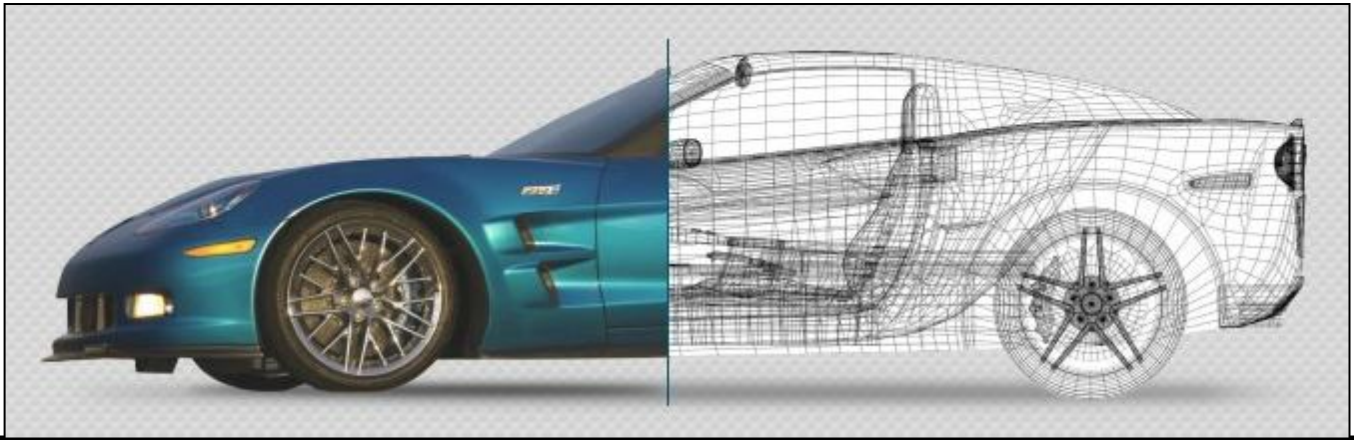
CARBON COMPOSITES

Entering Mainstream Automotive

Jackie Rehkopf, PhD

NHTSA Mass-Size-Safety Symposium

May. 13-14, 2013



OUTLINE

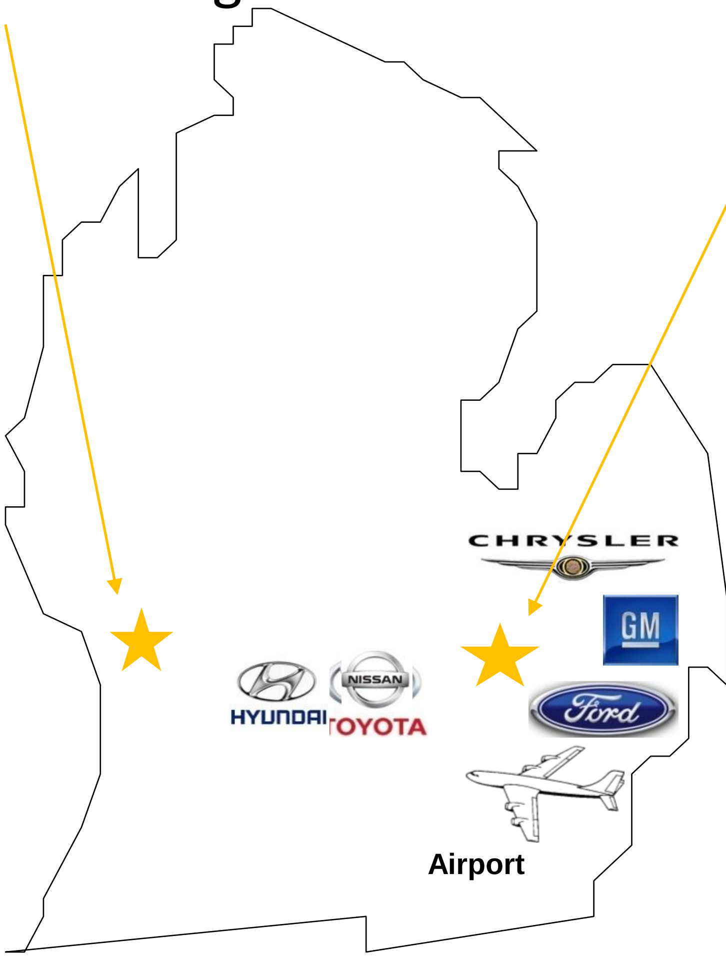
- Introduction to Plasan Carbon Composites
- Opportunities for CFRP in Mainstream Automotive
- Requirements for Efficient Production of CFRP
- Evolution from Niche to Mainstream Automotive via Technology Development

PLASAN'S INTERNATIONAL OPERATION

MICHIGAN FACILITIES

Manufacturing

Customer Development Center



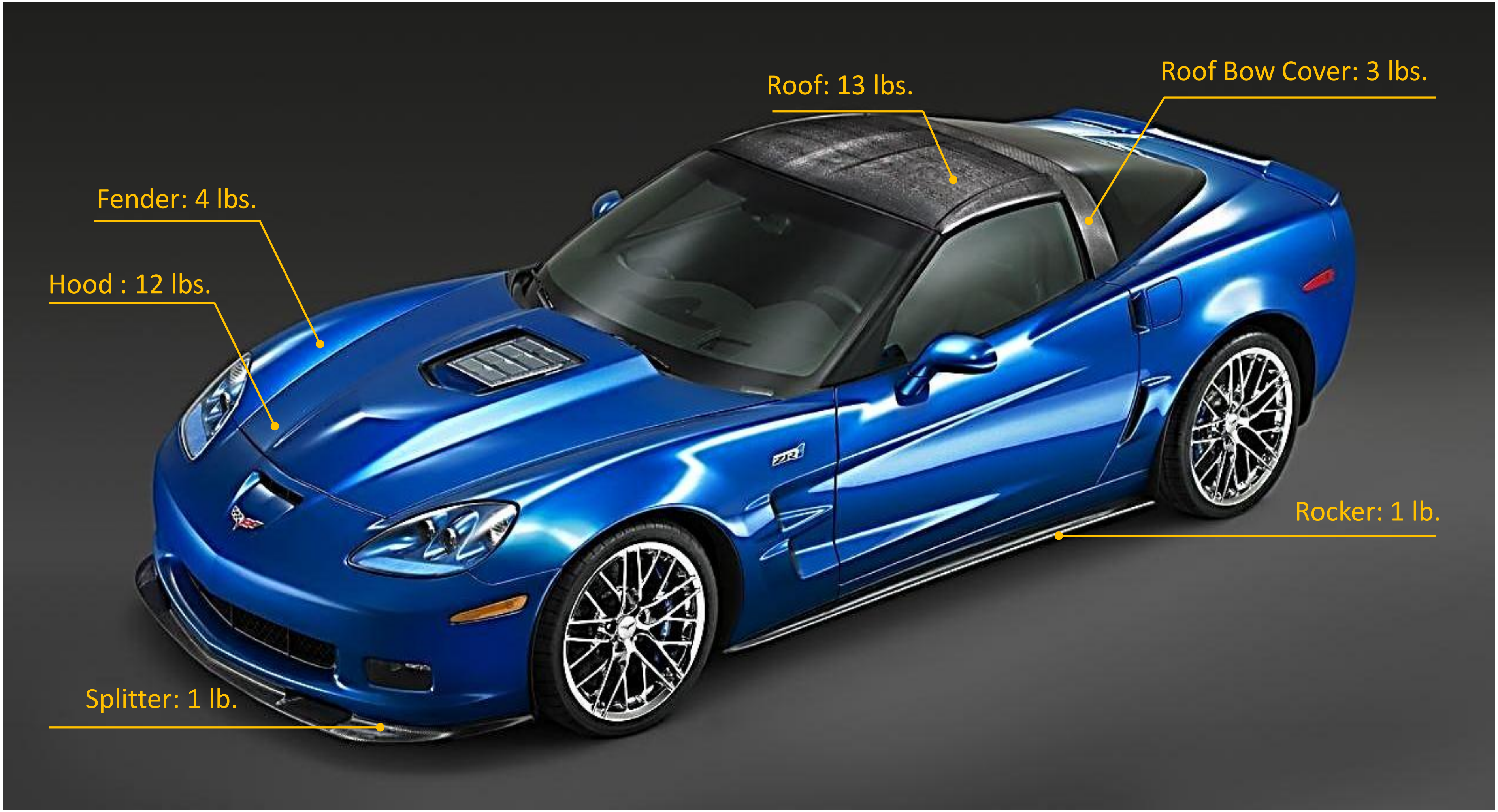
- 24,000 square foot Facility
  - *~ ½ Manufacturing Space*
- Scale-up Facility for New Technology
  - *Production-Representative*
- Focus on Market Penetration

New Mfg Facility in Walker, MI

- 197,000 square feet Manufacturing
- Incentives from the Michigan Economic Development Corporation (MEDC)
- > $20M in Capital Investment
- > 200 New Jobs
- Geared to Higher-Volume Production
- Incorporates Plasan's New Manufacturing Methods
- Plasan's CFRP Processing Breakthroughs

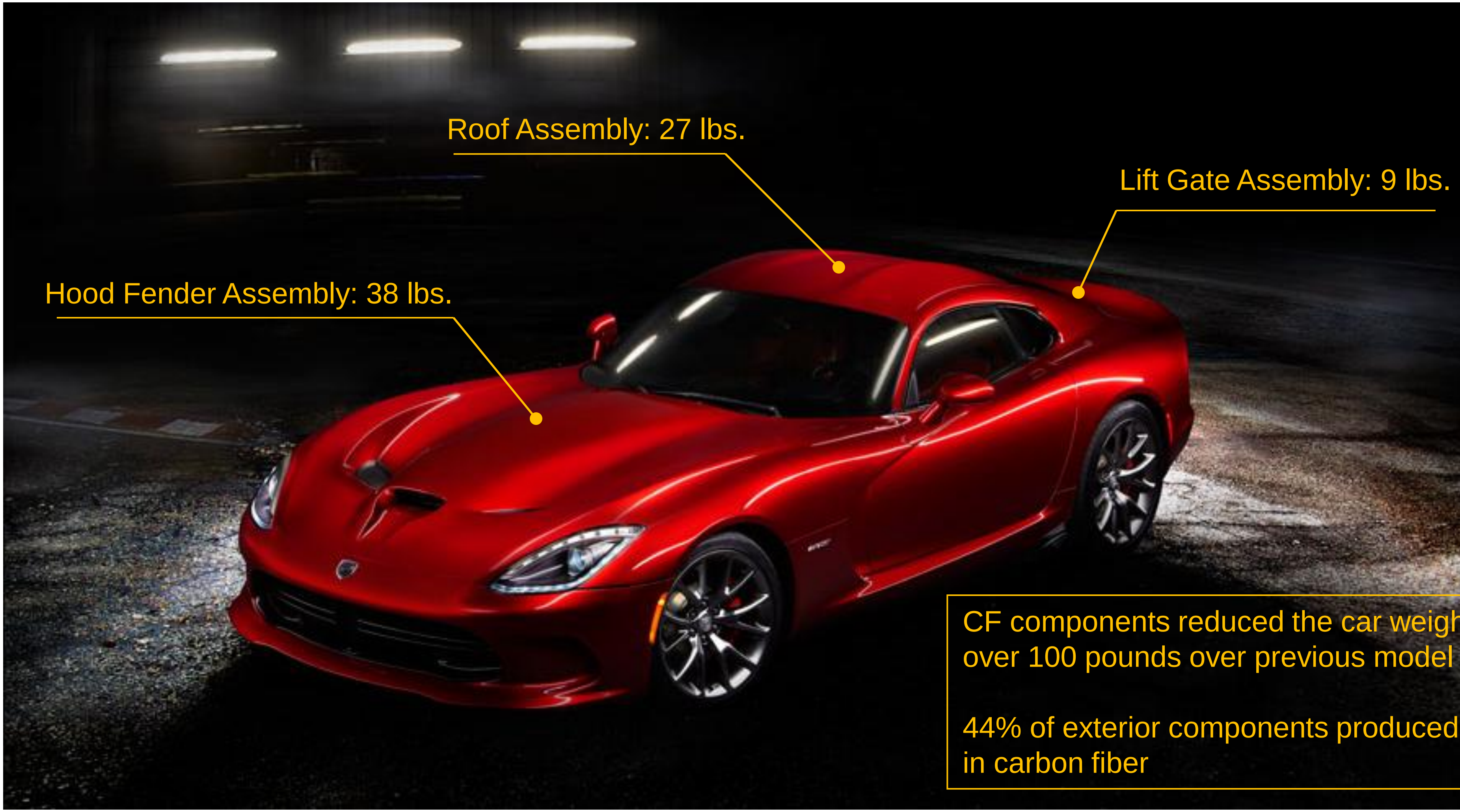
- **Supports 30K-50K Vehicles per Year**
- **Future Improvements to Reach 100K**

