AGENCY SPONSORED MASS REDUCTION STUDIES FOR THE MIDTERM EVALUATION

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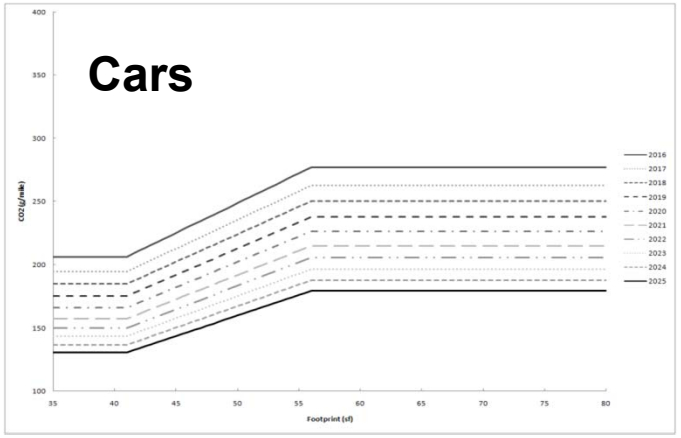
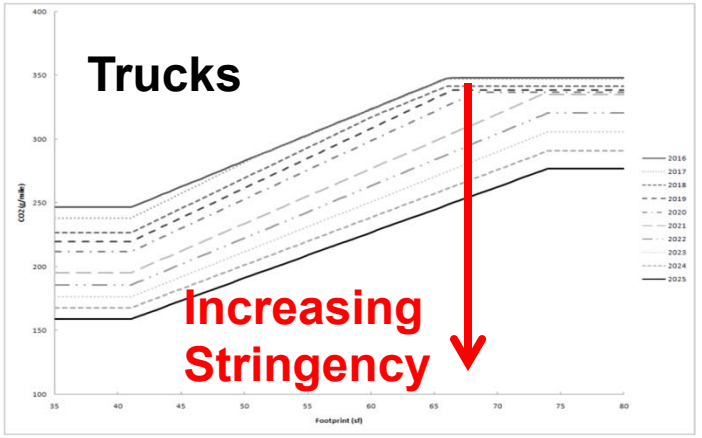
SAE INTERNATIONAL

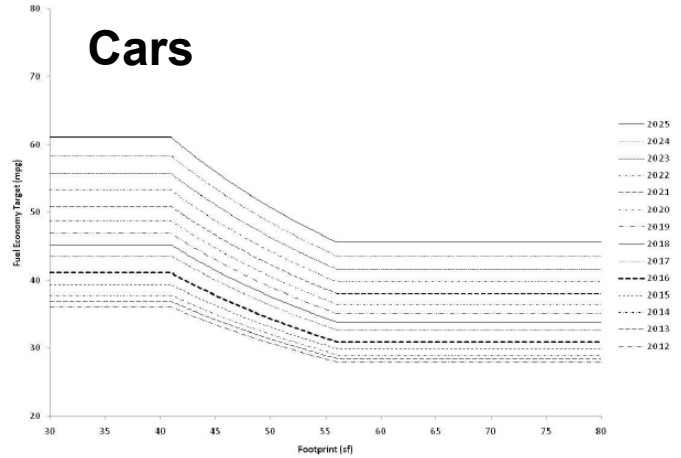
LD GHG MYs 2017+ CO_2 and Fuel Economy Targets (Based on Footprint)

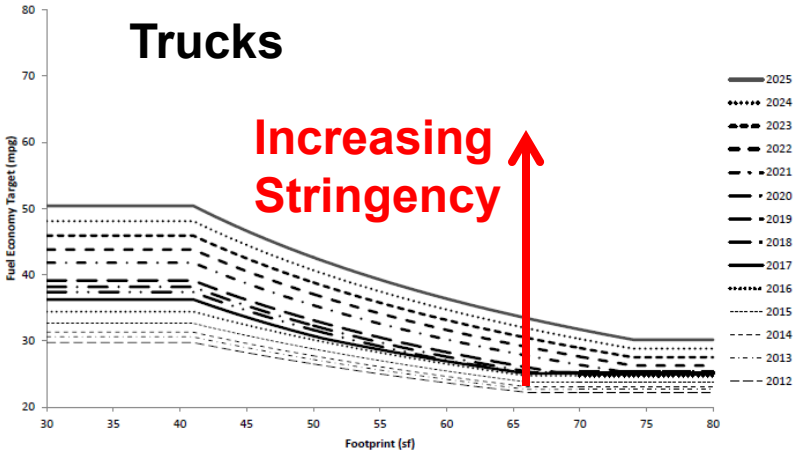
EPA (2017-2025): CO_2 (g/mile)





