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National Highway Traffic Safety Administration

NHTSA's Recent Activities on Light-Duty Fuel Economy

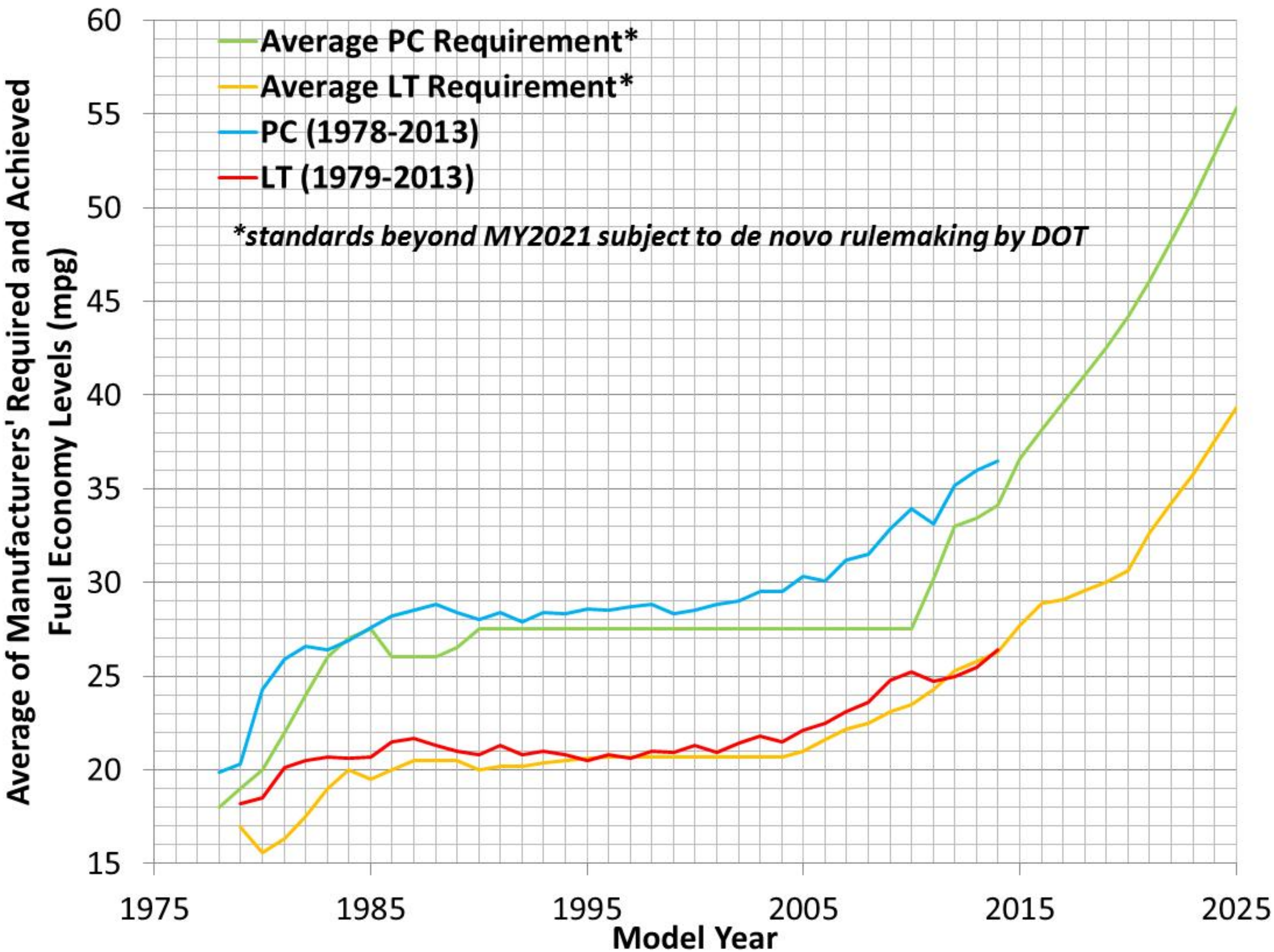
Briefing for the NRC

June 23, 2014

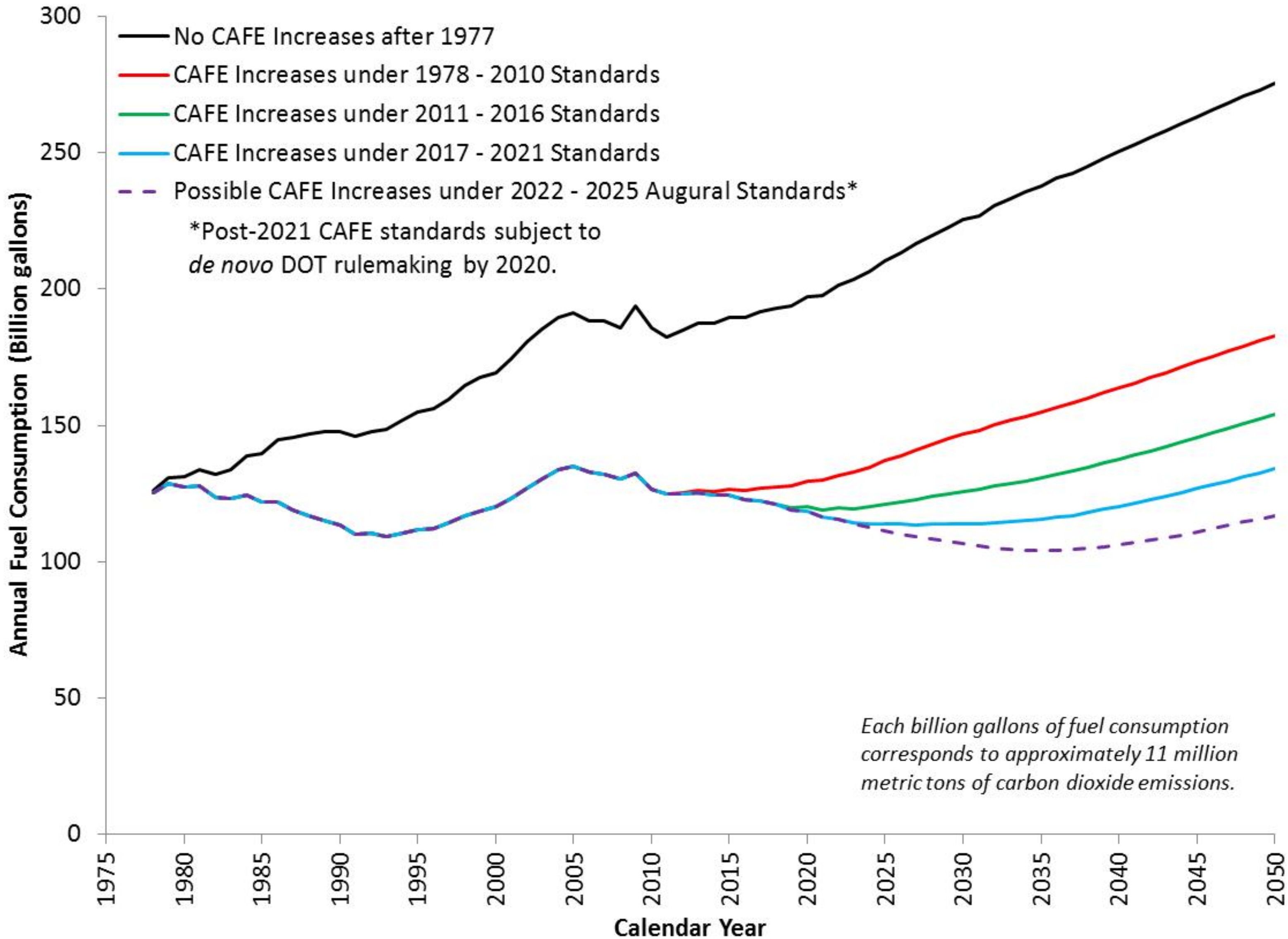
Topics

- Opening Remarks
- CAFE Modeling System – Expansion and Refinement
- CAFE Model Simulation Approach
- Mass Reduction Studies
  - Mid-Size Passenger Car Small Overlap Update
  - Full-Size Pickup Truck Lightweighting Project
- Safety Studies
  - Vehicle Fleet Simulation
  - Mass-Size-Safety Statistical Analysis
- Consumer Choice Model
- Vehicle Attribute Study

CAFE: Required Fleet Fuel Economy and Actual Fuel Economy



Impact on Fuel Consumed by U.S. Passenger Cars and Light Trucks



Mid Term Evaluation

MY 2017

MY 2025

Standards final unless changed by rulemaking

MY 2017-2021
Final

MY 2022-2025
Augural

Joint Technical Assessment Report
(draft by November 15, 2017)

CAFE Modeling System Expansion and Refinement

Accounting for Technology Impacts

- Technology Effectiveness -
  - Current approach uses sequenced decision trees, incremental effectiveness, with “synergy factors” to adjust cases where the effectiveness of combinations of technologies is not mathematically additive (“2 + 2 ≠ 4”)
  - An alternative is a more simulation-centric approach.
  - DOT working with Argonne National Lab to develop database of simulation results, and examining potential to modify CAFE model to use these results. (Details on slides 11 – 27)

- Technology Cost
  - Considering implementing explicit volume-based learning in lieu of time-based learning as proxy.
    - Volume-independent time-based learning may overestimate learning under less stringent regulatory alternatives, and may underestimate learning under more stringent regulatory alternatives.

Accounting for Product Cadence

- Current approach – Redesign and refresh
  - Most technologies applied during redesign, then carried forward until next redesign.
  - Some technologies applied during freshening, or at any time, then carried forward.
- Under development – Add platform accounting
  - Grouping vehicle models into common platforms
  - Limiting “splintering” of engines shared among vehicles with different redesign schedules

Accounting for Standards

- Publicly available version of model handles attribute-based CAFE standards for passenger cars and light trucks.
- CAFE model is being updated to handle Phase 2 MD/HD Fuel Efficiency standards for MD/HD pickups and vans.
- Investigating accounting for interactive effects of LD CAFE and MD/HD Fuel Efficiency standards.

