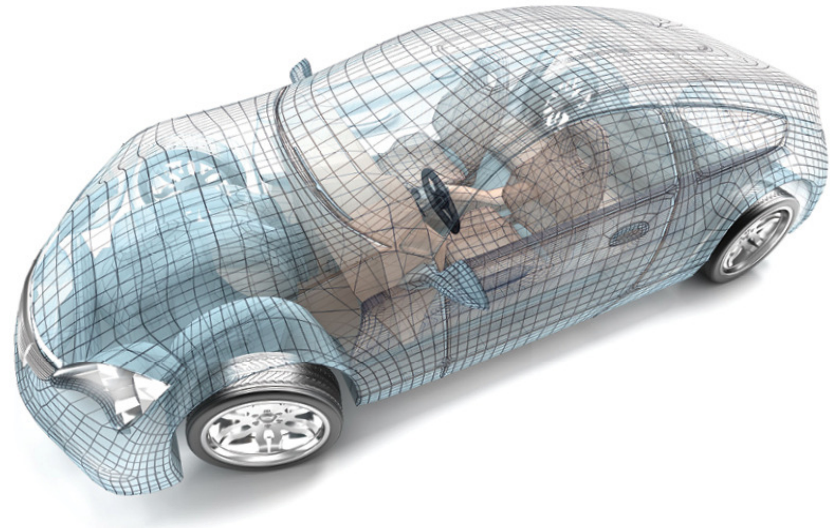
TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



Automotive Trends & Market Solutions for High Performance Thermoplastic Composites

Presented By: Patrick Blanchard
Technical Leader for Advanced Polymer Systems
Ford Research & Advanced Engineering

Introduction

Patrick Blanchard

Ford Research & Advanced Engineering

Joined Ford in 1999 – Technical Specialist

2009 Composites Group Leader

2019 Technical Leader
– Advanced Polymer Systems

Working on a broad range of composite processing technologies ranging from compression, injection and liquid molding. Currently serving as a corporate Technical Leader for polymer composites, leading global multi-disciplinary research projects in support of automotive fuel economy, emissions and sustainability targets.

Ford/ACMA Composites Technology

Ford/ACMA Technology Days

Two Programs: 2018 and 2019

Educational program for over 700 Ford engineers, managers, designers, and decision makers held inside Ford Global HQ in Dearborn

40 companies

24 technical presentations

Over 100 Parts displayed

Overview

- Customer focused design
- Automotive history and legacy infrastructure
- The current role of polymer composites
- Disruption in the automotive market
- New customer use cases
- New opportunities for composites and multi-material solutions

Which Attributes Are Improved?

- Cost reduction
- Weight reduction
- Design innovations
- Feature and functional integration
- Quality improvement
- Productivity improvement
- Environmental/eco -improvement

Customer Requirements

….Weight influences many vehicle attributes but is <u>not</u> considered by most as a primary vehicle characteristic

▼

Therefore, weight strategies should be <u>*part of*</u> overall vehicle attribute strategies (e.g. CAFE, fuel economy, CO_2, safety- not an end item in itself!)

Typical Vehicle Road-Test/ Rating System

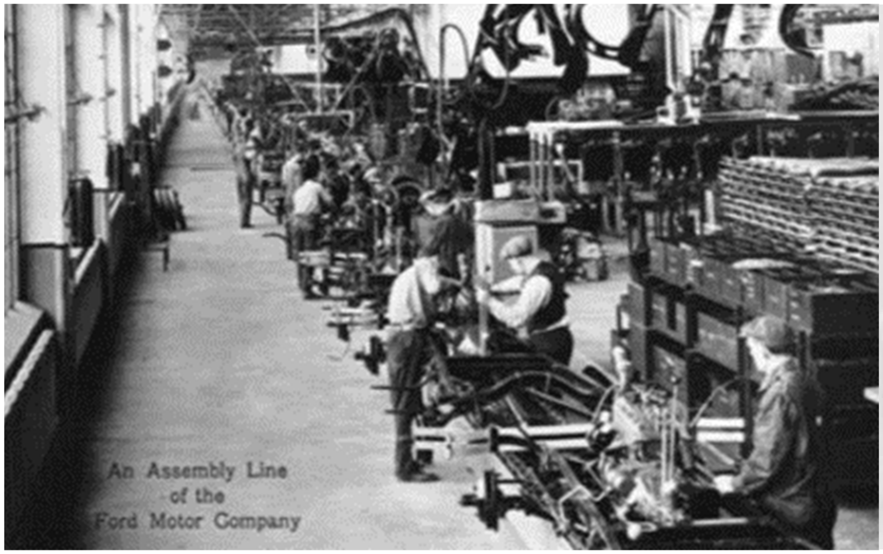
	Vehicle Styling	7.49
✓	Braking	7.78
✓	Handling	7.58
✓	Fuel Economy	7.29
	Interior Comfort	7.84
✓	Acceleration	8.43
	Dependability	7.41
	Fit and Finish	6.85
	Transmission	7.17
✓	Ride	8.06