NHTSA (2017-2021): Fuel Economy (mpg)





Timing for Mid Term Evaluation (MTE)

Schedule	Milestone in the Midterm Evaluation Process
June 2016	EPA, NHTSA and CARB jointly issue a **Draft Technical Assessment Report (TAR)** for public comment
Between the Draft TAR and Final Determination	EPA issues for public comment a Proposed Determination on the appropriateness of the MYs 2022-2025 standards NHTSA (potentially jointly with EPA) issues a Notice of Proposed Rulemaking
No later than April 2018	EPA issues a **Final Determination** on the appropriateness of the 2022-2025 standards

The Draft Technical Assessment Report (TAR) is the first step in the process, to seek public comment that will inform decisions regarding standards for MYs 2022-2025 – it is a technical report, not a decision document.

What factors will we consider for the Midterm Evaluation?

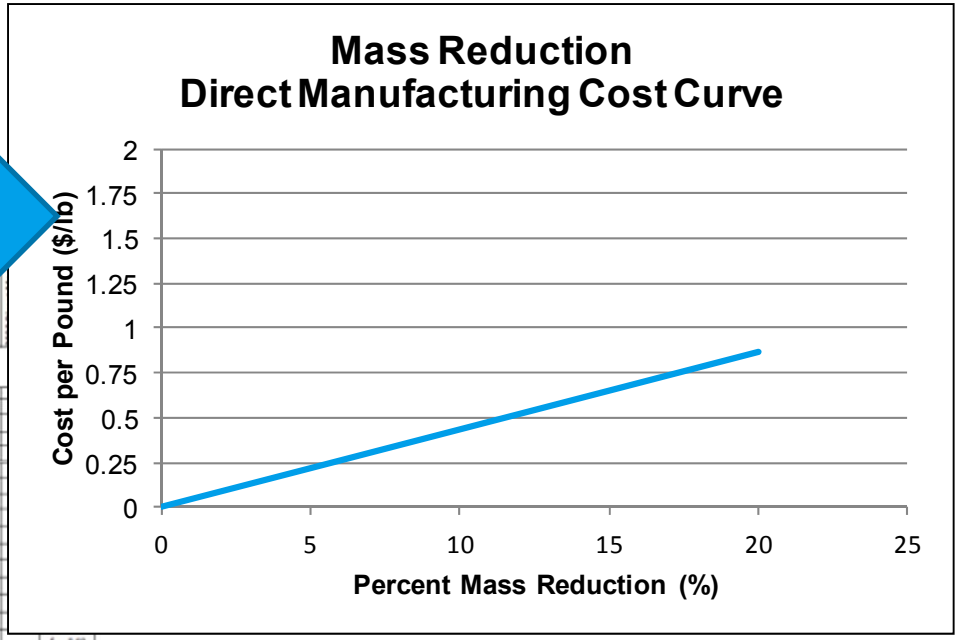
- ✓ Powertrain improvements
- ✓ Light-weighting and impacts on vehicle safety
- ✓ Market penetration of fuel efficient technologies
- ✓ Consumer acceptance
- ✓ Payback periods for consumers
- ✓ Fuel prices
- ✓ Fleet mix
- ✓ Infrastructure
- ✓ Employment impacts
- ✓ Any others …

Mass Reduction for MYs 2017+ CAFE and GHG Final Rule
(2008/2010 Baseline)

- **Cost and feasibility estimates were not based on any single study**
- **Wide range of sources considered, and aggregated into a cost curve**

Table 3-128 Mass Reduction Studies Considered for Estimating Mass Reduction Cost for this FRM studies

