



coreform

Better simulation through better geometry

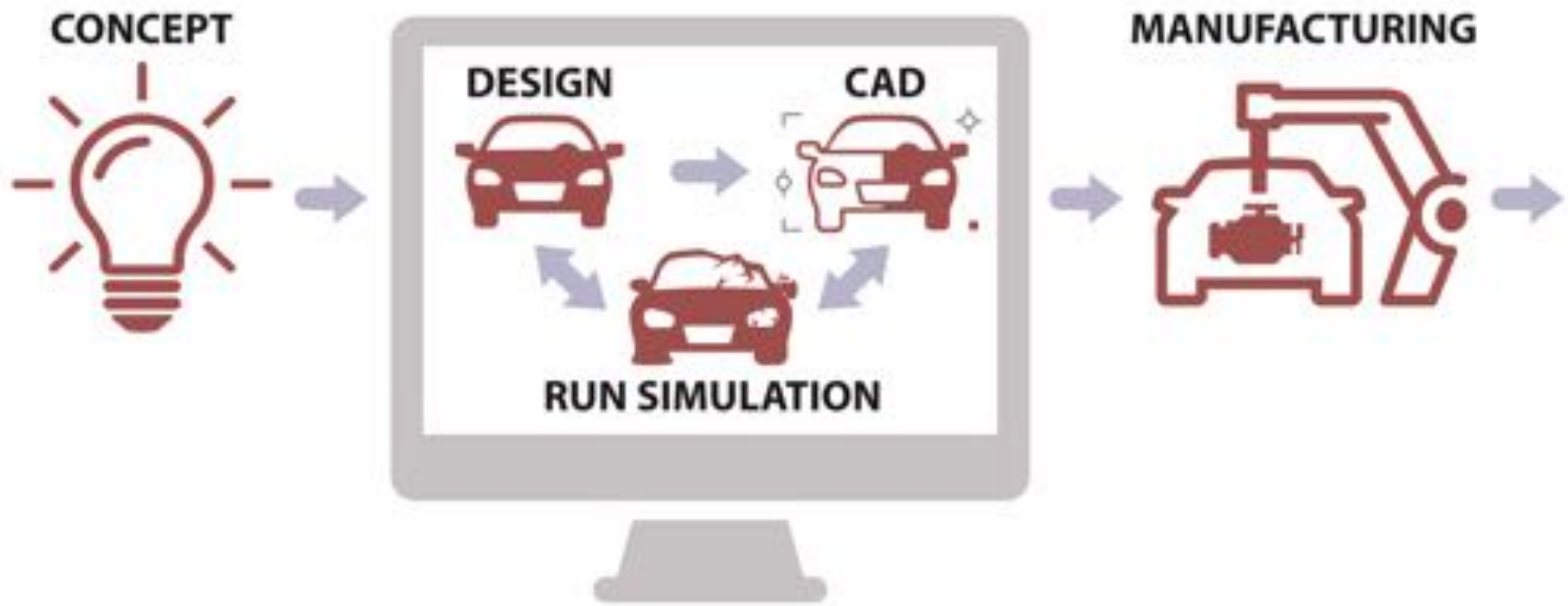
Spline-based simulation

Matthew Sederberg
CEO, Coreform LLC

The agenda

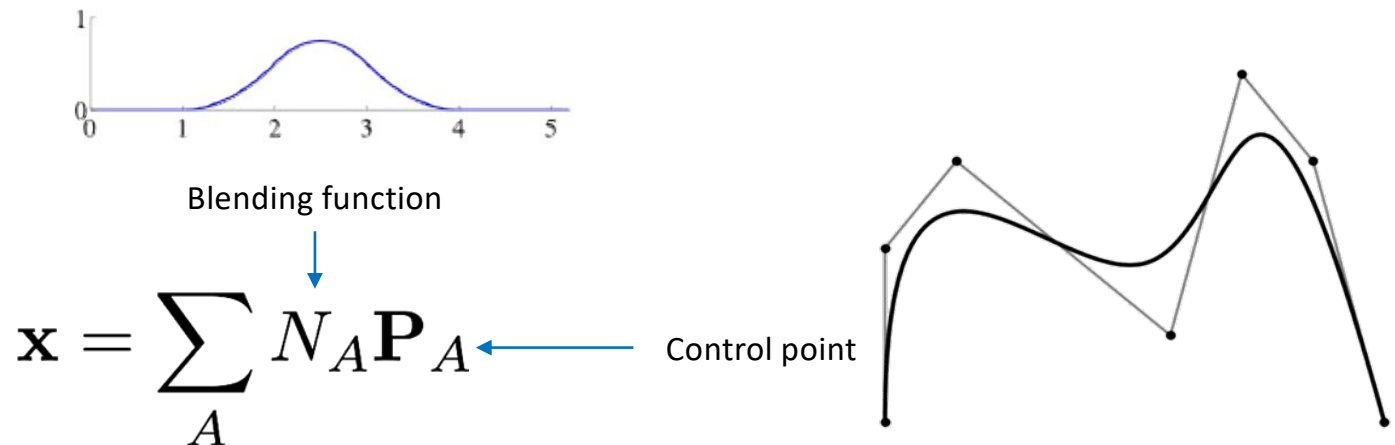
- 1 Introducing Coreform
- 2 Benefits of spline-based simulation
- 3 Coreform products
- 4 Getting involved with Coreform

We believe the future vision of IGA!

