North American Pultrusion Conference

Automotive Applications Featuring Pultrusion in Continuous Composite Systems

Hank Richardson

L&L Products

ACMA American Composites Manufacturers Association | EPTA

Why Composite Materials

- Fibers can provide strong physical properties that cannot be achieved with bulk materials
- Fibers are well-suited for the manufacture of ropes or fabrics, but not for complex structures with increased loading conditions
- Fibers often have a property magnitude more than ten times larger than the **matrix**
- Composites are often expensive and difficult to produce at high volumes for automotive applications

Pultrusion for Composite Materials

- **Continuous fiber reinforced composites production can be extremely cost-intensive**
- Pultrusion is the only relatively **inexpensive manufacturing method**
- Limited freedom of design (**straight parts with constant cross sections**)
- The results are of recommendable **quality in terms of strength and stiffness**

Continuous Composite Systems™ (CCS™)

A fiber-reinforced **composite carrier** is combined with highly engineered **sealants and adhesives** in a **two-dimensional profile** designed to provide strength, stiffness, and rigidity to a lightweight structure.

When integrating Composite Body Solutions™ (CBS™) with CCS™, a 3D multicomponent assembly can be developed that can also incorporate steel stamping.

L&L Products

Continuous Composite Systems™
a fiber-reinforced composite carrier with highly engineered sealants and adhesives in a two-dimensional profile

BASF
We create chemistry

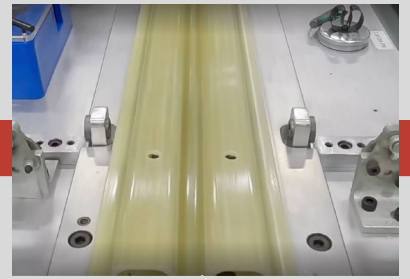
BASF Elastocoat® Polyurethane
a high-tech spraying system from **BASF** for the reliable and lasting protection of all surfaces