	Cost Year	Cost Information from Studies									
		Mass Reduction [lb]	Compounding Factor	Mass Reduction with Compounding [lb]	Baseline Vehicle Weight [lb]	Mass Reduction w/Compounding [%]	Cost [$]	RPE	Dollar Multiplier to 2009	2009 Direct Manufacturing Cost [$]	Unit Cost of Mass Reduction [$/lb]
Individual Cost Data Points											
AISI, 1998 (ULSAB)	1998	105	1	105	2977	3.5%	-$32	1.0	1.28	-$41	-$0.40
AISI, 2000 (ULSAC)	2000	6	1	6	2977	0.2%	$15	1.0	1.24	$18	$2.99
Austin et al, 2008 (Sierra Research) - ULS Unibody	2008	320	1	320	3200	10.0%	$209	1.61	1.01	$131	$0.41
Austin et al, 2008 (Sierra Research) - AL Unibody	2008	573	1	573	3200	17.9%	$1,805	1.61	1.01	$1,134	$1.98
Austin et al, 2008 (Sierra Research) - ULS BoF	2008	176	1	176	4500	3.9%	$171	1.61	1.01	$107	$0.61
Austin et al, 2008 (Sierra Research) - AL BoF	2008	298	1	298	4500	6.6%	$1,411	1.61	1.01		
Bull et al, 2008 (Alum Assoc.) - AL BIW	2008	279	1	279	3378	8.3%	$455	1.0	1.01		
Bull et al, 2008 (Alum Assoc.) - AL Closure	2008	70	1	70	3378	2.1%	$151	1.0	1.01		
Bull et al, 2008 (Alum Assoc.) - Whole Vehicle	2008	573	1	573	3378	17.0%	$122	1.0	1.03		
Cheah et al, 2007 (MIT) - 20%	2007	712	1	712	3560	20.0%	$646	1.0	1.03		
Das, 2008 (ORNL) - AL Body & Panel	2008	637	1	637	3363	19.0%	$180	1.5	1.01	$121	$0.19
Das, 2008 (ORNL) – FRPMC	2008	536	1.0	536	3363	15.9%	-$280	1.5	1.01	-$189	-$0.35
Das, 2009 (ORNL) - CF Body & Panel, AL Chassis	2009	933	1	933	3363	27.7%	$1,490	1.5	1.00	$993	$1.06
Das, 2010 (ORNL) - CF Body & Panel, Mg Chassis	2010	1173	1	1173	3363	34.9%	$373	1.5	1.00	$248	$0.21
EEA, 2007 - Midsize Car - Adv Steel	2007	236	1	236	3350	7.0%	$179	1.0	1.03	$185	$0.78
EEA, 2007 - Midsize Car - Plast/Comp	2007	254	1	254	3350	7.6%	$239	1.0	1.03	$247	$0.97
EEA, 2007 - Midsize Car – Al	2007	586	1.35	791	3350	23.6%	$1,388	1.0	1.03	$1,434	$1.81
EEA, 2007 - Midsize Car – Mg	2007	712	1.35	961	3350	28.7%	$1,508	1.0	1.03	$1,558	$1.62
EEA, 2007 - Light Truck - Adv Steel	2007	422	1	422	4750	8.9%	$291	1.0	1.03	$301	$0.71
EEA, 2007 - Light Truck - Plast/Comp	2007	456	1	456	4750	9.6%	$398	1.0	1.03	$411	$0.90
EEA, 2007 - Light Truck - Al	2007	873	1.35	1179	4750	24.8%	$1,830	1.0	1.03	$1,891	$1.60
EEA, 2007 - Light Truck - Mg	2007	1026	1.35	1385	4750	29.2%	$1,976	1.0	1.03	$2,042	$1.47
Geck et al, 2008 (Ford)	2008	1310	1	1310	5250	25.0%	$500	1.0	1.01	$506	$0.39
Lotus, 2010 – LD	2010	660	1	660	3740	17.6%	-$121	1.0	1.00	-$120	-$0.18
Lotus, 2010 – HD	2010	1217	1	1217	3740	32.5%	$362	1.0	1.00	$360	$0.30
Mantaibo et al, 2008 (GM/MIT) - Closure - HSS	2008	25	1	25	4000	0.6%	$10	1.0	1.01	$10	$0.41
Mantaibo et al, 2008 (GM/MIT) - Closure - AL	2008	120	1	120	4000	3.0%	$110	1.0	1.01	$111	$0.92
Mantaibo et al, 2008 (GM/MIT) - Closure - Mg/AL	2008	139	1	139	4000	3.5%	$110	1.0	1.01	$111	$0.80
Plotkin et al, 2009 (Argonne)	2009	683	1	683	3250	21.0%	$1,300	1.0	1.00	$1,300	$1.90



Agency Sponsored Holistic Vehicle Mass Reduction Studies

Since then, the agencies have sponsored several mass reduction projects for unibody designed passenger cars and CUVs and body-on-frame designed pickup trucks.

(EPA) Midsize CUV
(2012):
Baseline: MY2010 Venza
Unibody
Towing 1000-3500 lbs
2G Optimization; Secondary Mass
HSS body structure with limited use of Al closure

(ARB) Midsize CUV
(2012):
Baseline: MY2010 Venza
Unibody
Towing 1000-3500 lbs

Al intensive design

(EPA) Light Duty Pickup Truck
(2015):
Baseline: MY2011 Silverado
Body on Frame
Towing up to 12,000 lbs
2G Optimization; Secondary Mass
Al intensive and HSS frame

(NHTSA) Midsize Passenger Car
(2012):
Baseline: MY2011 Honda Accord
Unibody
Towing 1000 lbs
3G Optimization
AHSS body structure with Al Closure

(NHTSA) Light Duty Pickup Truck
(2016):
Baseline: MY2014 Silverado
Body on Frame
Towing up to 12,000 lbs
3G Optimization
AHSS frame with Al/AHSS cab structure and closure

EPA Sponsored Light Duty Pickup Truck Lightweighting Study - Overview

Scope of Study:

Base Truck: 2011 Silverado 1500, Crew Cab, 4x4

Methodology: Similar to EPA's Midsize CUV 2012

- Contractor: FEV w/Subcontractors EDAG, Munro, etc.