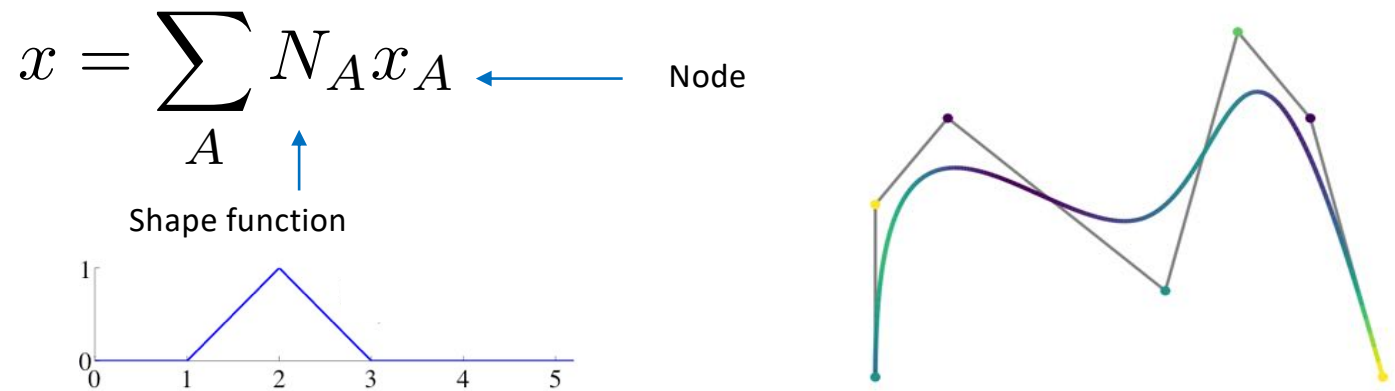


Today, we have *spline-based simulation*

CAD



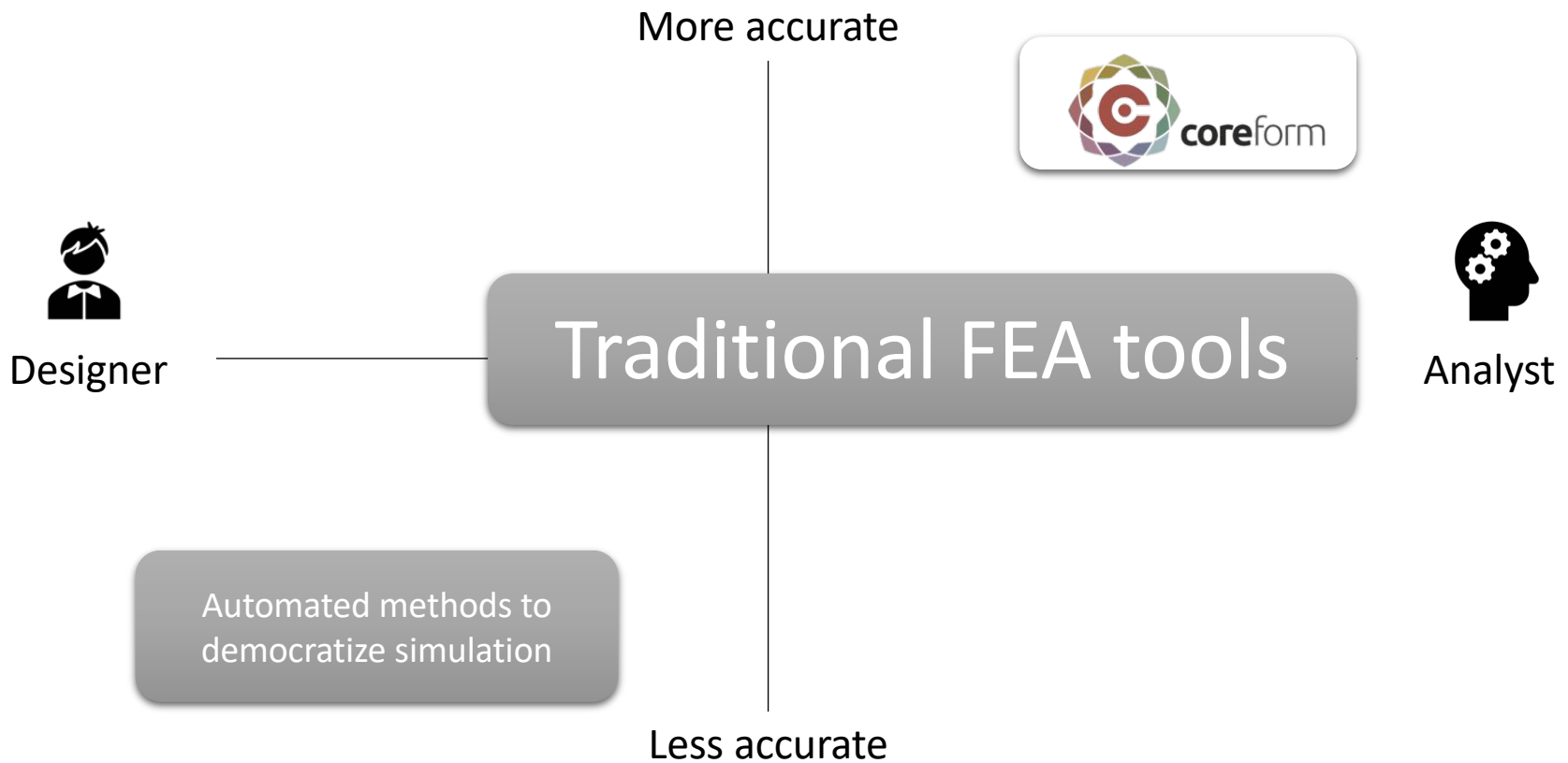
Simulation based Simulation



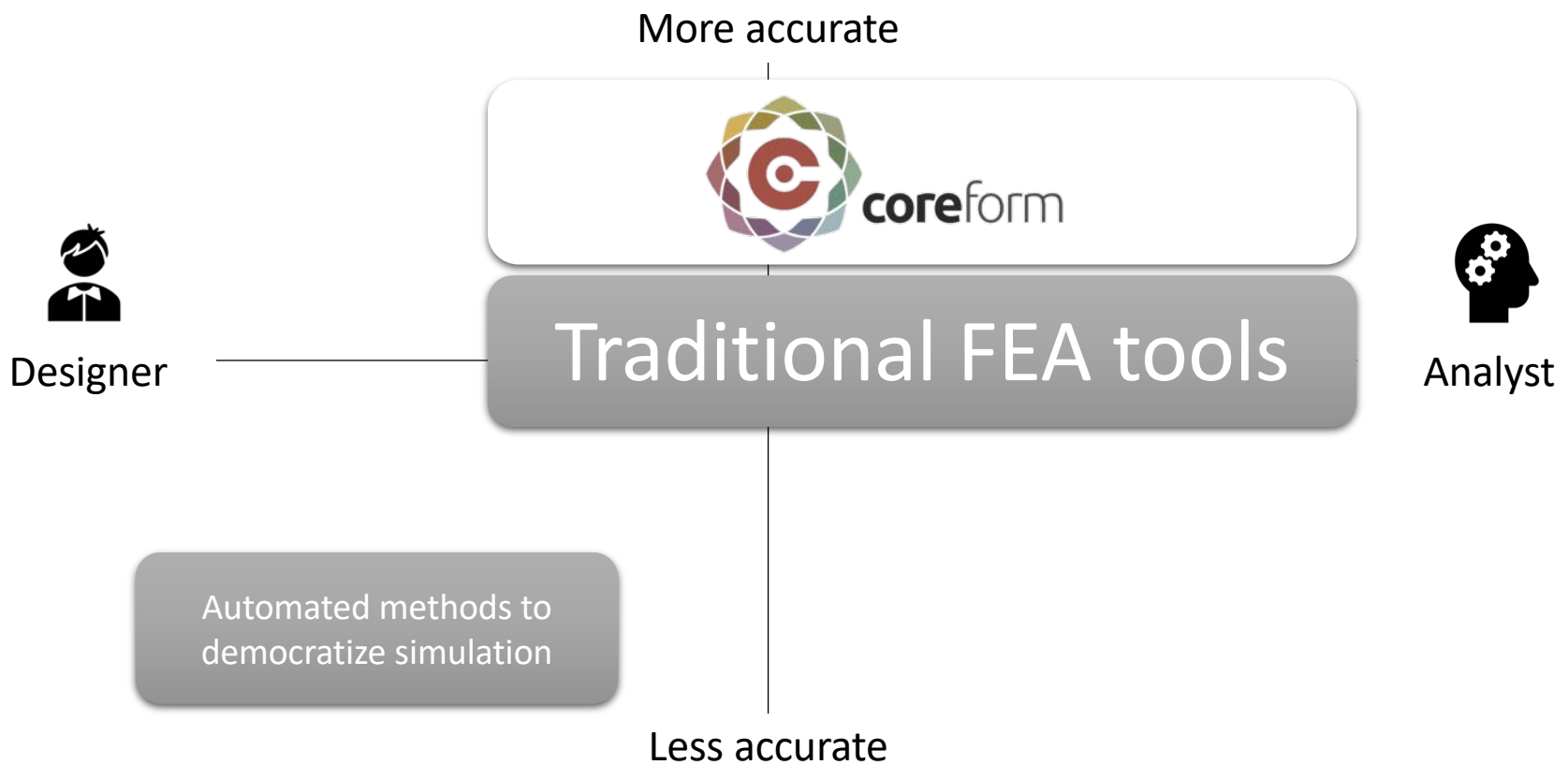
Coreform: 100% focused on commercializing spline-based simulation

- ❖ Developing the first commercial native spline-based solver
- ❖ Driving interop with legacy solvers
DYNA, MOOSE, others
- ❖ Working with leading commercial and government partners

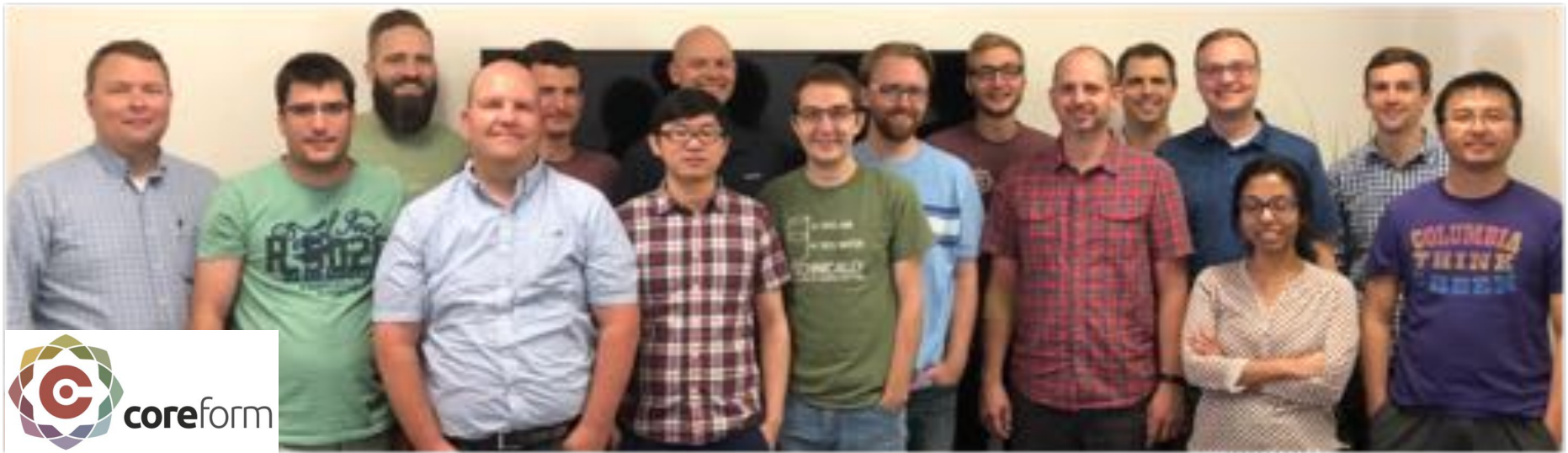
Better simulation through better geometry



Better simulation through better geometry



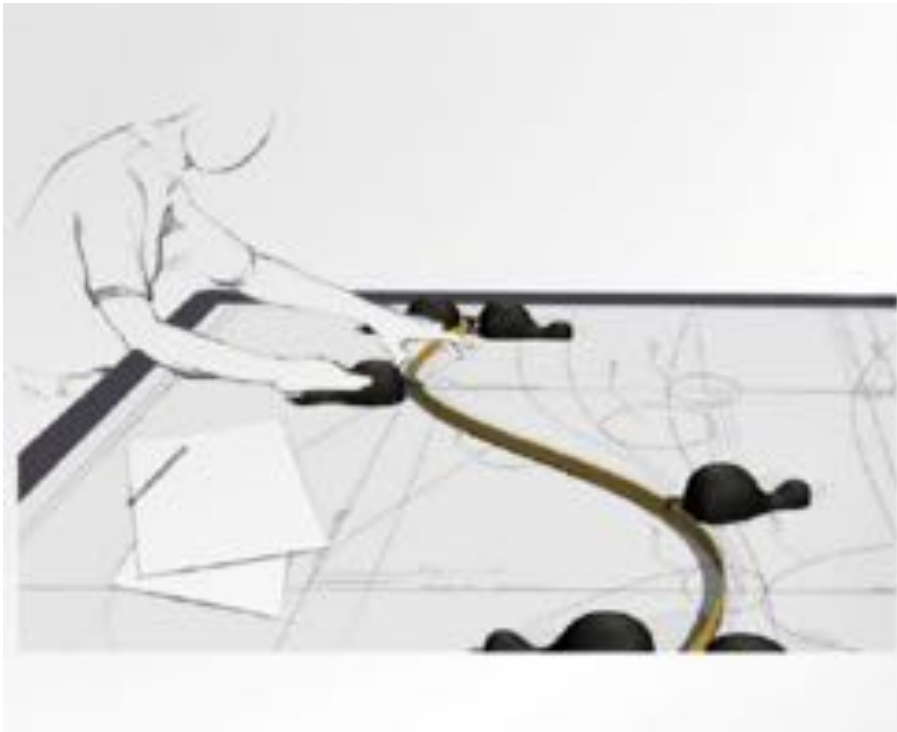
Coreform acquires csimsoft on 6 Sept 2019



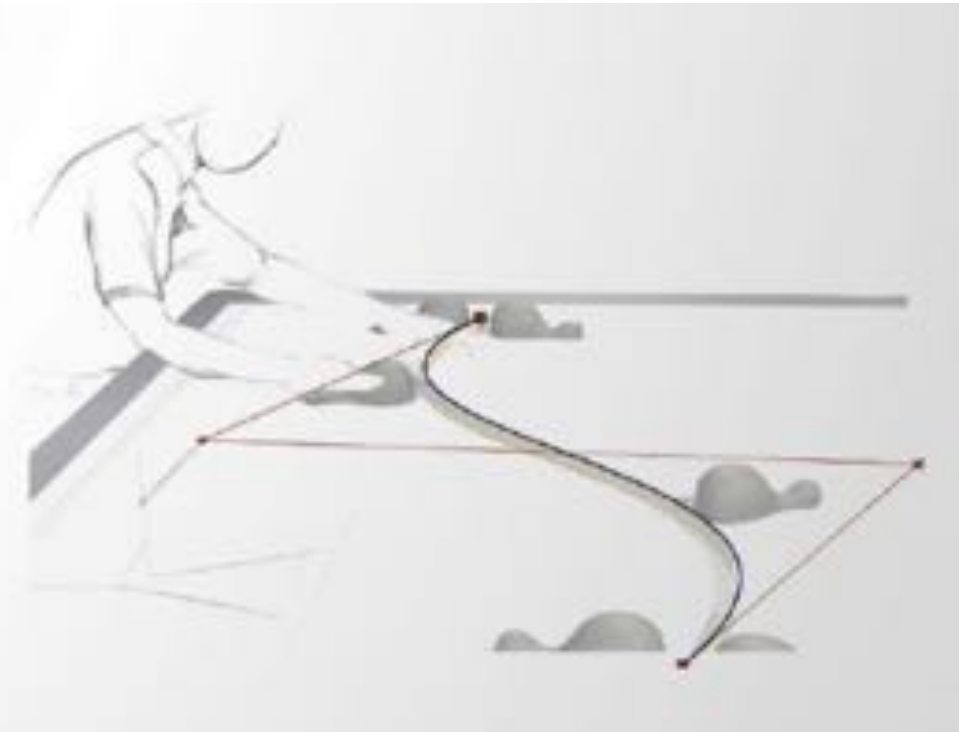
About csimsoft

- Elite team with over 150 years of meshing experience
- csimsoft's CUBIT/Trelis software will accelerate our commercialization of spline-based simulation
- Based 12 miles from Coreform





Traditional spline



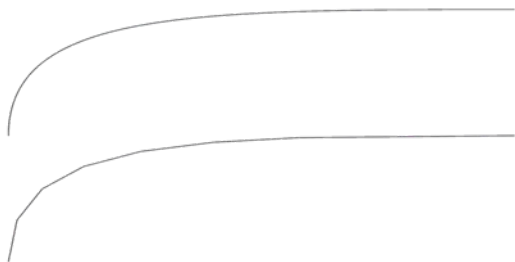
B-spline

Image courtesy Kerry Kingston and Autodesk

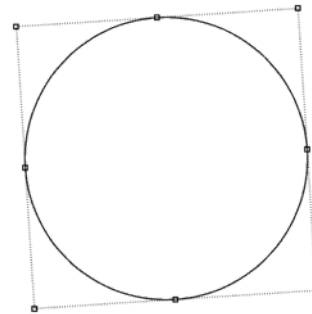
Non-Uniform Rational B-Splines (NURBS)

NURBS are the foundation of computer-aided design (CAD)

NURBS are an accurate, smooth representation of a curve...



