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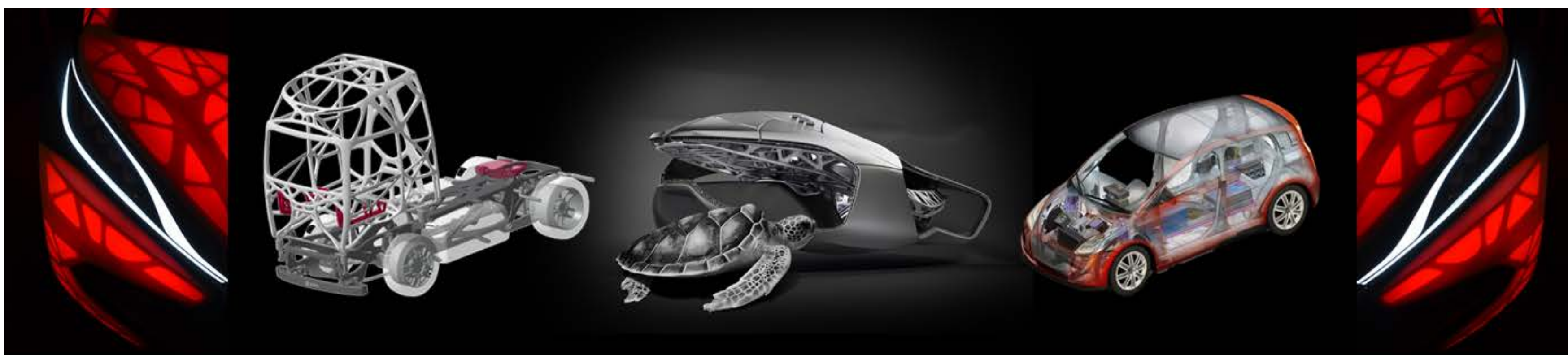
ATG Silverado Body Lightweighting Study

Final Report January 13th, 2017



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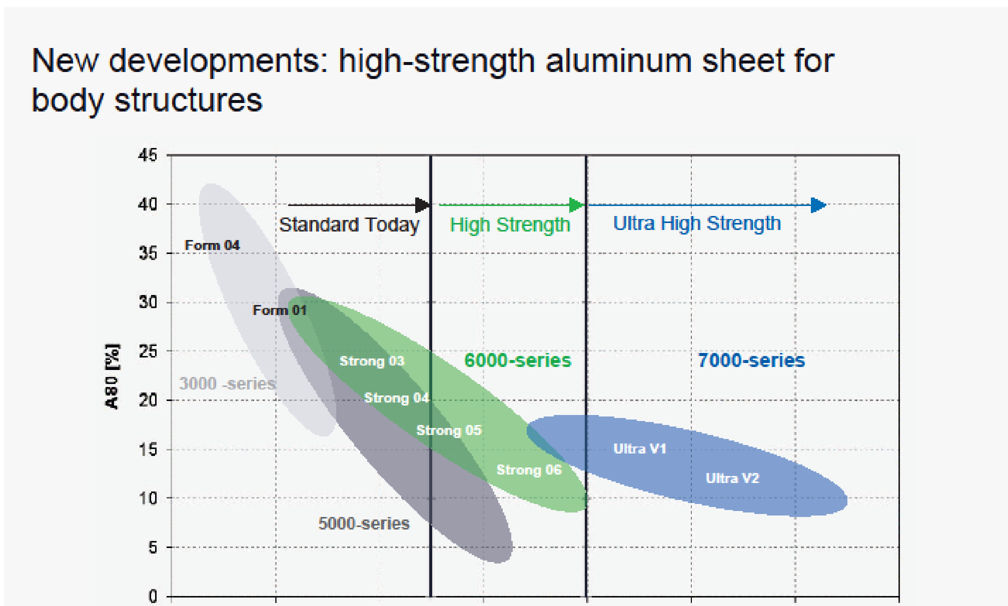
ATG Project Objectives

Impact of Aluminum Property Advancements (Since 2012)

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

Understand impact of Gauge and Stiffness limitations on Mass Reduction



Slide Courtesy: Constellium - Alex Graph

BASELINE: NHTSA / EDAG Light Weight Truck (LWT) Study

Draft Final Report

Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025

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Report - April 22, 2016 Rev1 (Prior to Peer review)

Objectives:
- Maximum Feasible Mass Reduction
  - <u>Total Vehicle</u>
- 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)

EDAG / ATG 2025 Light Weight Truck (LWT) Body Study

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)