Corvette Specialty Model: ZR1



PLASAN CARBON COMPOSITES

SRT Viper



Roof Assembly: 27 lbs.
Lift Gate Assembly: 9 lbs.
Hood Fender Assembly: 38 lbs.
CF components reduced the car weight over 100 pounds over previous model
44% of exterior components produced in carbon fiber

Opportunities for CFCs in Mid-Volume Vehicles

Current Automotive Evolution

Key Drivers for Improved Fuel Economy

- Government: CAFE Regulations
  Energy Independence Initiatives
- Consumer: High Gasoline Prices
  Environmental Concerns

Affected Vehicle Aspects

- Drive trains / Propulsion Systems
- Aerodynamics
- Parasitic Losses
- Mass Reduction

Carbon Fiber Advantages

- Low Density

% Lighter than:

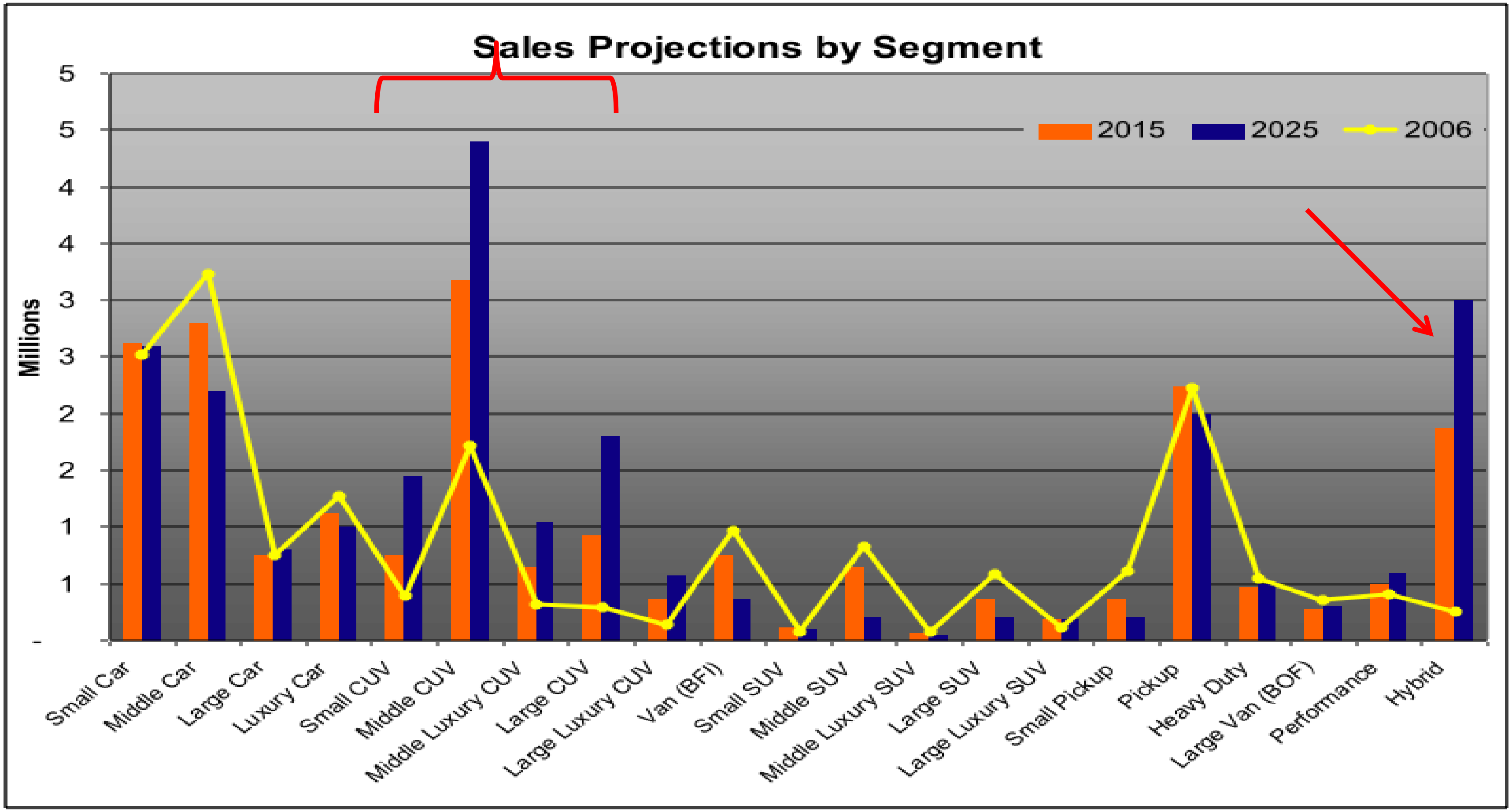
Steel	Aluminum	Mg Alloy	SMC
70%-80%	30%-40%	30%-35%	40%-50%

- Excellent Strength & Stiffness to Weight Ratios
- Excellent Corrosion resistance
- Thermal Stability & Moisture Stability
- Improved NVH characteristics
- Design Flexibility
- Part Consolidation
- Short Lead Times
- Low Capital Cost

Consumer Benefits

- Improved Structural Rigidity
  - E.g. Roof - Increased Torsional Rigidity in the Vehicle
- Lighter Weight
  - Lower Center of Gravity (depending on component, eg. Roof, Hood)
  - Improved Vehicle Dynamics
  - Improved Power to Weight Ratio
- Improved Corrosion Resistance

Market Evolution



Both Hybrids & CUVs have Significant Mass Reduction Needs (Battery Pack & Large Vehicle Size)

CFC Entry into Automotive

- Off-shoot from Aerospace
- Autoclave Process
- Process Attributes
  - High Quality Parts
- Process Limitations
  - Slow Cure Cycle
  - Thermally Inefficient
  - N2 Atmosphere
  - Labor Intensive
  - Supports Low Volumes

Key Requirements for Efficient Production

- > 50K Units per Year
- Cost-Effective
  - Less Than 3-4 X Cost of Lightweight Metal
- Low Void Content, High Surface Quality
- Readily Fastened/Assembled to Other Components

Source: Good Car Bad Car

June 2012 YTD Top 260 Best-Selling Vehicles In America - Every Vehicle Ranked

Camaro
Traverse
Mustang
3-Series
Impreza
Terrain
Charger
Tundra
RX
Liberty
Sonic/Aveo
Acadia
300
Forte
Taurus
C-Class
Forester
Journey

#45 Chevrolet Camaro ~ 100 K / y

#59 Ford Taurus ~ 76 K / y

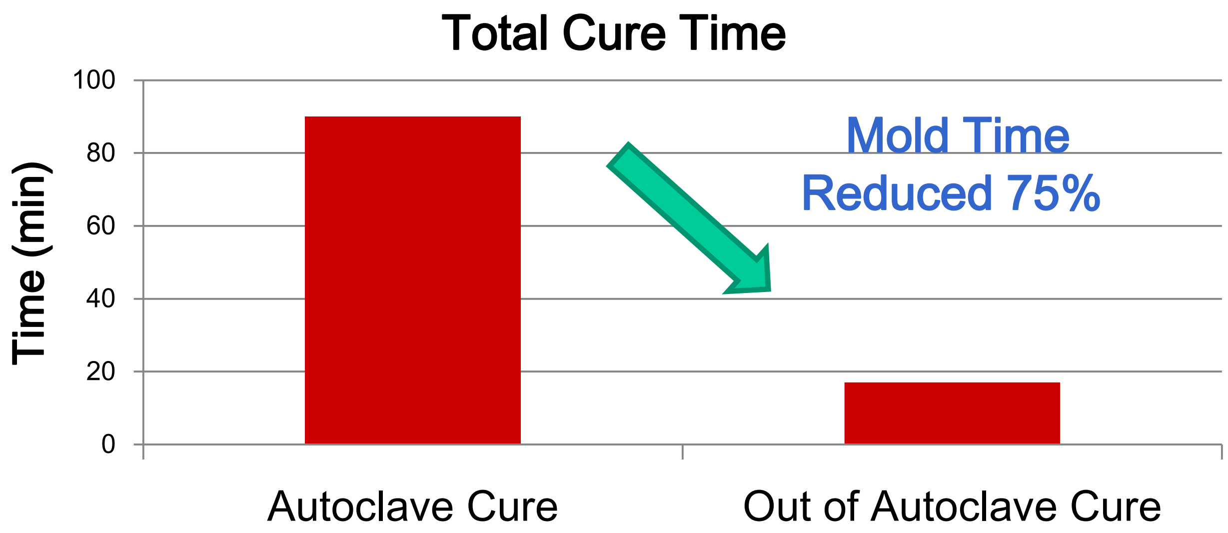
#62 Dodge Journey ~ 74 K / y

#78 Mazda 6 ~ 50 K / y

#45	Chevrolet Camaro	49,697
#46	Chevrolet Traverse	48,866
#47	Ford Mustang	48,624
#48	BMW 3-Series	46,762
#49	Subaru Impreza	46,702
#50	GMC Terrain	46,602
#51	Dodge Charger	45,763
#52	Toyota Tundra	45,111
#53	Lexus RX	44,017
#54	Jeep Liberty	42,339
#55	Chevrolet Sonic/Aveo	42,296
#56	GMC Acadia	42,160
#57	Chrysler 300	40,801
#58	Kia Forte	40,800
#59	Ford Taurus	38,221
#60	Mercedes-Benz C-Class	37,686
#61	Subaru Forester	37,096
#62	Dodge Journey	36,751
#63	Hyundai Accent	36,470
#64	Hyundai Santa Fe	34,440
#65	Chevrolet Tahoe	33,274
#66	Jeep Patriot	32,707
#67	Ford Fiesta	31,326
#68	Buick LaCrosse	30,892
#69	Mercedes-Benz E-Class	30,366
#70	Nissan Maxima	30,104
#71	Nissan Frontier	29,385
#72	Infiniti G	28,749
#73	Buick Enclave	27,866
#74	BMW 5-Series	27,751
#75	Nissan Murano	27,179
#76	Cadillac CTS	25,483
#77	Cadillac SRX	25,450
#78	Mazda 6	25,369