...not a representation by small, straight line segments

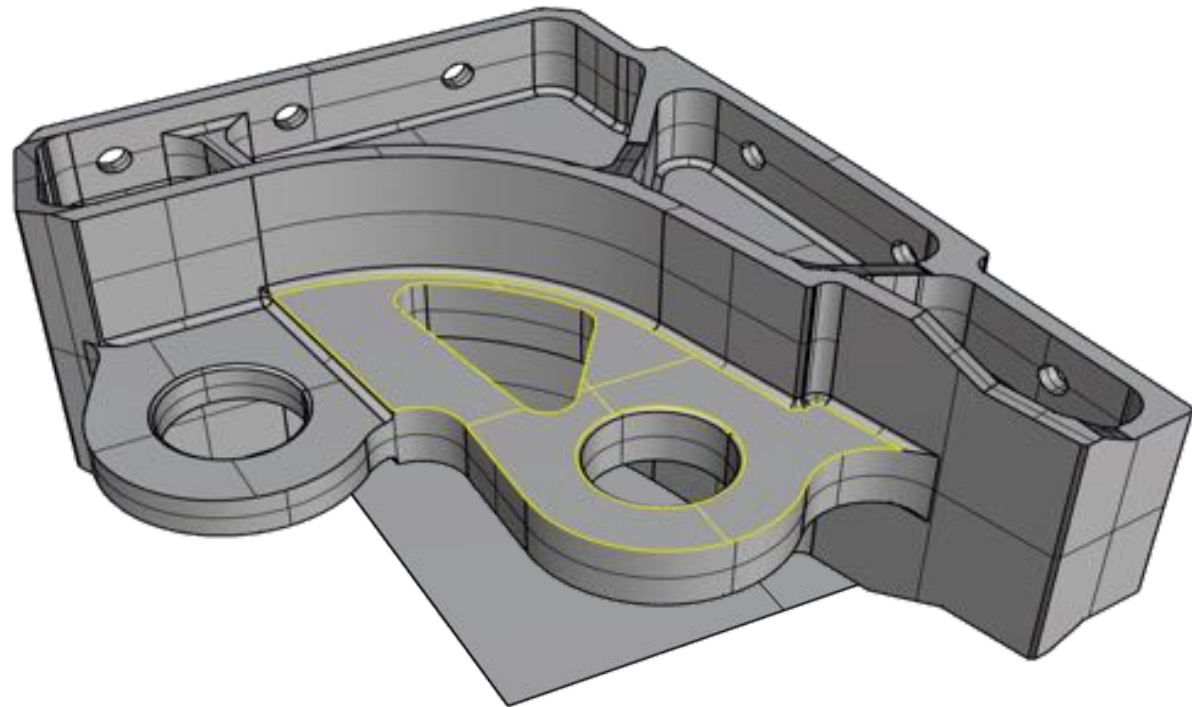


NURBS represent conic sections (i.e., circles, fillets) exactly

NURBS and complex shapes

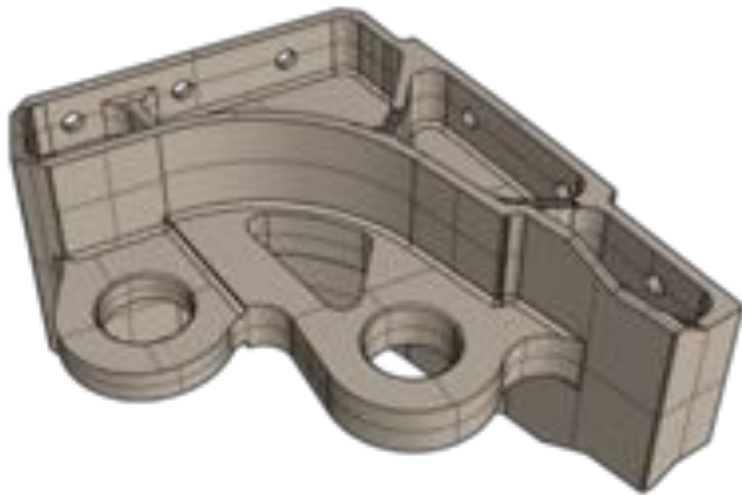
NURBS can be trimmed and combined to represent complex shapes.

**Trimmed NURBS
Boundary
Representation
(BREP)**

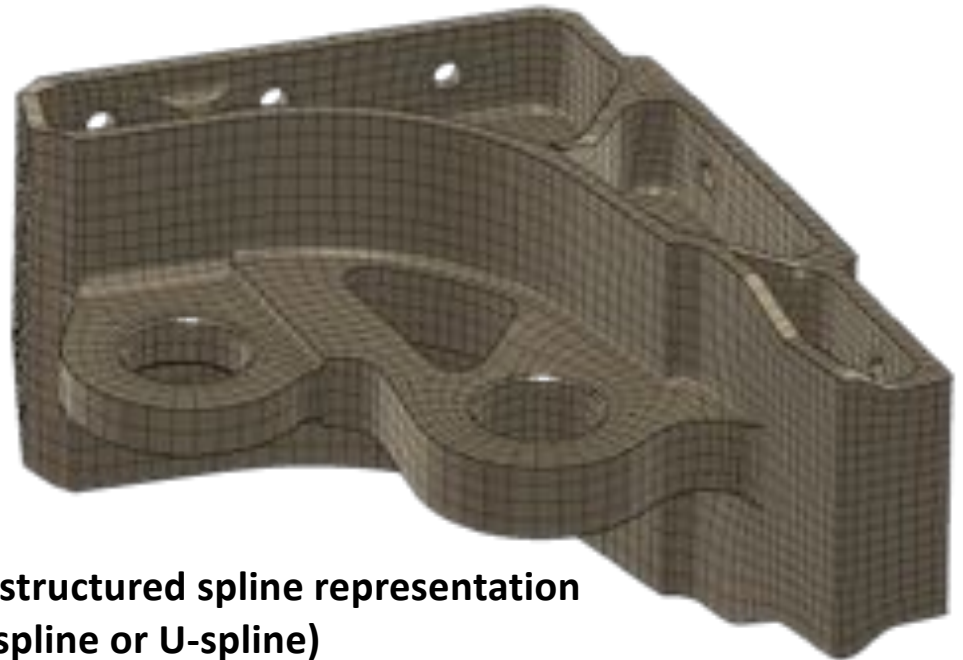


Unstructured splines

Represent complex shapes and are suitable for analysis



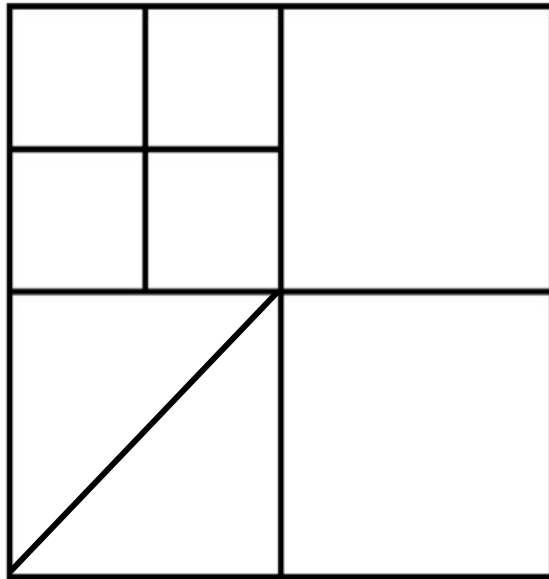
Trimmed NURBS Boundary Representation (BREP)



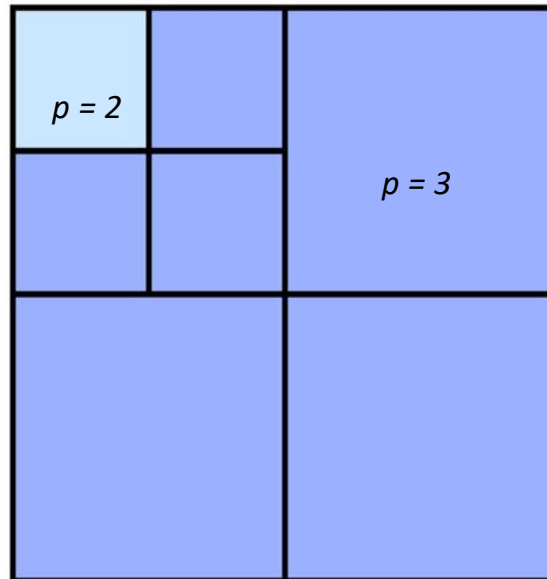
Unstructured spline representation (T-spline or U-spline)

