ATG Silverado Body Lightweighting Study
Final Report January 13th, 2017

Harry Singh – Director Lightweighting, Vikrant Mogal – CAE Engineer, Pranesh Jayakumar – CAE Engineer
Impact of Aluminum Property Advancements (Since 2012)

Strength:
- 5XXX, 6XXX + 10-20%
- 7XXX + 50%

Understand impact of Gauge and Stiffness limitations on Mass Reduction

New developments: high-strength aluminum sheet for body structures

Slide Courtesy: Constellium - Alex Graph
Objectives:
Maximum Feasible Mass Reduction
Total Vehicle
Maintain Safety, Functionality
Cost increase < 10 %

Results:
Total Vehicle    - 406 Kg   (- 17 %)
Body                - 198 Kg   (- 39 %)
Aluminum - sheet/extrusions
AHSS - reinforcements, door inner
Magnesium/Aluminum - Rad. Supp.

Ford F-150 (2015)
Baseline Body
2014 Silverado 1500 (Body-on-Frame)
cab, front end sheet metal, hood, doors, box, tailgate
Material: HSS, AHSS, Aluminum (Hood)

NHTSA LWT Body
Mass Optimization (2025)
Multi Material Vehicle (MMV)
Aluminum sheet, extrusions
2011 grades, gauges
AHSS reinforcements, door inner
Magnesium/Aluminum radiator support

36% Body Mass reduction

ATG LWT Body (Up-date)
Multi Material Vehicle (MMV)
Aluminum sheet, extrusions
2017-20 production grades, gauges
Aluminum Door Inner
AHSS reinforcements
Magnesium radiator support
Project Outline

1. Design Review – Identify potential alloy upgrade components
   NHTSA EDAG MY2025 lightweight design (EDAG - LWT)

2. Revise CAE Models
   Aluminum gauge reductions – sheet, extrusions
   Grades and gauges (typ. 2017 production) - ATG recommended

3. CAE Crash Analysis - LSDYNA
   NCAP frontal impact
   NCAP side impact
   NCAP side pole impact
   FMVSS No. 216 Roof Crush
   FMVSS No. 301 Rear Impact
   IIHS side impact
   IIHS moderate overlap
   IIHS small overlap

4. CAE Analysis - NASTRAN
   Torsional Stiffness (CAB)
   Bending Stiffness (CAB)
   Strength and Durability loads (Pickup Box)
### Torsion and Bending Stiffness Comparison

<table>
<thead>
<tr>
<th></th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Sill Loading (N/mm)</td>
<td>3034</td>
<td>2990</td>
<td>-1.4%</td>
</tr>
<tr>
<td>Bending Frame Loading (N/mm)</td>
<td>3577</td>
<td>3578</td>
<td>0 %</td>
</tr>
<tr>
<td>Torsion (KN-m/DEG)</td>
<td>6.97</td>
<td>6.92</td>
<td>-0.7%</td>
</tr>
</tbody>
</table>
Total Body Mass Savings - Findings

LWT Results:

- **EDAG NHTSA (MMV) LWT design (MY2025)**
  39% Body Mass Reduction (198 Kg)
  - Aluminum - sheet and extrusions
  - 2012 Grades, Gauges
  - AHSS - door inner, reinforcements
  - Magnesium/Aluminum - radiator support

- **EDAG ATG (MMV) LWT designed (MY2025)**
  46% body mass reduction (231 Kg)
  - Aluminum sheet and extrusions
  - 2017 Aluminum Grades, Gauges (ATG)
  - AHSS - reinforcements
  - Magnesium/Aluminum - radiator support

