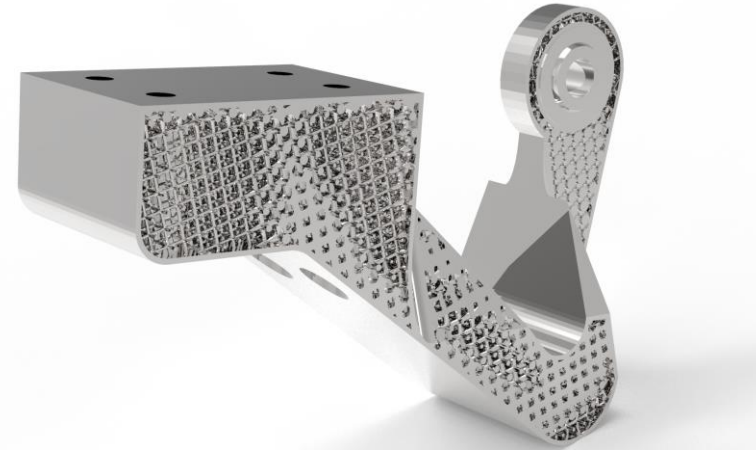
Lattice Optimization

- Solid material is substitute by beam structures depending on FEA calculation
- Outer shape doesn't change
- Knockdown factors are a fast approach for validation, properties of lattices are mapped onto solid elements

Ansys Mechanical Results



Knuckle	Original	TO
Weight [kg]	14.54	8
Max. Stress [MPa]	225	205
Saving [%]		55



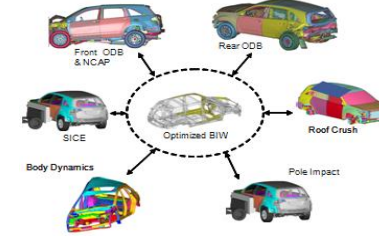
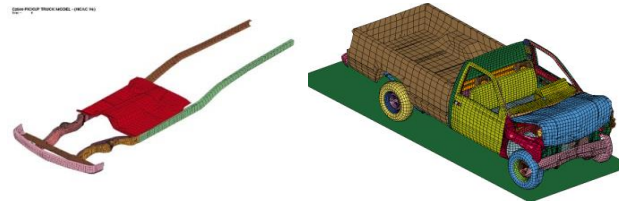
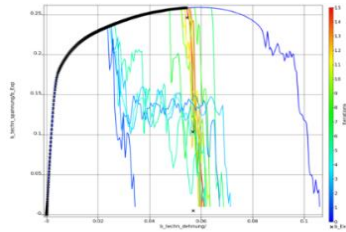
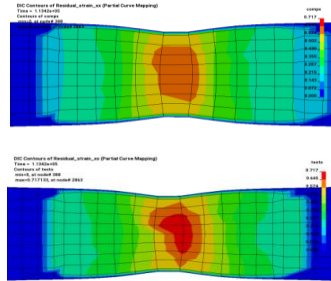
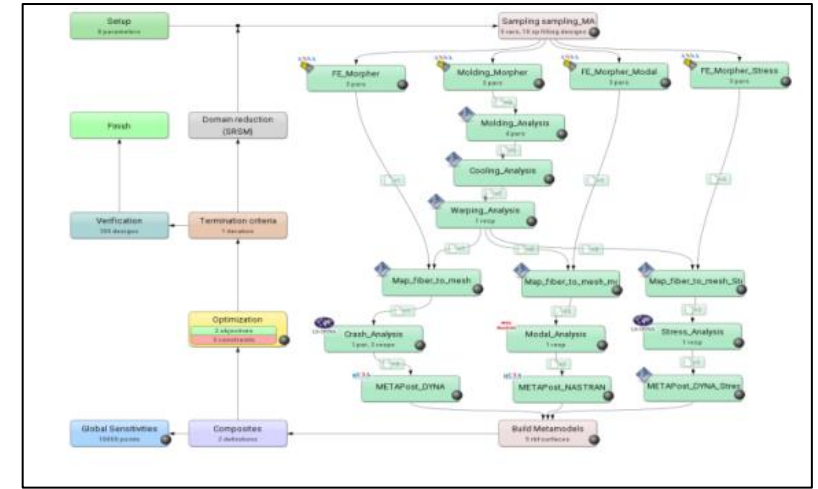
Alcoa Bracket	Original	Lattice
Weight [g]	859	448
Max. Stress [MPa]	855	821
Max. Disp. [mm]	1.17	2.15
Saving [%]		52