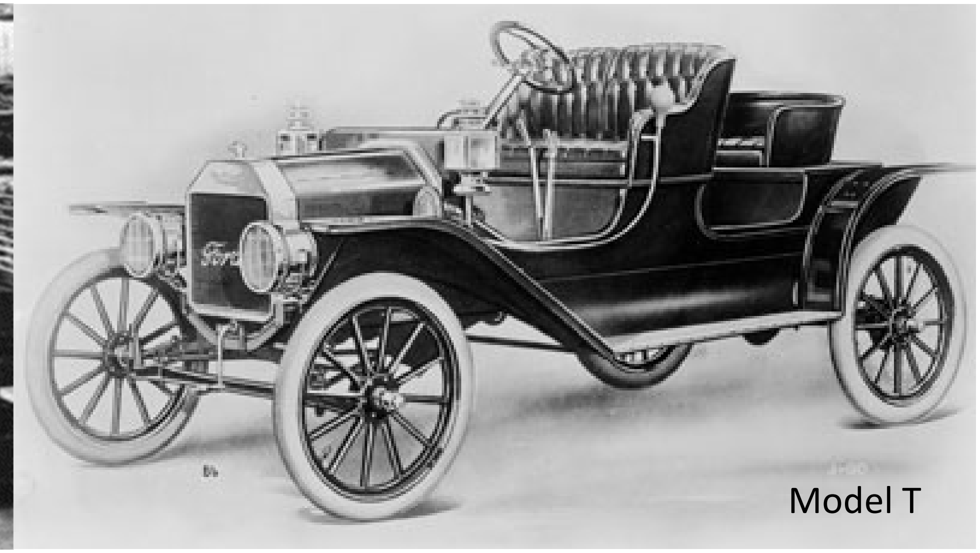
Rating Scale: 1 = Worse 10 = Best

Source: Car & Driver

Light-weighting is One Of Many Solutions, Not the Goal

Henry Ford Invents The Moving Assembly Line



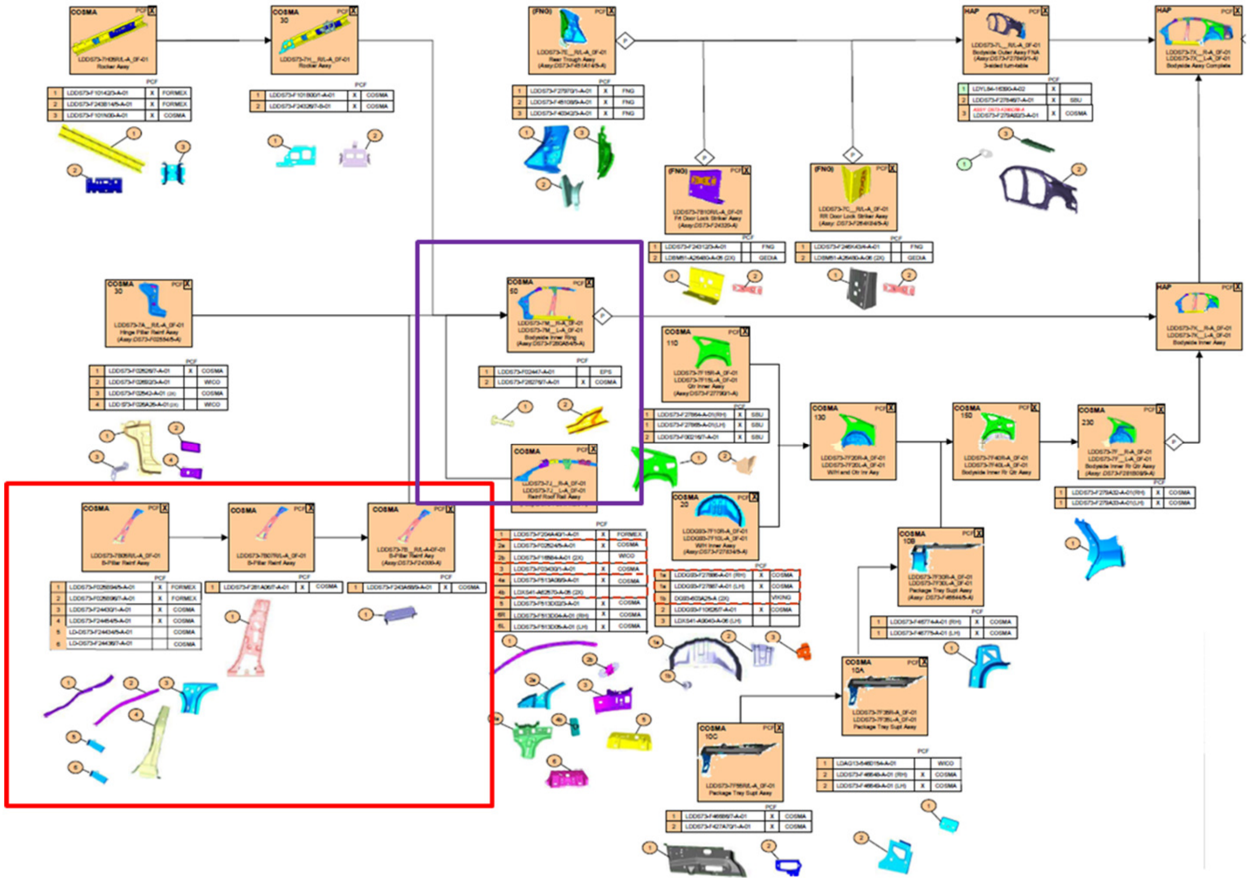


- Ford Motor Company incorporated in 1903. Opened the Piquette Plant in 1908.
- In 1913 Ford's Highland Park becomes the first auto plant to feature a moving assembly line.
- Vehicles are conveyed to the worker as opposed to the worker roaming from station to station.
- Reduced assembly time for Model T chassis from 12.5 to 1.5 hours.
- Increased throughput reduced overhead cost and enabled Henry Ford to lower the price of the vehicle. Cars become affordable to the general population.
- Ford sold 15 million Model Ts before ceasing production in May 1927.

Modern Day Assembly Plant

- Moving assembly line breaks down complex operations into simple steps of <30s.
- Typical assembly plant throughput 60 - 100 vehicles per hour.
- This innovation in assembly methodology has been replicated by all Auto OEMs and now supports a global automotive business that produces 90MM vehicles per year.

Bill Of Process For High Volume Manufacturing

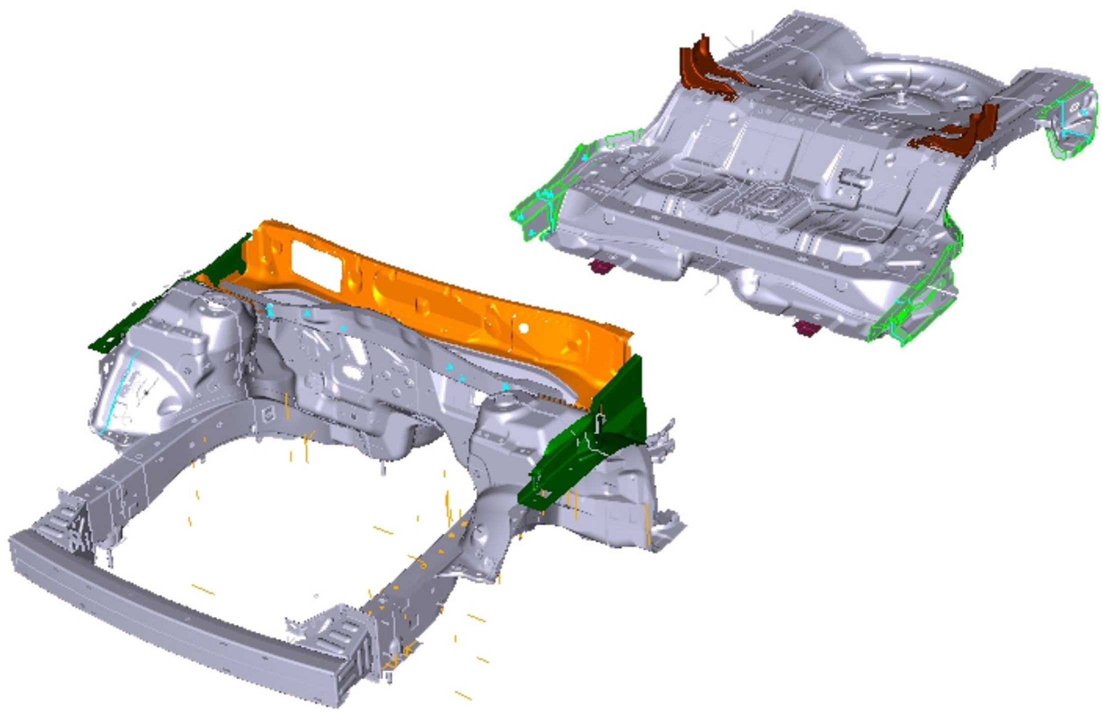


Quality operating systems and joining and assembly methods developed to maximize throughput for a given plant size