CCS™ Production Process

Bulk Material

Dispensing

Pultrusion



Cutting

Injection Molding

CCS™ Production Process Options

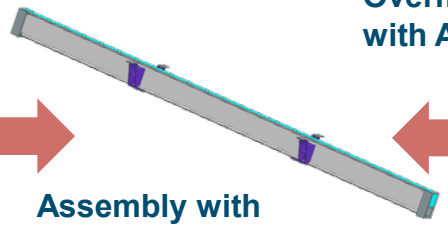
Bulk Material

Dispensing

Pultrusion

Inline Adhesives

Cutting



Assembly with
Ambient Curing Adhesives

Injection Molding

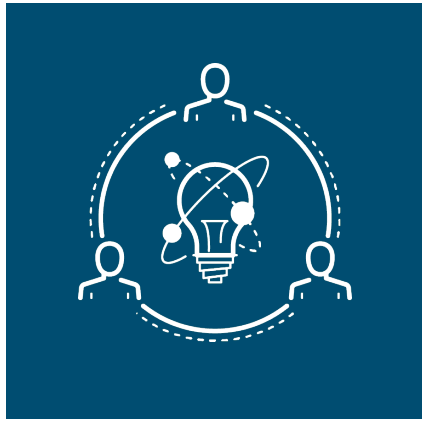
Overmolding
with Adhesives

CCS™ Value Proposition

STRENGTH
Ultra-high strength-to-weight ratio

EXPERTISE
In-house engineering expertise

PROCESS
Seamless integration of adhesives & rapid curing

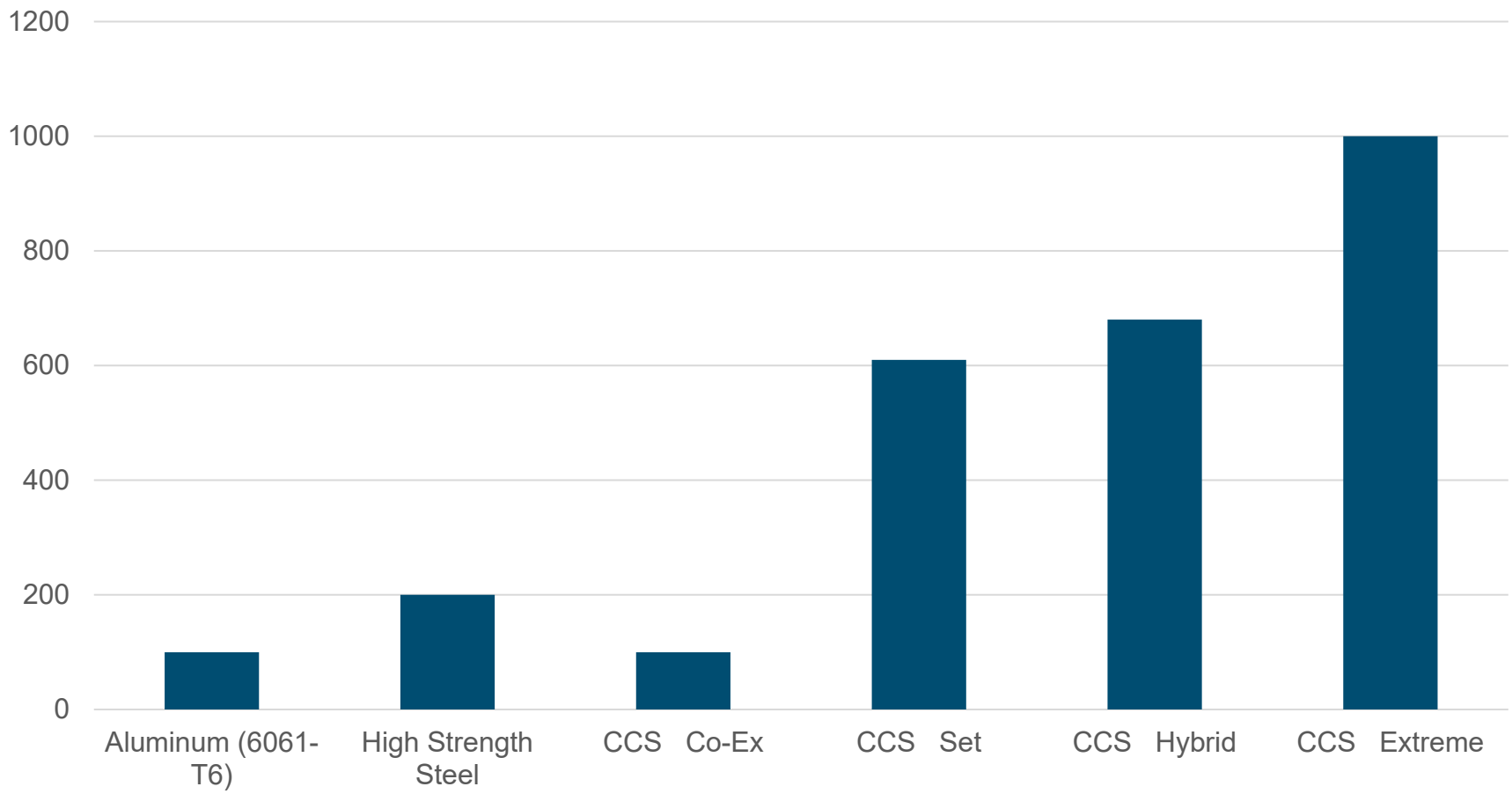


CAPABILITIES
Advanced CAE capabilities

COMPETITIVE
Competitive pricing

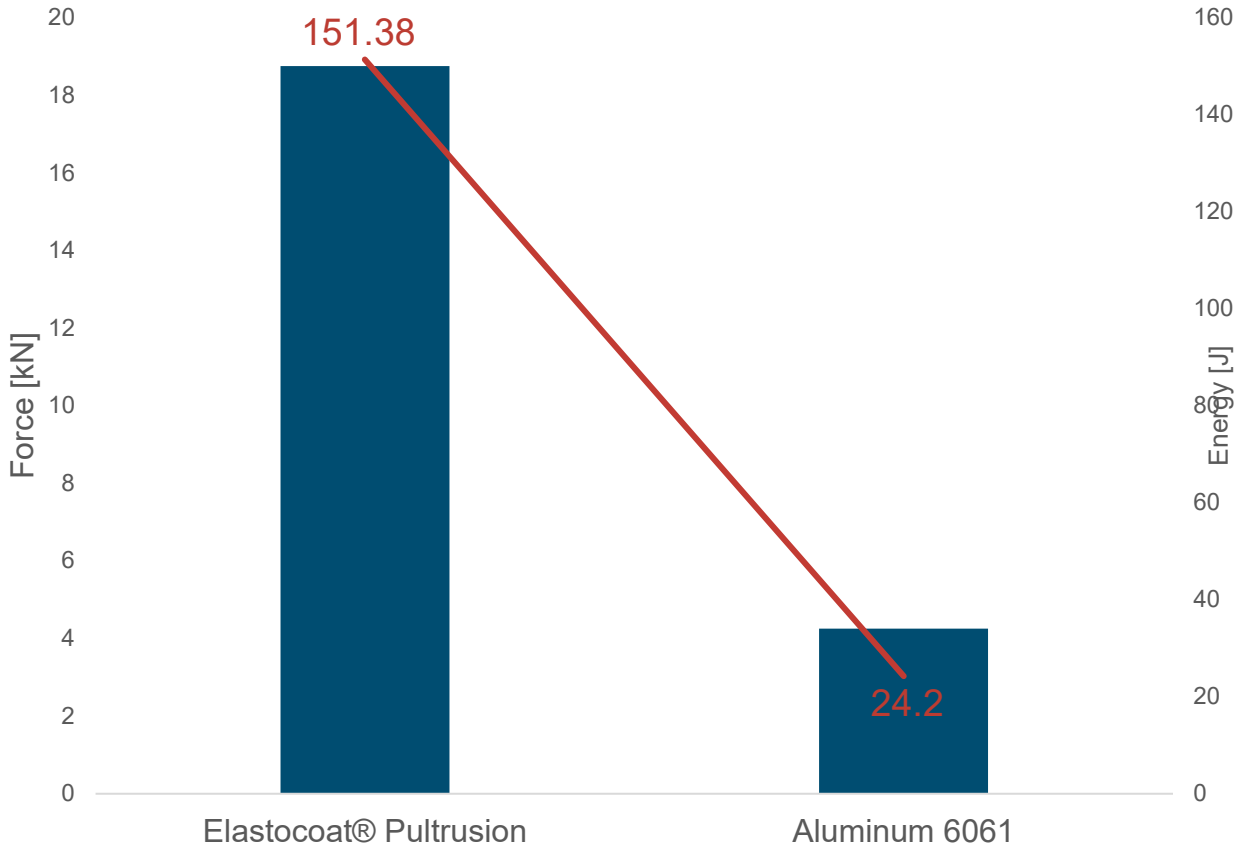
STRENGTH

Ultra-High Strength-to-Weight Ratio



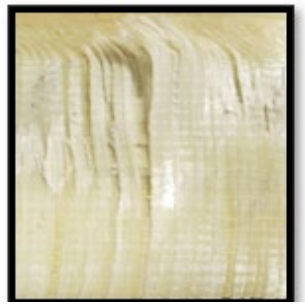
The numbers were created assuming ultimate tensile strength (MPa) over density (g/cc). These were normalized to 100 based upon aluminum as a baseline.