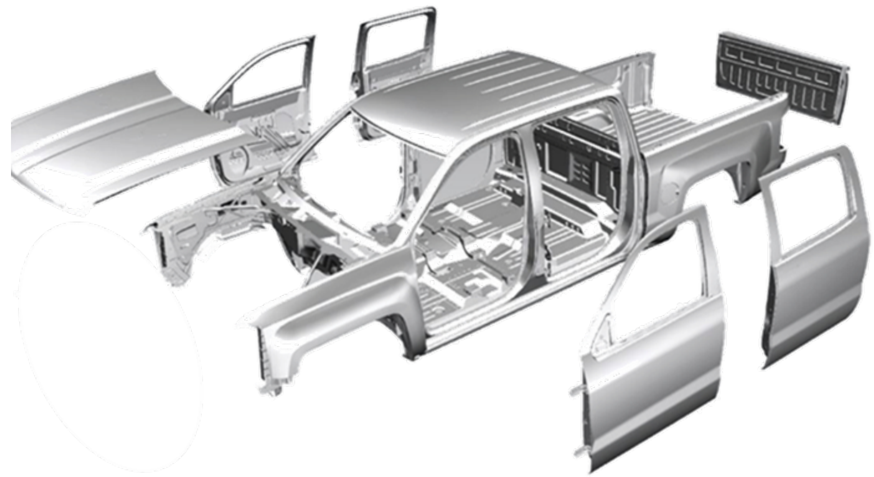
Aluminum sheet, extrusions

2017-20 production grades, gauges

Aluminum Door Inner

AHSS reinforcements

Magnesium radiator support



2.0 Program Steps

Project Outline

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

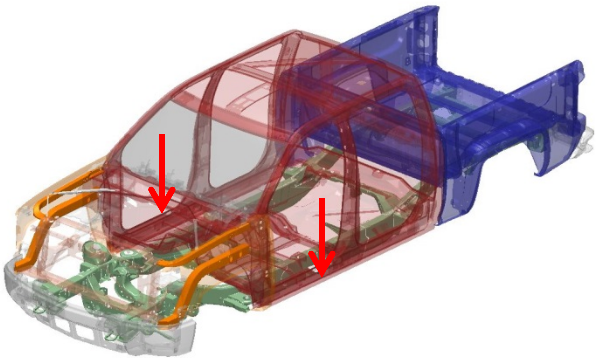
2. Revise CAE Models
   - Aluminum gauge reductions – sheet, extrusions
     - Grades and gauges (typ. 2017 production) - ATG recommended

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

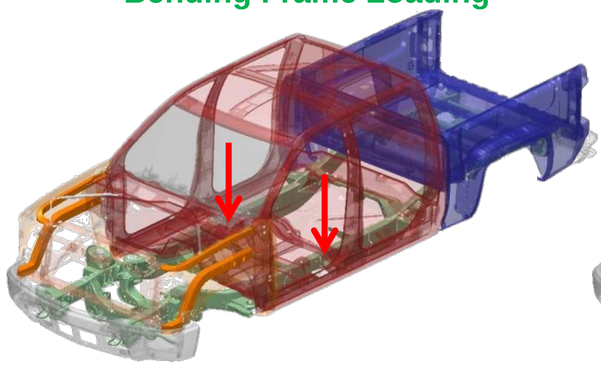
3. CAE Crash Analysis - LSDYNA
   - NCAP frontal impact
   - NCAP side impact
   - NCAP side pole impact
   - FMVSS No. 216 Roof Crush
   - FMVSS No. 301 Rear Impact
   - IIHS side impact
   - IIHS moderate overlap
   - IIHS small overlap