Addition of Dynamic and Durability Analyses

- Dynamic: instrument vehicle and run on test track
- Bed and frame durability (CAE) under loaded conditions

Boundary Conditions

Maintain function and performance (including payload and towing capacities) (2011)

No degradation in safety from the baseline vehicle (2011)

Capable of being mass produced in the 2020-2025 timeframe (450,000/yr)

10% maximum increase in direct manufacturing costs

Report Status: Post Peer Review - Online April '15 – EPA Website

EPA Sponsored Light Duty Pickup Truck Lightweighting Study - CAE LOADCASES

CAE was used for a variety of analyses, including:

- -NVH (frame, box, cabin, body on frame)
- -Crash and Safety (FMVSS, IIHS)
- -Durability and Full Vehicle Dynamics

NEW

NEW

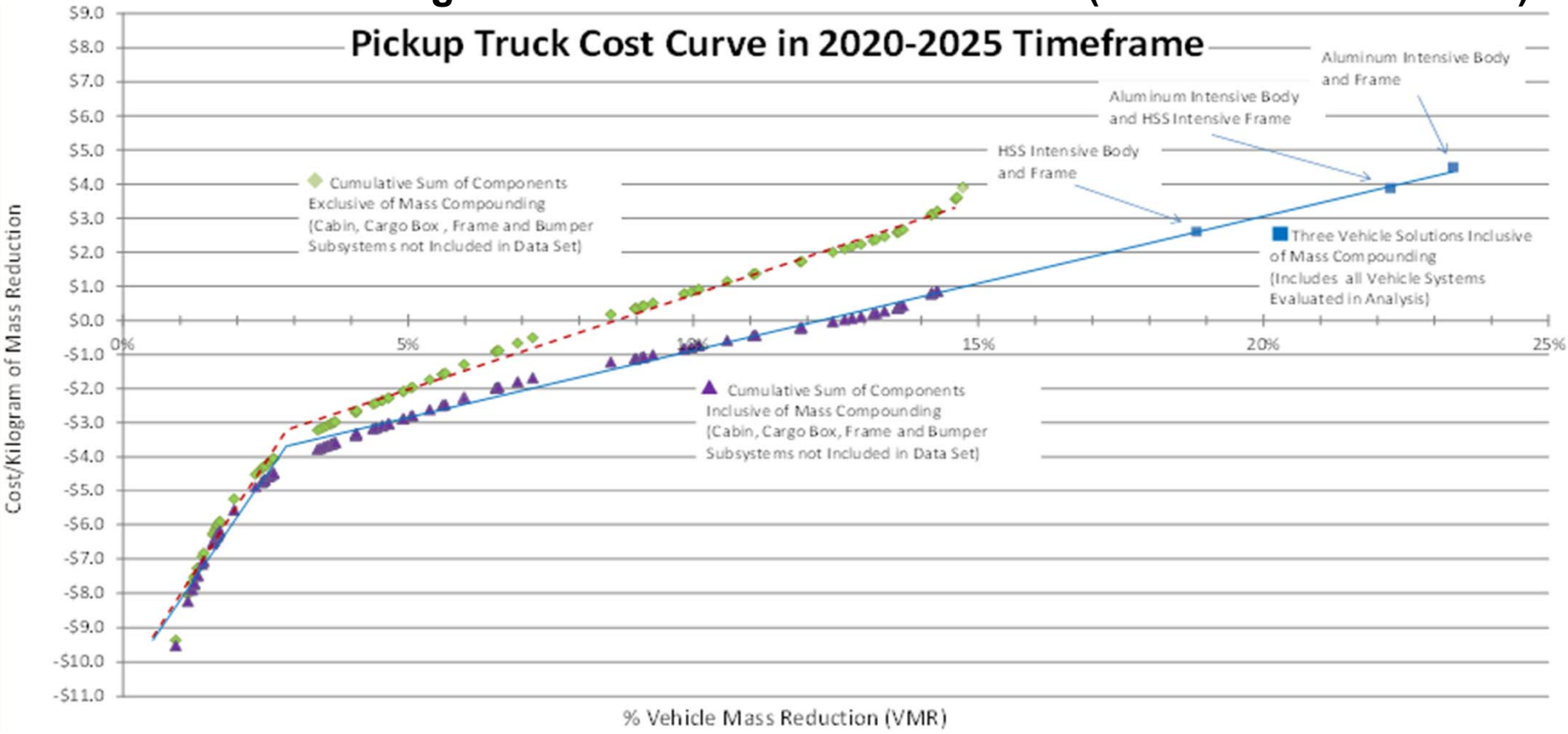
Discipline	System	Loadcase	Measures
Durability	Frame	Fatigue	Components Life cycle
	Doors	Frame rigidity	Stiffness
		Beltline compression	Stiffness
		Beltline expansion	Stiffness
		Torsion	Twist stiffness
		Sag	Vertical deformation
		Oil canning	Outer Panel deformation
	Hood	Bending	Stiffness
		Torsion	Twist stiffness
		Oil canning	Outer Panel deformation
	Tail gate	Torsion	Twist stiffness
		Oil canning	Outer Panel deformation
Vehicle Dynamics	Full Vehicle	Constant Radius	Understeer Gradient
			Cornering Compliance
			Roll Gradient
		J-Turn	Tire Load
		Frequency Response	Steering Response Gain
			Steering Response Phase lag
		Static Stability Factor (SSF)	Track width/(2 x CG height)