BASF Elastocoat® Polyurethane Pultrusion Impact Performance with CCS™

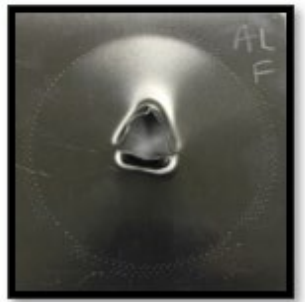


Superior Impact vs Aluminum, Steel

Pultrusion can absorb over **6x more** energy compared to aluminum



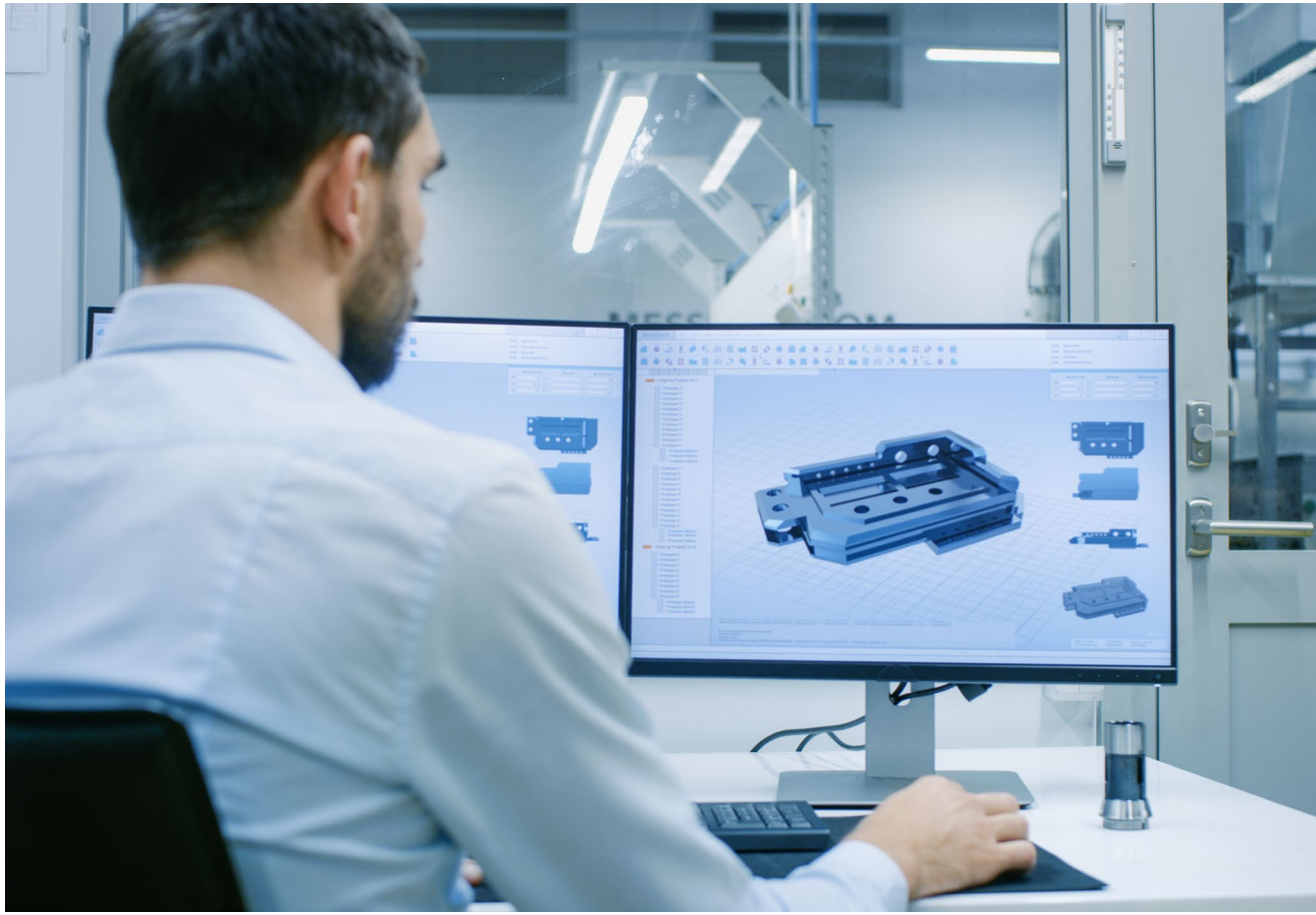
Elastocoat® Pultrusion



Aluminum 6061

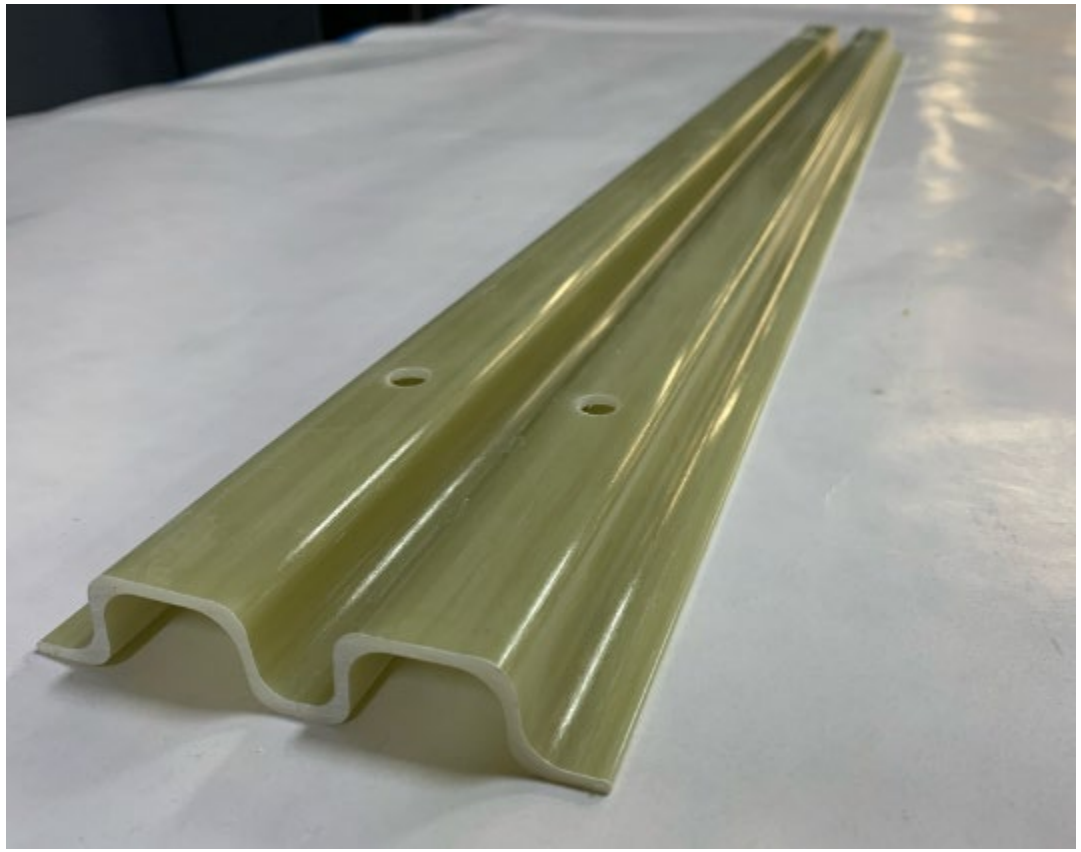
L&L Products Expertise

- Modeling
- Integrated designs and processes
- Creating 3-dimensional shapes with straight section profiles
- Integrating multi-material structures