Torsion and Bending Stiffness Comparison

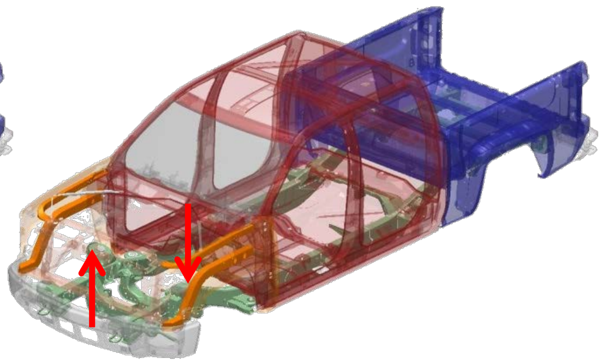
Bending Sill Loading



Bending Frame Loading

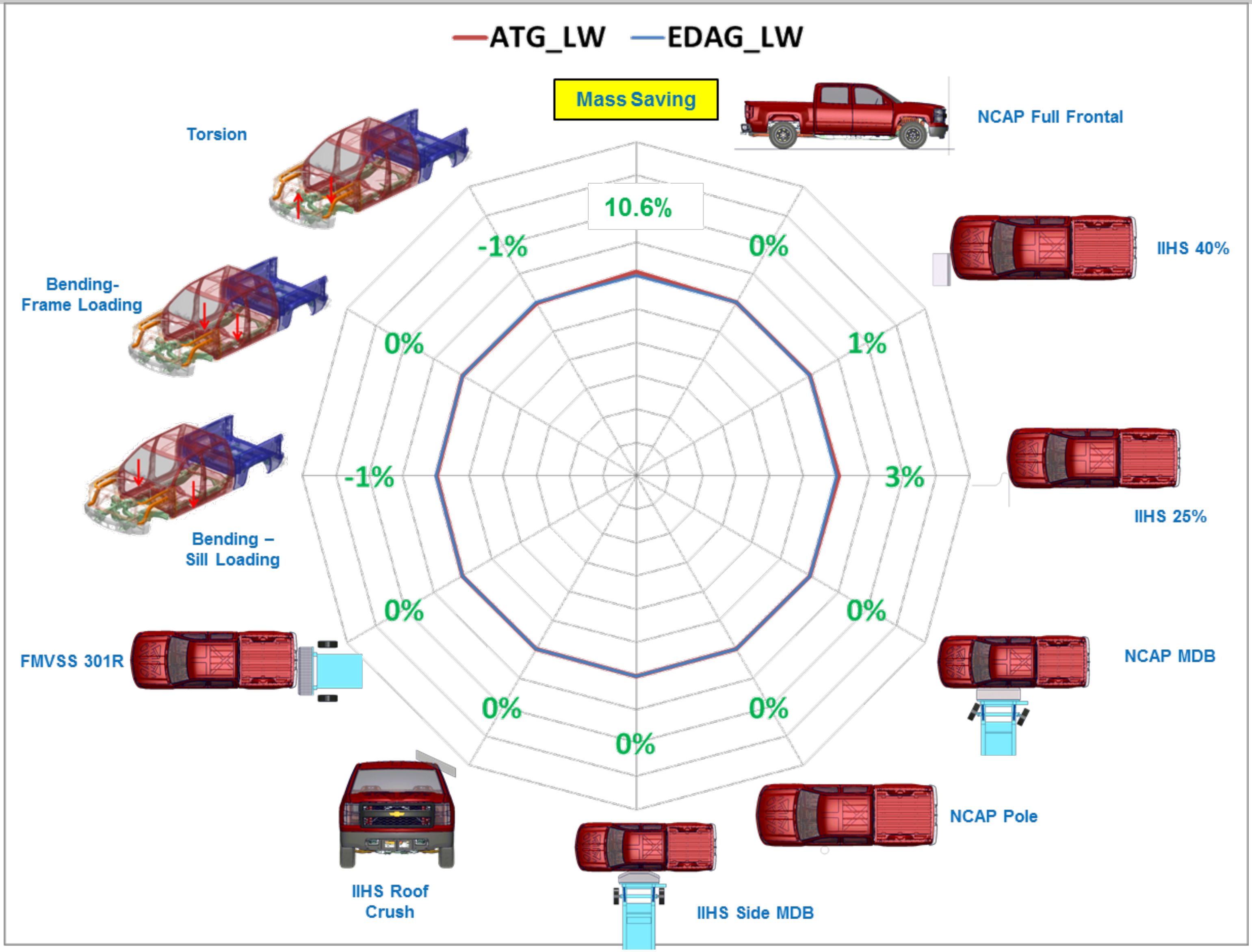


Torsion

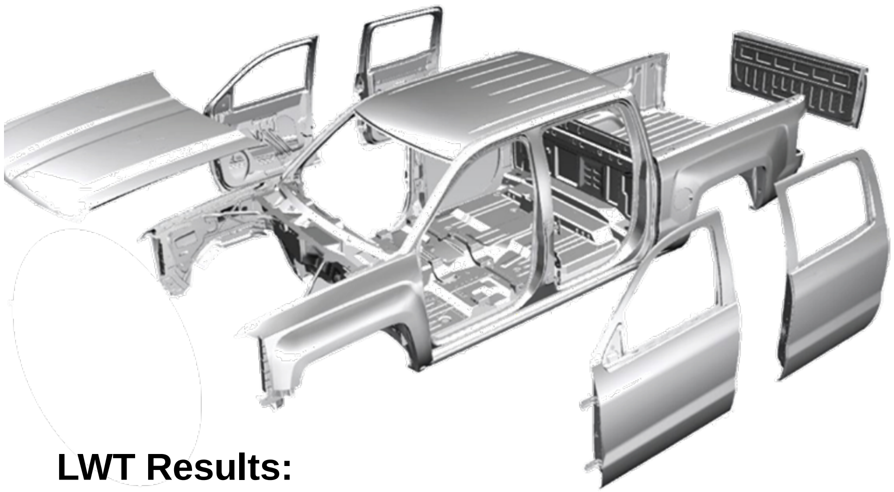


	EDAG NHTSA	EDAG ATG	Difference
Bending Sill Loading (N/mm)	3034	2990	-1.4%
Bending Frame Loading (N/mm)	3577	3578	0 %
Torsion (KN-m/DEG)	6.97	6.92	-0.7%