*Alcoa Bracket Challenge from GrabCAD

Design Optimization With LS-DYNA

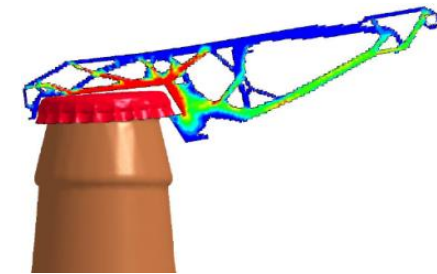
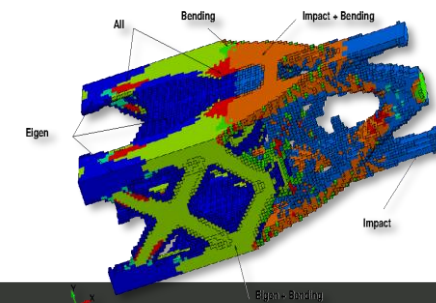
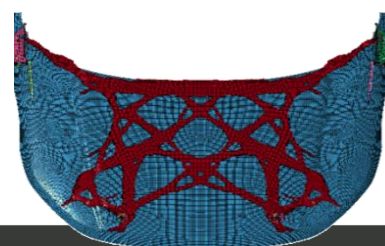
LS-OPT

- Size optimization
 - shell thickness is designed per part basis
- Shape optimization (using mesh morphing tools)
- Reliability, robustness, and reliability-based design optimization
- Material parameter identification (including digital image correlation)



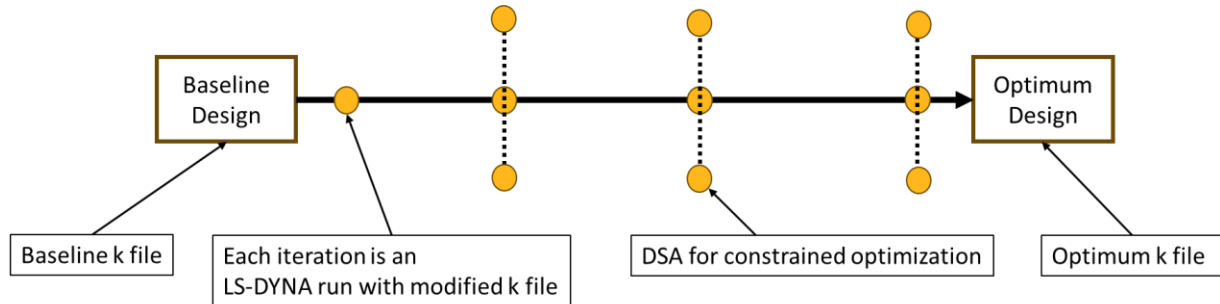
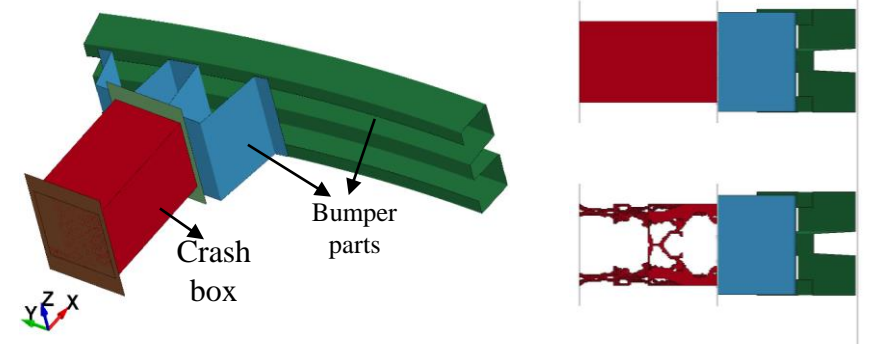
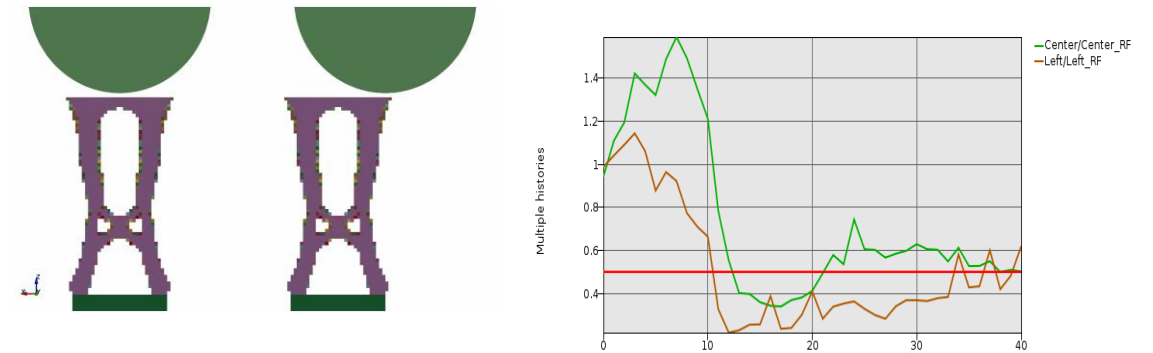
LS-TaSC