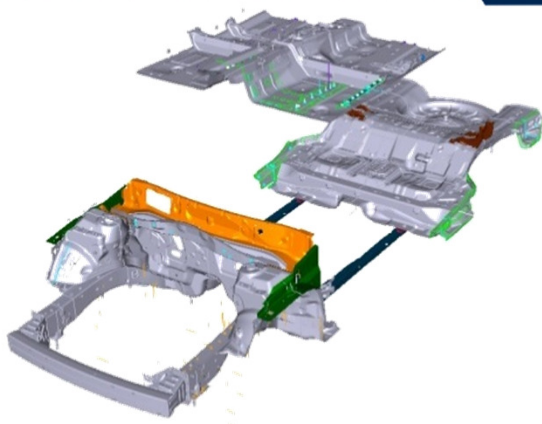
Underbody Modules

<u>Base Underbody Sub-System</u>

- Front structure
- Rear floor assembly

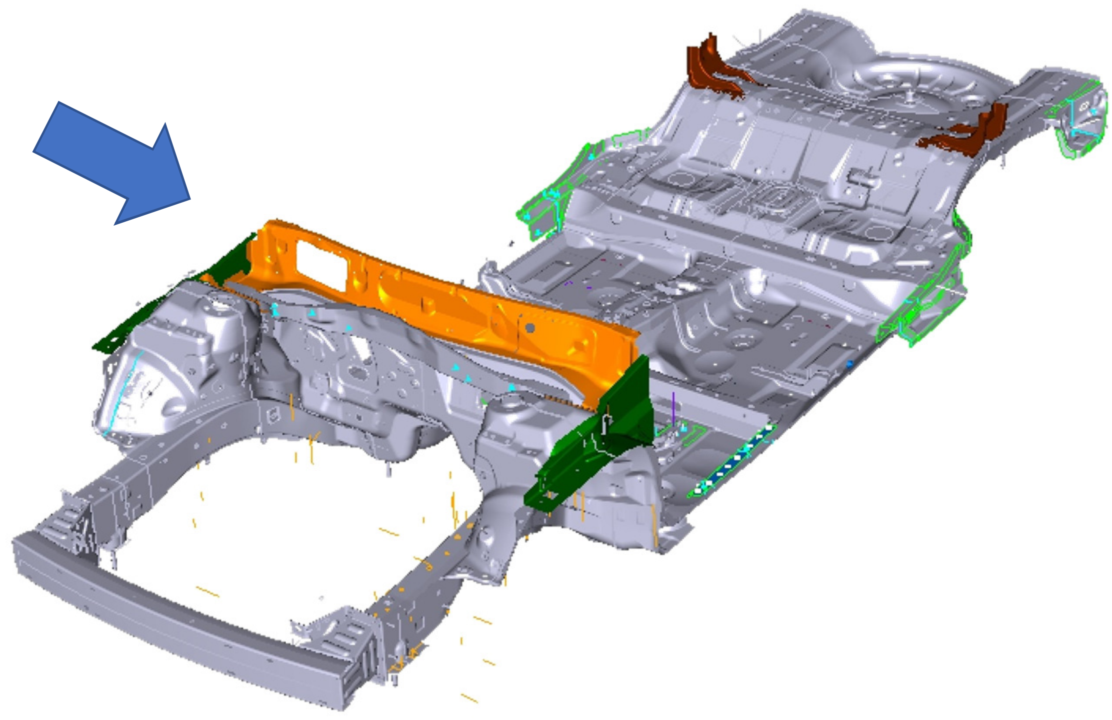


Underbody Build



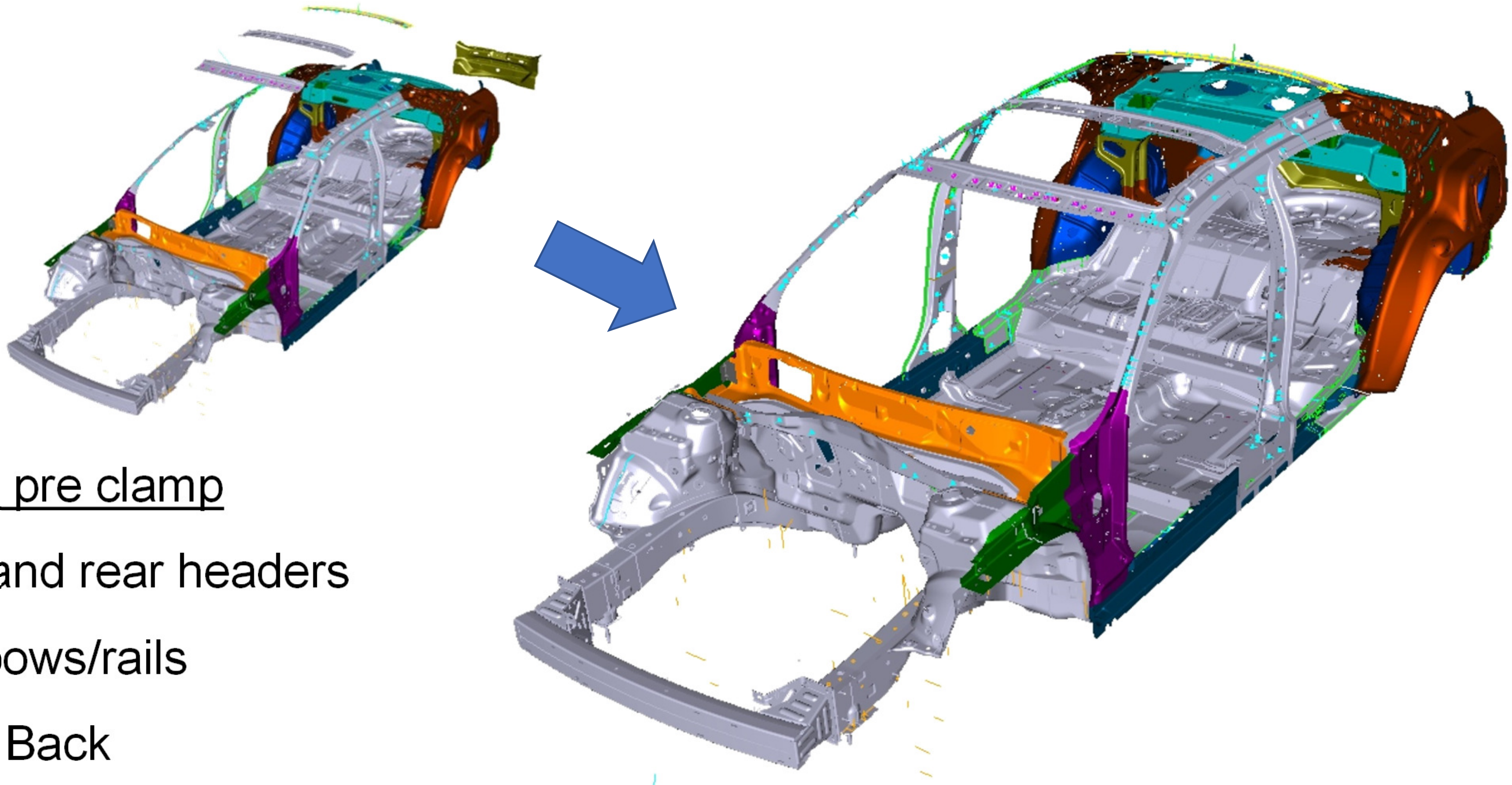
Underbody

- Add front floor assembly



A combination of geo-setting and supplementary welds/fasteners applied to maintain a station TAKT time of less than 30 seconds.

