Go Further

Sustainable Materials & Manufacturing
NCMS – NIST - University of Kentucky - IMTI

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Global Materials & Mfg R&D
Outline

Sustainability at Ford Motor Company

- Corporate Initiatives
  - Eco-Boost Engines
  - Vehicle Light Weighting
  - Material Utilization
  - High Value Recycling
  - Green Materials
PRODUCT DEVELOPMENT STRATEGY

Near Term
Leverage Existing Technologies at High Volume
- EcoBoost Engines
- Electric Power Steering
- 6-Speed Transmissions
- Next Generation Diesels
- World-Class Hybrids

Mid Term
Substantial Weight Reduction & Expand Electrification
- Vehicle Weight Reduction
- Auto Stop-Start

Long Term
High Volume Electrification and Alternative Energies
- Energy Management
- New Materials
- Hydrogen Powered
- High Volume Electrification
- Alternative Energies
Integrated Computational Materials Engineering

**Downsize & Boost**

- 20% FE Improvement, 15% Emissions Reduction
- Increased fuel efficiency and performance
- Decreased Powertrain Weight
Emissions Reduction

Fuel Economy Improvement

Near Term

Up To 20%

Up To 15%

Fuel Efficiency

Lower Emissions

CO₂
Mid Term

Weight Reduction of 250–750 lbs, (113 – 340) kg

- Smaller displacement engines
- Smaller components
- Lightweight materials
Weight Distribution

Future Technologies

- Degree of Electrification & Hybridization
- Start Stop Technology
- Boosted Engines
- Low Rolling Resistant Tires
- Aerodynamic Solutions

Powertrain - 25%
Body Structure - 25%
Glazing - 3%
Interiors - 14%
Closures - 8%
Chassis & Suspension - 21%
Other - 4%
Electrical, Fluids, etc.
Global Car Sales Seen Rising to 85 Million in 2014

Rising Emerging Market Wealth, moderate gas prices to Drive Demand

By MIKE RAMSEY and NEAL BOUDETTE

The global auto industry is expected to produce 85 million sales in 2014, up from an estimated 62 million this year, IHS: Automotive said in a forecast Monday. By 2018 sales are forecast to break 100 million, according to the unit of business-information provider IHS Inc.
85 Million Vehicles – Assume Ford Fusions

~93,500,000 tons of steel

~18,700,000 tons of plastics

~12,000,000 tons of aluminum

~4,250,000 tons of glass

~650,000 tons of magnesium

Note

~ 75,000 tons of Carbon Fiber in Production
(Primarily Dedicated to Aerospace)

(150,000,000 lbs ~ 2 lbs /vehicle)

* CF supply expected to increase to 200 -300 M lbs
Material Deliver Weight Reduction

- **Advanced High Strength Steel** – Weight savings potential additional 7 to 10%  
  - Most mature technology  
  - Stamping, Joining & Assy Infrastructure Exists  
  - Lowest cost alternative  
  - Hydroforming  
  - Tooling upgrades required (Hot Stamping)

- **Aluminum** - Weight savings potential 40 to 50%  
  - Solid experience with Al Sheet (Closures)  
  - Material cost is higher than advanced steels  
  - Slight tooling upgrades required  
  - Extrusions & Castings offer part consolidation opportunities

- **Magnesium** - Weight savings potential 50 to 60%  
  - Casting is currently the only economically viable manufacturing process  
  - Corrosion can be an issue in some applications  
  - Material supply base and converters in a state of flux  
  - Sheet development in research phase

- **Polymer Composites** - Weight savings potential 10 to 60+%  
  - Good supply base for Injection Molding & sheet molded composite (SMC)  
  - Class B surface and semi-structural applications  
  - Carbon Fiber only starts to look promising @ $5 -8 / lb  
  - Infrastructure to Make CF small and needs to grow

- **Multi-Materials Lightweight Vehicles** – Optimizing all materials systems

Component level up to 30% Wt Save
Advanced High Strength Steel Vehicles
Material – Ford Fusion BIW

Mild Steel
BH - HSLA (YS < 300)
HSLA (YS > 300)
DP 600
DP 800
DP 1000
Boron - Martensitic

Average Yield Strength = 348 MPa
Optimized Materials Utilization - Cost Saving opportunity for Body & Stamping

- $6 Billion/yr in steel
- 60% MU means 40% Scrap
- 1% Improvement
  - $60M annually in cost saving
  - Less Material waste
  - Sustainability
Material Utilization - Optimization Strategies

Single Part Design Optimization

- Blank nesting, bend radii, critical edge softening, design for optimal coil width, etc.