Accent
Santa Fe
Tahoe
Patriot
Fiesta
LaCrosse
Maxima
Frontier
Infiniti G
Enclave
5-Series
Murano
CTS
SRX
Mazda 6

PLASAN'S PRESSURE PRESS TECHNOLOGY

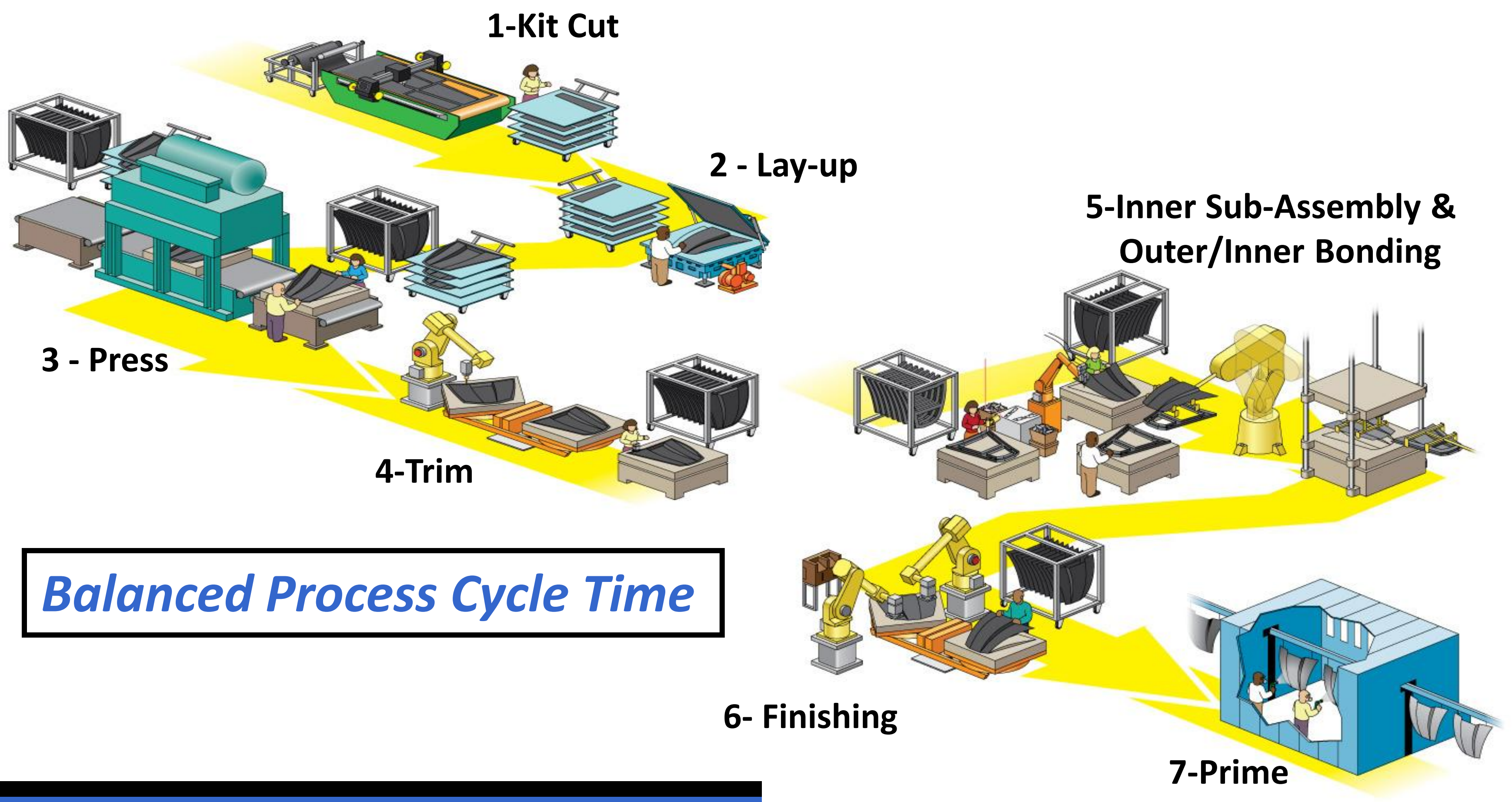


- Class A & Structural Parts
- 1 Coat Primer
- Production Volumes of 30K-100K per Year
- Development Continues to Further Reduce Cycle Time