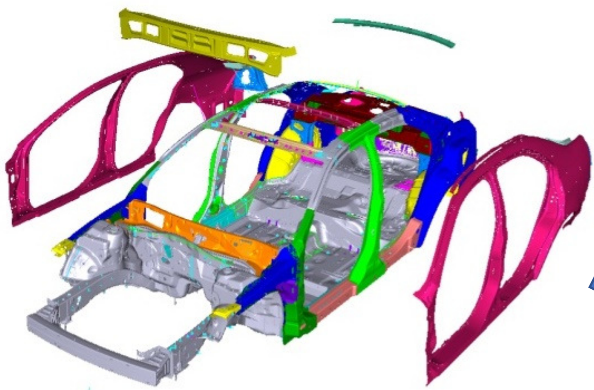
Framing Sequence

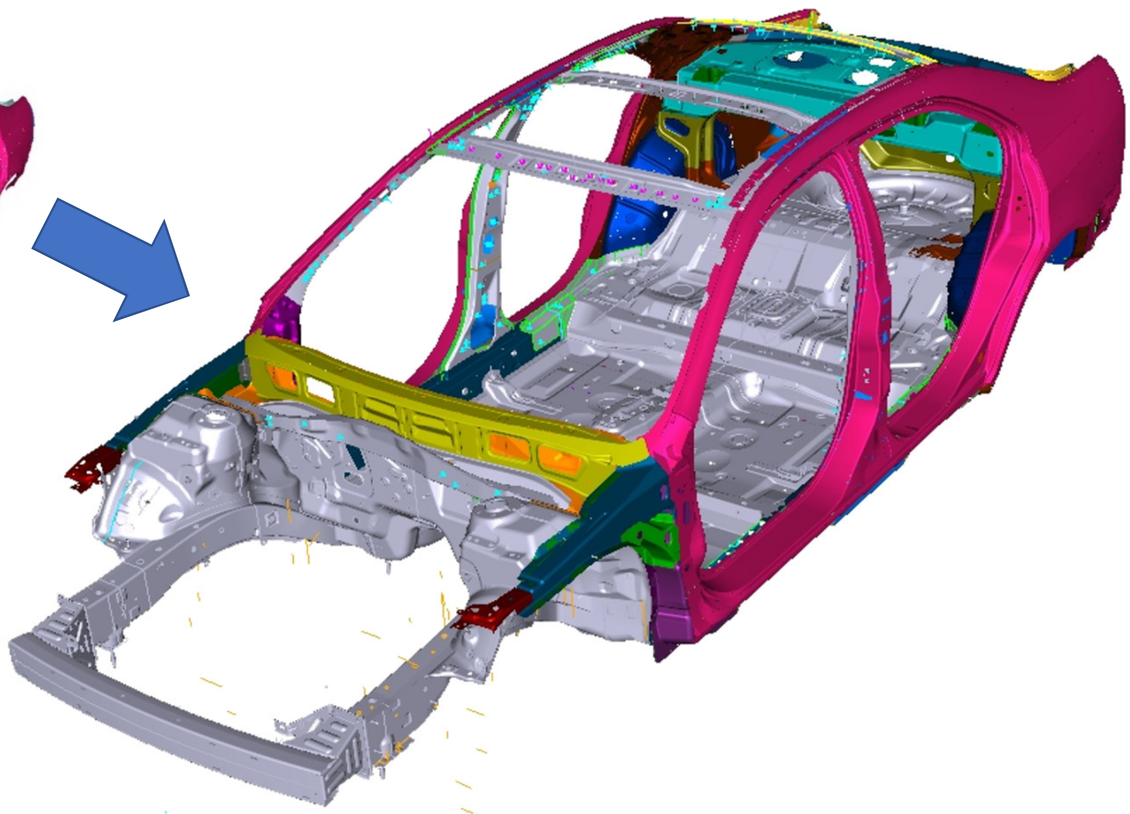


<u>Framing pre clamp</u>

- Front and rear headers
- Roof bows/rails
- Lower Back

Framing Sequence





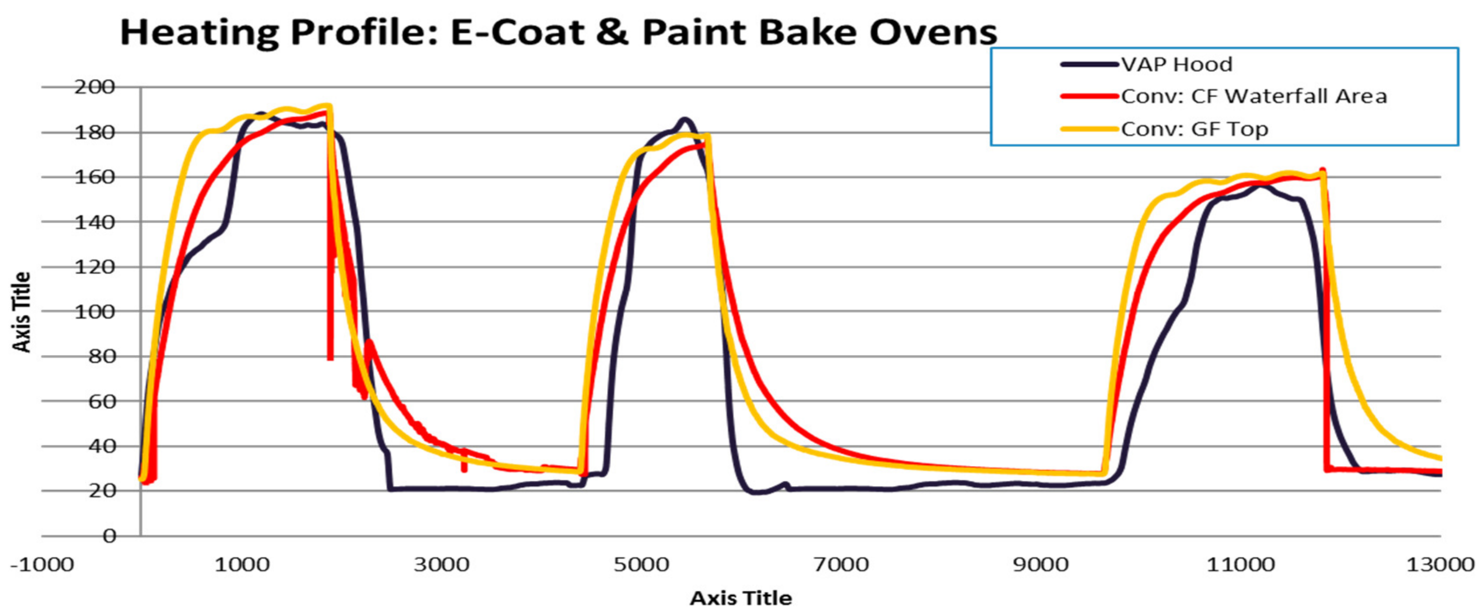
Framing stage

- Body side outer rh / lh
- Cowl top outer s/a
- Package tray upper rear
- Lower back outer rr

Roof and closure panels added to complete the vehicle body in white

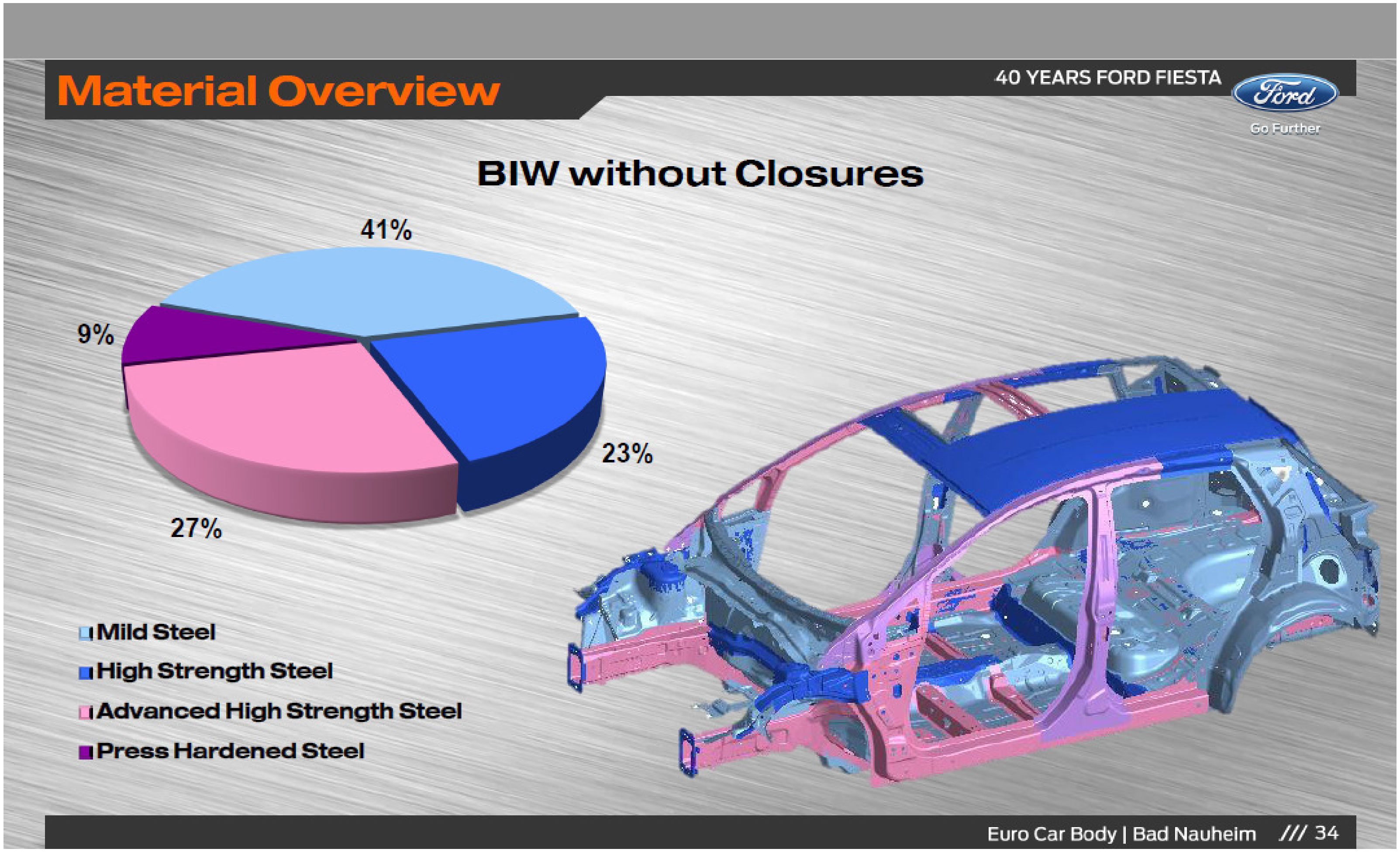
E-Coat & Paint Bake Thermal Cycle

Thermal Cycles:
- 190°C for 30min
- 180°C for 20min
- 160°C for 35min



Dictates minimum thermal requirements for all body shop installed parts

Typical BIW Material Content



So where have polymer composites played a role?