### Components Revised in ATG Study

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Baseline 2014 Silverado 1500 Mass (Kg)</th>
<th>NHTSA EDAG LWT Mass (Kg)</th>
<th>EDAG ATG LWT Mass (Kg)</th>
<th>Mass Saving Compared with NHTSA LWT (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAB</td>
<td>240.10</td>
<td>140.94</td>
<td>130.97</td>
<td>-9.97</td>
</tr>
<tr>
<td>CARGOBOX</td>
<td>108.95</td>
<td>65.03</td>
<td>60.10</td>
<td>-4.93</td>
</tr>
<tr>
<td>FRT_DOORS</td>
<td>47.00</td>
<td>32.64</td>
<td>24.8</td>
<td>-7.84</td>
</tr>
<tr>
<td>RR_DOORS</td>
<td>43.48</td>
<td>28.96</td>
<td>20.46</td>
<td>-8.50</td>
</tr>
<tr>
<td>FENDERS</td>
<td>32.47</td>
<td>16.20</td>
<td>14.96</td>
<td>-1.24</td>
</tr>
<tr>
<td>TAILGATE</td>
<td>21.30</td>
<td>11.01</td>
<td>11.01</td>
<td>0.00</td>
</tr>
<tr>
<td>HOOD</td>
<td>11.16</td>
<td>11.21</td>
<td>11.21</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>504.46</strong></td>
<td><strong>306.14</strong></td>
<td><strong>273.66</strong></td>
<td><strong>-32.29</strong></td>
</tr>
</tbody>
</table>

- Mass Saving Compared with Baseline: **-39.3 %**
- Mass Saving Compared with NHTSA EDAG LWT: **-10.6 %**

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Mass Analysis Sub Systems:

<table>
<thead>
<tr>
<th>Large Panels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass reduction Parts</td>
</tr>
<tr>
<td>Mass increase Parts</td>
</tr>
<tr>
<td>Doors</td>
</tr>
</tbody>
</table>

Mass Reduction (NHTSA LWT: ATG LWT) - 32.3 Kg (10.6% of NHTSA LWT Body)
5.5 Mass Reduction: “Top 25” Large Panels

<table>
<thead>
<tr>
<th>Panel Type</th>
<th>Baseline</th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab Back Panel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(kg)</td>
<td>102.8</td>
<td>99.1</td>
<td>-3.75</td>
</tr>
<tr>
<td></td>
<td>% B Mass</td>
<td>31%</td>
<td></td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Observations - “Large Panels”:
- Majority of Body Mass
- Minimal strength dependency
- Gauge limitations – manufacturing (mill, fabrication), stiffness
- 20% strength: 1.2% mass reduction
Mass Reduction / Increase Parts

Mass Reductions:
- Grade, Gauge

Mass Increases:
- Restore Stiffness
- Efficient stiffness components

Mass Reduction Parts

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.2</td>
<td>54.4</td>
<td>- 15.8</td>
<td></td>
</tr>
<tr>
<td>21 %</td>
<td></td>
<td>- 5.2 %</td>
<td></td>
</tr>
</tbody>
</table>

Mass Increase Parts

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3</td>
<td>10.6</td>
<td>+ 3.6</td>
<td></td>
</tr>
<tr>
<td>2 %</td>
<td></td>
<td>+ 1.2 %</td>
<td></td>
</tr>
</tbody>
</table>

Net Mass Reduction

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.9</td>
<td>43.5</td>
<td>- 12.2</td>
<td></td>
</tr>
<tr>
<td>19 %</td>
<td></td>
<td>- 4.0 %</td>
<td></td>
</tr>
</tbody>
</table>

Observations - Strength Dependent components:
- Gauge limitations – Component stiffness constraints
- Global Stiffness constraints
- 20% Strength increase: net 4.0% mass reduction
### Observations:
Door Inner (4) - Steel to Aluminum
Mass reduction 5.3% of NHTSA LWT Body

<table>
<thead>
<tr>
<th></th>
<th>EDAG NHTSA</th>
<th>EDAG ATG</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>62</td>
<td>45.2</td>
<td>16.3</td>
</tr>
<tr>
<td>% NHTSA Mass</td>
<td>19%</td>
<td></td>
<td><strong>5.3%</strong></td>
</tr>
</tbody>
</table>
Mass Reduction (Kg) (ATG LWT: NHTSA LWT)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Panels</td>
<td>3.75</td>
</tr>
<tr>
<td>Mass reduction Parts</td>
<td>15.76</td>
</tr>
<tr>
<td>Mass increase Parts</td>
<td>-3.56</td>
</tr>
<tr>
<td>Doors: Steel to Alum Inner Structures</td>
<td>16.34</td>
</tr>
<tr>
<td><strong>Total Mass Savings</strong></td>
<td><strong>32.29</strong></td>
</tr>
</tbody>
</table>
(10.6)%