Faster Cycle AND Improved Surface Quality

Pressure Press Technology

Sub 20-Minute Production



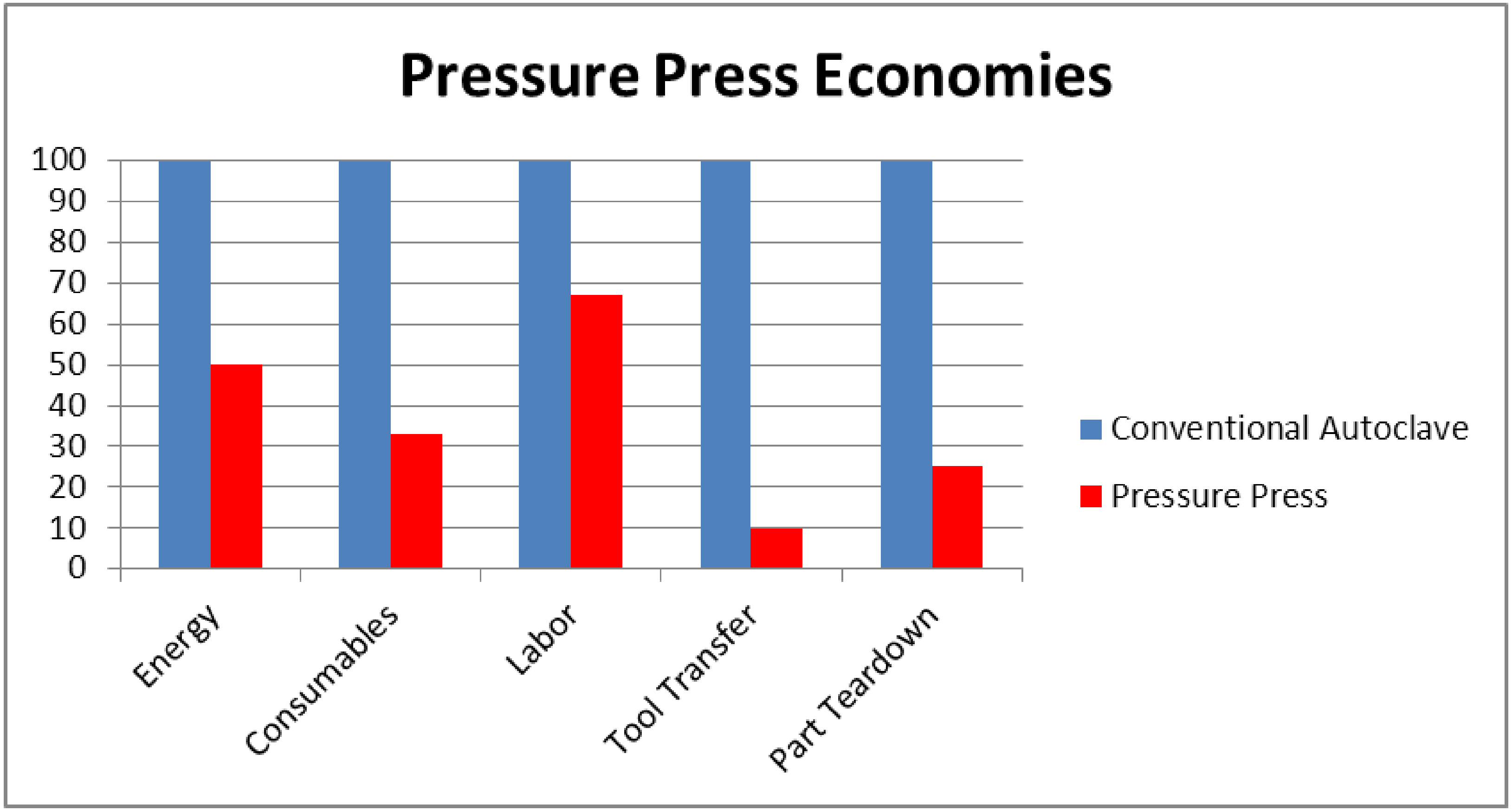
Balanced Process Cycle Time

For High Volume Automotive

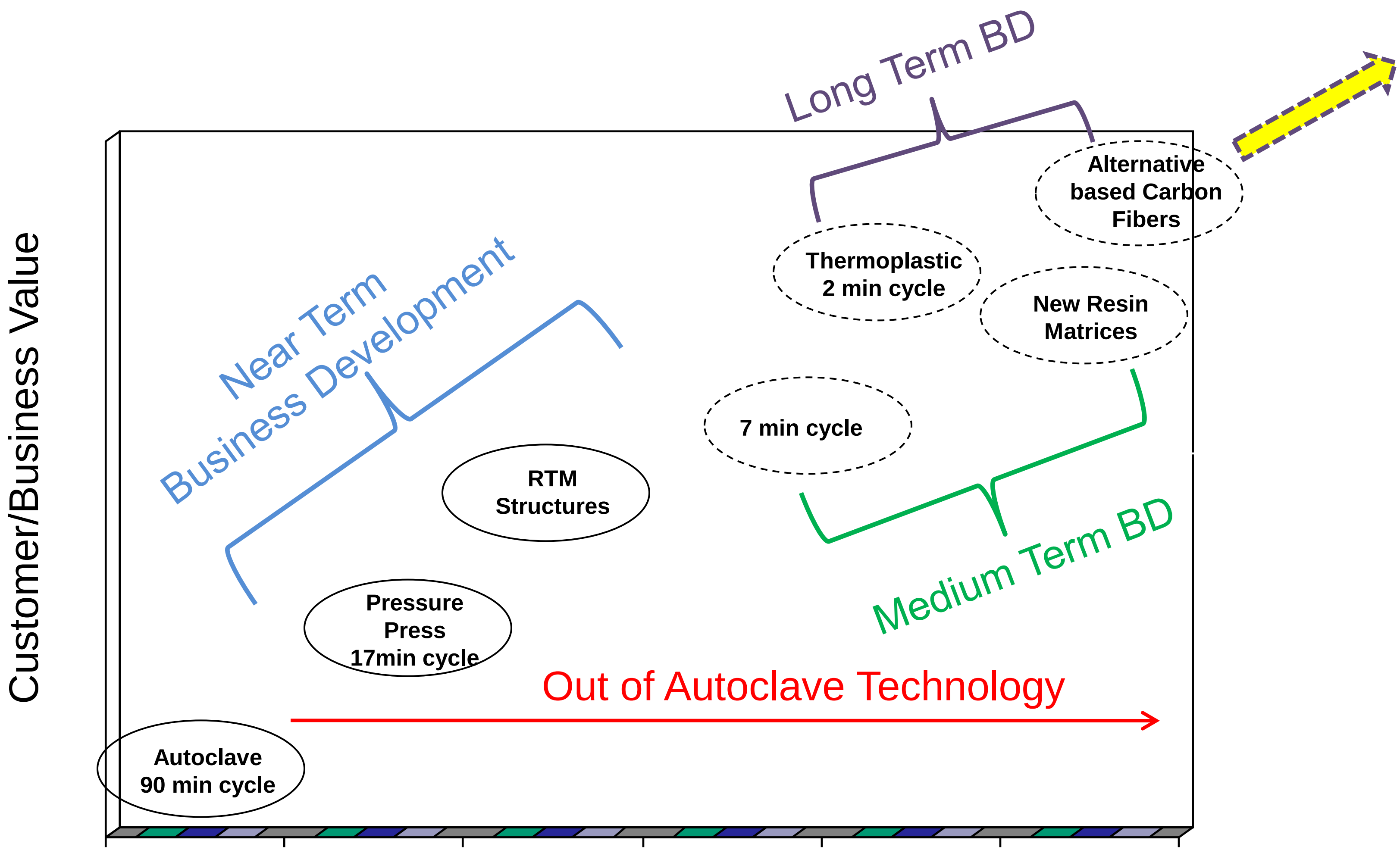
Pressure Press < 20 minute

Same Material System
Same End Properties

Pressure Press v Autoclave



TECHNOLOGY DEVELOPMENT LINKED WITH BUSINESS DEVELOPMENT



Technology Developments for 100K +

- Advanced Mold Tooling to Reduce Cycle Time
- Laser Placement for Localized Thickness Variations
- Water Jet Trimming for Level Process Flow
- Automated Tape Lay
- Advanced Resin Development
- Automated Etching for Paint Preparation
- Pre-Forming
- RTM Molding

BUSINESS DEVELOPMENTS FOR 100K +

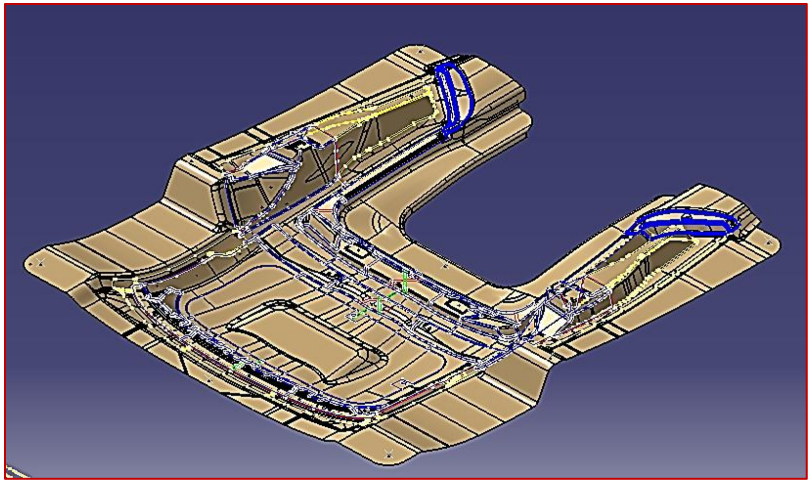
- Just-In-Time Material Supply
- Reduce Time & Distance from Material Source to CFC Mfg
- Minimize Material Supply Risk via Multiple Qualified Sources
- Lead Qualification Advancements as Technologies Develop
- Expand Mfg Process & Material Portfolios for Customers
- Expand CFC Design & Analysis Tools

CASCADING TECHNOLOGY FROM NICHE TO MAINSTREAM

Technologies in the SRT Viper Hood Assembly

- Large Complex Clamshell Geometry
  - Up to 3000 vehicle sets / year
- Textured surface on B-side of Outer Panel
- Exposed Weave Inner Panel
- Integrated Mounting Points using riv-nuts and studs on inner hood.
- Meets Structural Requirements through Local Section Thicknesses

TECHNOLOGIES IN THE SRT VIPER ROOF ASSEMBLY

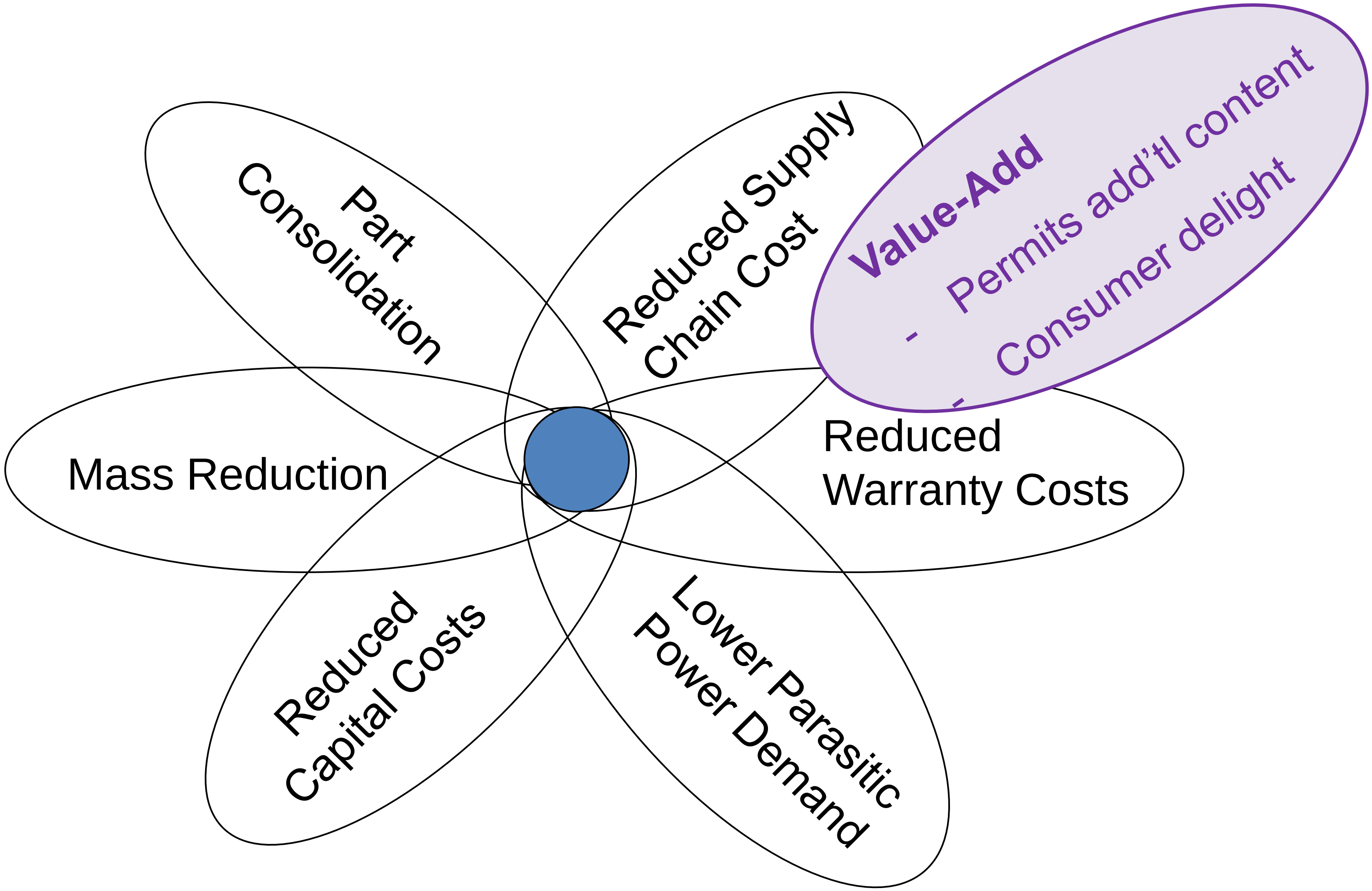


- Key Structural Component of the Vehicle - Meets Roof Crush
- Layup Thickness & Orientation Custom Tuned to Meet Various Part Requirements
- CAE Permits Kits & Work Instructions Developed Before Tools Arrive
- CAD-Driven Laser Placement System Ensures Accurate Layup

Carbon Fiber Composite Strategy

- Engage & Collaborate with OEM Early in Design Stage
- Combine Several CFC Advantages:
  - Mass Reduction
  - Increased Stiffness and/or Strength
  - Part Consolidation
  - Design Flexibility /Aerodynamics
  - Safety – Pedestrian Impact and Others
  - Improved NVH
- Assess Cost from a Comprehensive Systems Model
  - Evaluate Cost Across Development, Manufacturing & Life Cycle