Front End Modules / GORs

Edge Underbody Aero Shields

Edge Front End Bolster

Explorer Front End Bolster

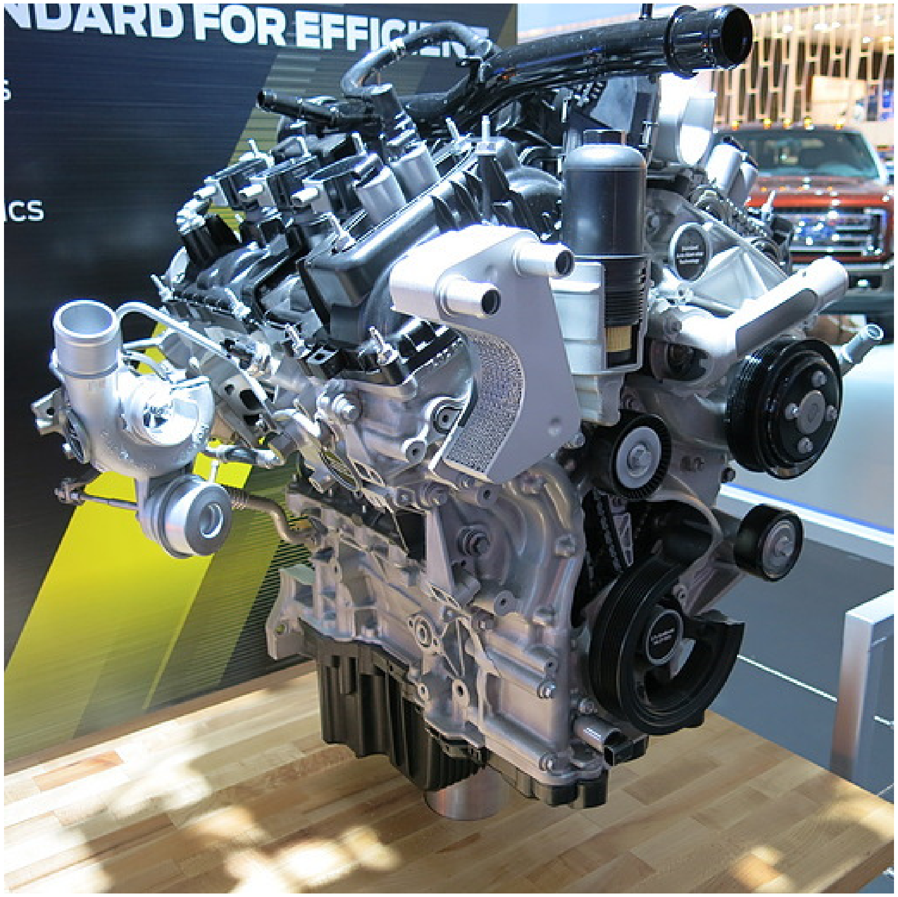
Class A Body Panels

Interior Components

Ford C-Max Composite Cross Car Beam

Ford Mustang
Second Row Seat Back

Powertrain Components



2015 Ford 2.7-L EcoBoost V6

MMLV Oil Pan & Front Cover Concepts

CONNECTIVITY

FORD SMART MOBILITY

SYNC®

2007: Launched on 12 Ford vehicles

2016: More than 15 million SYNC-equipped vehicles on the road globally

2020: Expected deployment reaching 30 million vehicles globally

Democratization of New Technologies

Technology Trends

Revolution in Computing & Software

Data/Analytics Artificial Intelligence & Visualization

Biology & Brain Machine Interface

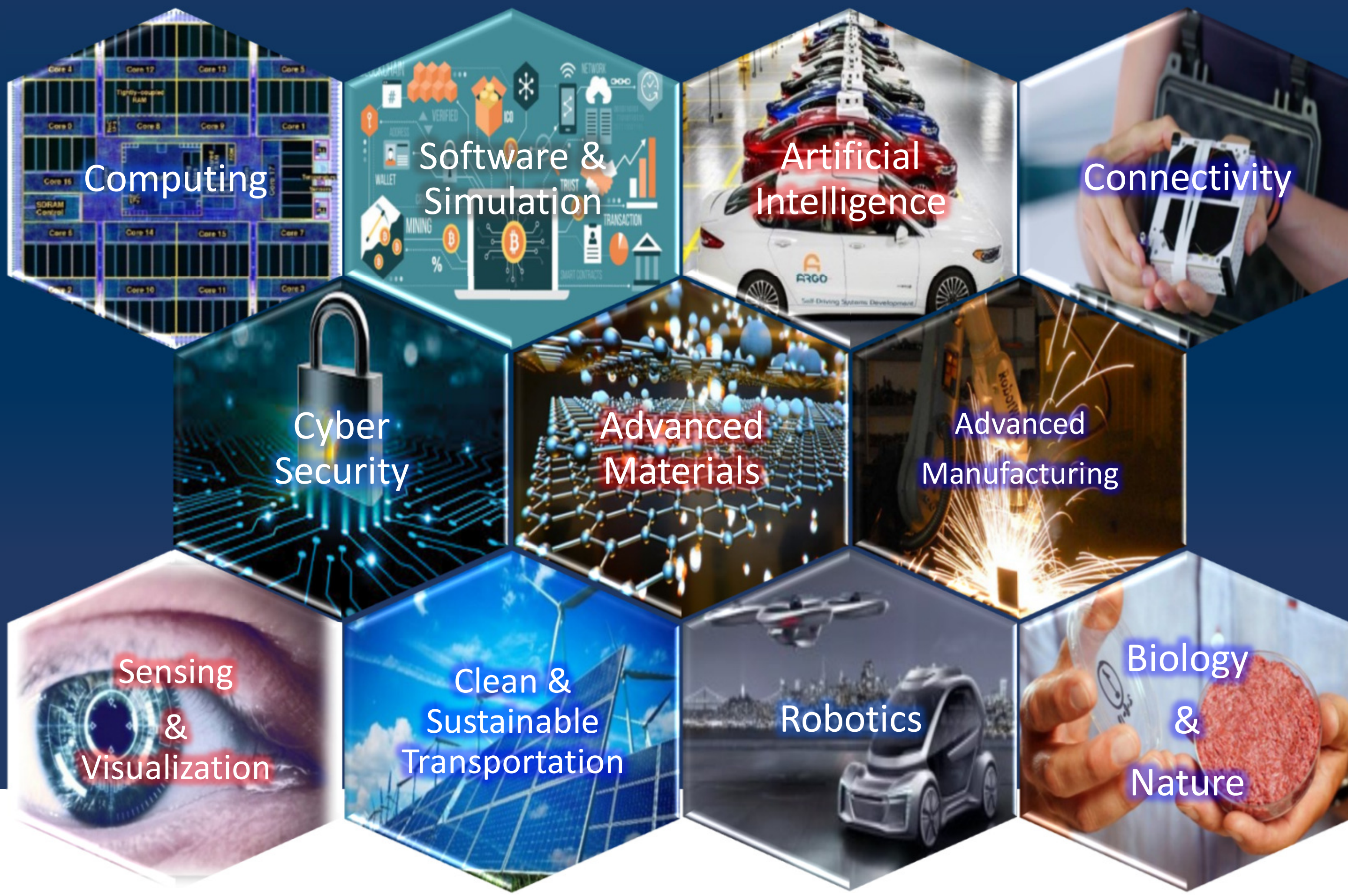
Connectivity Networking / Internet of Everything

Advanced Materials & Manufacturing

New Mobility & Autonomy

Clean Energy & De-carbonation

FORD IS LEANING FORWARD TECHNOLOGICALLY TO DESIGN SMART VEHICLES FOR A SMART WORLD



The Impact On New Vehicle Design?

- New Use Cases And Ownership Models
  - Personal / Shared ownership
  - Ride Share – UBER/LYFT/AV
  - Delivery services
  - New vehicles for first/last mile mobility solutions

Re-definition of vehicle use cases presents a unique opportunity to re-invent the primary vehicle architecture to meet the need for future functionality

New Opportunities For Composites

Redefining The Occupant Space

- Reconfigurable seating (forward/rear facing and articulating seat systems)
- Interior cabin experience
  - Most contact surfaces for the occupant are produced from polymer composites
  - Smart surfaces and integrated sensors
- NVH enhancements for BEV platforms
- Auto grade open source AM materials for mass customization
- Adaptive energy absorbing structures and foams
- Composites as an enabler for sensor integration (internally/externally facing)
- Closed loop recycling of sustainable materials
- Weight management with increased vehicle content.