CAE - Crashworthiness Performance
Results Summary



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

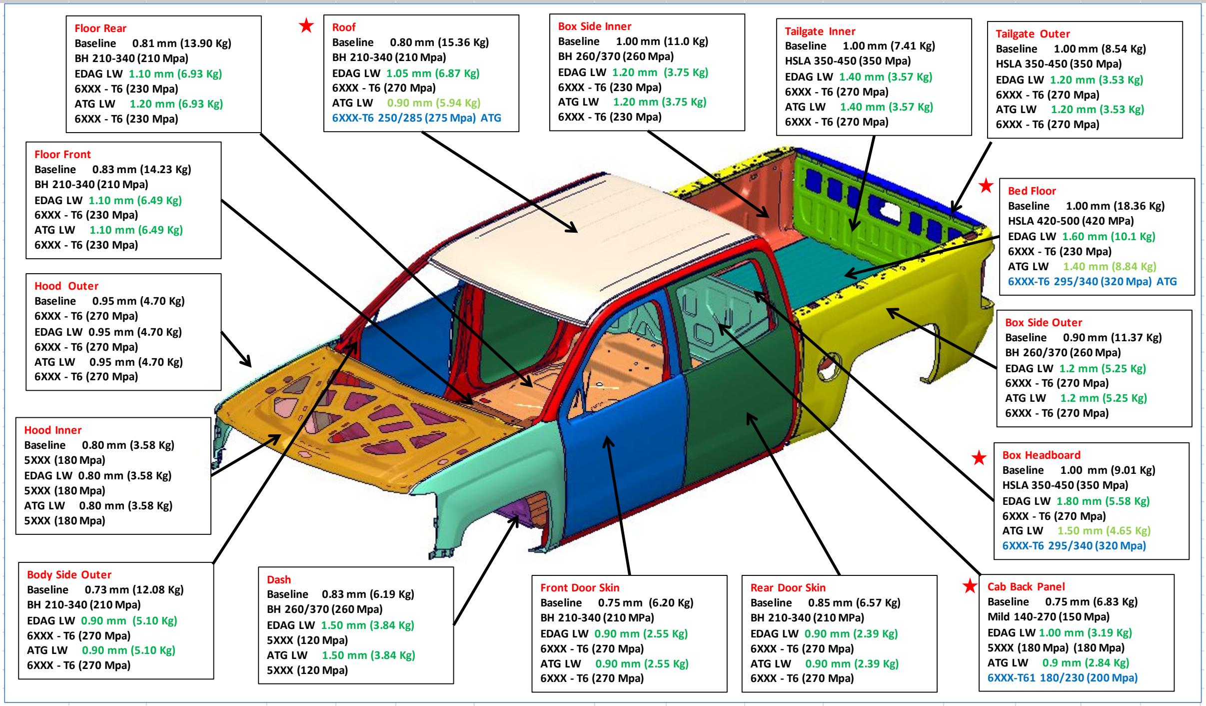
Subsystem	Baseline 2014 Silverado 1500 Mass (Kg)	NHTSA EDAG LWT Mass (Kg)	EDAG ATG LWT	
			Mass (Kg)	Mass Saving Compared with NHTSA LWT (Kg)
CAB	**240.10**	140.94	130.97	-9.97
CARGOBOX	**108.95**	65.03	60.10	-4.93
FRT_DOORS	**47.00**	32.64	24.8	-7.84
RR_DOORS	**43.48**	28.96	20.46	-8.50
FENDERS	**32.47**	16.20	14.96	-1.24
TAILGATE	**21.30**	11.01	11.01	0.00
HOOD	**11.16**	11.21	11.21	0.00
TOTAL	**504.46**	**306.14**	**273.66**	**-32.29**
	Saving Compared with Baseline	**-39.3 %**	**- 45.8 %**	
	Mass Saving Compared with NHTSA EDAG LWT		- 10.6 %	

ATG LWT Summary – Compared to NHTSA LWT

Mass Analysis Sub Systems:
Large Panels
Mass reduction Parts
Mass increase Parts
Doors

Mass Reduction (NHTSA LWT: ATG LWT) - 32.3 Kg (10.6% of NHTSA LWT Body)

5.5 Mass Reduction: “Top 25” Large Panels

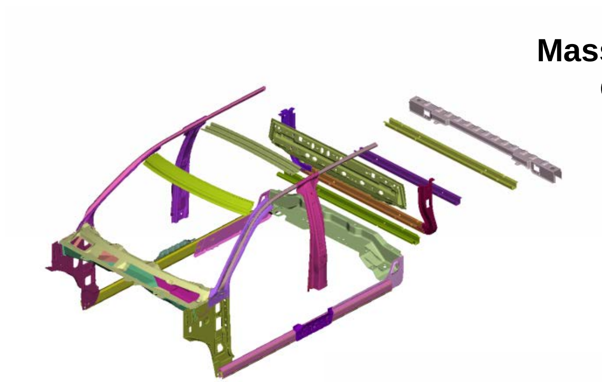


	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	102.8	99.1	- 3.75
% NHTSA B Mass	31 %		- 1.2 %