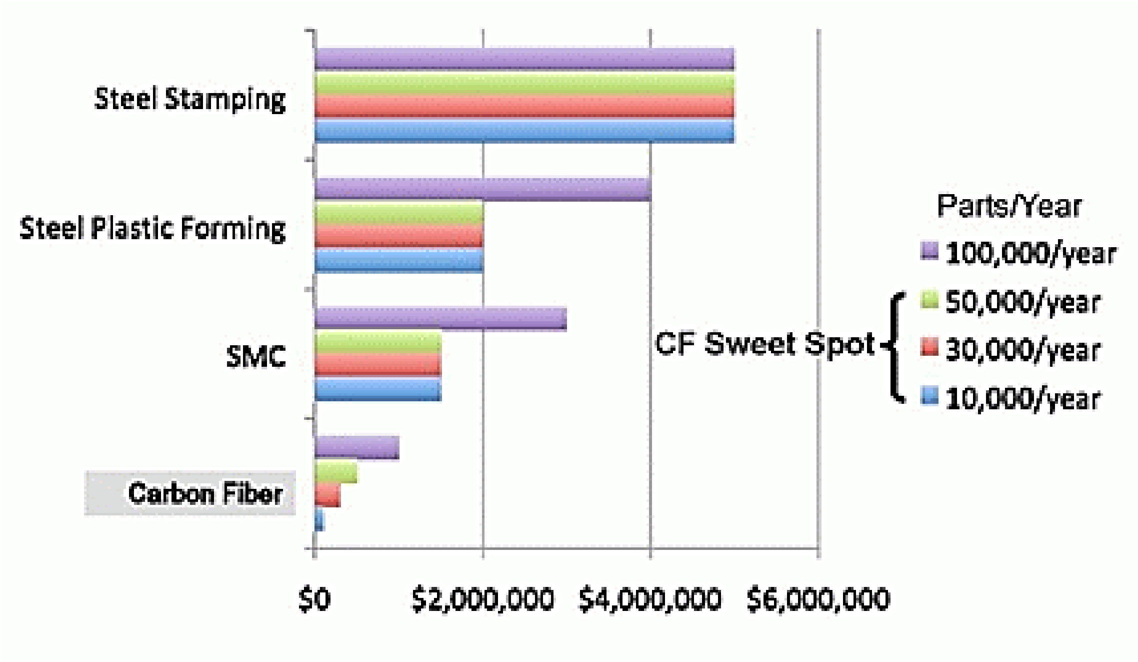
SYSTEM APPROACH TO EVALUATE COST



PLASAN CARBON COMPOSITES

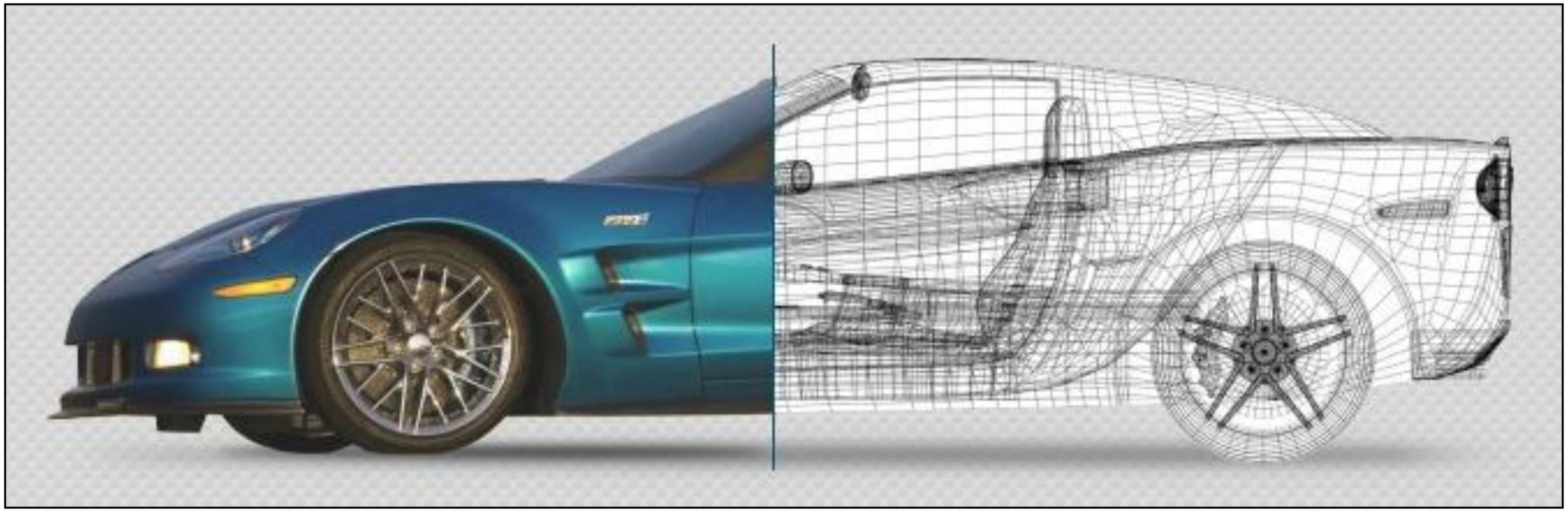
The Big Cost Factors

Mold or Forming Tooling Costs



- Lower Capital Costs for CFRP vs SMC or Sheet Metal
- Finished Assembly Costs Dramatically Reduced Via Continuous Development:
  - 2008-2012, $/lb of a bonded, finished prepreg assembly ↓ 39%

Composite Design & Analysis Tools

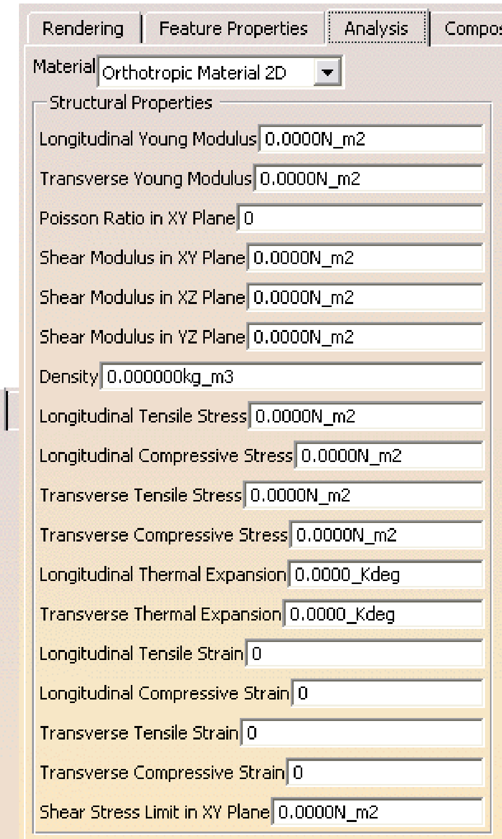


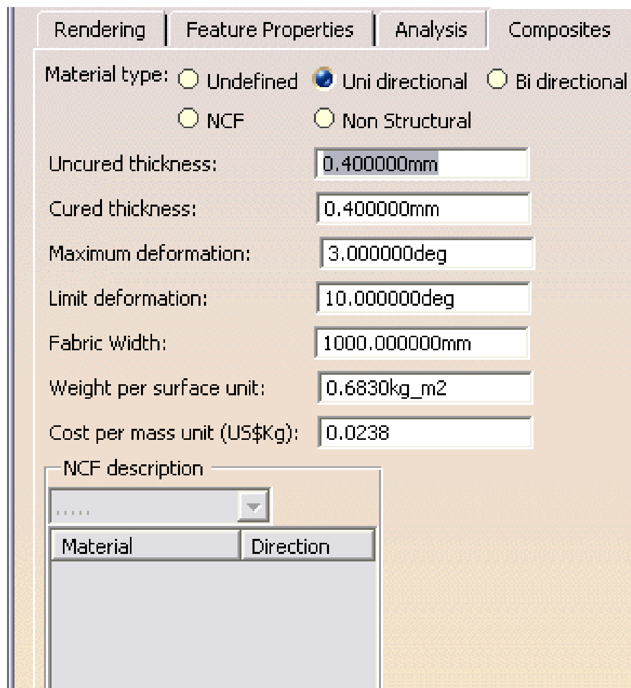
Integration of software tools and composite part design practices leads to improvements in throughout a company.

R&D Quoting Prototyping PPAP Manufacturing

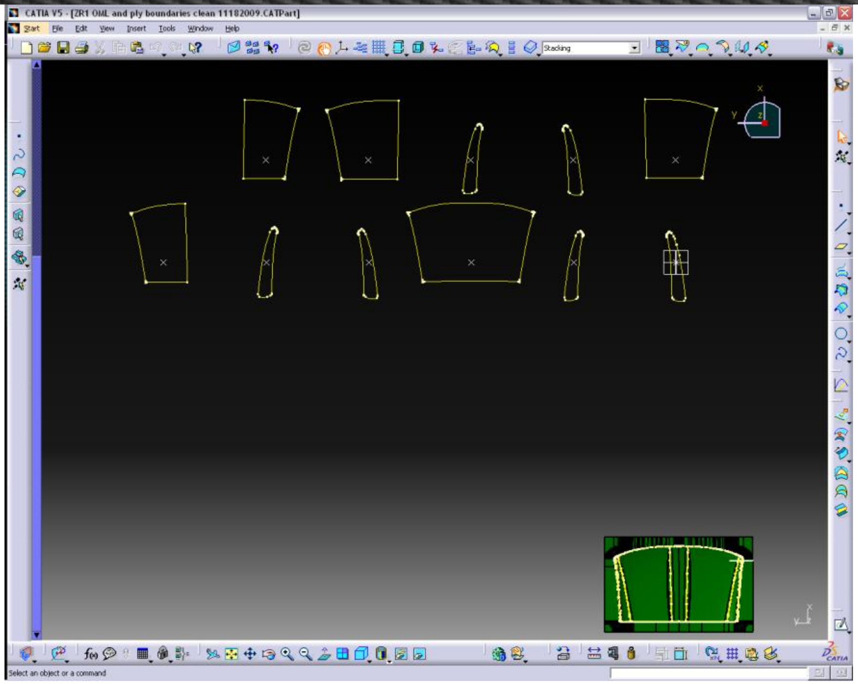
Material Models Database

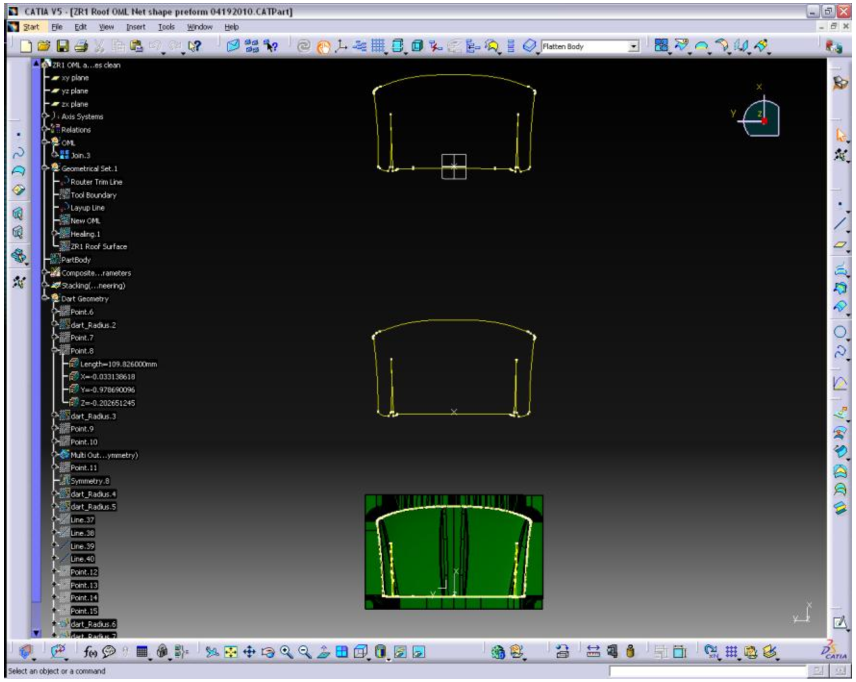
- Production & Non-Production Materials Kept Separate
- Relevant Composite Info Included
- FEA Material Cards Quickly Added
- Shared Material Library