Conclusions:
- Strength driven Mass reduction limited by stiffness - Local and Global
- gauge limitations: Manufacturing (Mill, Fabrication)
- Aluminum strength increases 2011-16 ~ 15 % - 20 %
- Body Mass reduction increase ~5% over NHTSA LWT
- Largest mass reduction (50% of total)
  conversion of steel door inner to aluminum
- 7XXX (50% higher strength) limited stiffness, gauge limitations
Automotive Aluminum Recycling Rate Study
Sean Kelly
Diran Apelian
Project Goal

- Overall recycling rate of automotive aluminum
  - ELV to Ingot
- Value Stream
  1. Dismantlers
  2. Downstream separation systems
  3. Secondary recyclers (i.e. secondary smelters/re-melters)
Methodology: Data Collection

Processor Surveys
- Dismantlers
  - In-person surveys
- “Auto” Shreaders
  - Questioner
    regional Recycling Organization Directors across US
- Secondary aluminum “smelters”
  - phone interviews
    heavy and light gauge scrap recovery process efficiencies
Material collection: Dismantling

End of Life (ELV) Vehicle → Dismantling Operation → Shredding Operation → Reuse/Refurbish/Separate Recycling Stream/Re-melt → Heavy gauge scrap melting
Recycling rate of material in product (RR%) 

\[ RR\% = ([MC] \times R_L) \times \text{Light recovery material flow} + (MC \times R_H) \times \text{Heavy recovery material flow} \]

\[ RR\% = \left[ ([D \times S] \times R_L) \times l \right] + \left[ (D \times R_H) \times h \right] \]

Assumptions:

1) Aluminum recycled to useable processing form: ingot, billet, slab
2) Product collection rate - out of scope of process material flow analysis
3) All ELVs enter a dismantling operation
4) 0% loss at shredding operations
5) Aluminum sorted into other commodity streams is not lost aluminum
6) Deduction in material collection efficiency and process (i.e. re-melt) efficiency results from aluminum metal units that flow to landfill
Final Results:
Aluminum Recycling – Recovery Processes

**Heavy Gauge (i.e. Al alloy wheels/bumpers)**
- Weighted average process efficiency: 95%
- Process efficiency range: 91% to 98%

**Light Gauge (auto-shred scrap)**
- Weighted average process efficiency: 91% *
- Process efficiency range: 81% to 98% *

* Note: recoveries quoted are from “DIRTY” scrap attached paints, oils, foreign material, … recoveries after dross reprocessing
Proportioned Automotive Aluminum Recycling

**Heavy Recovery Process**
Avg. Al loss: 5 wt. %
Range: 2 – 9 wt. %

Removed parts that will be re-melted
10 – 18%

Recycled Al product from heavy gauge scrap

Re-melt
10 – 18%

Al loss to landfill
2 – 20 wt. %

Recycling Rate (range)
80 – 98%

**Dismantling Process**
Avg. Al loss: 0.1 wt. %
Range: 0.01 – 0.25 wt. %

Removed parts that will be shredded
24 – 32%

Hulk crushing
58%

**Shredding Process**
Avg. Al loss: 0 wt. %
Range: 0.03 – 0.25 wt. %

**Sorting**
82 – 90%

**DSS Process**
Avg. Al loss: 0.2 wt. %
Range: 2 – 19 wt. %

**Light Recovery Process**
Avg. Al loss: 9 wt. %
Range: 0.03 – 0.25 wt. %

- Major source of metal loss – Oxidation at re-melt
  Dross: Al2O3

Weighted Average Auto-Al Recycling Rate (RR %): 91%
Conclusions: Auto Aluminum Recycling