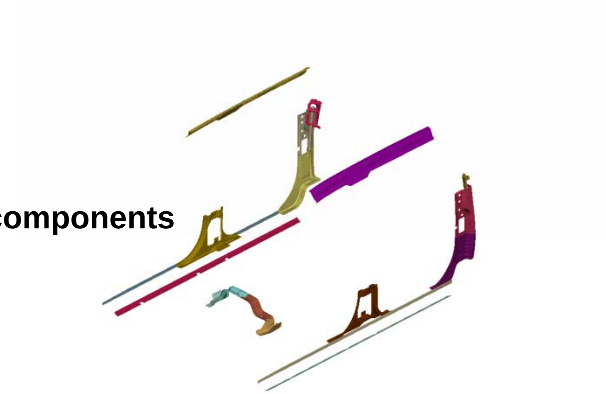
Observations - “Large Panels”:

- 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

Observations - Strength Dependent components:
Gauge limitations – Component stiffness constraints
Global Stiffness constraints
20% Strength increase: net 4.0% mass reduction

Mass Reduction Parts

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	70.2	54.4	- 15.8
% NHTSA B Mass	21 %		- 5.2 %

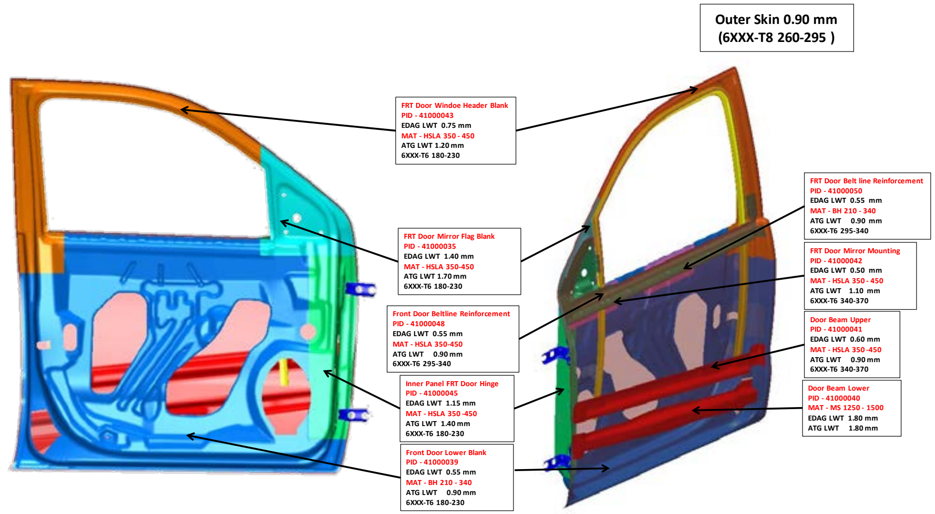
Mass Increase Parts

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	7.3	10.6	+ 3.6
% NHTSA B Mass	2 %		+ 1.2 %

Net Mass Reduction

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	62.9	43.5	- 12.2
% NHTSA B Mass	19 %		- 4.0 %

Mass Reduction - Doors



	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	62	45.2	16.3
% NHTSA Mass	19 %		5.3 %

Observations:

Door Inner (4) - Steel to Aluminum

Mass reduction 5.3 % of NHTSA LWT Body

Conclusions – ATG LWT Study

Mass Reduction (Kg) (ATG LWT: NHTSA LWT)		
Large Panels	3.75	
Mass reduction Parts	15.76	
Mass increase Parts	-3.56	
Doors: Steel to Alum Inner Structures	16.34	
Total Mass Savings	32.29	(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