SANDBOX FOR NEW DESIGN TECHNIQUES

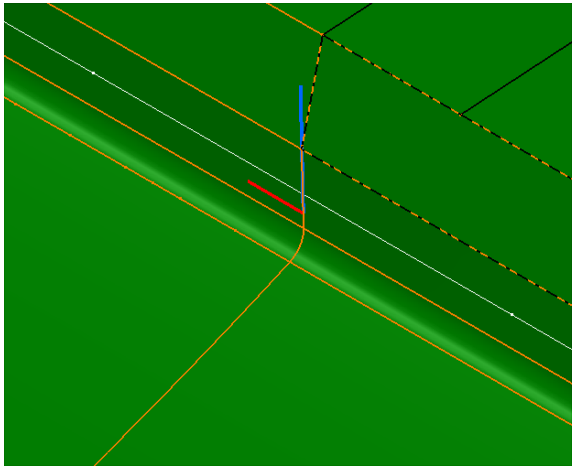


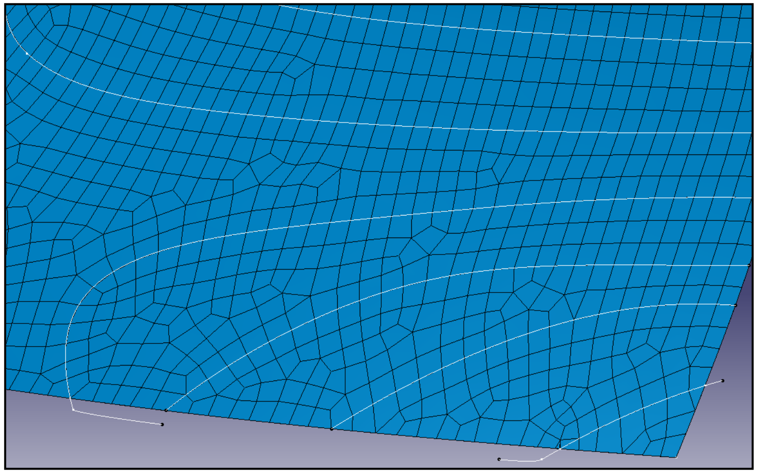


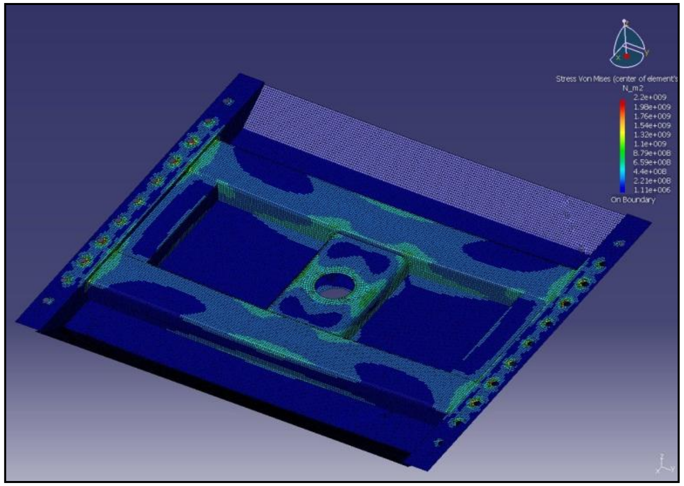
- Easily Substitute Production Materials for Latest Supplier Offerings
- Test Producibility of New Layup & Ply Design Techniques Without Using Material, Tooling or Operators
- Roll Width – ⬇Ply Count – ⬇ Cycle Time – ⬆ Production Volume

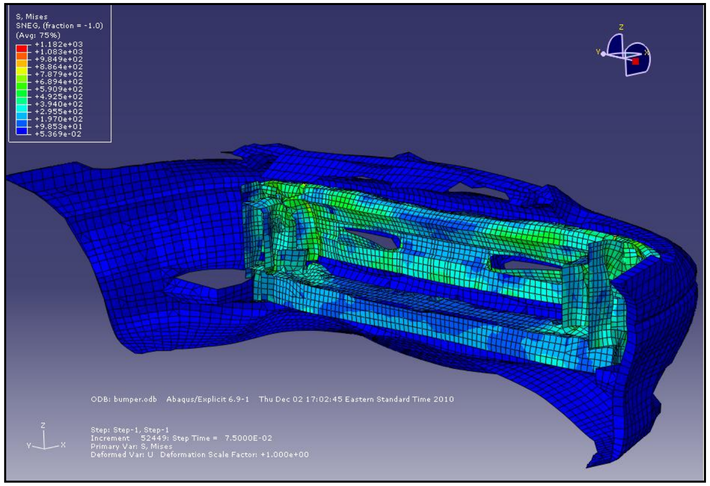
Fast Preparation for FEA

Virtual Analysis of Ply Structures Lead to Fewer Physical Prototypes

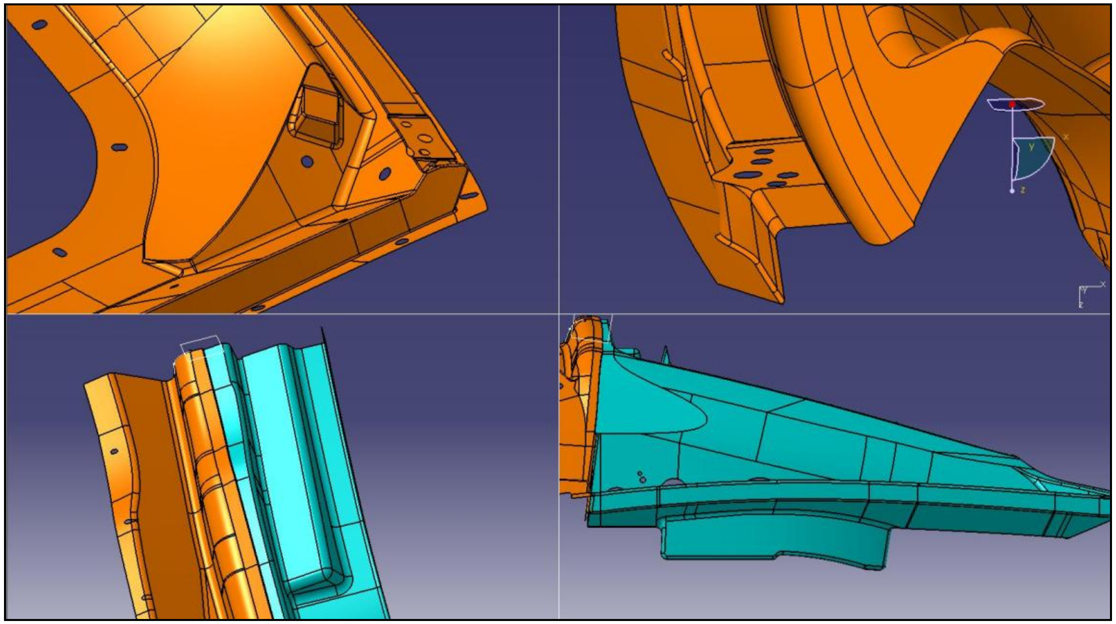


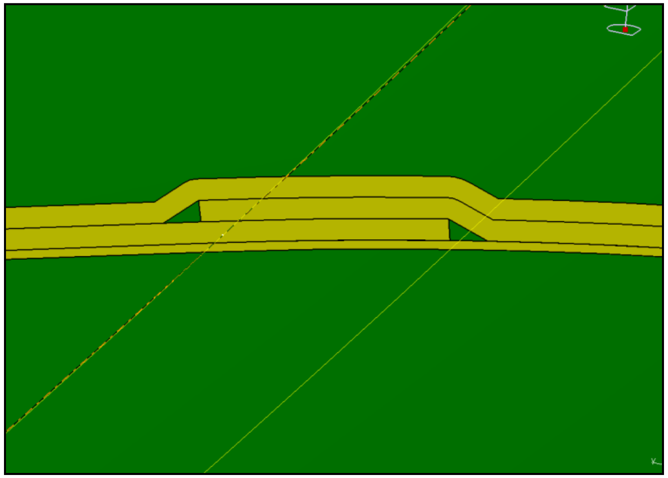






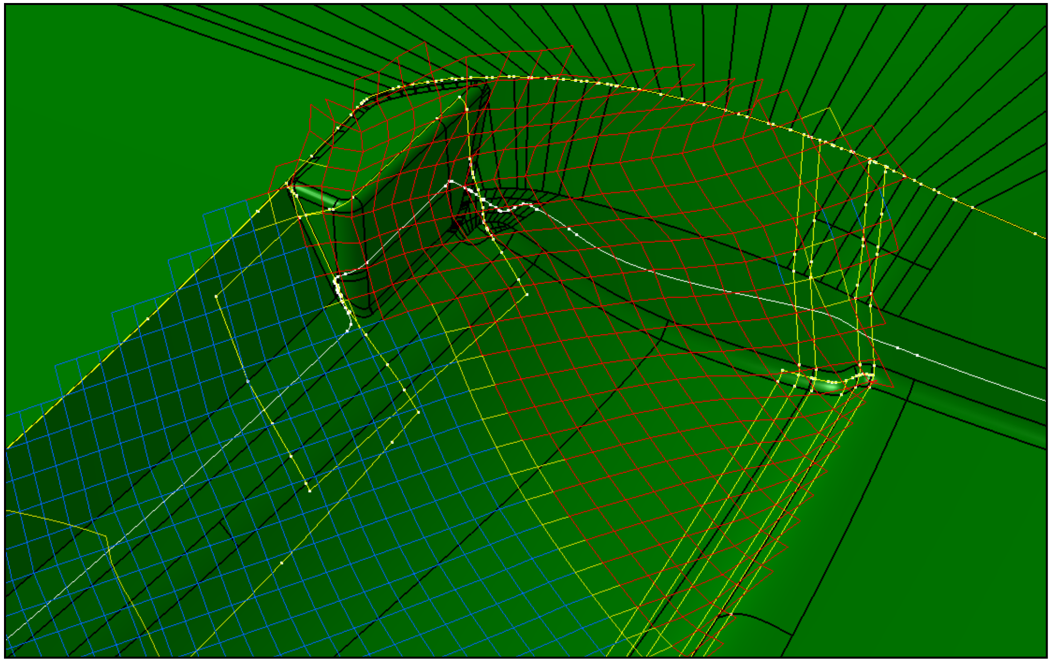
QUICK DESIGN FEEDBACK TO CUSTOMERS

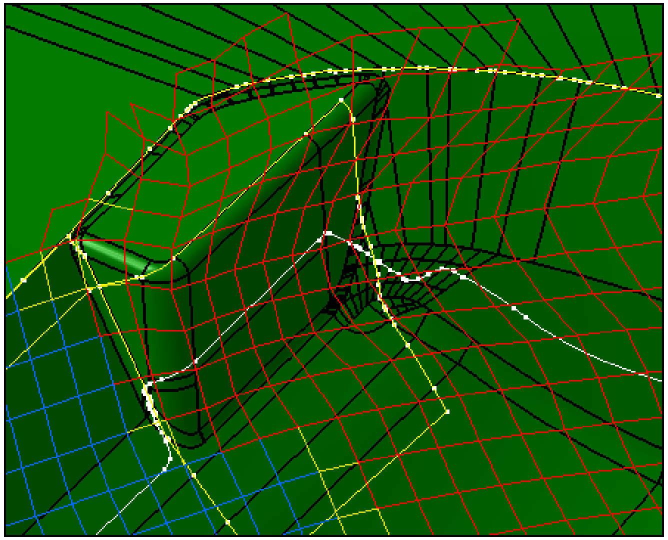




- Effectively Communicate Design Constraints & Limitations
- Easily Export FEA Models with Material Definitions
- Show Joint Construction & Nominal Thickness with Cross Sections