Single Part Process Optimization

- Transfer die, ilo progressive die, hydroforming/rollforming, PDPD templates, etc.

Multiple Parts ilo Single Part to Use

- Offals

- Single Part MU Reduction to Increase Offal Usability

- Die-in-die Parts

- Offals as Blanks

- Laser/Patch Welded Blanks using Offals

- Offals as Reinforcements

Part Resourcing to Improve MU

- Part Gage/Grade Changes to Improve MU

Part Level Assembly

- Opportunities

• Accurate and up-to-date data including geometry
• Geometry processing & comparison
• Sophisticated business case what-if and trade-off analysis capability
• Changes be made early in design
• Process discipline and associated tools to carry decisions downstream

Material Utilization - Optimization Strategies
RApid Freeform Sheet Metal Forming (RAFFT): Technology Development and System Verification

Ford Motor Company, Dearborn, Michigan (Lead)
Northwestern University, Evanston, Illinois
The Boeing Company, Seattle, Washington
Massachusetts Institute of Technology, Cambridge, Massachusetts
Penn State Erie - The Behrend College, Erie, Pennsylvania

Total program value: $10.51M
Program duration: 36 months
Innovation/Key Attribute of Idea

RAFFT is a revolutionary technology for rapid sheet metal prototyping and low-volume production where:

- A sheet blank is clamped around its periphery and gradually deformed to a complex 3D freeform part by two strategically aligned stylus-type tools that follow pre-described toolpaths;
- Geometric-specific forming dies are completely eliminated, together with their associated high cost and long lead time for engineering, construction and machining.
- The gradual local deformation provides ultimate formability, process control and process flexibility compared to conventional forming processes.

Specific Outcome of THIS Project

- A prototype RAFFT system with unique machine architecture for rapid freeform sheet forming of the sheet size up to 1.5 m x 1.5 m.
- Toolpath algorithms and control software for achieving target cycle time (< 10 hours for industrial parts) and dimensional accuracy (bilateral profile tolerance < 1 mm).
- Microstructure and performance characterization of RAFFT-formed structures.

Impact if Successful

- Revolutionize the production of freeform sheet metal parts in diverse industries (e.g., aerospace, automotive, art) via distributed on-site and on-demand manufacturing
- Achieve annual energy saving of 15.2 TBTu and CO$_2$ reduction of 1 MTons.
- Achieve an annual cost saving of $2,360M.
- Reduce total cycle time for complex parts by 10x, from currently 8-12 weeks to 3-5 days
- Strengthen U.S. manufacturing base by eliminating the need for offshore fabrication of dies in low labor-cost nations
What we do today?
NG F3T Machine Concept Design

- Binder Track
- Sheet
- High Rigidity Binder support structure
Aluminum Vehicles
Aluminum F150 – Highest Volume Production Vehicle

Aluminum Sheet
(BIW, Closures, Bed)
(6111, 6022, 5754, 5182)

High Strength Steel
(Frame)
Aluminum Technology Leaders

Hydroformed Aluminum

Advanced Joining
(SPR’s & Flow Drill Screws)

Resistant Spot Welding

Higher Strength Aluminum

Advanced Pretreatments & Adhesives

RSW Cell at RIC
6xxx Al Alloy Processing - Post Form & Paint Oven Heat Treatment

Heat Treatment after stamping but prior to body construction results in significantly higher in service panel strength without introducing new and expensive alloys.

- Novel heat treatment process achieves >70 MPa increase without using new alloys.
- Higher Strength, Gauge Optimization & Materials Usage.
Aluminum Intensive Vehicles – Recycling Issues

- Energy to recycle aluminum is approximately 5% of the energy required to extract, process and fabricate new metal.