To accommodate a transformational shift in vehicle use cases, driving modes and powertrains, legacy bill of materials/processes will need to be updated.

Scale: Ford Designs and Production are Global

Drivers for Thermoplastic Composites

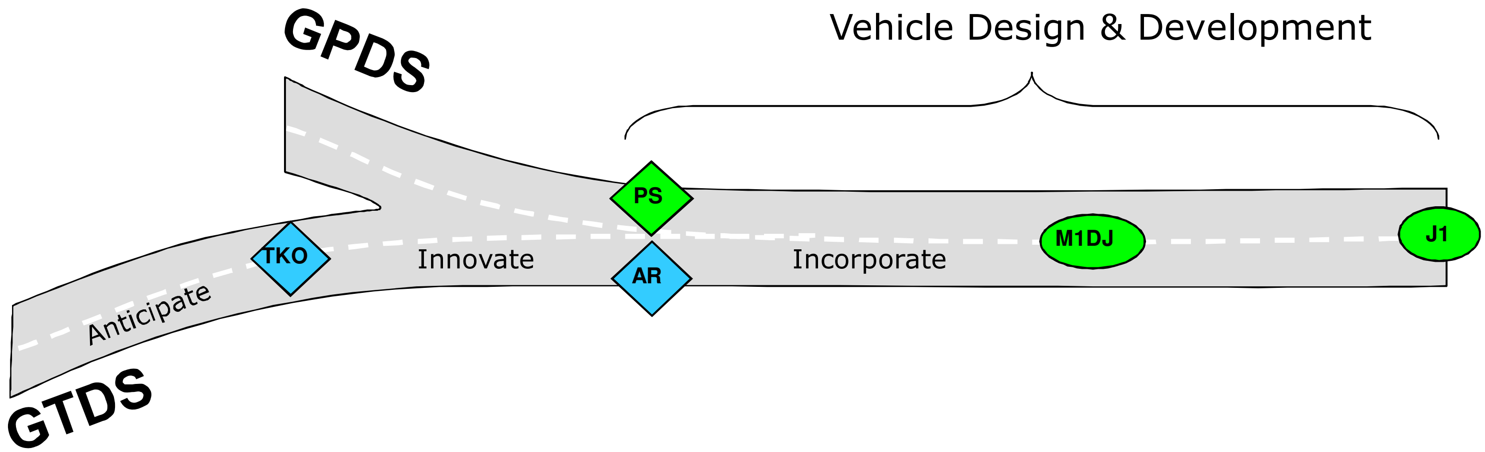
- Increased design complexity
- Recyclability
- Reduced cycle time – less than 2 minutes
- Automation for high volume manufacturing
- Hybrid overmolding
- Fewer secondary operations
- Large variety of joining methods

Quality operating systems and joining and assembly methods are required to maximize throughput for a given plant size

Potential Application Areas

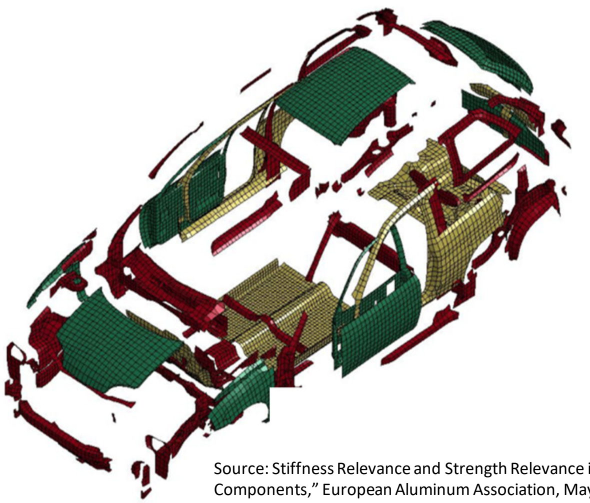
- Seat frames
- Battery trays
- Bumper beams
- Load floors
- Front ends
- Valve covers
- Rocker panels
- Under engine covers

Ford Product Development Process



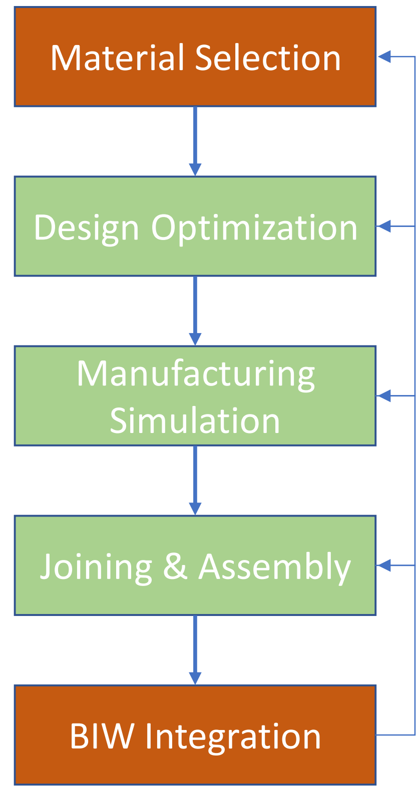
- New materials technologies need to be fully validated prior to <AR> milestone.
- Time to market, post <AR>, does not permit any additional prototyping & testing.
- Requires supply base to develop analytical tools capability for both material performance and manufacturing simulation.
  - Material CAE models for design and proposed manufacturing pathway.
  - Joining solutions for integration of materials into a mixed material environment

Vehicle Development Process



Source: Stiffness Relevance and Strength Relevance in Crash of Car Body Components," European Aluminum Association, May 2010

Stiffness Dominated
Strength Dominated
Stiffness & Strength



Composites design and analysis capabilities will need to be further optimized in order to compete with time to market to alternate metallic solutions. For the most part, mixed material solutions will have to conform to existing design space. Therefore effective material stiffness wil play a defining role in material selection

Composites Simulation Capabilities

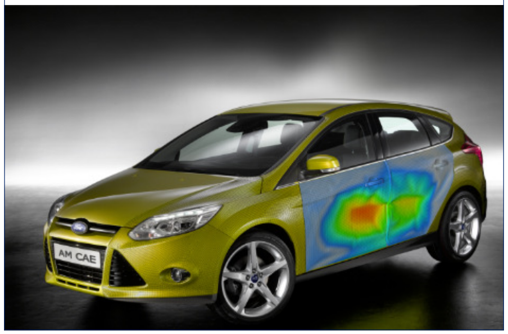
Domain	Characteristic, Behaviour	RADIOSS User Defined Material Model LAW29 - MF-GenYld+CrachFEM
ELASTIC	Non-Linear	-
	Strain Rate Dependant	x[1]
	Asymmetric Behaviour	x[2]
	Anisotropic Behaviour	x[3]
PLASTIC	Compressibility	x[4]
	Asymmetric Yield Surface	x[6]
	Strain Softening	x
	Strain Hardening	x
	Strain Rate Dependant Yield	x[7]
	Strain Rate Dependant Hardening	x*
	Anisotropic Behaviour	x[9]
DAMAGE	Damage Consideration	x[10]
FAILURE	Strain Rate Dependant	x
	Anisotropic Behaviour	x
	Load Dependant	x
	Necking, Instability	x[11]
FE-MODEL	Shell	x
	Solid	x

- Globally used within Product Development at Ford Motor Company
- Used within other OEMs
- Fully Commercialized Solution
- Globally Available from independent Company MATFEM
- Available for RADIOSS LS-DYNA ABAQUS PAM-CRASH