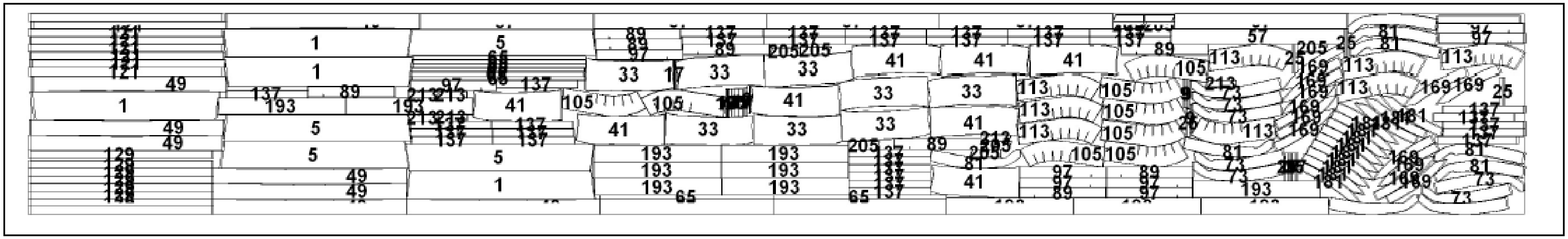
Quick and Reliable Kit Design

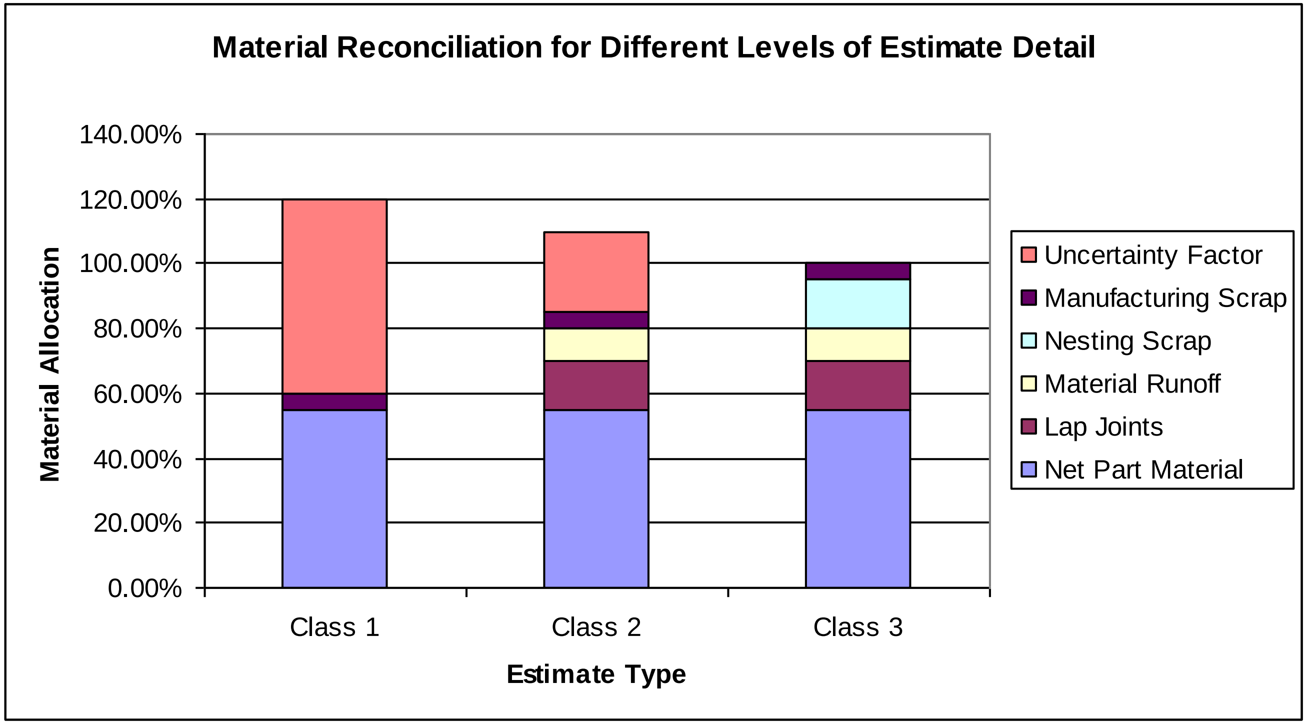




- Example Part: ***Old Way = 16 days*** ***New Way = 6.5 days***
- Eng'g Experience & Judgment Confirmed by Quantified Producibility Data
- Areas Prone to Bridging or Wrinkling Identified & Addressed Prior to Build

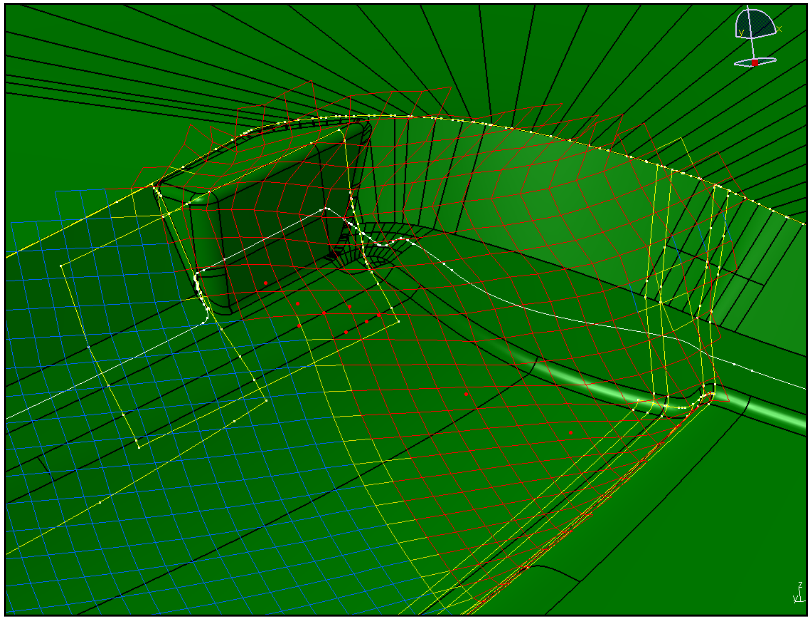
Cost Estimation Using Kit Design

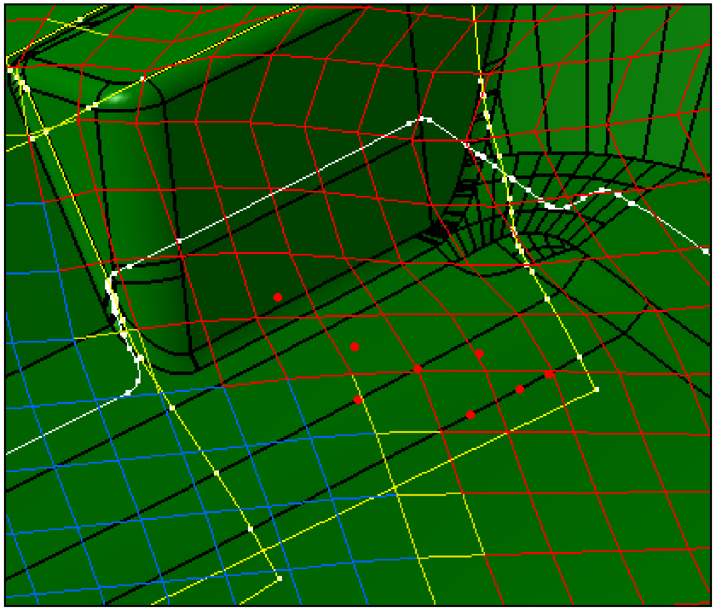




Class 1 Estimation:
30 minutes with PLM
(4 hours w/o PLM)

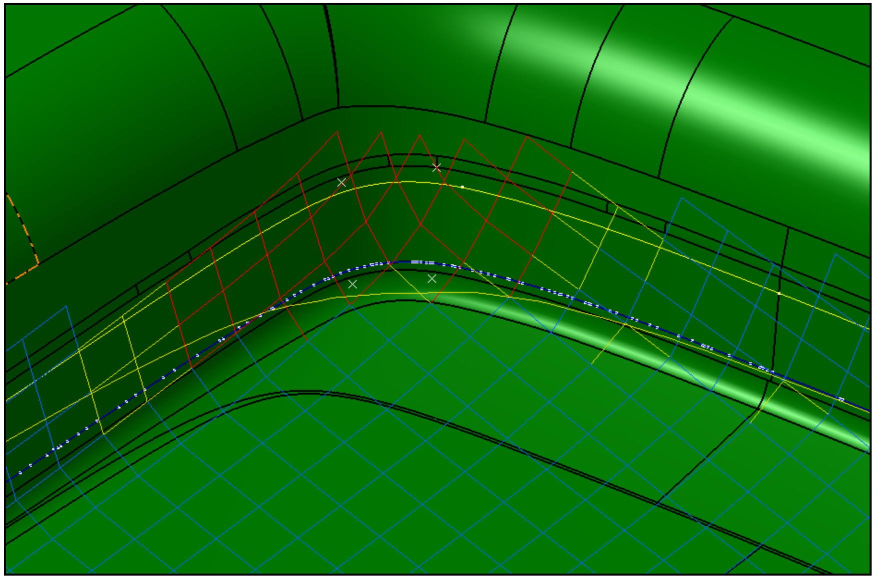
Improved Quality Controls

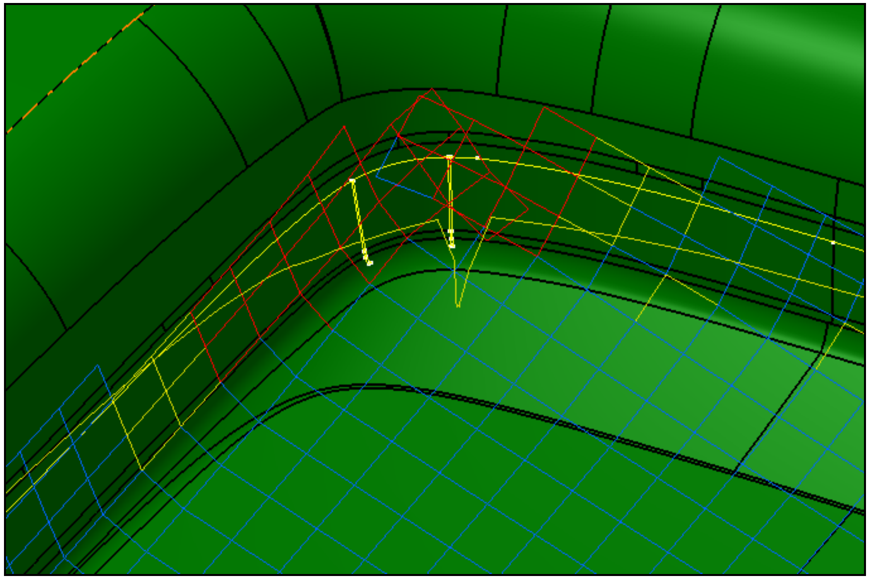




- Engineering Change Requests Justified by Producibility Simulations
- Flawed Parts can be Inspected on a CMM Generating a Point Cloud
- Digital Flaw and Scrap Tracking Allows Better Prediction of Scrap Parts