- Topology optimization
 - Obtain the best material layout for given loading and boundary conditions
 - MDO capabilities
- Topometry optimization
 - shell thickness is designed per element basis
- Shape optimization
 - a free shape of the outer surface contour is chosen

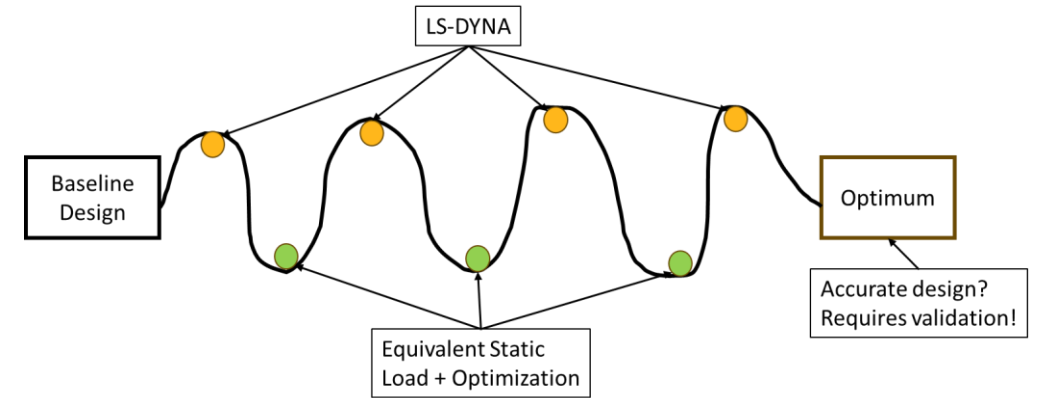


General Capabilities – LS-Dyna

- Topology and Topometric Optimization
 - Optimal material layout (solids/shells)
 - Nonlinear LS-DYNA models, large deformations, contact
 - Design variables: Element density/thickness
 - Local Objective: Maximize stiffness, fundamental freq.
 - Final topology is LS-DYNA input file (or STL file)