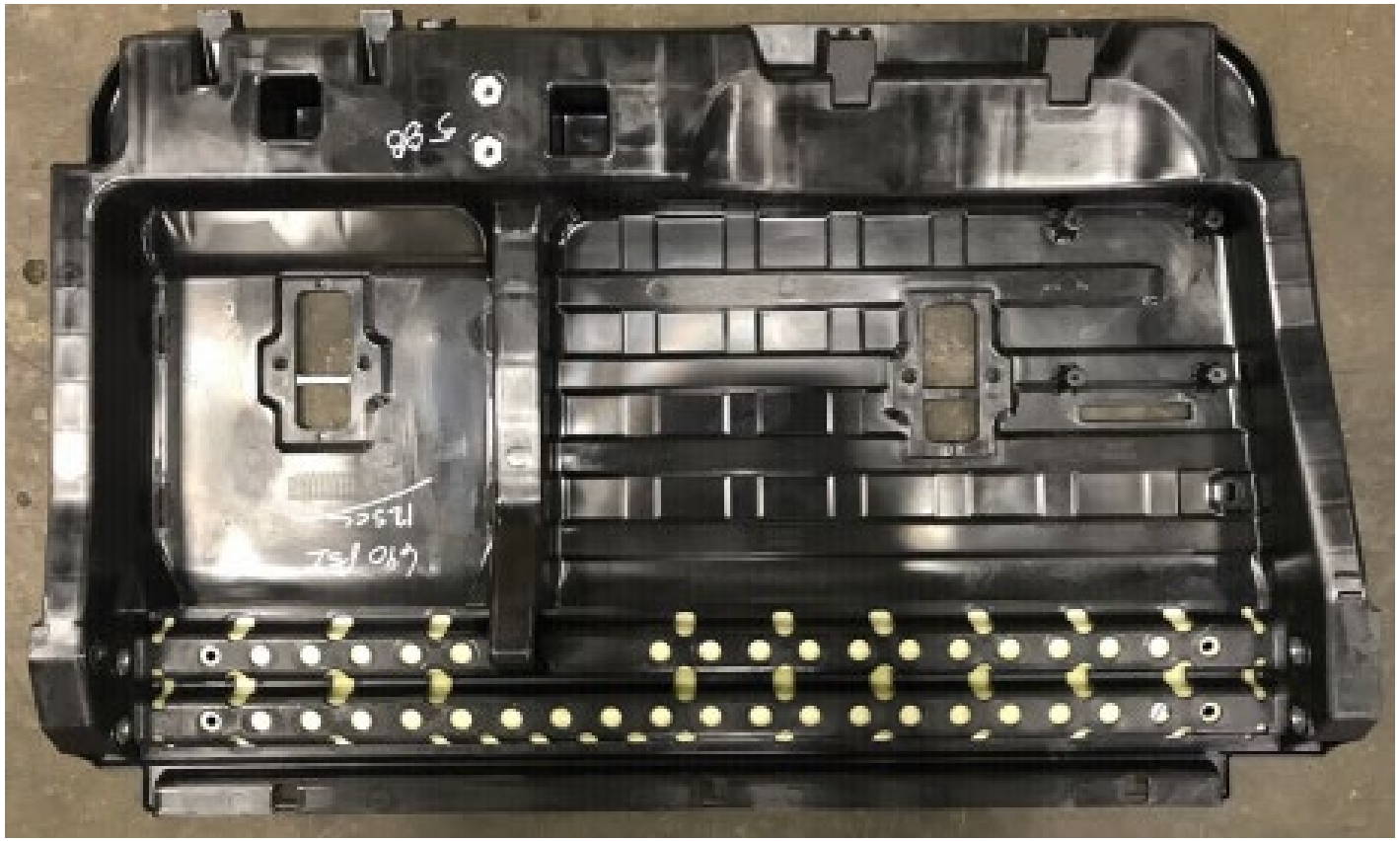


PROCESS

Combination of Two Composite Materials for Optimal Performance



BASF Elastocoat® pultruded profile beam for Tundra seat prior to overmolding



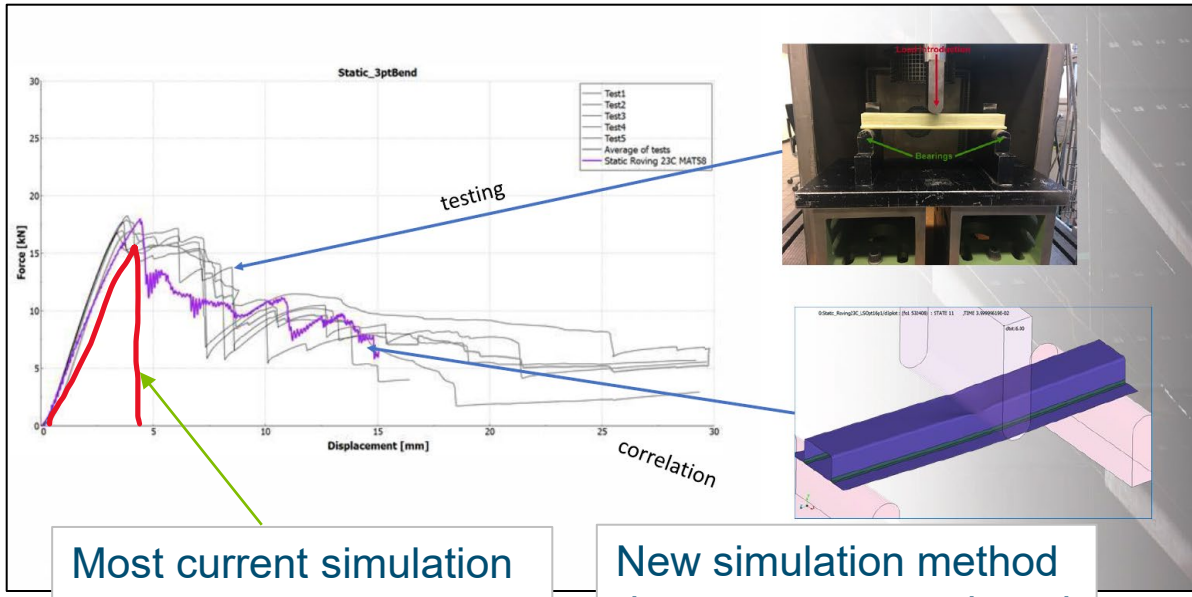
Combining pultrusion where strength needed most + feature integration achieved with injection molded material

High-Speed Processing

- **Higher processing speeds** were necessary to improve the value proposition and maximum capital utilization
- Multiple formulation changes were considered to maximize fiber “wet-out” (ability to surround the fiber with polyurethane), to **add high Tg material**
- Injection box alterations were made to **ensure the flow of resin will match the output** while maintaining good wet-out
- Multiple output is possible – one machine feeding more than one die
- Developing **multiple mat configurations**
- Developing **inline adhesive application** including L-5980, L-5905, L-5236

New Computer Simulation Methodology

- Conventional computer methodologies break down at the initial point of failure with composites
- These methods cannot reconcile the behavior of one component of the composite system failing while the other remains intact, leading to catastrophic failure in the model and ignoring the massive energy absorption post-failure seen in the actual part
- Through a rigorous testing plan and thousands of hours of simulation time, this was addressed to properly simulate the continuous fiber composite behavior in this and future applications