Discipline	System	Loadcase	Measures
NVH	Frame	Static Bending	Global bending stiffness
		Static Torsion	Global torsion stiffness
	Cabin	Static Bending	Global bending stiffness
		Static Torsion	Global torsion stiffness
	Cargo Box	Static Bending	Global bending stiffness
		Static Torsion	Global torsion stiffness
	Body On Frame	Static Bending	Global bending stiffness
		Static Torsion	Global torsion stiffness
Crash / Safety	Full Vehicle	FMVSS 208—35 mph flat frontal crash (US NCAP)	Pulse
			Crush
			Time-to-zero velocity
			Dash intrusions
		IIHS—35 mph ODB frontal crash	Pulse
			Crush
			Time-to-zero velocity
			Dash intrusions
		FMVSS 214—38.5 mph MDB side impact (US SINCAP)	B-Pillar velocity
			Side structure intrusions
		IIHS—31.0 mph MDB side impact	B-Pillar velocity
			B-Pillar intrusions
			Survival space
			Exterior crush
		FMVSS 214—20 mph 5th %ile pole side impact	B-Pillar velocity
			B-Pillar intrusions
			Structure intrusions
		FMVSS 301—50 mph MDB rear impact	Under structural zone deformation
			Door operability
			Fuel tank damage
		FMVSS 261a—Roof crush	Roof strength to weight ratio
		FMVSS 581—Bumper impact	Front end deformation

EPA Sponsored Light Duty Pickup Truck Lightweighting Study - Preliminary Cost Curve

Preliminary results (peer review revisions pending)

- **Results are a range of possible mass reduction – not a single point**
- **Multiple body and frame solutions included**
- **Some cost savings at low levels of mass reduction (from this base vehicle)**



EPA Sponsored Light Duty Pickup Truck Lightweighting Study - Non body and frame mass reduction examples with cost savings

Material and Design Optimization

C-70 vs. PM Connecting Rods

Material and Design Substitution

DuPont™ Vespel® SP-21 Thrust Washer vs. roller bearings

Material Processing

PolyOne & Mucell Applications

Material Substitution

Thermoplastic Vulcanizates (TPV) vs. EPDM, Static and Dynamic Weather Seals (Jyco)

Material and Part Consolidation

Passenger Side Airbag Housings (DSM)

Design and Processing

½ Shafts - Vari-lite® tube process (U.S. Manufacturing Corporation)