- In order to have “closed-loop recycling”, alloys must be segregated by composition.

- Dearborn Stamping has new technology that allows for 4-way segregation.
Aluminum Sheet Products

- F150 – 700K Trucks per year (52-55 JPH)
- 500M lbs Aluminum Sheet/Yr
  - 250K t/yr
  - 21K t/mo
  - 694 t/day
  - 43 t/hr ................(2) 8 hour shifts
  - 65% Utilization (35% closed loop recycled scrap)

500M lbs x 0.35 = 175M lbs in-plant recycled aluminum!

(A Very Valuable In-plant recycled commodity)
Mixed Material Vehicles
(Research & Development)
MMLV Vehicle Concept (23.3% mass reduction from 2013 Fusion)

**Interior**
- CF Seats
- CF IP Beam
- Foamed Plastics

**BIW**
- Vacuum Die Cast Al
- AHSS & Al Sheet

**Body Exterior**
- Al Sheet
- Closures
  - Al, Mg & PH Steel
- Bumpers
  - Al Roll Formed

**Tires**
- Narrow Tires
- CF & Al Wheels

**Glazing**
- PC & Toughened Glass

**Powertrain**
- Al & CGI block
- CF – FEAD and Oil Pan
- Mg – Valve Body

**Chassis**
- Al Subframes
  - Hollow Steel, FRC & Ti Springs
  - Al thermal-sprayed brake rotors
### MMLV – Body Structure ideas

<table>
<thead>
<tr>
<th>Vehicle Subsystem</th>
<th>Fusion (kg)</th>
<th>MMLV (kg)</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PMT 1 - Body Exterior and Closures</td>
<td>594</td>
<td>456</td>
<td>-138</td>
<td>-23%</td>
</tr>
<tr>
<td>Total PMT 2 - Body Interior and Climate Control</td>
<td>206</td>
<td>161</td>
<td>-45</td>
<td>-22%</td>
</tr>
<tr>
<td>Total PMT 3 - Chassis</td>
<td>350</td>
<td>252</td>
<td>-97</td>
<td>-28%</td>
</tr>
<tr>
<td>Total PMT 4 - Powertrain</td>
<td>340</td>
<td>267</td>
<td>-73</td>
<td>-21%</td>
</tr>
<tr>
<td>Total PMT 5 - Electrical</td>
<td>69</td>
<td>59</td>
<td>-10</td>
<td>-14%</td>
</tr>
<tr>
<td>Total Vehicle</td>
<td>1559</td>
<td>1195</td>
<td>-363</td>
<td>-23%</td>
</tr>
</tbody>
</table>

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ENGINE – Weight reduction of 20% to 48% on components

- Cast aluminum engine block for 1.0 liter I3 engine with Powder Metal forged billet crackable bulkhead inserts.
  - saves 48%, 11.8 kg
- Carbon fiber structural oil pan.
  - saves 30%, 1.2 kg
- Carbon fiber front cover with mount.
  - saves 30%, 1.0 kg
- Carbon Fiber + Aluminum cam carrier.
  - saves 20%, 1.3 kg
- Forged aluminum connecting rods.
  - saves 40%, 0.7 kg

MMLV (Powertrain)

TRANSMISSION – Weight reduction of 30% to 60% on components for reduced torque automatic

- Cast magnesium (AZ91D) case and bell housing
  - saves 30%, 5.0 kg
- Aluminum pump cover
  - saves 55%, 1.8 kg
- Cast magnesium valve body
  - saves 35%, 1.0 kg
- Steel + Aluminum clutch hub (friction spin weld)
  - saves 60%, 0.4 kg
MMLV (Chassis)

SUSPENSION COMPONENTS – Weight reduction of ~30% on these components

- Tall, Narrow Tires 30% save
  - 155/70R19 new materials and constructions
- Wheels 19 inch x 5 inch 30% save
  - cast aluminum or carbon fiber
- Delete Spare Tire/Wheel
- Aluminum Brake Rotors 35% save
  - Cast A356 Al, Thermal Spray Coated
- Coil Springs 35% ~ 55% save
  - hollow micro alloy steel with intensive shot peening, Glass Fiber composite
- Stabilizer Bars 35% ~ 55% save
  - high hardness steel, with internal and external shot peening