U-splines offer novel analysis features

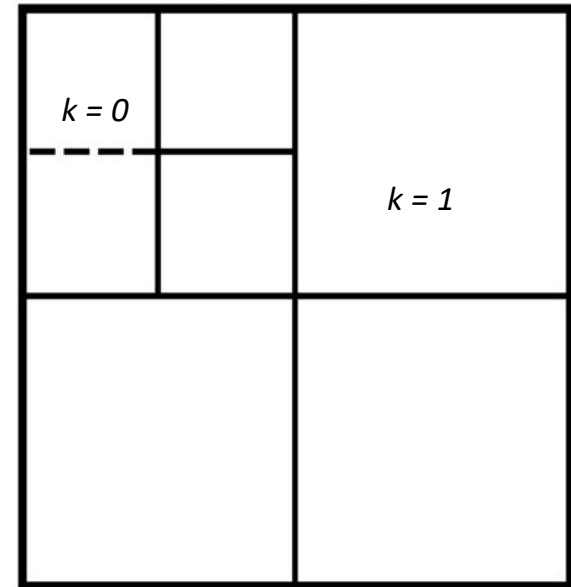
Non-uniform topology



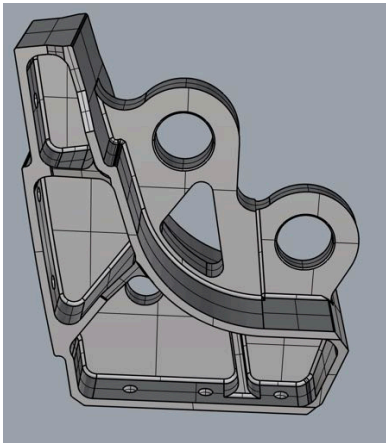
Non-uniform degree



Non-uniform smoothness



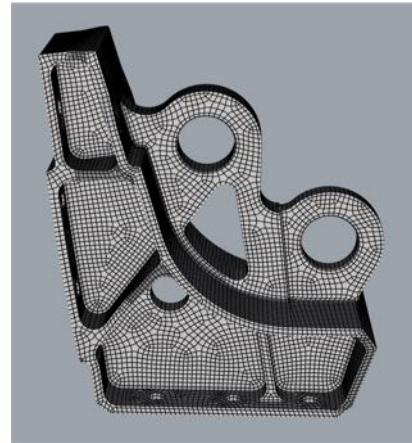
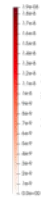
U-splines: suitable for CAD/CAM/CAE



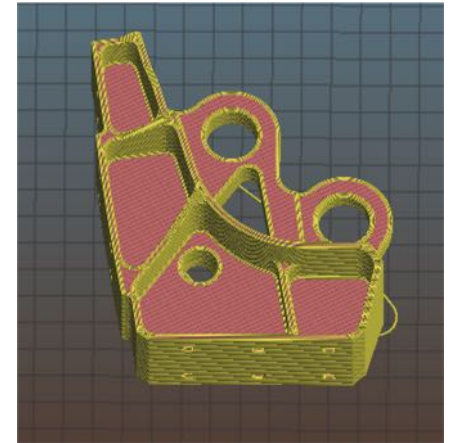
STEP



U-spline surface
(with analysis)

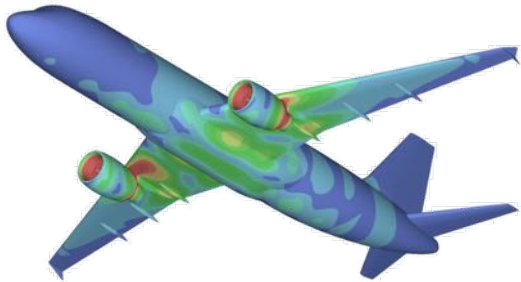


Exported to Rhino
(watertight BREP)



Slice file

Benefits of spline-based simulation



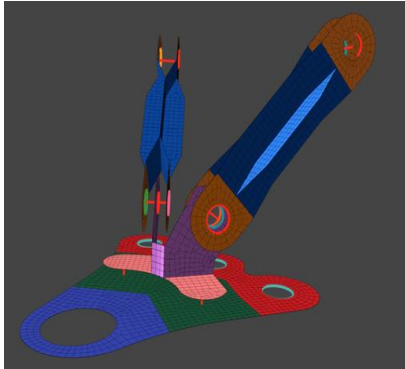
Better accuracy in less time



Increased robustness

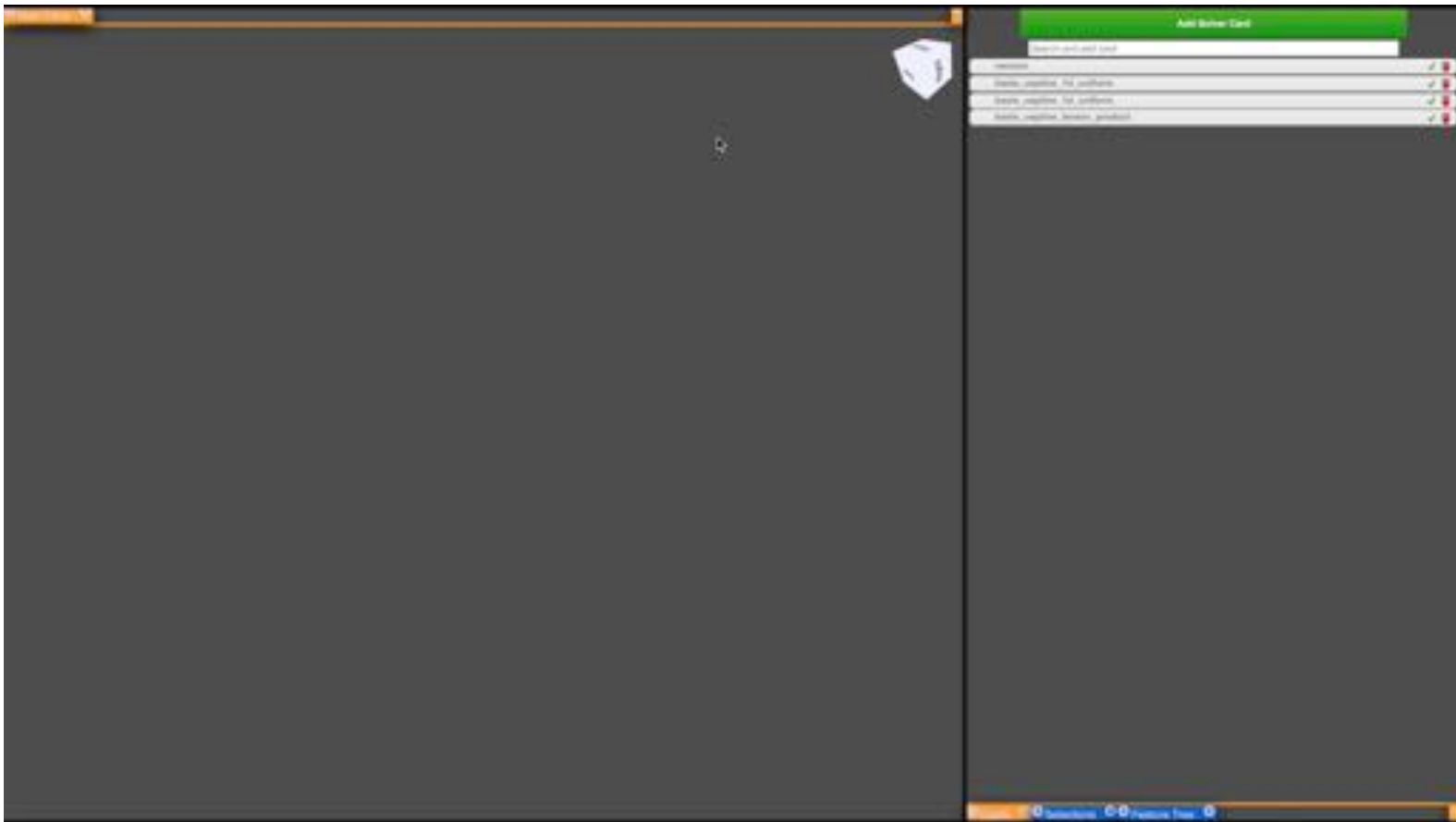


Lower simulation costs



Minimal change to your workflow

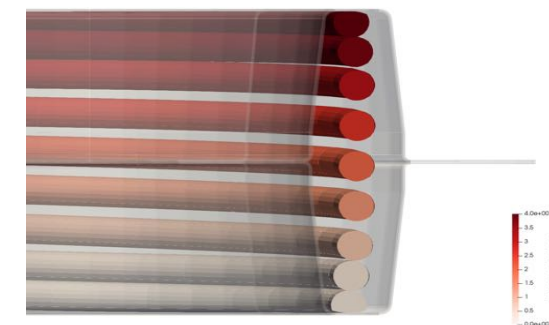
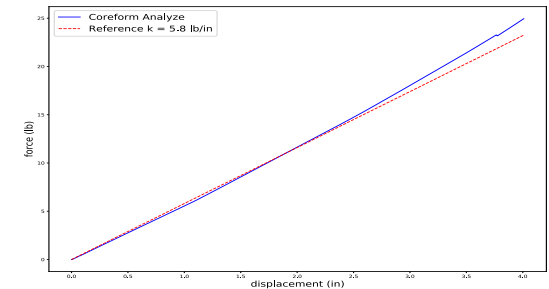
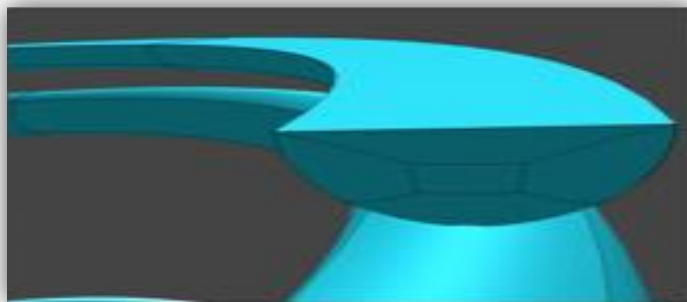
Better accuracy, less time and effort



Better accuracy

50 times faster with 500 times fewer elements

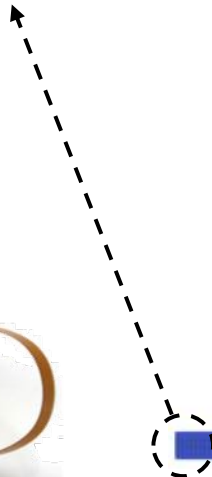
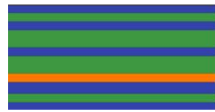
	FEA	U-Splines
Elements	225,000	500
Total compute hours	384	8