MF-GenYld+CrachFEM at Ford

Ford Motor Company Crash Codes

RADIOSS / LS-DYNA



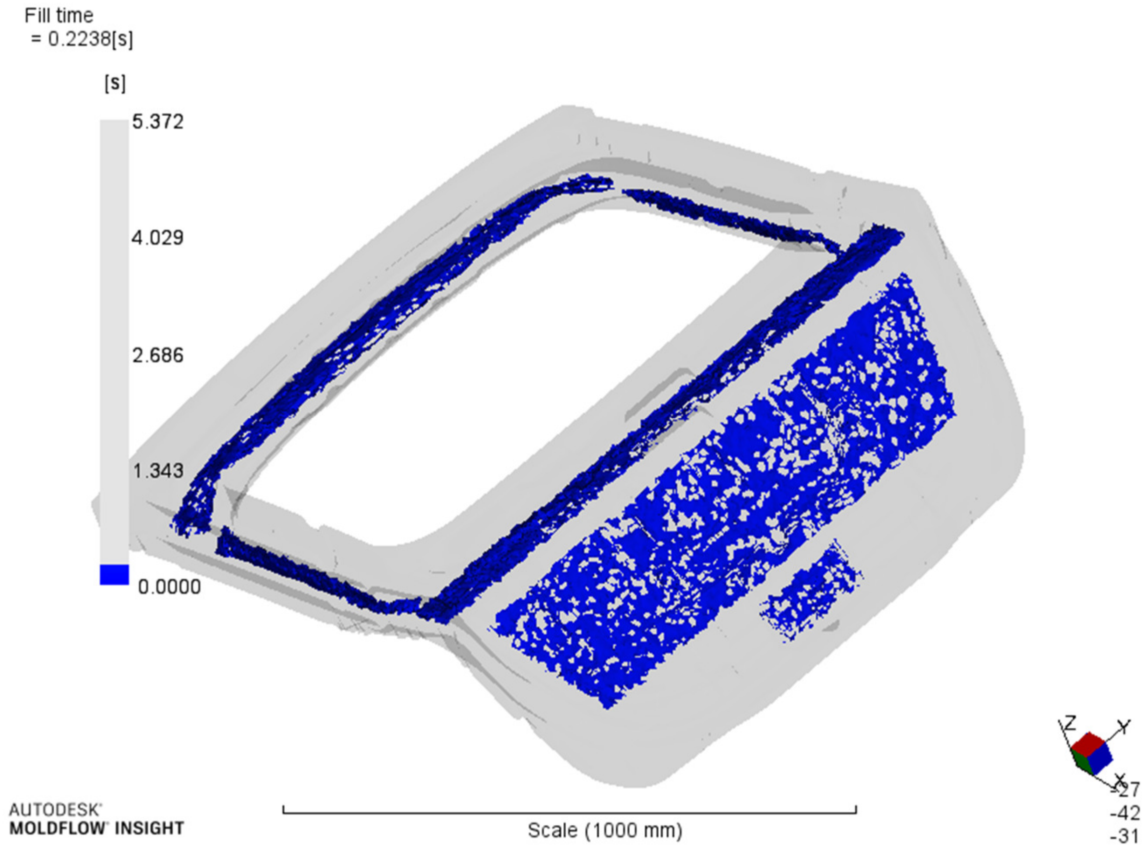
User-Defined Material Model

MF-GenYld	Elasto-plastic material behavior
CrachFEM	Failure prediction

- → **Fully Commercialized Solution**
- → **Globally Implemented at Ford Motor Company since 2007**
- → **Globally used within Product Development**

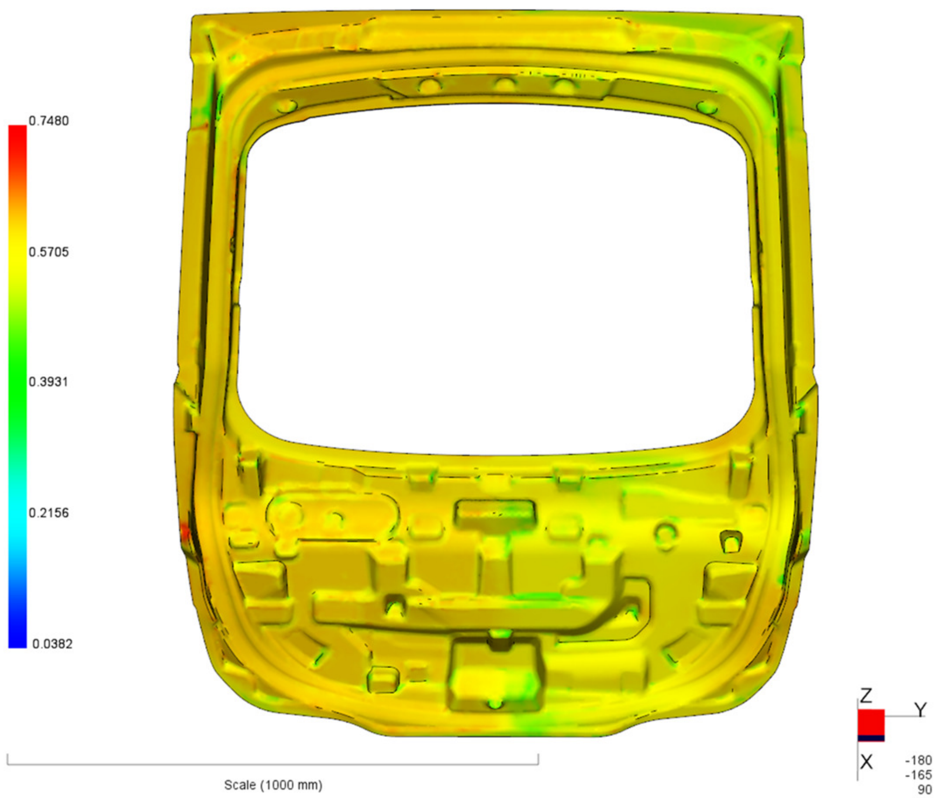
MATFEM Material Model MF-GenYld+CrachFEM