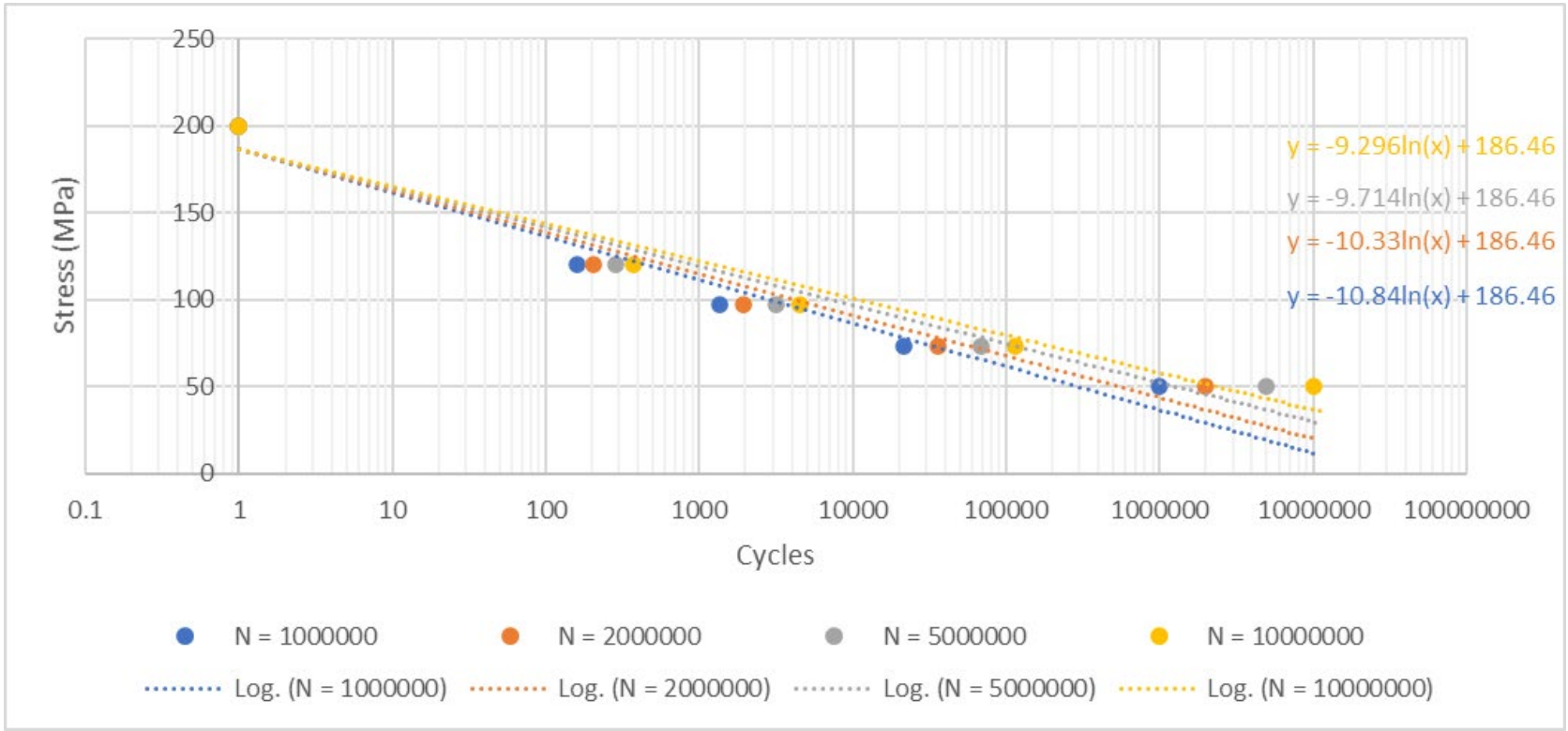


Most current simulation methods predict catastrophic failure near the yield point of the structure (Red line)

New simulation method demonstrates continued energy management and load carrying capability after yield (Purple line)

Fatigue Project Update

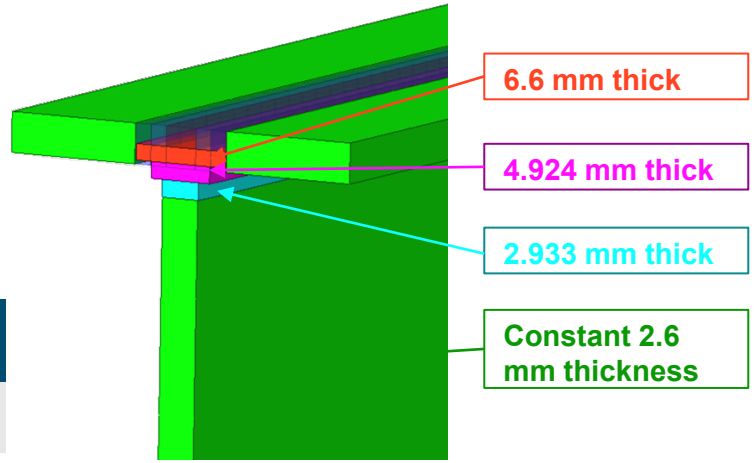
CCS™ I-beam 3pt Fixed-Fixed Fatigue Prediction

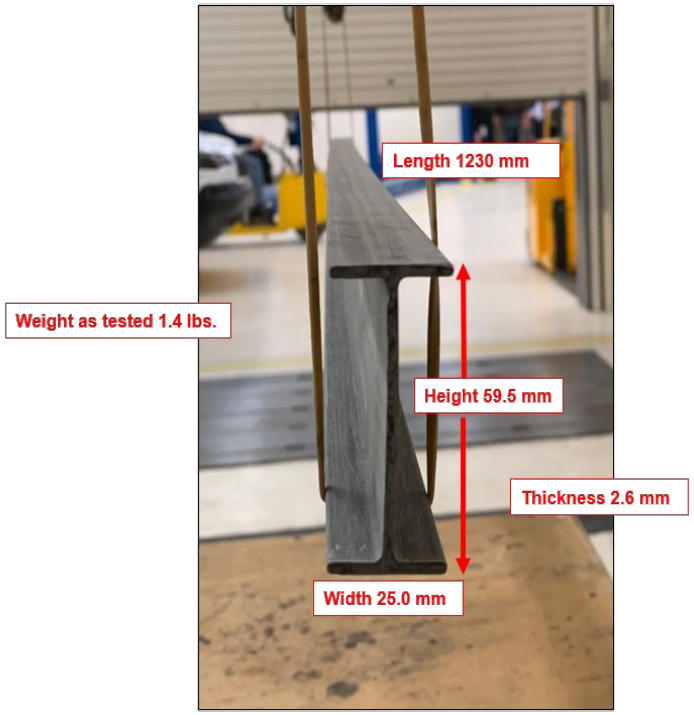


Frequency Analysis

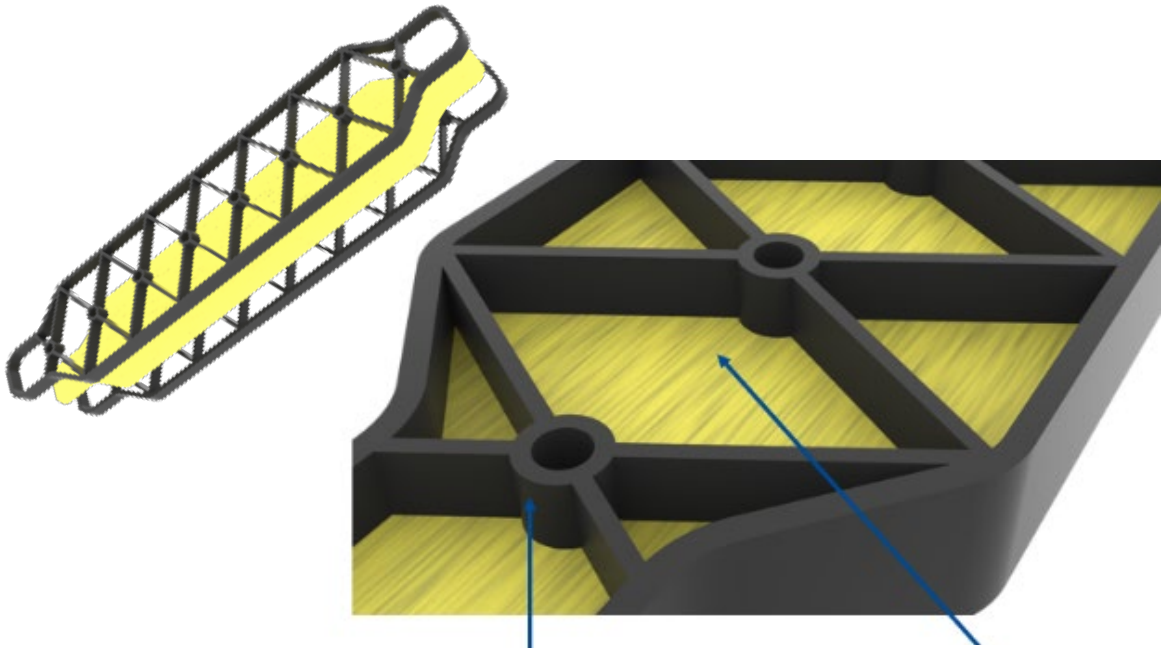
CCS™ I-Beam CAE Correlation of Free-Free Modal Analysis