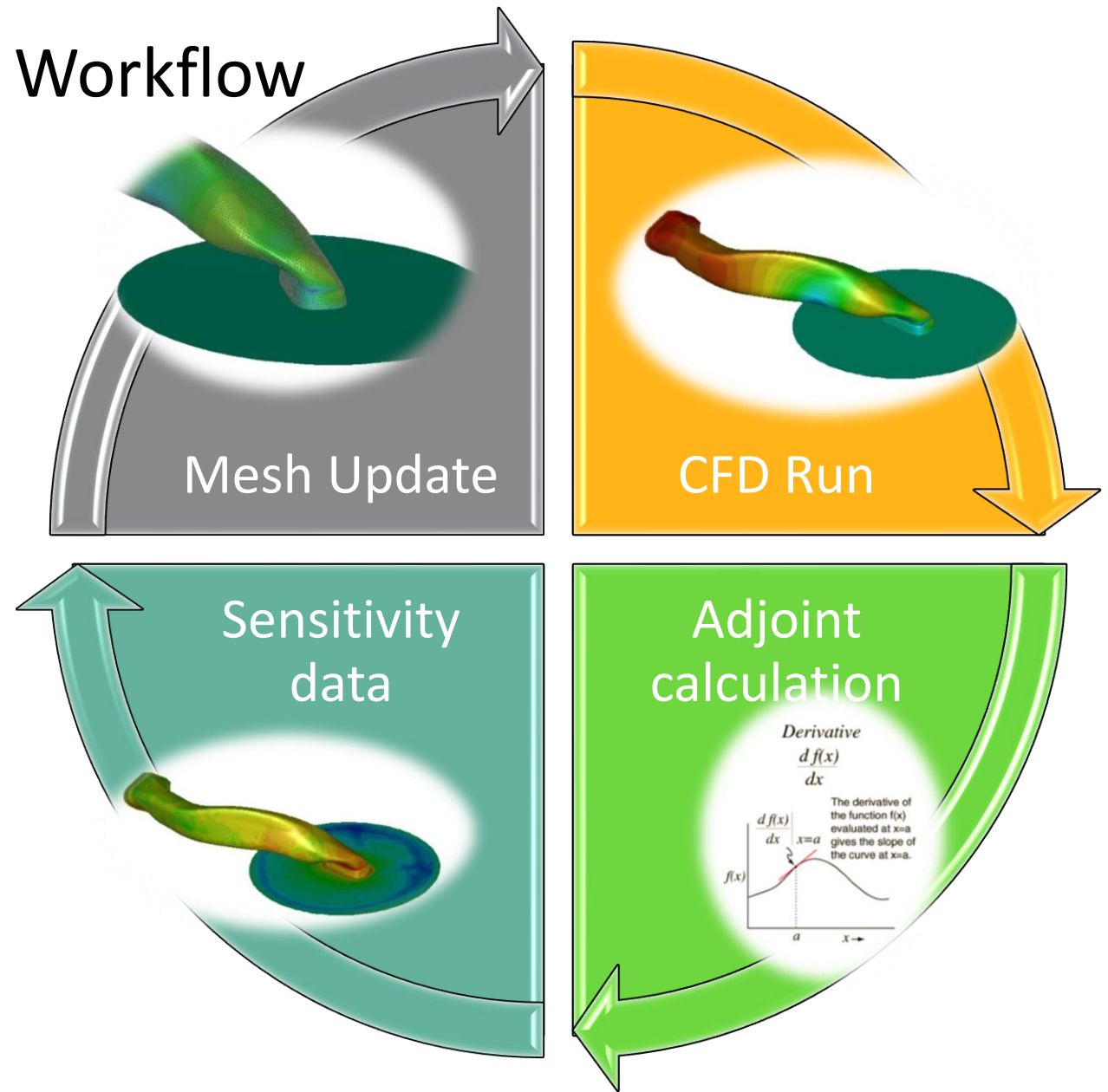
Ansys LS-TaSC



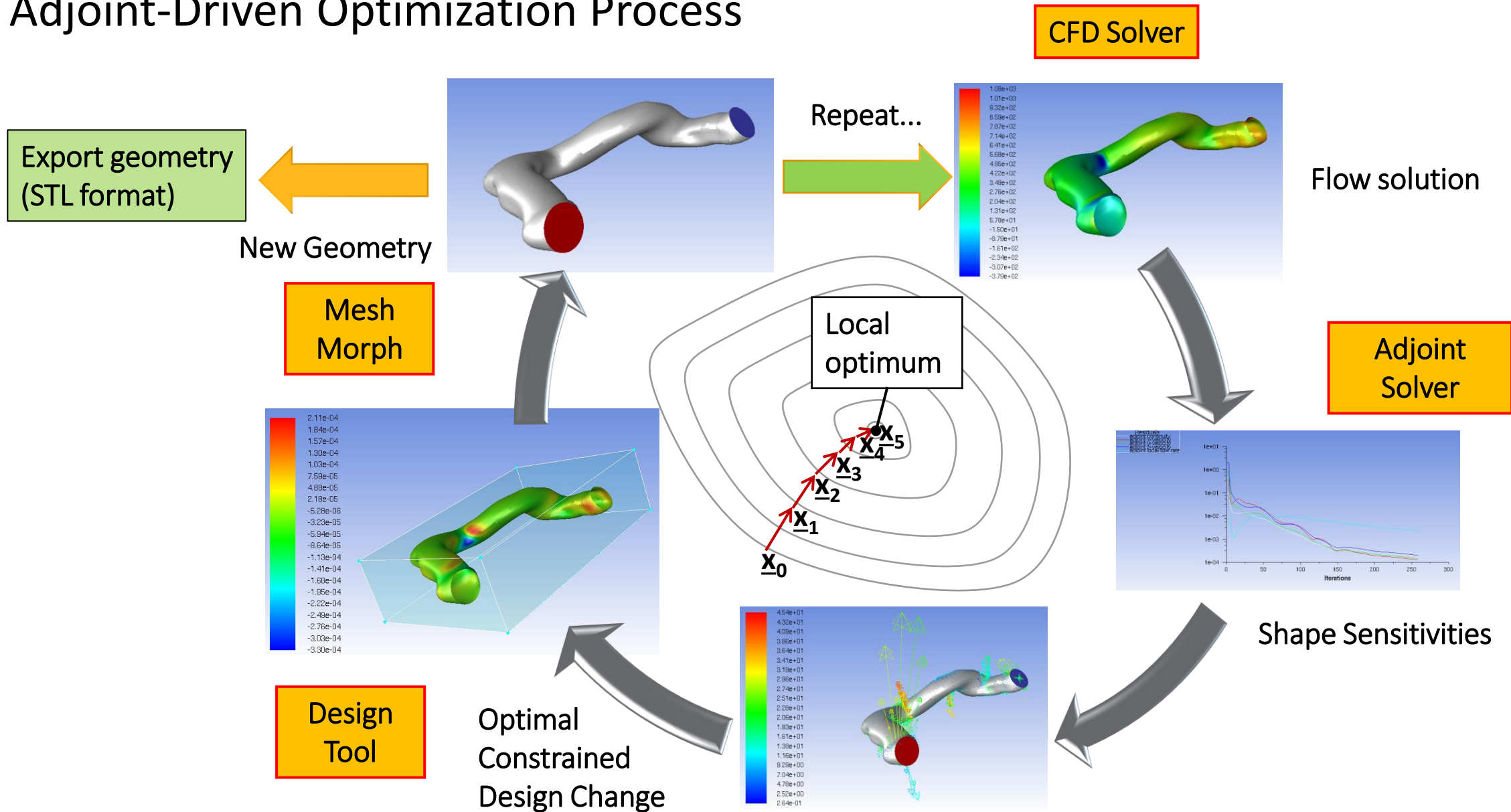
Other tools

Overview of the Fluent Adjoint Workflow

- The workflow can be viewed as a four-step process
 1. CFD Run (known process)
 2. Calculate the derivatives (gradients)
 3. Sensitivity data
 - Mapping sent back by derivatives
 4. Update the shape (Mesh)
 - Based on the sensitivity data
 - Based on the environment constraints
- This four-step process can be run multiple times to reach an optimum evolution for the design...