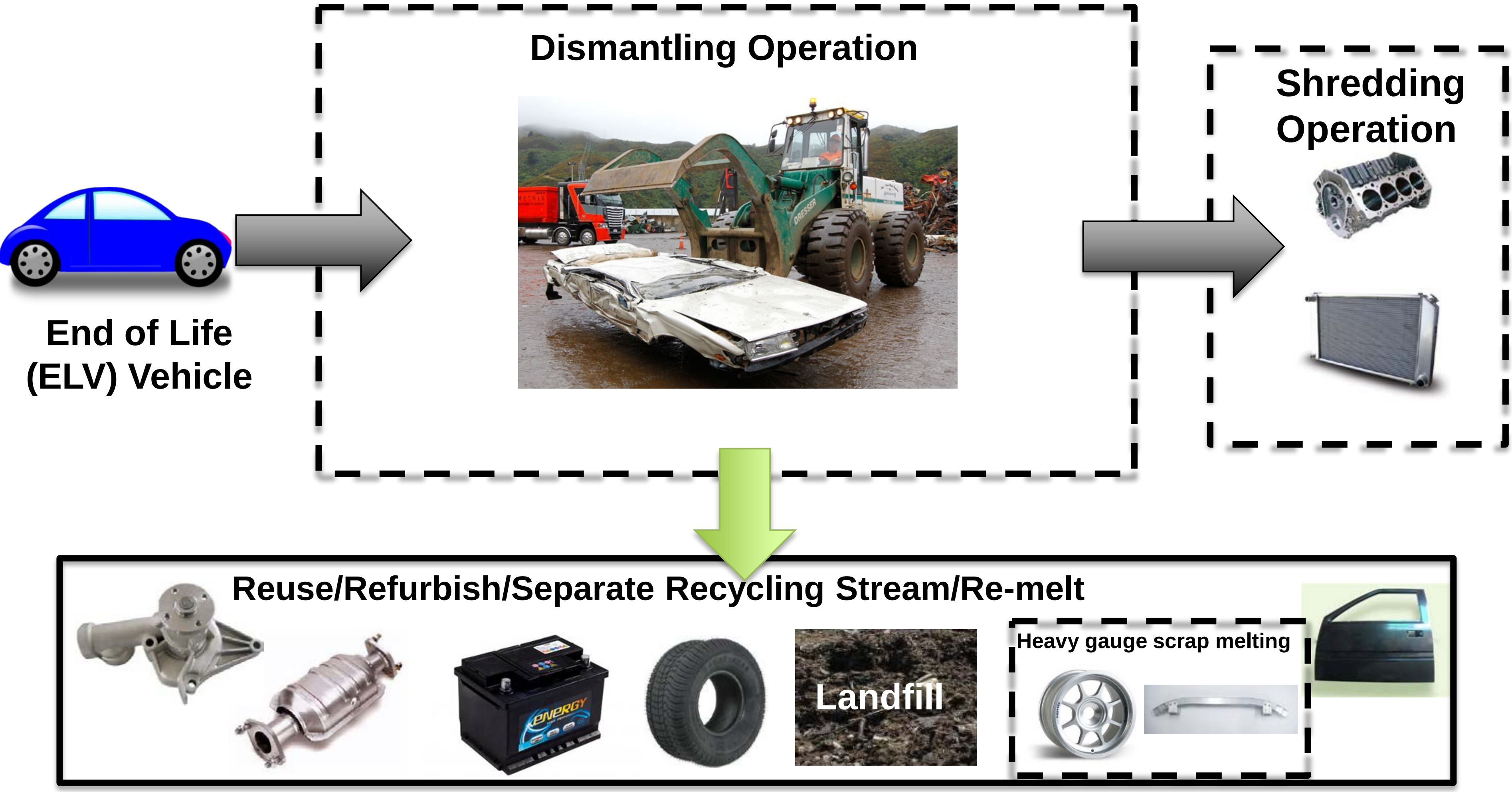
Processor Surveys

- Dismantlers
  - In-person surveys
- “Auto” Shreaders
  - Questioner

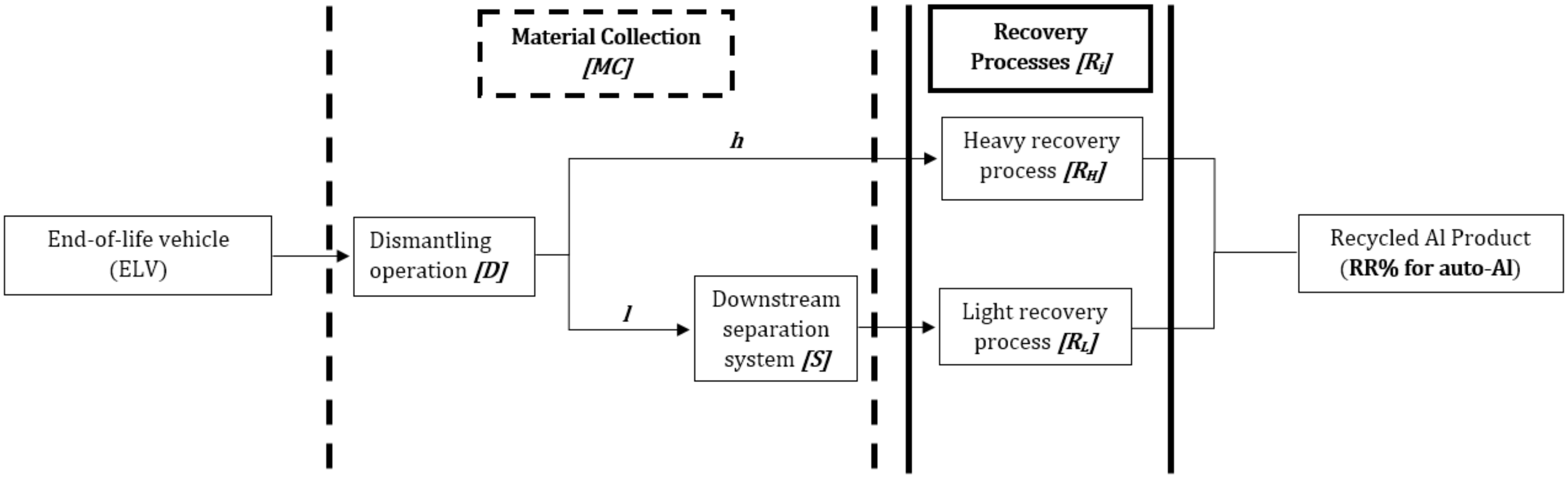
    regional Recycling Organization Directors across US
- Secondary aluminum “smelters”
  - phone interviews

    heavy and light gauge scrap recovery process efficiencies

Material collection: Dismantling



Recycling Process Material Flow Model



$$\textbf{Recycling rate of material in product } (RR\%) = \textbf{Product collection rate} \times \textbf{material collection rate} \times \textbf{recovery process efficiency}$$