	SAMPLE 1	T SECTION WITH DIFFERENT THICKNESS	
MODE DESCRIPTION	**FREQUENCY (Hz)**	**FREQUENCY (Hz)**	**DELTA %**
1st ORDER TORSION	51.1	50.4	-1%
1st ORDER LATERAL BENDING	61	57.7	-5%
2nd ORDER TORSION	126.7	124.1	-2%
2nd ORDER LATERAL BENDING	166.8	157.5	-6%
3rd ORDER TORSION	252.9	243.9	-4%
1st ORDER VERTICAL BENDING	267.3	261.6	-2%
3rd ORDER LATERAL BENDING	318.2	302.5	-5%
4th ORDER TORSION	439.3	419.4	-5%





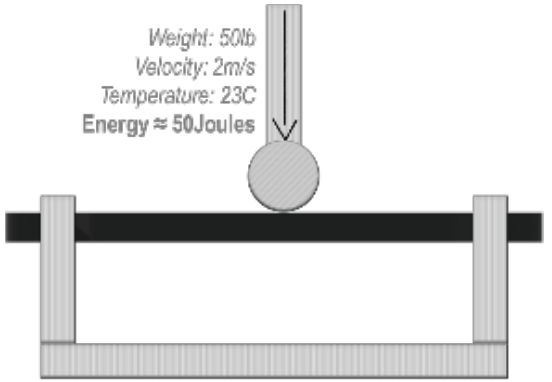
Highly Accurate Modeling Needed for Complex Seat Structure



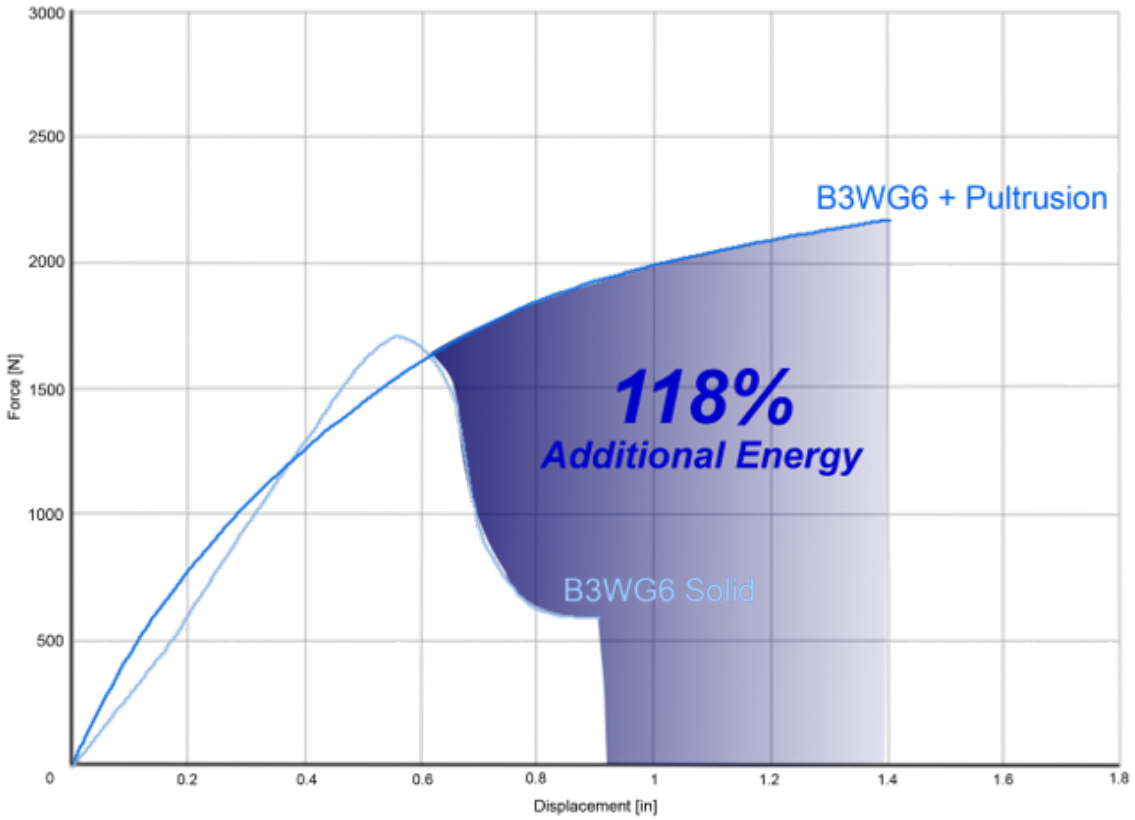
Thermoplastic Overmolding
Ultramid® B3WG6

Pultrusion Insert
Elastocoat® 74850
All Roving

Tested in 3-point
Bend, Torsion, etc.



CCS™ Overmolded Performance



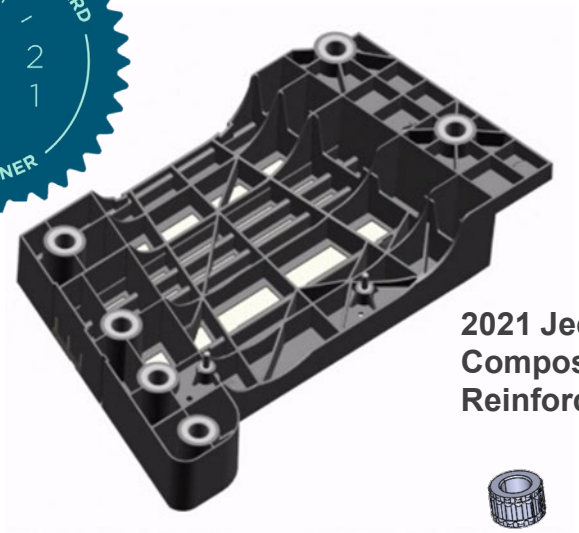
BASF Elastocoat® pultrusion +
Ultrimid B3WG6
VS
Ultrimid B3WG6 Solid

Jeep 2021 Grand Cherokee, Grand Cherokee L

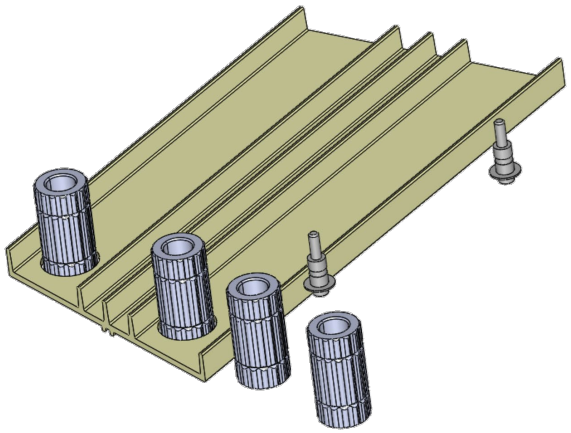
- The transmission mounting system (TMS) was one area of focus for reduction in mass and improvement in durability without compromising safety performance
- The use of Continuous Composite Systems™ (CCS) pultrusion technology along with polyurethane chemistry from BASF were key factors in the success of the CTR