• Recycling Industry - Highly Effective in Metals Recovery
• Overall Aluminum Recycling Rate 91.4 % (Apparent)
  ELV to Secondary Ingot
• Metal unit loss to Landfill (Fluff) <0.2 %
• Metal Unit loss at Re-melt ~9% (Al2O3)*
  * Apparent – may include loss of non-metallic content

• Additional Studies
  – Non-aluminum content in re-melt material - Project in process
Scrap Characterization to Optimize the Recycling Process

Project Status Review Document
Scrap Recovery Process Map

Consumer Durables (Home appliances)

ELVs
End of life vehicles
Cars/light trucks

Recipe: 2 grapples of light iron pile to 1 ELV

Shredding

Magnetic Separation

Ferrous scrap

Non-ferrous scrap (Zorba)
Background: Scrap Recovery Process

- Non-ferrous scrap (Zorba)
  - Aluminum
  - Copper
  - Brass
  - Zinc etc.
  - Stainless
  - Other

- Sink-float density separation

- Floating Fraction: TWITCH
  - Aluminum
    - 95-98wt% Al alloys

- Sinking Fraction: Zebra
  - Copper
  - Brass
  - Zinc etc.
## Alloy Distribution – Zorba, Twitch

<table>
<thead>
<tr>
<th>Category</th>
<th>Zorba Samples</th>
<th>Twitch Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supplier 1</td>
<td>Supplier 2</td>
</tr>
<tr>
<td>Wrought (wt. %)</td>
<td>35%</td>
<td>42%</td>
</tr>
<tr>
<td>Cast (wt. %)</td>
<td>9%</td>
<td>42%</td>
</tr>
<tr>
<td>Total Al Alloy Content</td>
<td>44%</td>
<td>84%</td>
</tr>
</tbody>
</table>

 Typically → ~65% Al alloy

 ~94-98% Al alloy
## Major category distribution (wt. %)

<table>
<thead>
<tr>
<th>Category</th>
<th>Zorba Samples</th>
<th>Twitch Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supplier 1</td>
<td>Supplier 2</td>
</tr>
<tr>
<td>Other Metals</td>
<td>12%</td>
<td>10%</td>
</tr>
<tr>
<td>Mixed Metals</td>
<td>17%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Mixed Materials</td>
<td>24%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Free Polymer</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Total Non-Al Content</td>
<td>56%</td>
<td>16%</td>
</tr>
</tbody>
</table>
**Phase 3: Scrap Characterization**

Polymer characterization – Polymeric/organic burn-off

### Procedure for cleaning (paints/coatings/oils/lubricants):

1. Burn off in furnace for 60 min at 380°C (onset of vaporization)/425°C
2. Ultrasonically clean for 60 min
3. Heat in furnace to dry at 380°C/425°C for 10 min
   *thermal oxidation of aluminum does not occur until ~450°C [1]*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Free polymer wt. %</th>
<th>Average mass loss % after burn</th>
<th>Average mass loss % after clean</th>
<th>Average total mass loss %</th>
<th>Total mass loss % (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1 (380 °C)</td>
<td>0.80%</td>
<td>0.40%</td>
<td>0.13%</td>
<td>0.53%</td>
<td>0.33 – 0.75%</td>
</tr>
<tr>
<td>Supplier 2 (380 °C)</td>
<td>1.80%</td>
<td>0.47%</td>
<td>0.29%</td>
<td>0.75%</td>
<td>0.46 – 1.21%</td>
</tr>
<tr>
<td>Supplier 3 (425 °C)</td>
<td>0.80%</td>
<td>0.40%</td>
<td>0.23%</td>
<td>0.63%</td>
<td>0.20 – 1.17%</td>
</tr>
<tr>
<td>Supplier 4 (425 °C)</td>
<td>1.80%</td>
<td>0.58%</td>
<td>0.19%</td>
<td>0.76%</td>
<td>0.41 – 1.09%</td>
</tr>
</tbody>
</table>