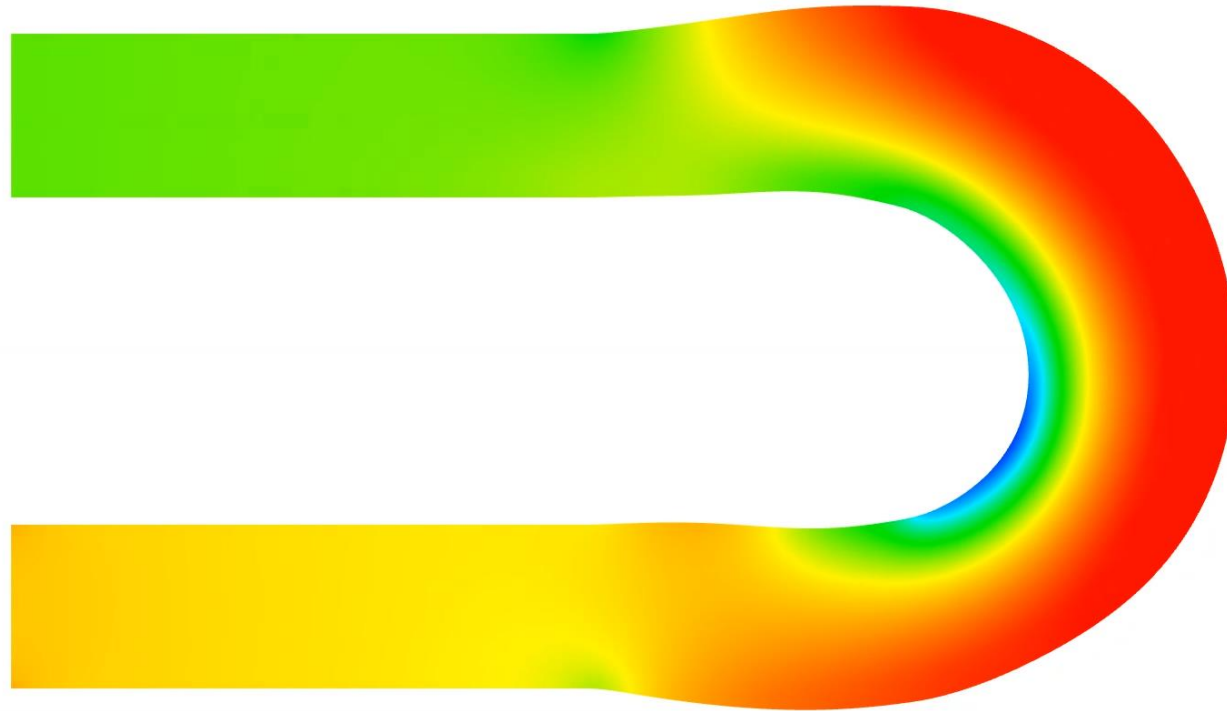
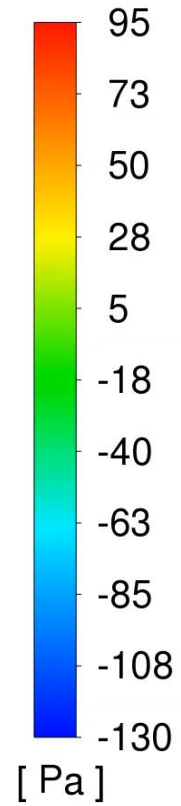


Adjoint-Driven Optimization Process



/ A Simple Example – Pipe U-Bend

contour-pressure
Static Pressure

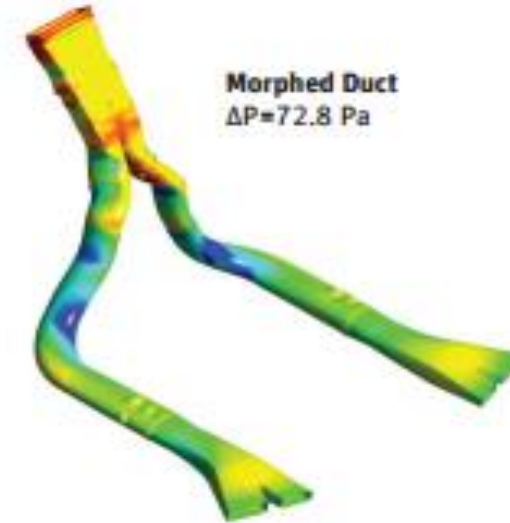


Adjoint Optimization Example – HVAC Duct

- Rear Cabin Automobile HVAC Duct - Minimize Total Pressure Drop



33% reduced pressure drop

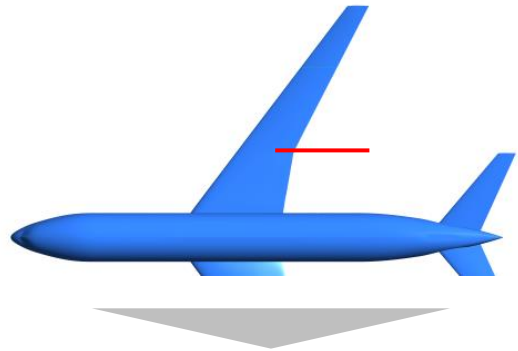


- Small geometry changes determined by Adjoint optimization / mesh morphing results in significant performance improvement!
 - This is a result of computing node displacements for specified portion of domain based on the adjoint solution.