Carbon fiber wheels

Tall, Narrow Tires

Aluminum brake rotor with thermally sprayed wear resistant coating

Evaluate composite & hollow steel coil springs
Sustainable Materials Research

Bio-based Foams
- castor
- soy
- palm

Bio-based Resins
- wheat straw
- coconut
- cellulose

Natural Fiber Composites
- sugarcane
- corn
- dandelion

Recycled Materials
- jeans
- bottles
- money
Can we use oil from soybeans to make seats?

Technology Overview: Use of soy polyol in formulating flexible polyurethane foam for automotive applications.
Implementation of Wheat Straw on 2010 Ford Flex—with IAC

Wheat Straw / Polypropylene Composite

Reduces petroleum usage by some 20,000 pounds per year and reduces CO₂ emissions by 30,000 pounds per year
Implementation of Cellulose Fiber

December, 2013—with JCI

1 Origin
Cellulose is extracted from sustainably grown and harvested trees and related forestry byproducts, such as chips.

2 Structure
Cellulose fiber, found in plants and trees, is one of the most common organic compounds in the world. Its fiber provides excellent reinforcement for plastic composites.

3 Performance
Ford has validated cellulose reinforced plastics—supplied by forest products leader Weyerhaeuser—for performance, durability, and thermal resistance for interior components.

4 Implementation
The first use of cellulose fiber for a structural component to be announced soon.
Vision for Sustainable Rubber

1.) Domestic sources for elastomers
- Russian Dandelions
- Guayule Shrub*
- Bioisoprene (Biomass)

2.) Renewable fillers
- Corn Starch
- Recycled Tread
- Cellulose Ester

3.) Bio-based extender oils
- Orange Oil
- Tall Oil*
- Soy Oil*

*photos courtesy of USDA
Thank you for your attention!

Questions
Applications

Over 30 lbs of foam per vehicle

- Head Rest
- Instrument panel
- Arm Rest
- Seat Cushion
- Headliner
- Seat Back

Also rigid foam applications: package tray, energy absorption
CO₂ Emissions Reduction

Reduces by 25 million lbs annually
Implementation of Kenaf Fiber on 2013 Ford Escape—with IAC

Kenaf Plant = Edible + Ecological + Economical

Improves fuel economy

Reduces weight

Saves over 300,000 pounds of oil-based resin per year

door bolster

Ford Motor Company

Biomaterials Research Group
Elastomers are used in hundreds of parts in a typical vehicle including:

- Gaskets and seals
- Engine mounts
- Hoses and tubing
- Splash and underbody shields
- Suspension bushings
- Tires
- Door weather strips
- Glass run channels
- Floor coverings and mats
Do Sustainable Materials Sell Cars?

Not directly yet, but….

- brand image value
- protecting the business for future unknowns
- reduce environmental impact
- next generation of customers
The Power of Collaboration

- Farmers
- Universities
- Chemical Companies
- Tier 1
- NGOs
- Non-Competing Partners
- Resin Producer
- Research

Non-Competing Partners

Farmers

Universities

Chemical Companies

Tier 1

NGOs

Non-Competing Partners

Resin Producer

Research

The Power of Collaboration
Our Heritage

“I am looking for a lot of people who have an infinite capacity to not know what can’t be done”
Closing Thoughts

- Understand global needs and future trends.
- Automotive industry provides a wide array of opportunities in technical fields.
- Collaboration across discipline areas, with external companies and universities is key for success.
Production Examples

2012 Focus Body structure - 55% high-strength steel

2013 Fusion – UHSS & Reinforced thermoplastic bolster

Ford Mustang: Aluminum hood, Aluminum fenders & aluminum engine with composite coated Cylinder bores

F150 - Aluminum Body, Closures and Truck bed, UHSS Frame

2010 Lincoln MKT: Light-weight magnesium and aluminum lift gate.

Flex - Natural fiber filled interior plastics
Vehicle Weight: 10 Year Comparison

**2003 Ford Taurus**
- Total Vehicle Weight: 1523 Kg
- Engine: 3.0l V6
- Fuel Economy: 21 MPG (Metro-Hwy)

**2013 Ford Fusion**
- Total Vehicle Weight: 1560 Kg
- Engine: 1.6l I4
- Fuel Economy: 37 MPG (Metro-Hwy)

What adds weight?