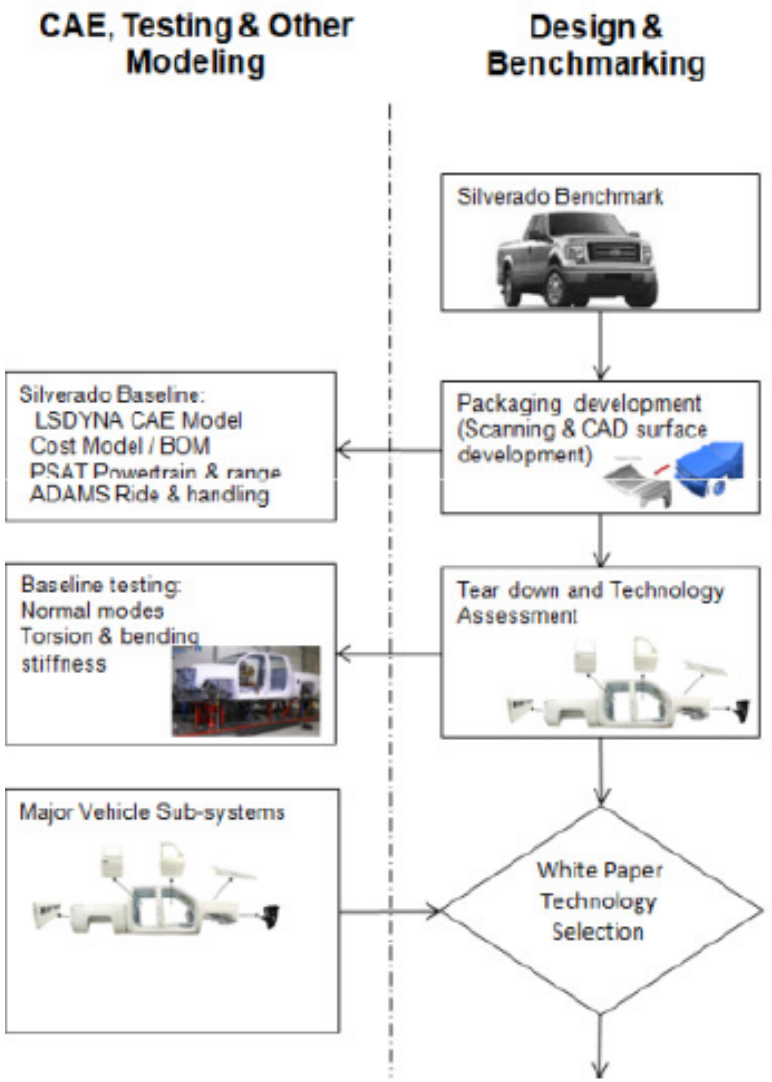
NHTSA Sponsored Light Duty Pickup Truck Lightweighting Study - Purpose

- **Purpose:** Design a light-weighted light-duty pickup truck that can
  - At minimum, meet the following performance functions of original baseline vehicle:
    - Safety
    - NVH
    - Fuel Economy, Utility/Performance (towing, acceleration)
    - Manufacturability
    - Durability
    - Serviceability, etc.
  - Control both direct and in-direct cost to maintain affordability
    - Maintain retail price parity of +/- 10% of baseline vehicle
  - Use advanced design, material and manufacturing process for MYs 2020-2030
  - Recommendation for cost curve for both passenger car and light truck: Single curve? Multiple curves? How to generalize the mass reduction amount and cost to the overall fleet?
  - Mass reduction for other light-duty vehicles

NHTSA Sponsored Light Duty Pickup Truck Lightweighting Study - Project Phases

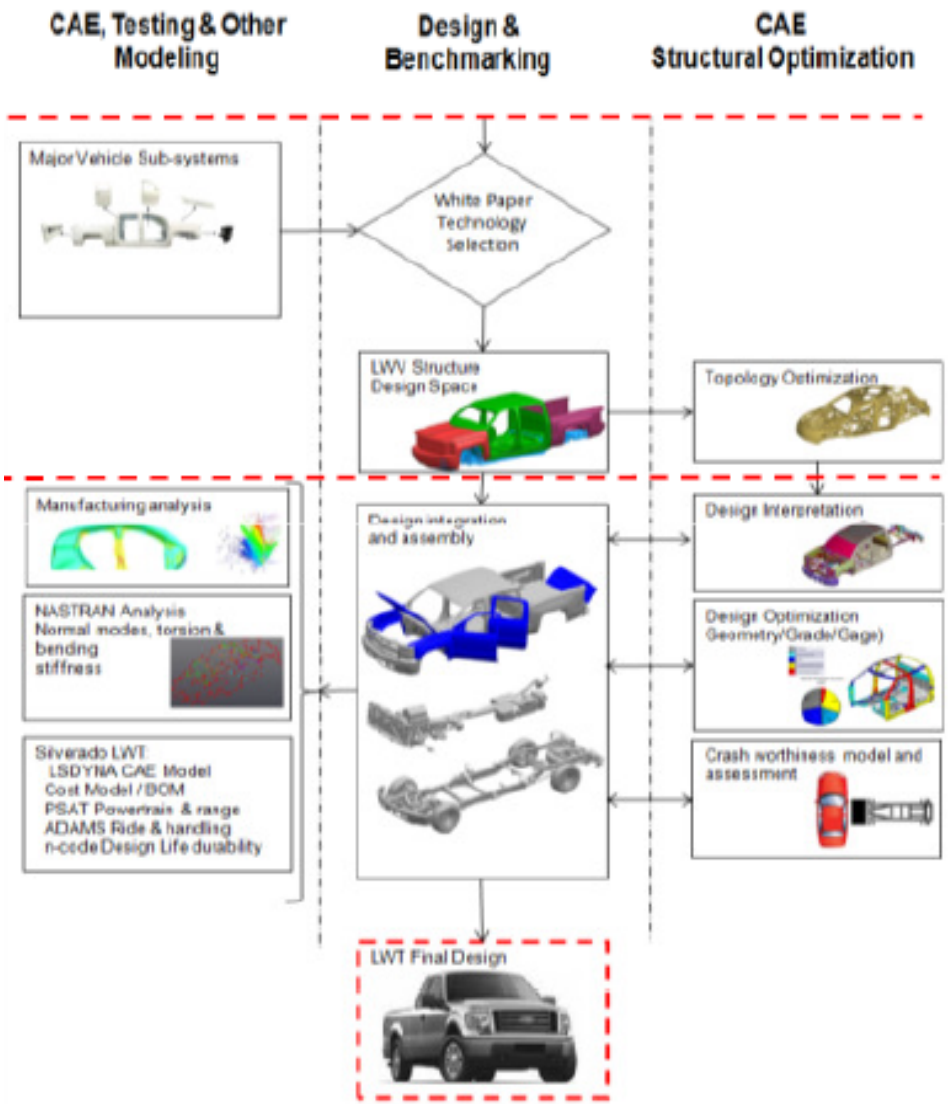
- **The work under this contract will occur in two phases and divided into three major parts as follows:**