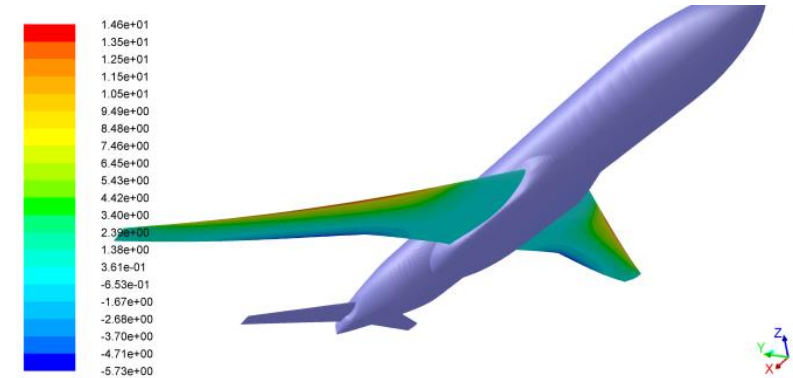
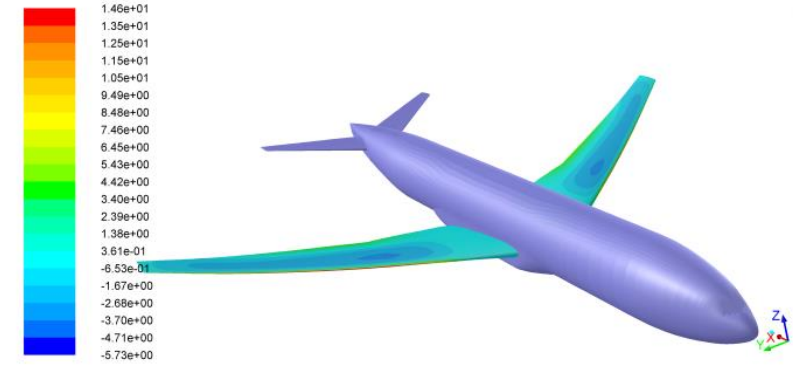
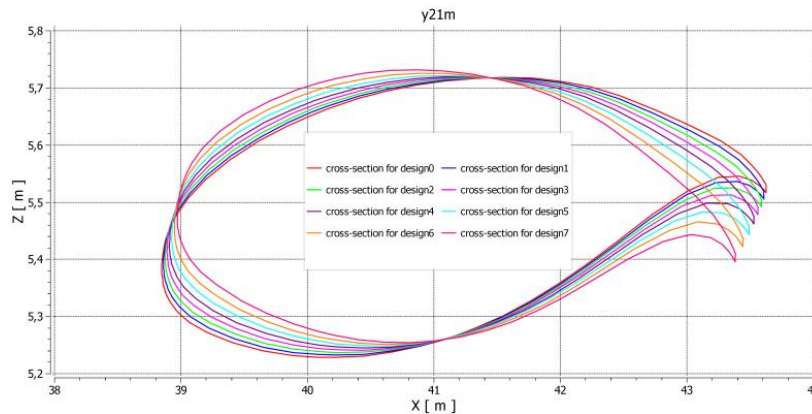
Adjoint Optimization Example – Full Aircraft Lift/Drag

- **Airplane – full scale - Maximize Lift/Drag**

- Optimize shape of the wing to increase lift to drag ratio
- Again, just small changes result in a significant



55% increased lift



Discovery – Correct Tool for Identifying Trends



Ansys Discovery

- is easy to use
- provides immediate feedback
- helps to find out the rough direction to go
- focuses on non-complex features



- ... like a **COMPASS** which helps
- not to get lost
 - find out which direction to go