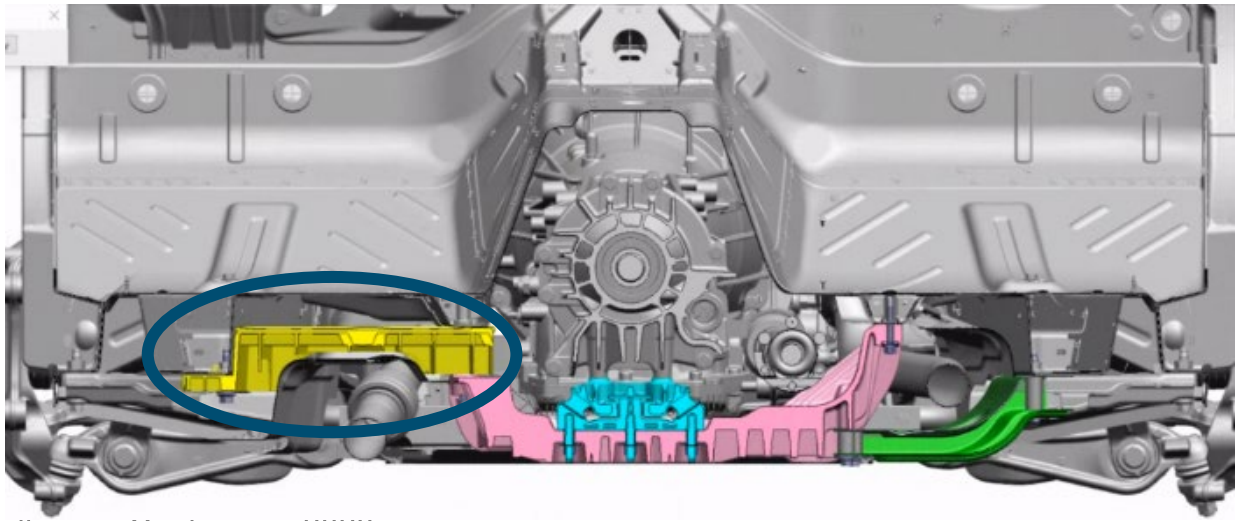
Stellantis 2021 Jeep Grand Cherokee

- Designed to carry 70 kN (15,700 lb) load cross-car in a shallow offset crash event
- 4.6 lb vehicle weight savings over traditional steel clamshell design
- Improved assembly process, with molded in clips, compression limiters, and threaded studs
- Overall cost savings compared to traditional component and assembly



2021 Jeep Grand Cherokee L Composite Tunnel Reinforcement





Finalist

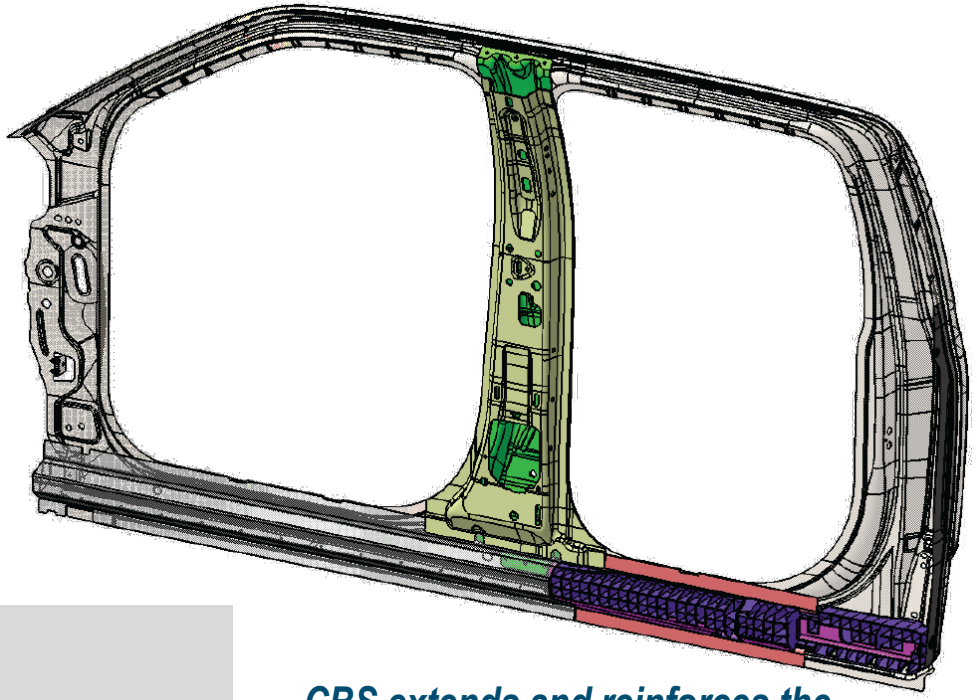
Ford 2022 F-150 Lightning

- To modify the existing F-150 frame for battery placement, the size of the crossmember had to be reduced without compromising strength
- The new crossmember design included L&L's Continuous Composites Systems™ (CCS™) and Composite Body Solutions™ (CBS™)

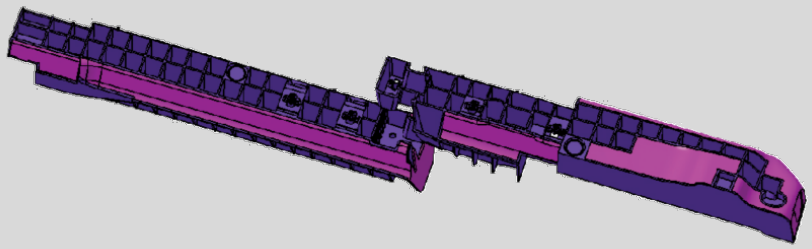
CCS™ crossmember reinforcement

Ford 2022 F-150 Lightning CBS™ Rocker

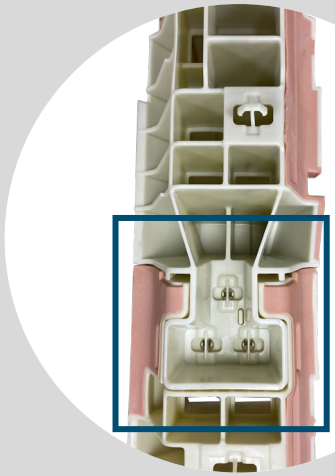
- L&L offered a two-piece CBS™ system, which allowed us to mold and assemble the part within cycle time requirements on existing capital equipment.
- For the carrier component, super tough nylon was used to absorb and dissipate energy.



CBS extends and reinforces the rockers on the Ford F-150 Lightning.



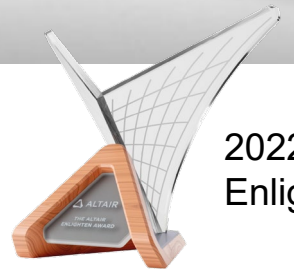
Two-piece design allowed L&L to mold the parts on existing capital equipment.



Connection between the two smaller sections.