More robust

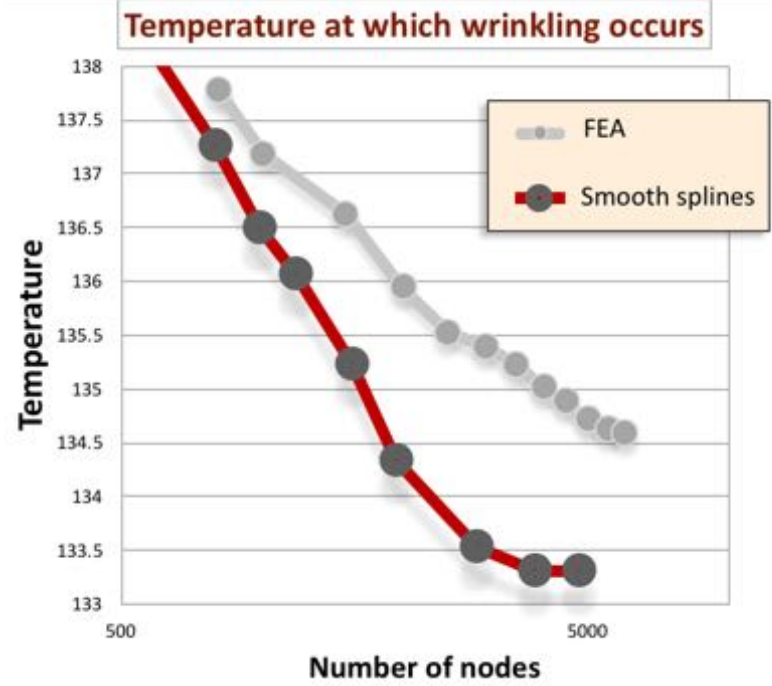
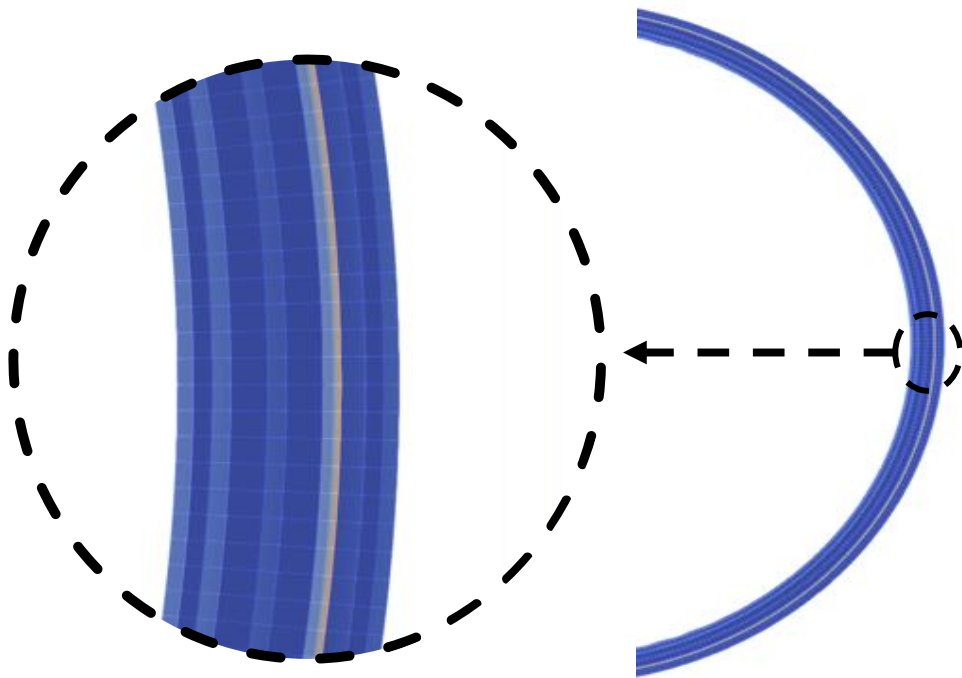
Splines are more robust for large deformations.

Flex cable
composed
of 9 layers
of different
materials

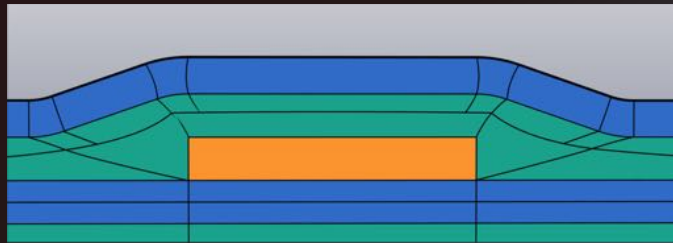


Wrinkling onset

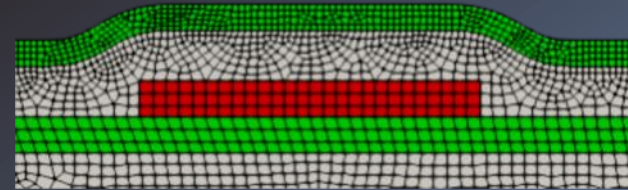
Splines capture wrinkling onset faster than FEA



U-spline solid flex cable: 1000x fewer elements than linear FEA!



U-spline: 10,900 total elements

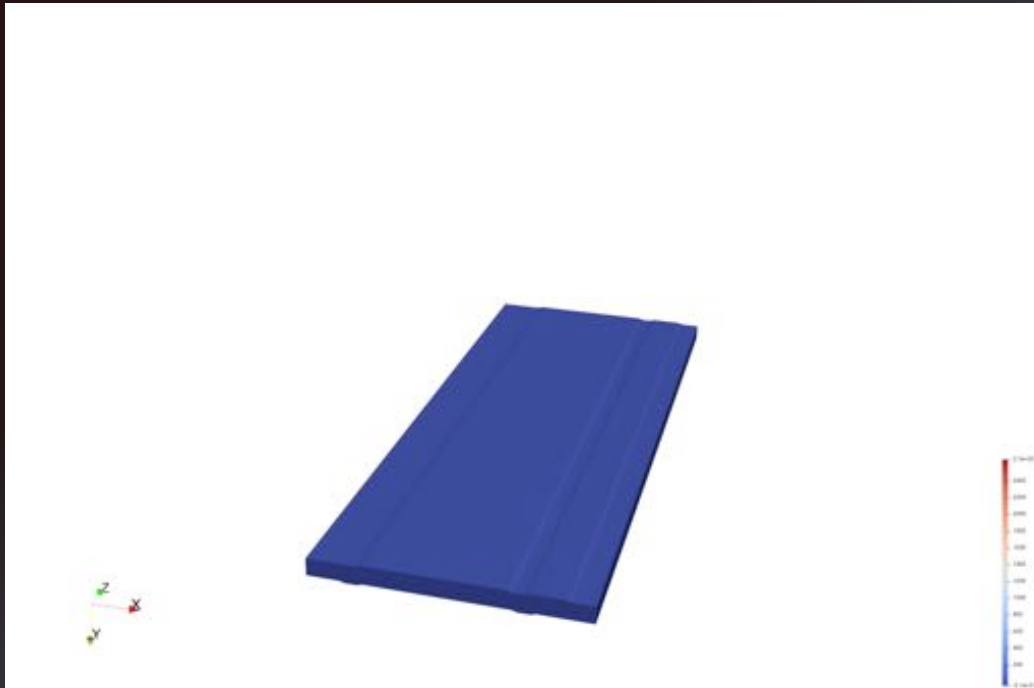


Reference linear mesh: 10M total elements

- Copper
- Kapton
- Adhesive

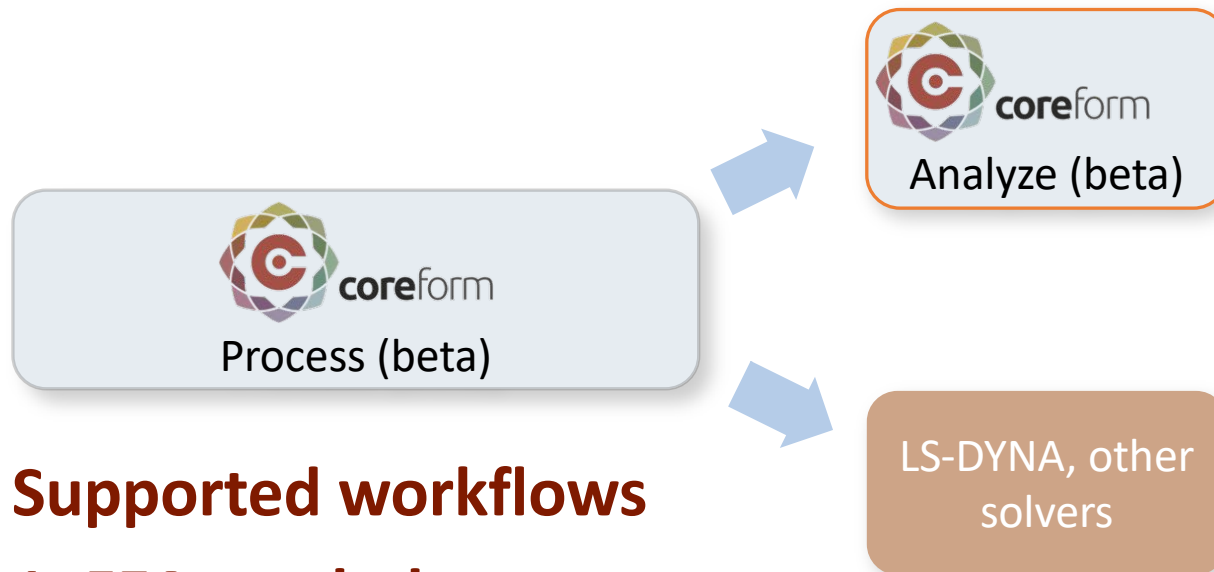


Lower simulation costs



	Customer Simulation using industry code	Coreform Analyze Simulation	
Total # of solid elements	10 million	10,900	~1000x fewer elements
Solution method and # of timesteps	Explicit Statics – 5 million timesteps	Implicit Dynamics - 250 timesteps	~20,000x fewer timesteps
Total compute hours	72,000	73	~1000x faster runtime
Geometric Representation	Approx.	Exact	Better geometry