Compression Molding Simulation for CF SMC

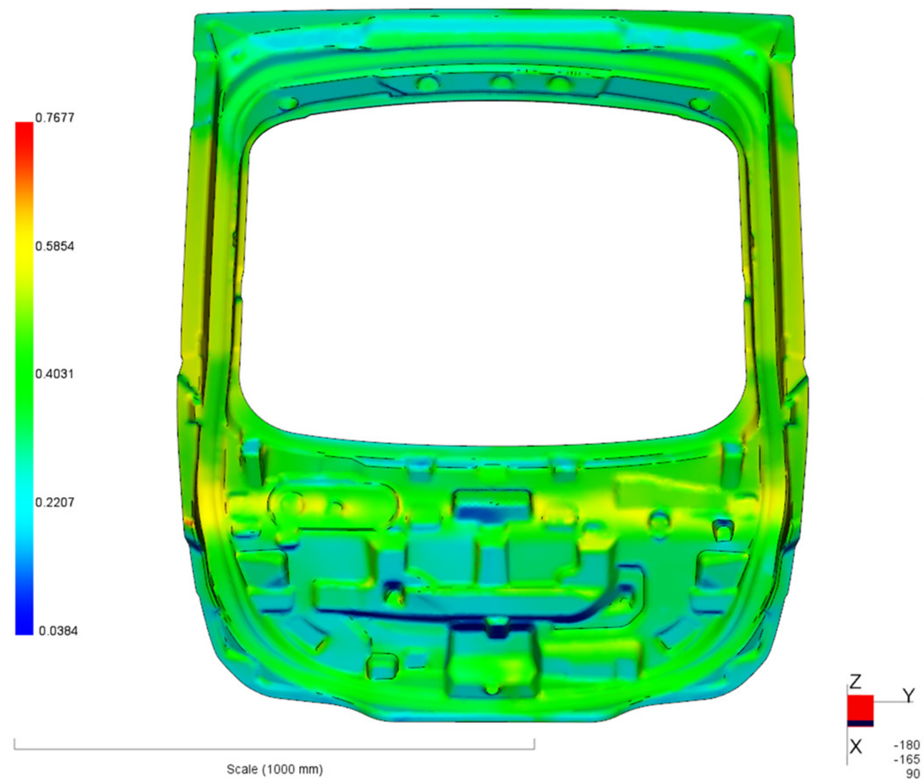


Animation of filling time

Compression Molding Simulation

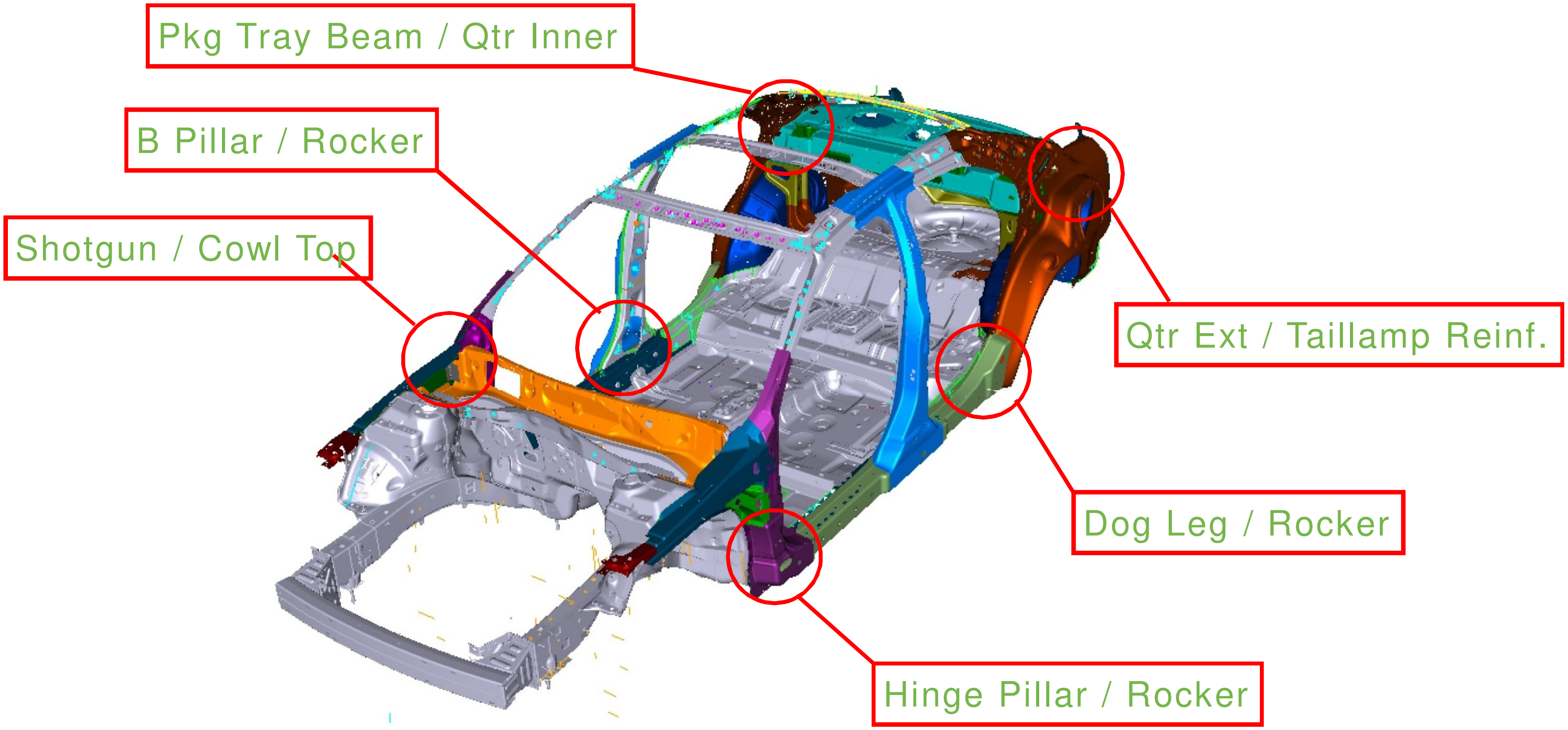


Fiber orientation in first principle direction



Fiber orientation in X direction

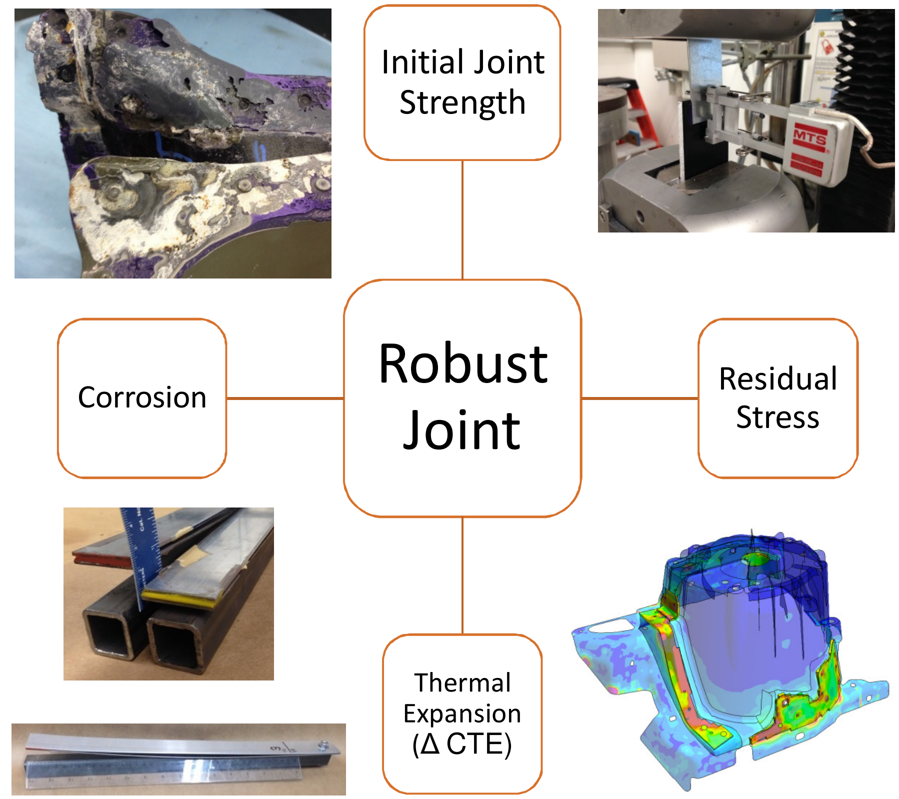
Conventional Build – Key Joints



Mixed material joining strategy will need to be developed for high volume production.

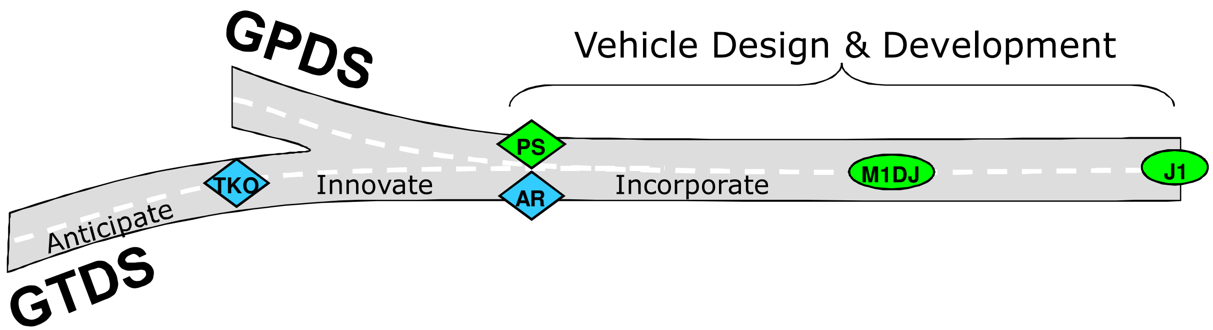
Mixed Material Technical Challenges

- Joining – Adhesive as primary joining? Mechanical joining primary?
- Corrosion –100% sealing strategy? Coatings? Location within the vehicle. Use case.
- Thermal Expansion Difference – design with nonplanar surfaces
- Residual Stresses – may not be detectable after ovens but could cause failure in service (corrosion)



Design requires a systems approach

Summary



- The invention of the modern day assembly line and subsequent legacy infrastructure has been an impediment to broad scale adoption of polymer composites in primary body structure
- However, re-definition of the automobile in the context of future mobility creates a unique opportunity to re-define material solution for future bill of process.
- Maintaining a competitive advantage regarding time to market will remain a key factor in final material selection as the option for any additional prototyping & testing will be limited.
- Support from the supply base is needed to develop analytical tools capability for both material performance and manufacturing simulation.
  - Material CAE models for design and proposed manufacturing pathway.
  - Joining solutions for integration of materials into a mixed material environment.

QUESTIONS ?