  – Phase I - Baseline Vehicle Tear-down and Finite Element Analysis Modeling
    - The Contractor shall pick a baseline vehicle that best represents the Contractor's expectation of the light-duty pickup truck fleet for MY 2021 and perform a teardown study to build the baselines for engineering analysis and cost analysis for the light-weighted design.



NHTSA Sponsored Light Duty Pickup Truck Lightweighting Study - Project Phases

- **The work under this contract will occur in two phases and divided into three major parts as follows:**
  - Phase II, Part 1 - Design and Optimization of the Light-Weighted Pickup Truck and Cost Modeling
    - The Contractor shall use advanced design, material and manufacturing processes that will likely be available during model years 2020-2030 to develop a light-weighted pickup truck concept vehicle that is capable of high volume production.



NHTSA Sponsored Light Duty Pickup Truck Lightweighting Study - Project Phases

- **The work under this contract will occur in two phases and divided into three major parts as follows:**
  - Phase II, Part 2 - Mass Reduction for Other Light-Duty Vehicles
    - Generalize the results from the midsize passenger car lightweighting project and pickup truck lightweighting project to other vehicle classes, such as small PC, large PC, CUV, and other size of pickup trucks.

NHTSA Sponsored Light Duty Pickup Truck Lightweighting Study - What's Special about NHTSA Pickup Truck Lightweighting Study?

- **Baseline vehicle is also the latest design at the beginning of the project with extensive use of AHSS, 5 star safety rating and lowest mass compared with other MY 2014 light duty trucks.**
- **Tear down and investigate a total of 3 vehicles**
  - Fully understand the impact on light-weighting from different body styles, powertrain combinations, driveline variations and towing/payload packages.
- **Use 3G optimization**
  - Redesign of structure to accommodate the usage of new materials, new manufacturing processes and joining processes.
  - Seek to identify maximum potential mass reduction for the vehicle structure (cab, box, closures and frame)
- **Integrate all the most recent safety tests including IIHS small overlap test and have the test fully integrated into the light-weighted design.**
- **Investigate mass reduction for other vehicle classes**

Estimated Vehicle Weight Impact of Safety Regulations – Final Rules

Final Rules by FMVSS No.	Passenger Cars Added Weight (kg)	Light Trucks Added Weight (kg)
111 Rear Cameras	0.19	0.15
214 Side Pole	5.64	5.25
216 Roof Crush	5.28	5.28
226 Ejection Mitigation	0.91	1.07
Final Rules Subtotal	**12.02**	**11.75**

Information from MY2017+ CAFE Final Regulatory Impact Analysis at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf. (Starting from Page 110)