Toyota 2022 Tundra Rear Seat Structure

- The seat structure is the first interior application for L&L's CCS technology, using partner BASF's Elastocoat polyurethane pultrusion system
- Together with BASF, Flex-N-Gate, and Toyota, this application was awarded the **2022 Altair Enlighten Award** for achievements in vehicle weight savings and the **2022 SPE Automotive Innovation Award** for the composite seatback design



2022 Altair Enlighten Award

51ST-ANNUAL spe AUTOMOTIVE INNOVATION AWARDS COMPETITION & GALA HONORING THE BEST IN AUTOMOTIVE PLASTICS 2022 AWARD WINNER

Toyota 2022 Tundra Rear Seat Structure

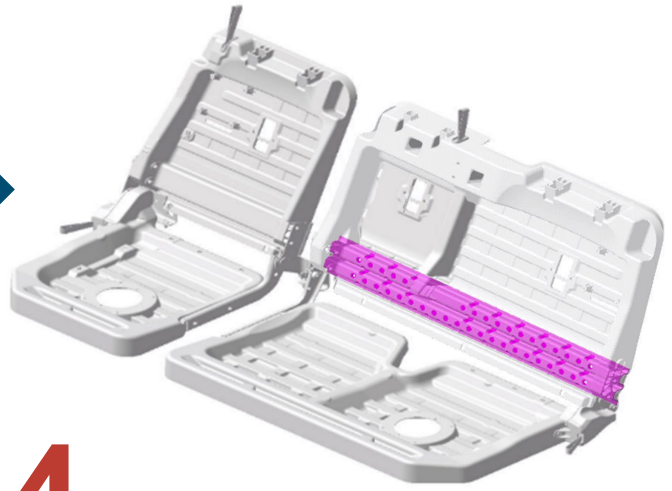
The Challenge

Previous Generation Tundra Steel Frame

60+

Components

2022 Tundra Composite Resin Frame

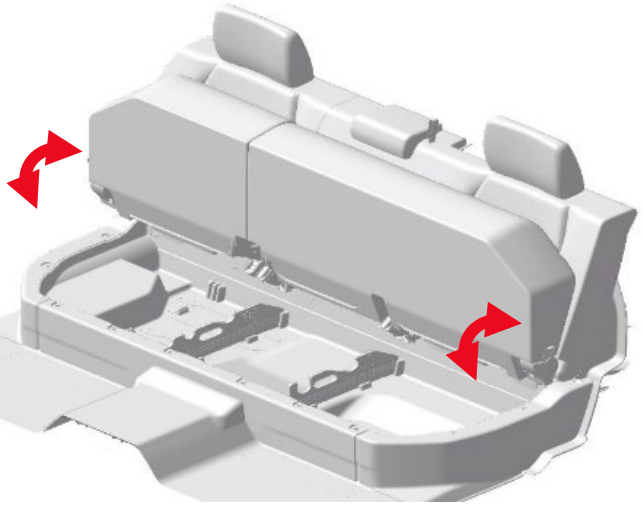


4

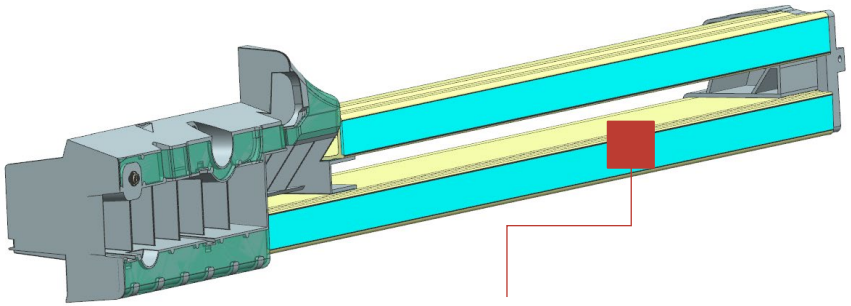
Molded Parts

spe Winner

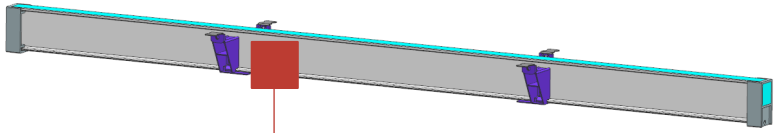
Feature Add in Composite Seats while **decreasing cost by 20% and mass by 20%**



What's Next?



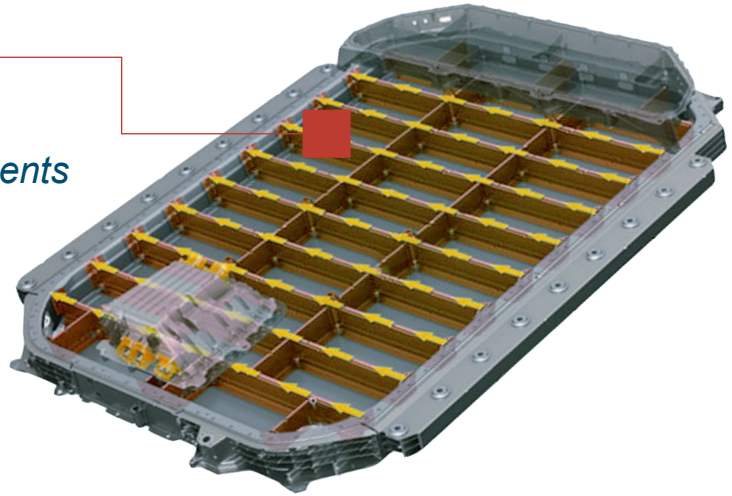
Hybrid Sill Applications



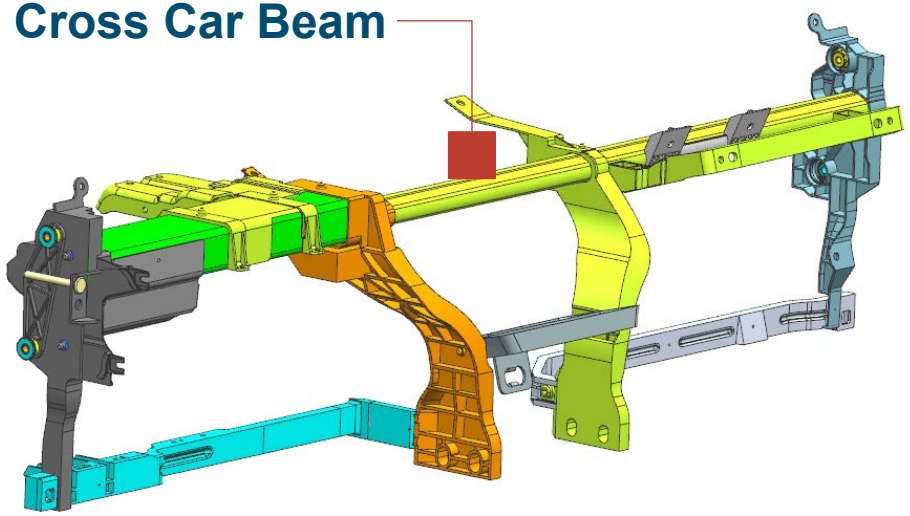
Truck Box Reinforcements

EV Battery Box Crossmember Reinforcements

Meets UL 94 V0 requirements



Cross Car Beam



Thank you.

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