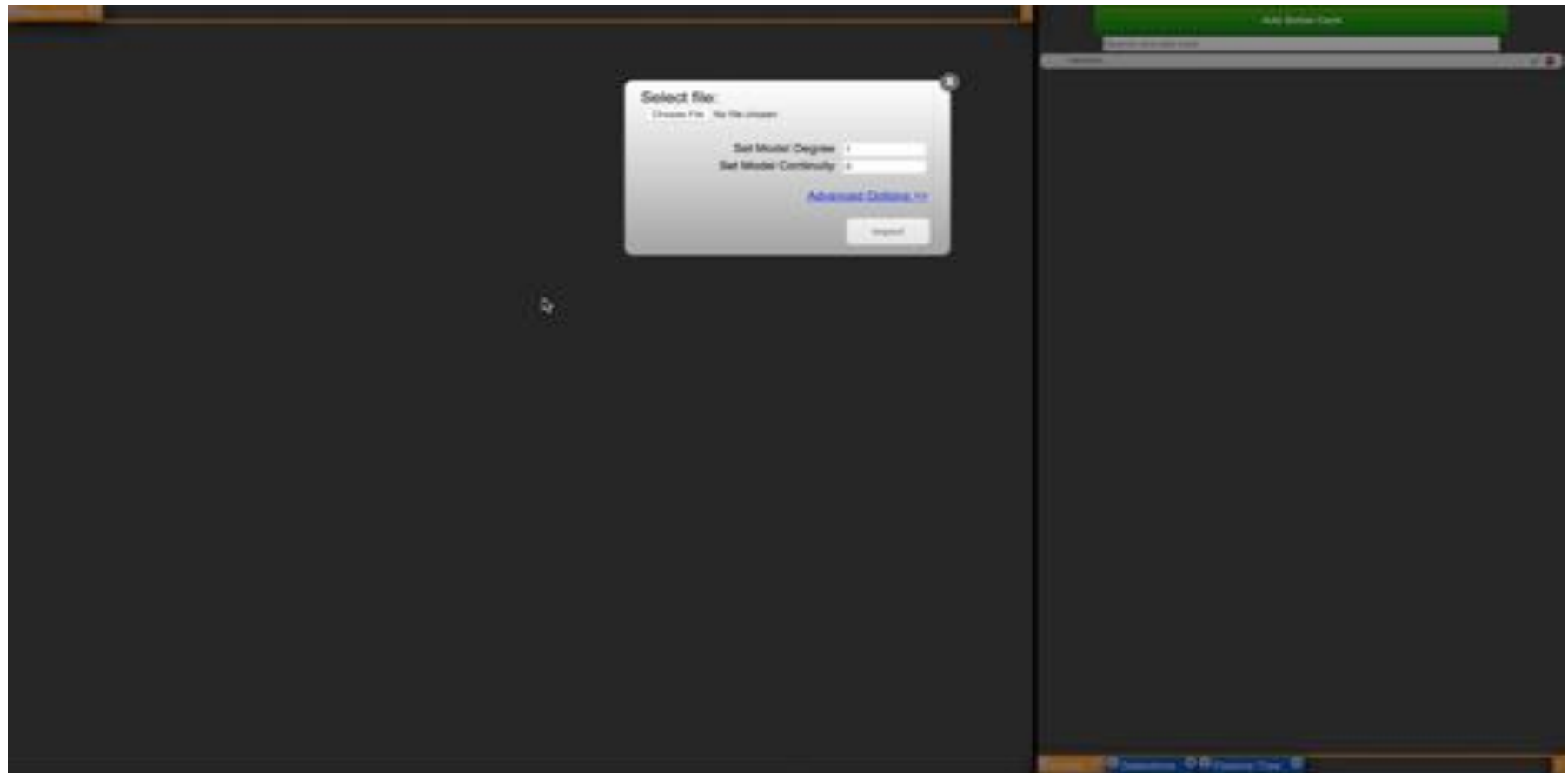
Minimal change to workflows



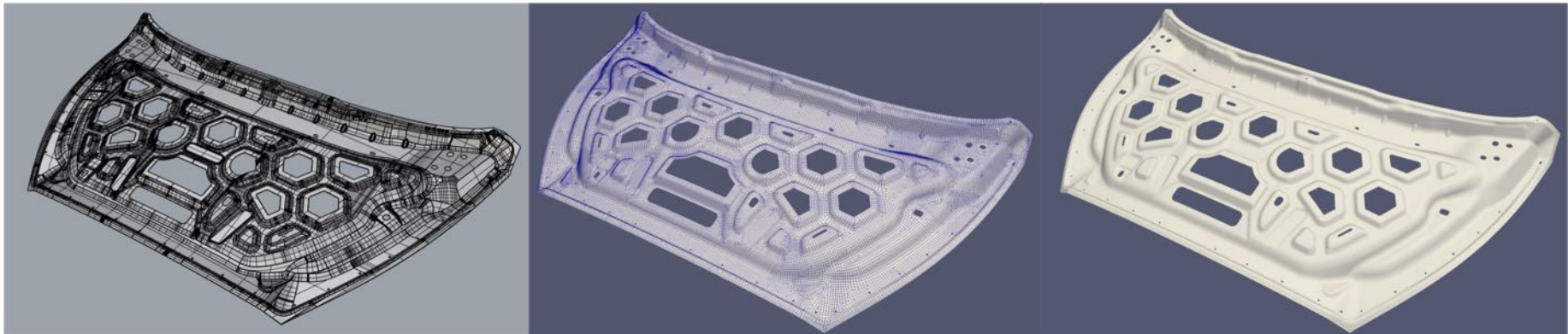
Supported workflows

1. FEA mesh data
2. CAD data
3. Next-gen CAD data

FEA mesh data workflow



FEA mesh data workflow

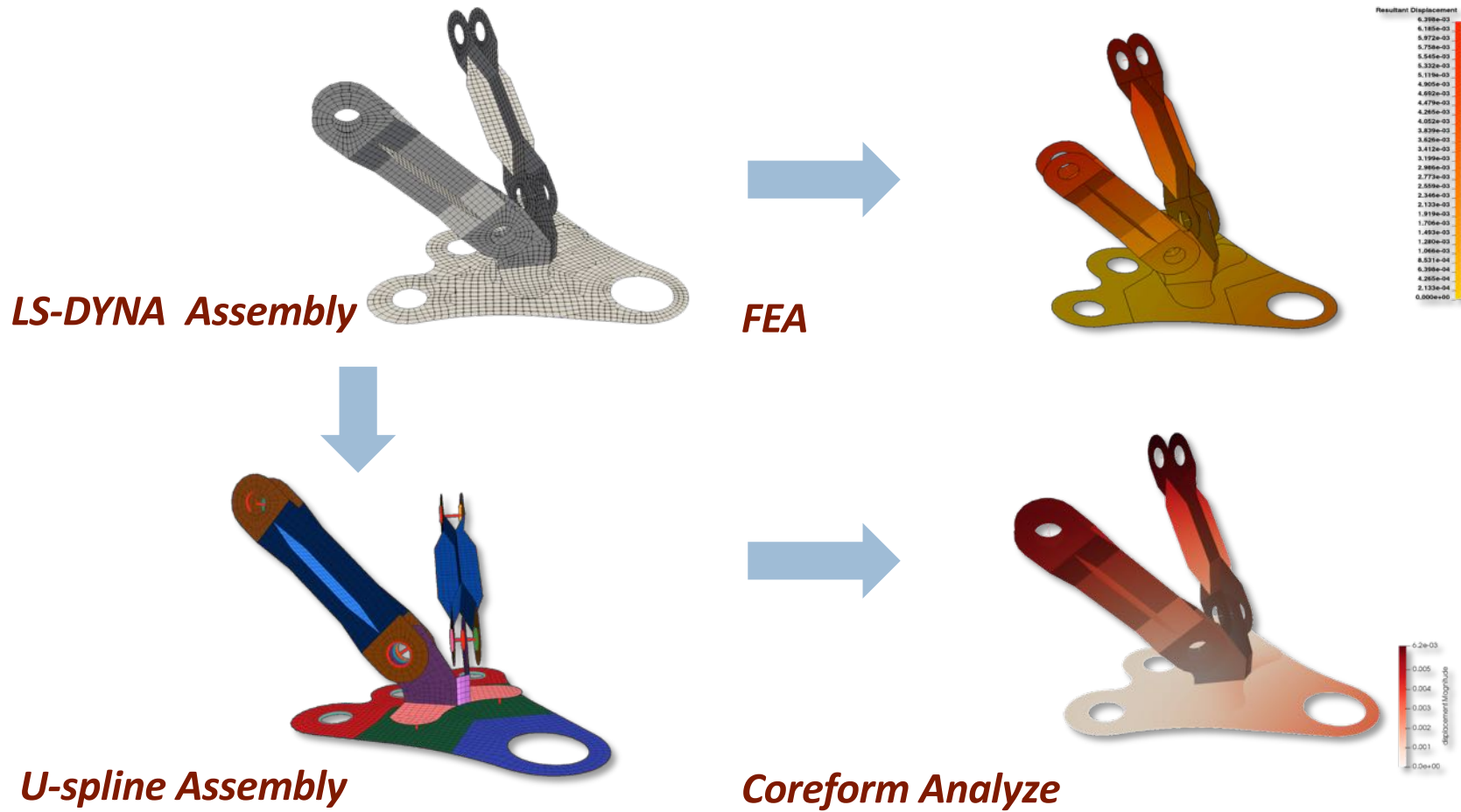


BREP file

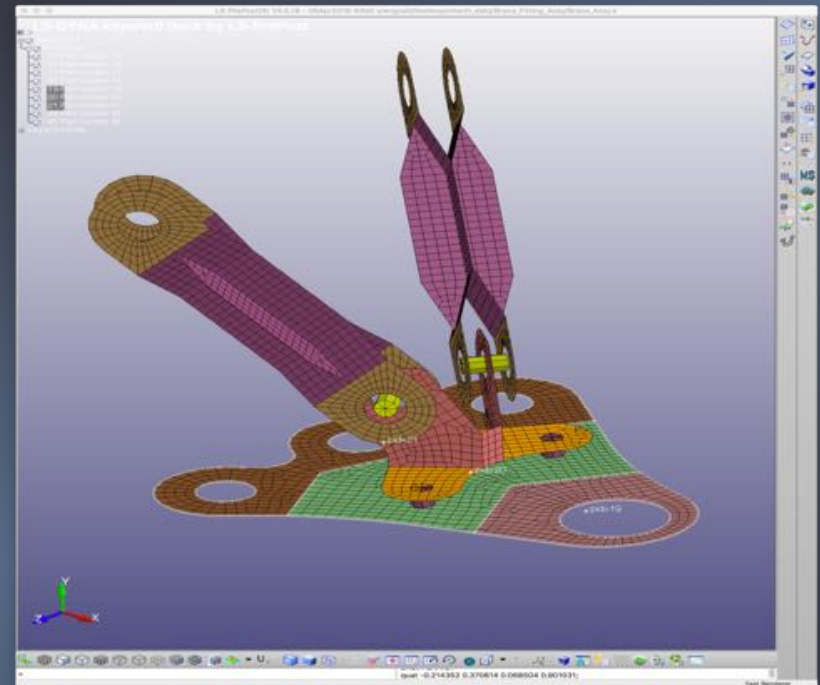
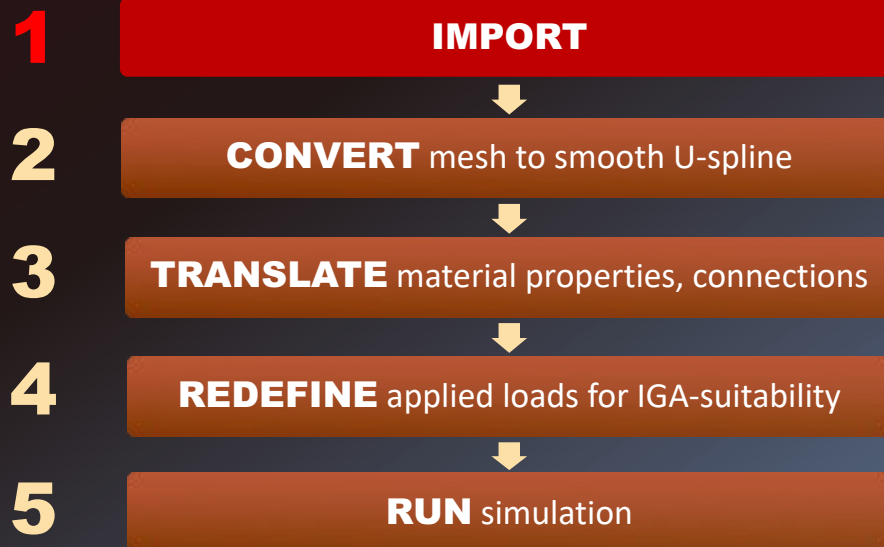
Reparameterization

Automatic Conversion to smooth U-spline (40,000 elements)