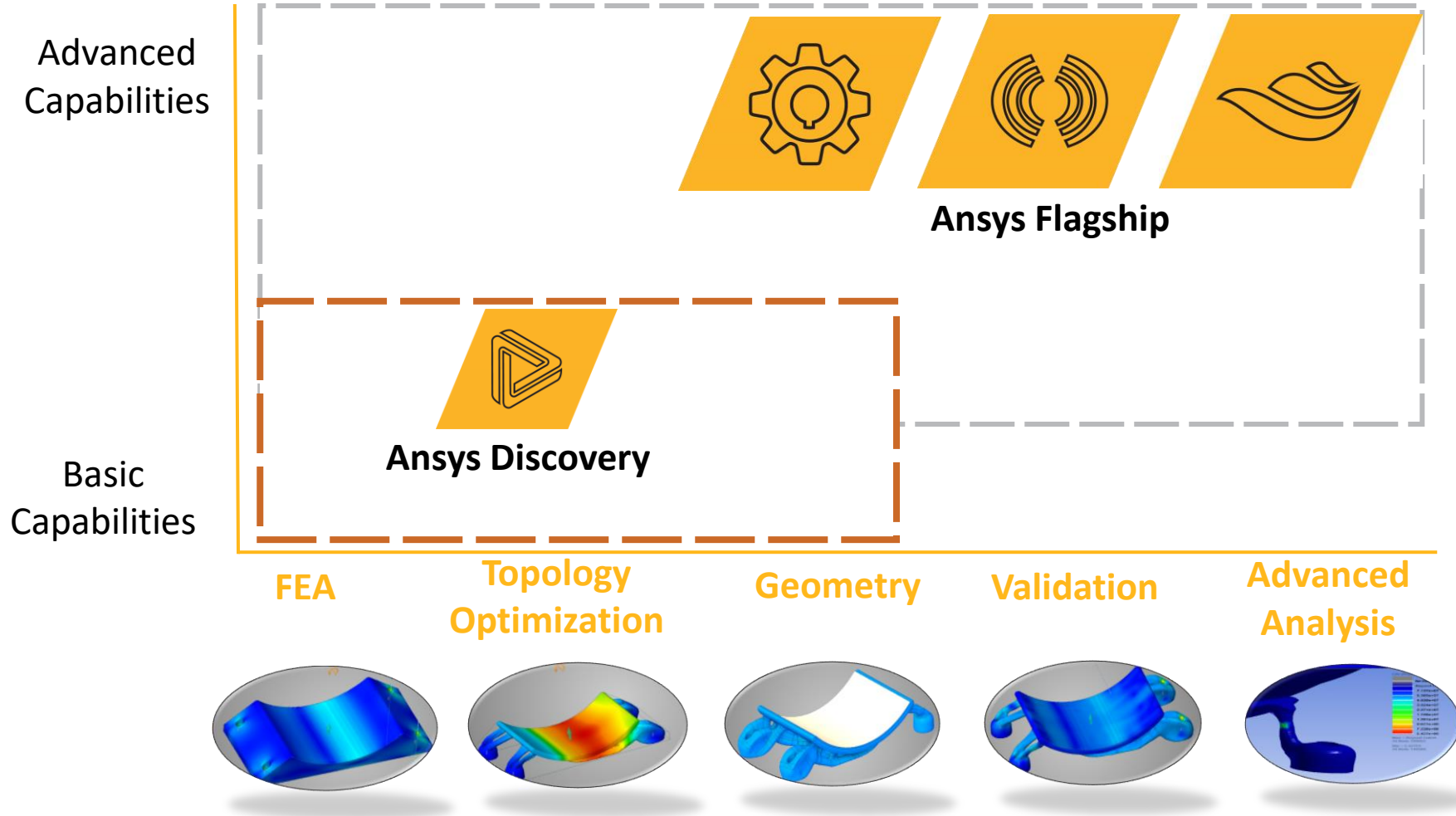
Ansys Flagship Products

- need skilled / trained users
- require calculation time
- can provide exact numbers
- are versatile in features



- ... like a **GPS**, which shows exactly
- distance and time to destination
 - path to follow to exact destination

A Topology Optimization Solution for Every Engineer



The Ansys logo consists of a yellow slanted bar followed by the word "Ansys" in a bold, black, sans-serif font.