Significant FE improvement
# Crash Safety Laws in NA & Europe

## Frontal Impact

- **FMVSS 203, 204, 205, 208, 209, 210, 212, 301**
- **EC - R 12, 14, 16, 33, 94**
- **EU NCAP, US NCAP**

## Side Impact

- **FMVSS 201, 205, 206, 214, 301**
- **EC - R 11, 95**
- **EG 74/297**
- **EU NCAP, US NCAP**

## Rear Impact

- **FMVSS 201, 207, 223, 224, 301, 581**
- **EC - R 17, 25, 32, 42**

## Roof Crush

- **FMVSS 216**

## Rollover

- **FMVSS 201, 208, 216, 216a, 301**
- **ECE - R 21, 44.04, US NCAP**

## Steering Wheel

- **FMVSS 203, 204**
- **EC - R 12**
- **EG 74/297**

## Bumper

- **FMVSS 581**
- **EC - R 42**

## Pedestrian Protection

- **2003/102/EG**
- **EU NCAP**

## Instrument Panel

- **FMVSS 201**
- **EC - R 21, 32, 33**
- **EG 74/60**

## Seats

- **FMVSS 201, 207**
- **EC - R 16, 17, 21, 44**
- **EG 74/60, 74/408**

## Seat Belts

- **FMVSS 208, 209, 210, 213**
- **EC - R 14, 16**
- **EG 76/115, 77/541, 96/79, 96/27**

## Head Rests

- **FMVSS 202**
- **EC - R 17, 25**
- **EG 78/932**
- **EU NCAP**

## Interior

- **FMVSS 201, 202, 203, 204, 205, 207, 213, 225**
- **EC - R 12, 16, 17, 21, 44**
- **EU NCAP**

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## NEW MILEAGE TARGETS FOR 2025

A look at the mileage targets and estimated window-sticker fuel-economy numbers for 2025 and how they compare with current models. The new targets will be reviewed again in 2017.

<table>
<thead>
<tr>
<th>Vehicle size (Example)</th>
<th>2012 EPA window sticker combined</th>
<th>Estimated 2025 window sticker combined*</th>
<th>2025 target combined CAFE rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact car (Honda Fit)</td>
<td>30 m.p.g.</td>
<td>45 to 48 m.p.g.</td>
<td>61.1 m.p.g.</td>
</tr>
<tr>
<td>Midsize car (Ford Fusion)</td>
<td>25 m.p.g.</td>
<td>41 to 43 m.p.g.</td>
<td>54.9 m.p.g.</td>
</tr>
<tr>
<td>Full-size car (Chrysler 300)</td>
<td>21 m.p.g.</td>
<td>35 to 36 m.p.g.</td>
<td>48 m.p.g.</td>
</tr>
<tr>
<td>Small SUV (Ford Escape 4wd)</td>
<td>23 m.p.g.</td>
<td>36 to 38 m.p.g.</td>
<td>47.5 m.p.g.</td>
</tr>
<tr>
<td>Midsize crossover (Nissan Murano)</td>
<td>20 m.p.g.</td>
<td>32 to 34 m.p.g.</td>
<td>43.4 m.p.g.</td>
</tr>
<tr>
<td>Minivan (Toyota Sienna)</td>
<td>21 m.p.g.</td>
<td>29 to 31 m.p.g.</td>
<td>39.2 m.p.g.</td>
</tr>
<tr>
<td>Large pickup (Chevrolet Silverado)</td>
<td>17 m.p.g.</td>
<td>25 to 26 m.p.g.</td>
<td>33 m.p.g.</td>
</tr>
</tbody>
</table>
Steel Grades

(THE STEEL INDUSTRY CONTINUES TO DELIVER WEIGHT SAVING MATERIALS)


3rd Gen UHSS