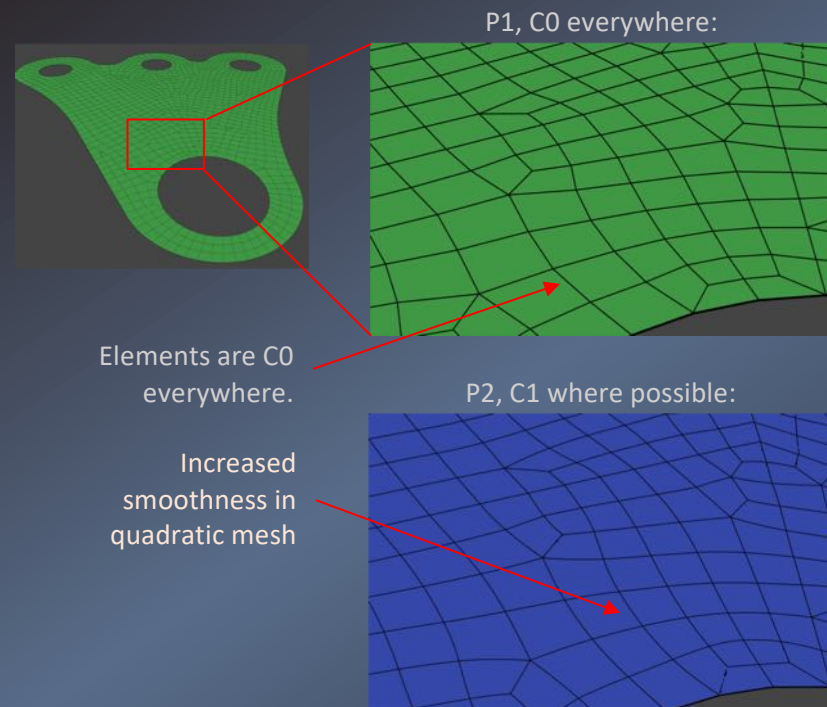
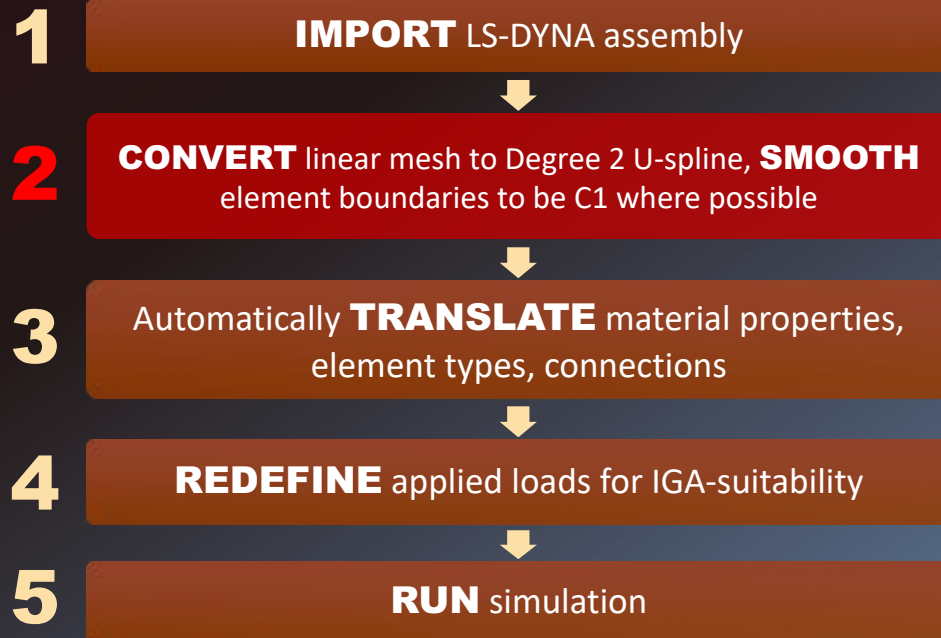
FEA mesh data workflow



FEA mesh data workflow

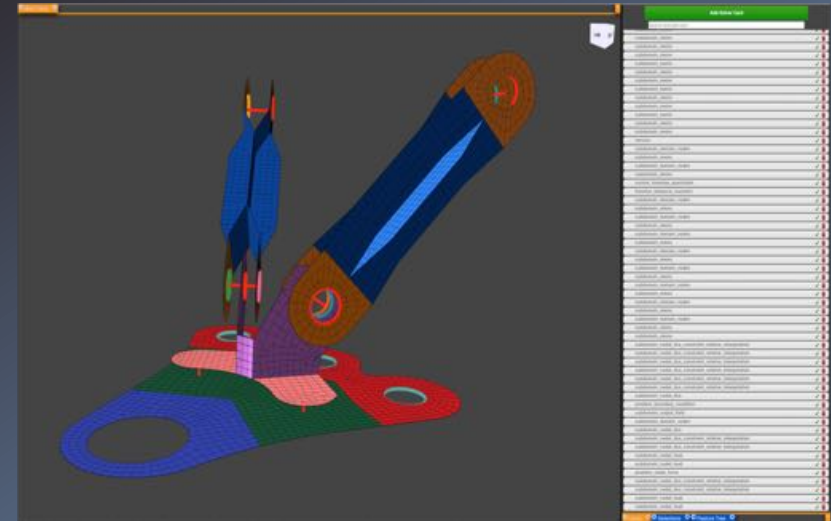


FEA mesh data workflow



FEA mesh data workflow

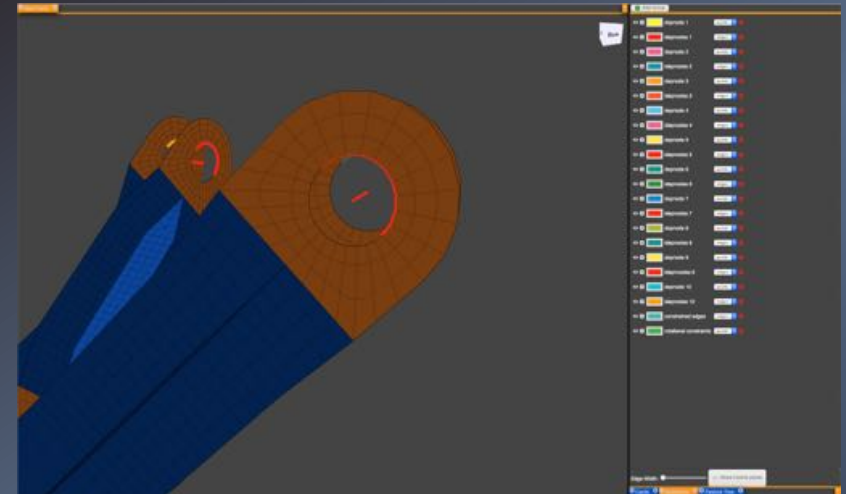
- 1** **IMPORT** LS-DYNA assembly
- 2** **CONVERT** linear mesh to Degree 2 U-spline,
SMOOTH element boundaries to C1 where possible
- 3** Automatically **TRANSLATE** material
properties, element types, connections
- 4** **REDEFINE** applied loads for IGA-suitability
- 5** **RUN** simulation



List of cards in the Coreform assembly

FEA mesh data workflow

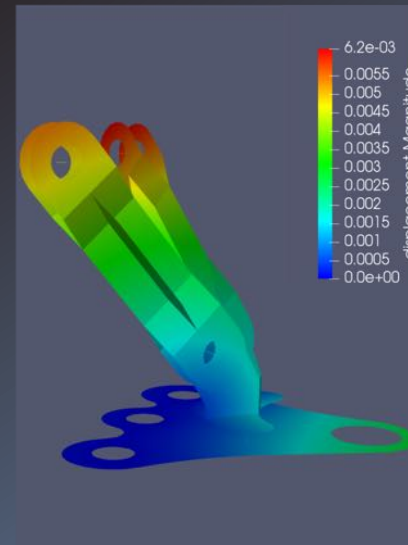
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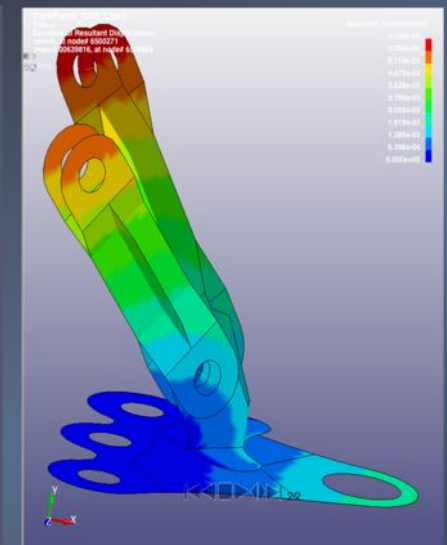
Loads and boundary conditions were assigned directly to the geometry instead of to nodes for improved accuracy.

FEA mesh data workflow

- 1** **IMPORT** LS-DYNA assembly
- 2** **CONVERT** linear mesh to Degree 2 U-spline, **SMOOTH** element boundaries to C1 where possible
- 3** Automatically **TRANSLATE** material properties, element types, connections
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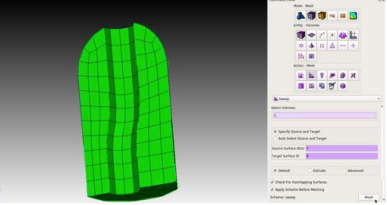


Coreform Analyze



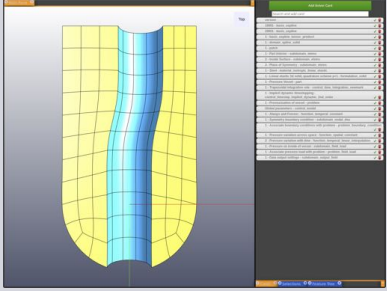
LS-DYNA (FEA)