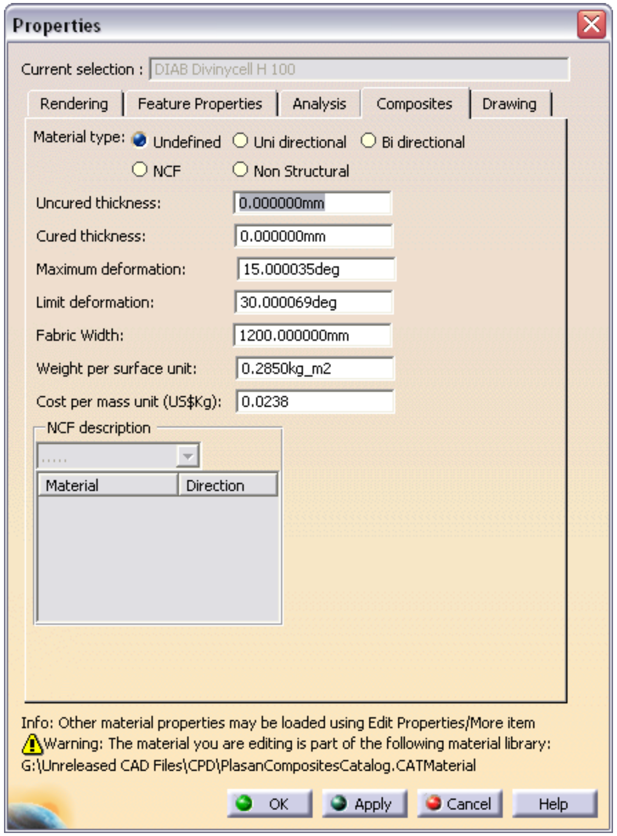
SHOP FLOOR AND ENGINEERING EXCHANGE

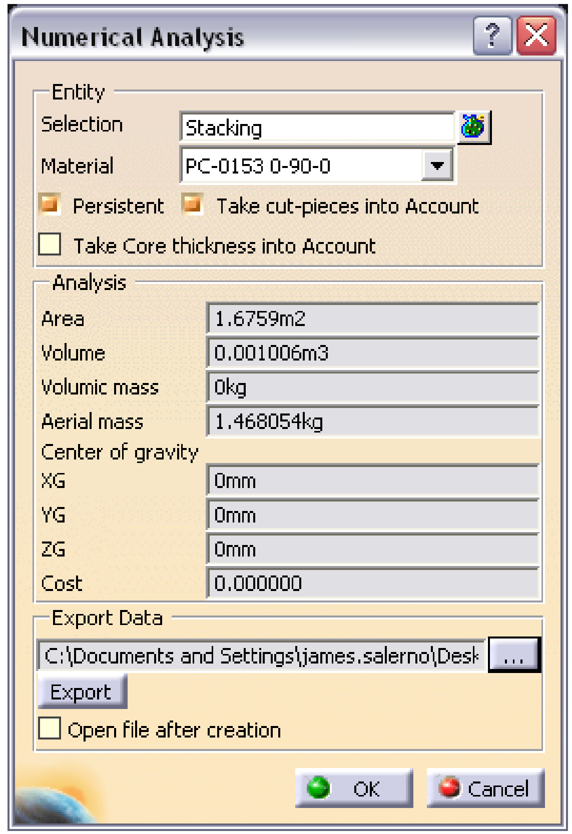




- Repetitive Operator Actions Accounted for by Revisions to Kit Designs
- Darts and Alignment Features Incorporated into Standard Kits

IMPACTS OF DESIGN CHANGES ON PART PRICE





Nest testing matrix for trial inner.					
	Material Width				
Number of	39.37	45	50	55	60
1	61.80%	61.80%	62.80%	62.9%	63.3%
2	63.70%	65.40%	64.40%	64.3%	65.1%
3	63.20%	63.70%	64.90%	64.9%	65.0%
4	63.10%	63.70%	64.50%	64.5%	64.8%
5	64.10%	64.10%	63.70%	64.6%	65.1%
6	62.30%	63.90%	64.40%	65.0%	64.8%

Material

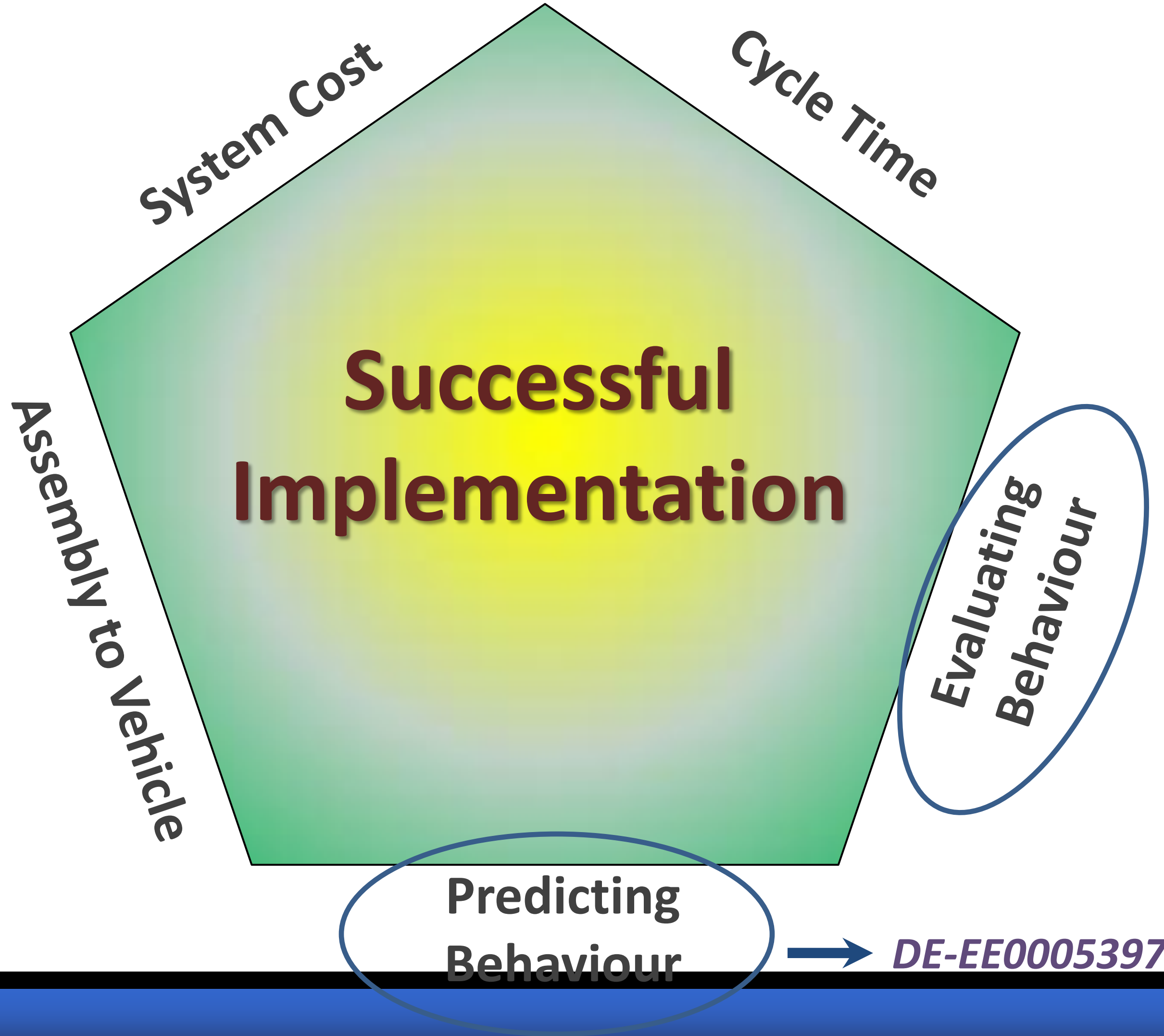
Material : 0-90-0
Thickness : 0.05 (In)
Sheet Size : 293.56 x 39.0 (In)
Plate Name :

Calculations

Sheet Utilization (Real) : 91.3 %
Distance Travelled : 6031.5 (In)
Profiling Distance : 8402.07 (In)
Time per Sheet : 02 : 55 : 28
Labelling Time : 0.0 (sec)

- Material Prices can be Directly Linked in a Material Model
- Changes in Part Design or Mfg Efficiency Tracked & Understood

CFRP IN MAINSTREAM AUTOMOTIVE - *Challenges*



Composite Processing

- Processing a Composite Structure is Significant Cost / Risk
- Material Equivalency Between Structure and Test Panels Essential
- Changes in Production Often Desired / Required
  - Design, Tooling, Layup, Local Thickness, Material Composition

The Science of the Process

Process ⟶ *Microstructure* ⟶ *Properties*

(Micro- Meso- Macro-)

Model the Composite Process *Gas Transport* / *Thermo-Chemical* / *Flow-Compaction* / *Stress-Deformation* ***to Predict Properties***

C7 Corvette Stingray

Pressure Press Process
17 minute Button-to-Button Cycle
Same Prepreg as the Corvette ZR01 Roof

Roof
Painted or Exposed Weave
1.2 mm nominal

Hood
Hot-Bonded Inner & Outer
Each 1.2 mm nominal

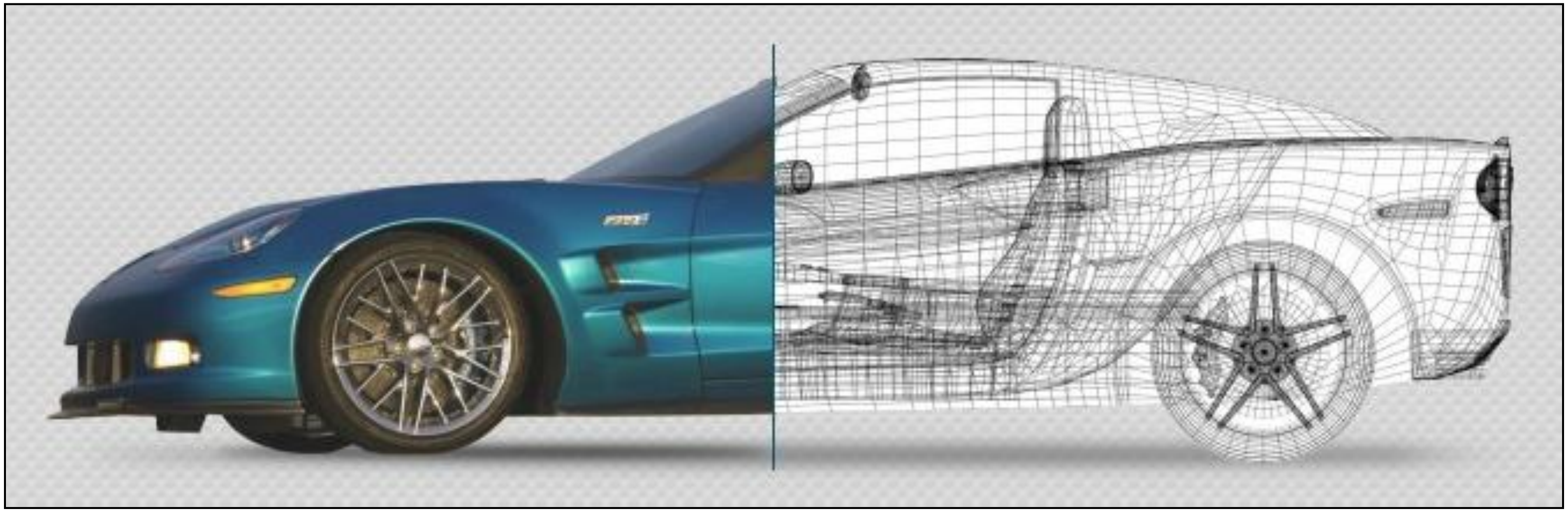
The Future for Automotive CFCs

- Variety of Material Constituents, Architectures, Processes

  Material System

- Material System + Process Are Linked ⟶ Part Performance
- Part Performance Can Be Achieved Multiple Ways
- Factors to Consider: System Cost
  - Part-to-Part Cycle Time
  - Vehicle Assembly
  - Capital Infrastructure/Investment
  - Life Cycle

The Material & Process Selected for a Component Will Depend on Performance & Business Case



Questions & Comments?