Estimated Vehicle Weight Impact of Safety Regulations – Potential Rules

Potential Rules	Passenger Cars Added Weight (kg)		Light Trucks Added Weight (kg)	
	min	max	min	max
Pedestrain Protection	?		?	
Forward Collision Warning (with Dynamic Brake Support and Crash Imminent Braking)	0.29	2.72	0.29	2.72
Lane Departure Warning	Included above		Included above	
Oblique/Offset Frontal	9.07	18.14	9.07	18.14
Part 563 EDR	0.04		0.04	
V2V	1.56		1.56	
Potential Rules Subtotal	**10.96**	**20.87**	**10.96**	**22.47**

Total	**22.98**	**32.89**	**22.72**	**34.22**

Conclusions

- **Over the past 5 years, the agencies (NHTSA, EPA and ARB) have invested millions of dollars into advancing our understandings of mass reduction cost, feasibility, and safety:**
  - These studies covered both unibody and body-on-frame design, from passenger cars to crossover utility vehicles to pickup trucks;

- **These studies helped the agencies better understand the engineering principles, material usages, design and manufacturing complexity and cost of mass reduction;**

- **These studies laid solid foundation for the inputs for rulemaking analyses for midterm review;**

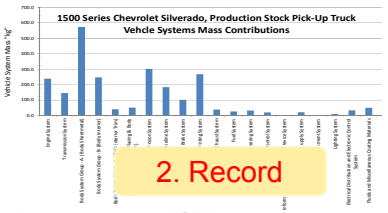
- **These studies (CAE models and cost models) are in public domain and helpful to foster more studies in understanding mass reduction and its costs.**

EXTRA SLIDES

EPA Sponsored Light Duty Pickup Truck Lightweighting Study
- Project Methodology Overview
(Source: FEV)

Finger Print Baseline Technology

1. Measure



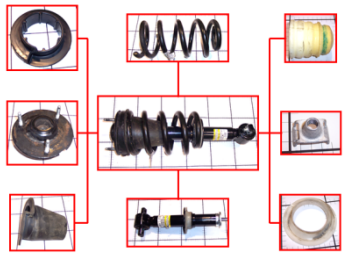
2. Record

3. Reproduce

4. Analyze

Teardown and Idea Generation

5. Evaluate



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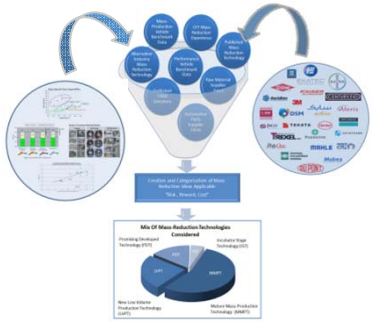
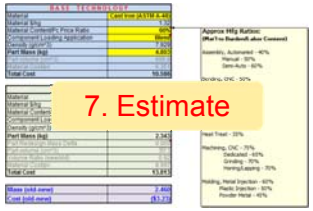
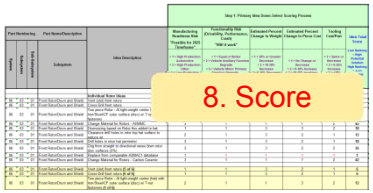


Mass-Reduction and Cost Optimization Process

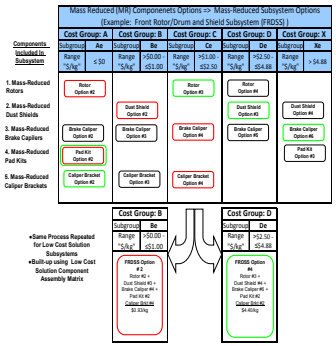


7. Estimate



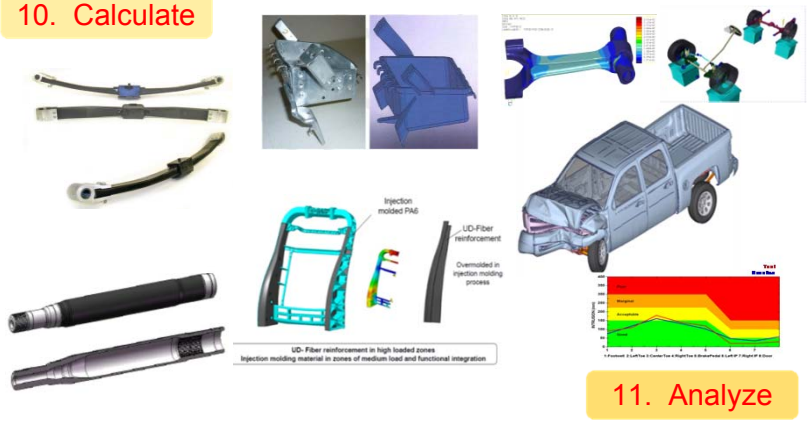
8. Score

9. Select



Detailed Mass-Reduction Feasibility and Cost Analysis

10. Calculate



11. Analyze