CAD data workflow today



Trelis
csimsoft

1. Input CAD
2. Generate mesh
3. Graphically apply boundary conditions

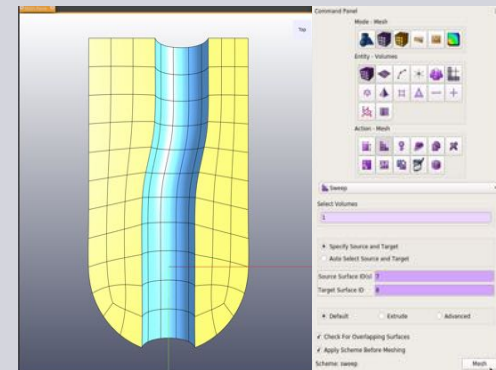


coreform

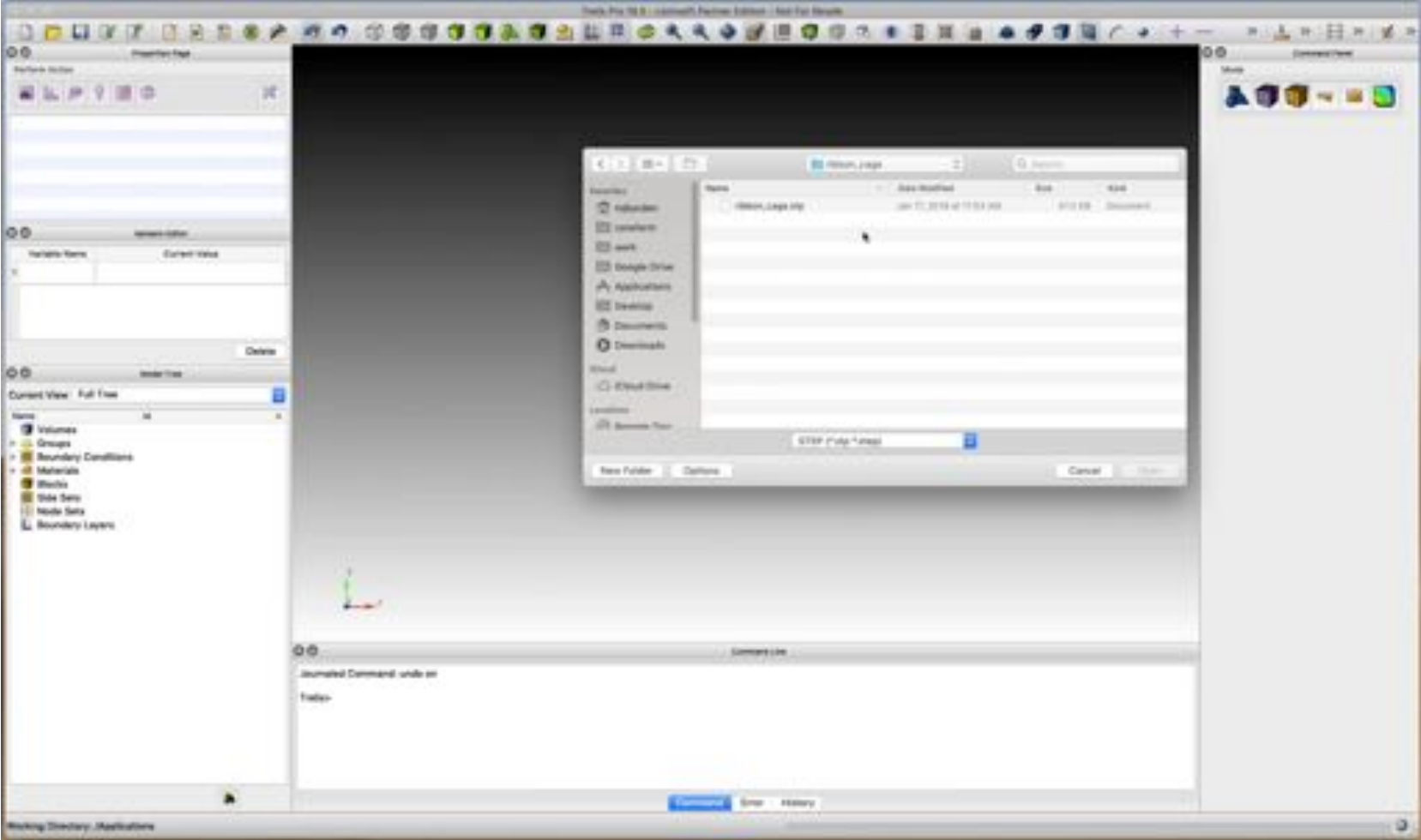
4. Convert to smooth U-splines
5. Set up simulation parameters
6. Run simulation in Coreform Analyze
7. Postprocess results

CAD data workflow tomorrow

1. Input CAD
2. Generate mesh
3. Graphically apply boundary conditions
4. Convert to smooth U-splines
5. Set up simulation parameters
6. Run simulation in Coreform Analyze
7. Postprocess results



CAD data workflow today



Next-gen CAD data workflow



Get involved

- Attend short course



- Theory and application
- Coreform offices in Utah, USA
- January 14-15, 2020

Get involved

- Attend short course
- Join forum

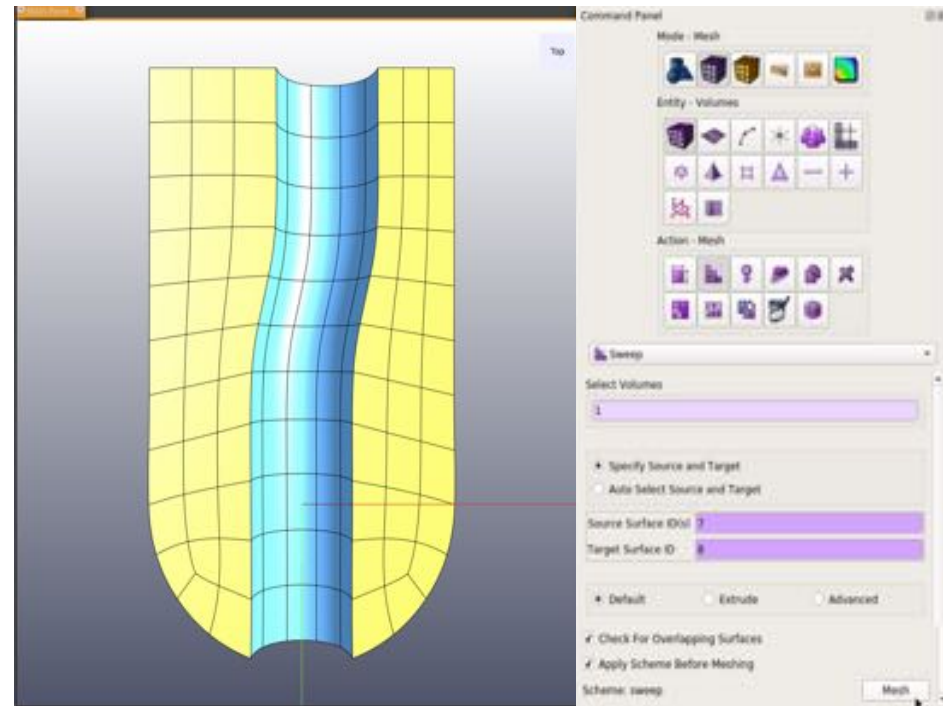
To make launching your new site easier, you are in bootstrap mode. All new users will be granted trust level 1 and have daily email summary emails enabled. This will be automatically turned off when 50 users have joined.

all categories **Labels** Top Categories + New Topic

Topic	Replies	Views	Activity
Coreform at IGA 2018	5	40	40%
LE10 Benchmark - Solid Modeling Question Coreform Process / Analyze	2	14	30
Preliminary Convergence data IGA Results	7	49	70
New Coreform marketing brochure	0	15	30
Enabling MathUsx Site Feedback	0	15	30
Number of control points in a U-Spline	3	31	30
Expansion of deep rolling short course example problem Coreform Process / Analyze	0	15	30
Principal Stress in outputs? Coreform Process / Analyze	0	20	30%
Importing Solid Bodies Error Coreform Process / Analyze	0	22	100
Weak Coupling of non-conforming meshes IGA Q&A	0	19	240
Welcome to Coreform's IGA Forum!	0	27	30%

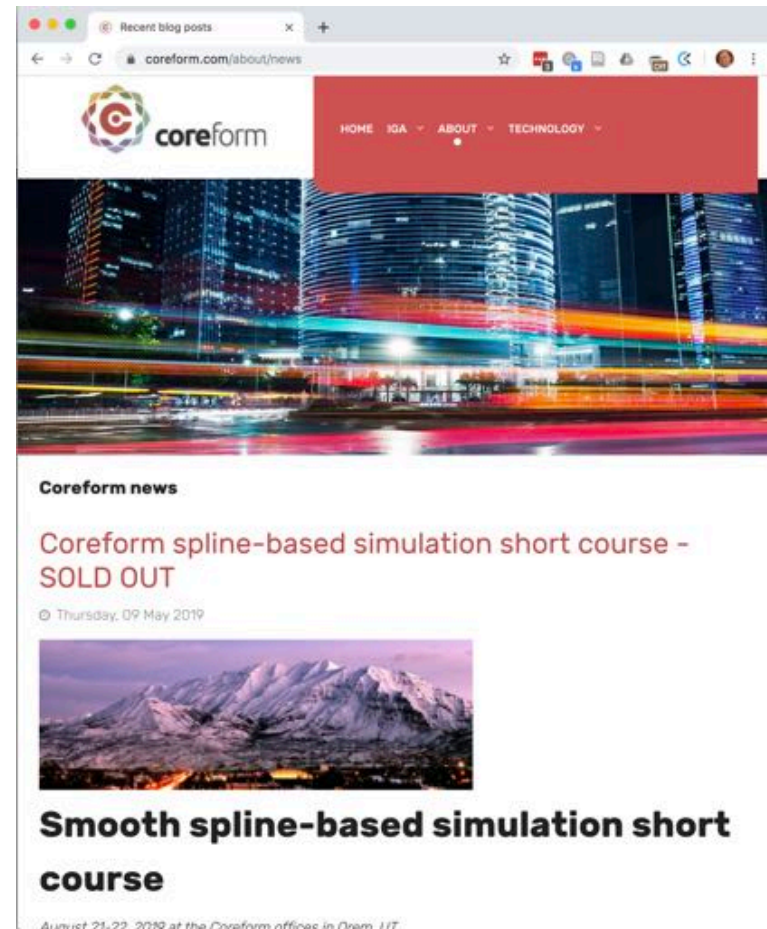
Get involved

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- Try beta software



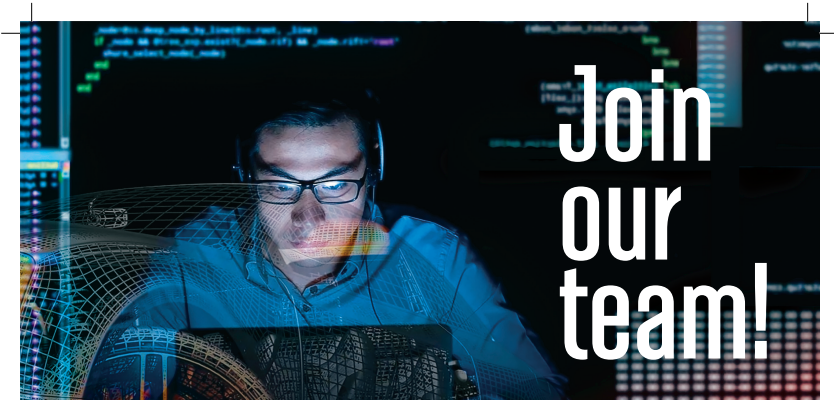
Get involved

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- Join forum
- Try beta software
- Write guest blog article



Get involved

- Attend short course
- Join forum
- Try beta software
- Write guest blog article
- Come work at Coreform!



Help us create the future.

At Coreform, we are commercializing the vision of isogeometric analysis. We foster an elite research and development environment with an emphasis on making an industrial impact. If you feel passionately about making a difference, both academically and commercially, let's talk.

We are currently hiring to fill the following positions:

- **FEA researchers** in the areas of spline-based simulation, geometry processing, or mesh manipulation
- **Software developers** with C++, mesh processing, or computer graphics expertise

Why join Coreform?

- Develop cutting-edge technology in an emerging industry
- Collaborate in a fast-paced environment
- Join a growing company with opportunities to advance
- Work with a globally recognized leadership team with a reputation for innovation
- Live and work in the USA, Europe, or anywhere remotely
- Enjoy a competitive compensation package



Better simulation through better geometry

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Thank you!

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