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

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

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*)

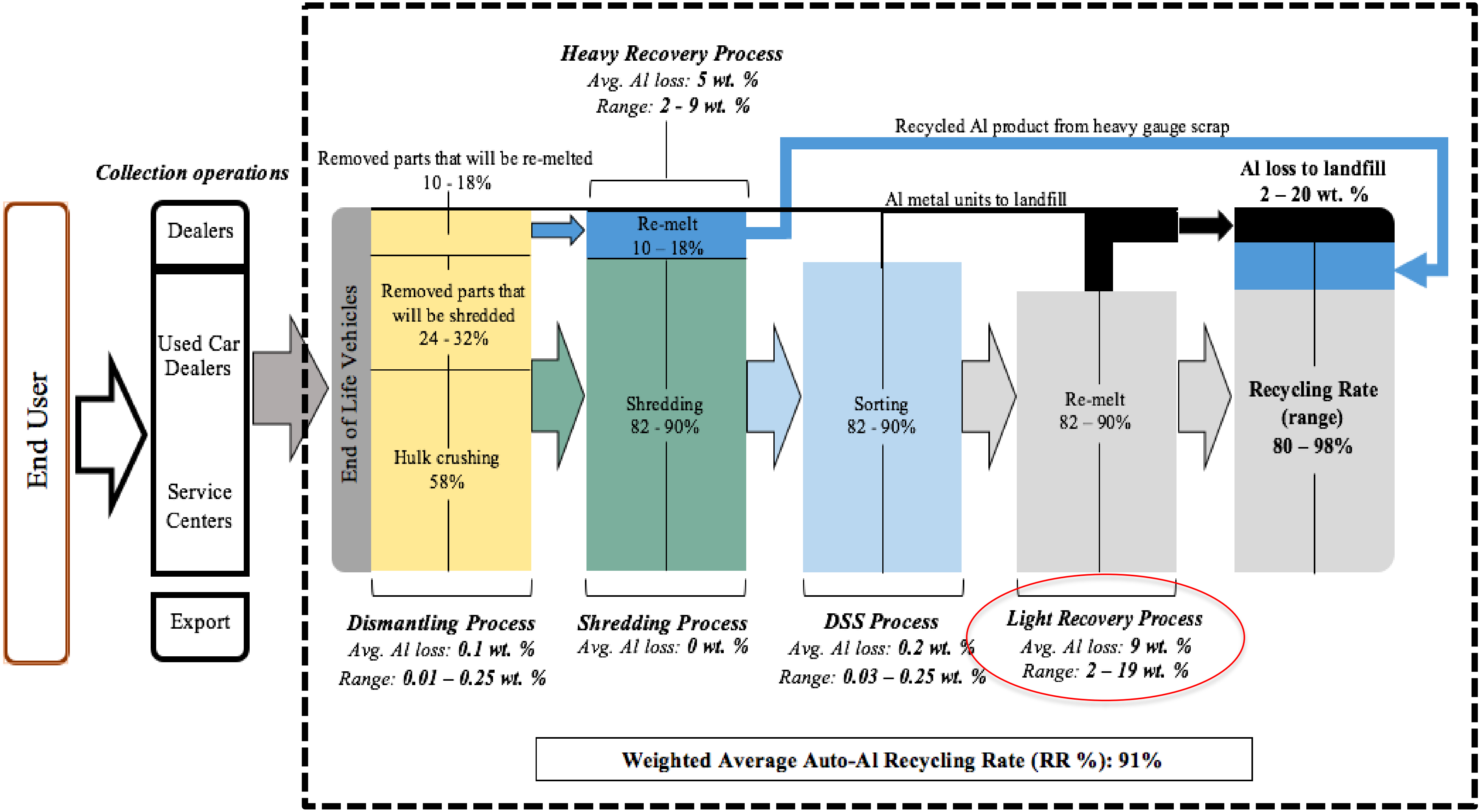
Weighted average process efficiency: 95%
Process efficiency range: 91% to 98%

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



- *Major source of metal loss – Oxidation at re-melt*

  Dross: Al_2O_3

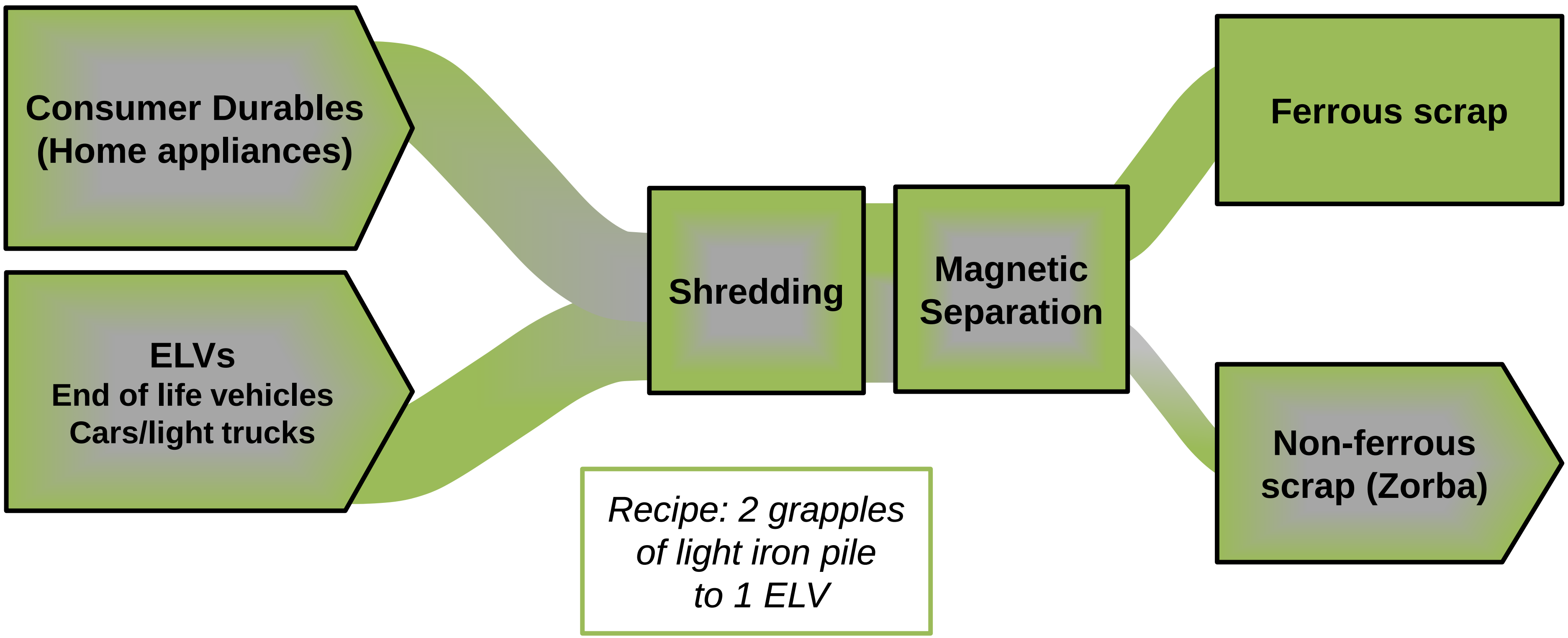
Conclusions: Auto Aluminum Recycling

- 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% (Al_2O_3)*
  * Apparent – may include loss of non- metallic content
- <u>Additional Studies</u>
  – 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



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

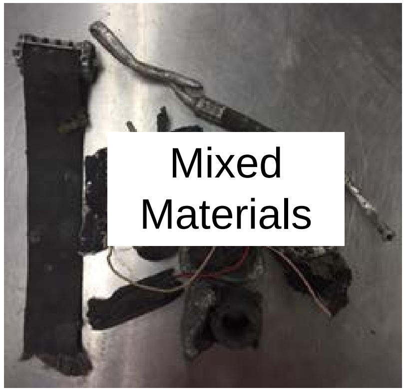
- Copper
- Brass
- Zinc etc.

Alloy Distribution – Zorba, Twitch

Category	Zorba Samples			Twitch Samples	
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Wrought (wt. %)	35%	42%	36%	32%	48%
Cast (wt. %)	9%	42%	21%	62%	48%
Total Al Alloy Content	44%	84%	57%	94%	96%

Typically → ~65% Al alloy ~94-98% Al alloy

Major category distribution (wt. %)



Category	Zorba Samples			Twitch Samples	
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Other Metals	12%	10%	28%	1%	1%
Mixed Metals	17%	0.5%	11%	2%	1%
Mixed Materials	24%	3.5%	0%	1%	1%
Free Polymer	3%	2%	4%	2%	1%
Total Non- Al Content	56%	16%	43%	6%	4%

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^{o}C (onset of vaporization)/425^{o}C
2. Ultrasonically clean for 60 min
3. Heat in furnace to dry at 380^{o}C/425^{o}C for 10 min

   *thermal oxidation of aluminum does not occur until ~450^{o}C [1]

Sample	Free polymer wt. %	Average mass loss % after burn	Average mass loss % after clean	Average total mass loss %	Total mass loss % (range)
Supplier 1 (380 ^{o}C)	0.80%	0.40%	0.13%	0.53%	0.33 – 0.75%
Supplier 2 (380 ^{o}C)	1.80%	0.47%	0.29%	0.75%	0.46 – 1.21%
Supplier 3 (425 ^{o}C)	0.80%	0.40%	0.23%	0.63%	0.20 – 1.17%
Supplier 4 (425 ^{o}C)	1.80%	0.58%	0.19%	0.76%	0.41 – 1.09%