  Run passenger car, LD truck, MD passenger vehicle and MD/HD pickup and van fleets simultaneously, accounting for shared platforms and engines

Other Fleet Accounting

- Model recently updated to simulate CAFE impacts in context of full on-road fleet
  - Calendar accounting necessary for Environmental Impact Statement analysis
  - Improves benchmarking against AEO and FHWA data

- Acknowledging vehicle market
  - Exploring options to modify LT share in response to CAFE
  - Investigating incorporating choice model and dynamic model of aggregate sales

CAFE Model
Simulation Approach

CAFE Model: Light-Duty Simulation

- Investigating simulating all technology combinations for all vehicle classes
  - Discontinue using “synergy factors” or other correction factors
  - Results placed in SQL database.
- Using Autonomie simulation model for vehicle simulations, under the support of Argonne National Labs
- Engine maps developed in GT Power by IAV
- Maximizing transparency and using tools widely-accepted by industry and academia
- Will update technologies and cost and effectiveness as appropriate

Why Use Autonomie?

- Autonomie is the lead vehicle simulation tool used by the U.S. DOE to evaluate all future technologies
- PSAT/Autonomie plant and control models have been developed and validated over the past 14 years using detailed test data from Argonne vehicle test facility as well as OEM partnerships for numerous configurations, including conventional, start-stop, HEV, PHEVs and BEVs
- Due to its increasing usage, Autonomie deployment and support now handled by LMS International
- Currently used by hundreds of engineers and researchers in industry, academia and government
  - **Light duty vehicle manufacturers**: GM, Ford, Chrysler, Hyundai, PSA Peugeot Citroen…
  - **Heavy duty vehicle manufacturers**: PACCAR, Cummins, John Deere, Daimler, Navistar, Oshkosh, CAT
  - **Suppliers**: Delphi, Eaton, Siemens, ArvinMeritor, Roush, SK Energy, LG Chem …
  - **Research organizations**: DOD, DOT, EPA, NREL, ORNL, INL, JRC, CATARC KATECH …
  - **Universities**: >20 US Universities (University of Michigan, MIT, Purdue..), Mines Paris, Tsinghua Univ., Beijing Institute of Technology, Seoul National Univ…

Improvements Over Previous Analyses

- Transparency: All assumptions and inputs would be clearly documented and releasable to the public
  - All engine maps and transmission calibrations would be releasable to public
  - Calibrations for transmissions would be compared to OEM production vehicles to make them realistic
  - A tool would be created to help the user review and analyze the result database
  - Model would be compiled and released to public so the users do not need to have Autonomie to run the model
- All possible technology combinations would be run, eliminating the need for synergy factors
- Database can be modified with new/updated technologies without having to re-run all simulations

Technologies Currently Being Considered

- Includes most technologies from 2017-2021 rulemaking
  - Eliminate “Shift Optimization”
- Additional technologies:
  - CVT
  - 9+ speed transmission? (Auto / DCT)
  - DCT + Torque converter?
  - Lean burn GDI?
  - Additional diesel engine technologies for light pickup truck (leverage simulation work for heavy-duty pickup truck)

Engines Currently Being Considered

DOHC

1. Baseline
2. VVT
3. VVL
4. GDI
5. Cylinder Deac

SOHC

1. Baseline
2. VVT
3. VVL
4. GDI
5. Cylinder Deac

OHV

1. Baseline
2. VVT+VVL
3. GDI
4. Cylinder Deac

DOHC Turbo

1. 16bar BMEP
2. 24bar BMEP
3. 24bar + Cooled EGR
4. 27bar + Cooled EGR

Diesel

1. Advanced Diesel
2. Diesel techs from 2b/3 analysis (light pickup only)

May add lean-burn GDI

Transmissions Currently Being Considered

Auto

1. 4spd - Baseline
2. 5 speed automatic
3. 6 speed automatic
4. 8 speed automatic*
5. High Effic. 8 spd*

Manual

1. 5 speed manual
2. 6 speed manual
3. High Effic. 6 spd

CVT

1. CVT

DCT

1. 6spd DCT
2. 8 spd DCT
3. High Effic. 8 spd DCT
4. *DCT + Trq Converter*

**ANL will also investigate benefits of 9-10spd transmissions*

Electrification Currently Being Considered

Micro/Mild

1. Micro HEV (stop/start)
2. BISG
3. CISG

*Combine with all engine and transmission technologies

Strong/Plug-in

1. Full HEV Pre-trans
2. Full HEV Power split
3. PHEV15 Power split
4. PHEV30 EREV
5. BEV 100
6. Fuel Cell Vehicle

*Assume Atkinson engine and dedicated transmission

Vehicle Tech Currently Being Considered

Mass Reduction

1. 0%
2. 5%
3. 10% (incl. engine downsize)
4. 20% (incl. engine downsize)

Rolling Resistance

1. 0%
2. 5%
3. 10%

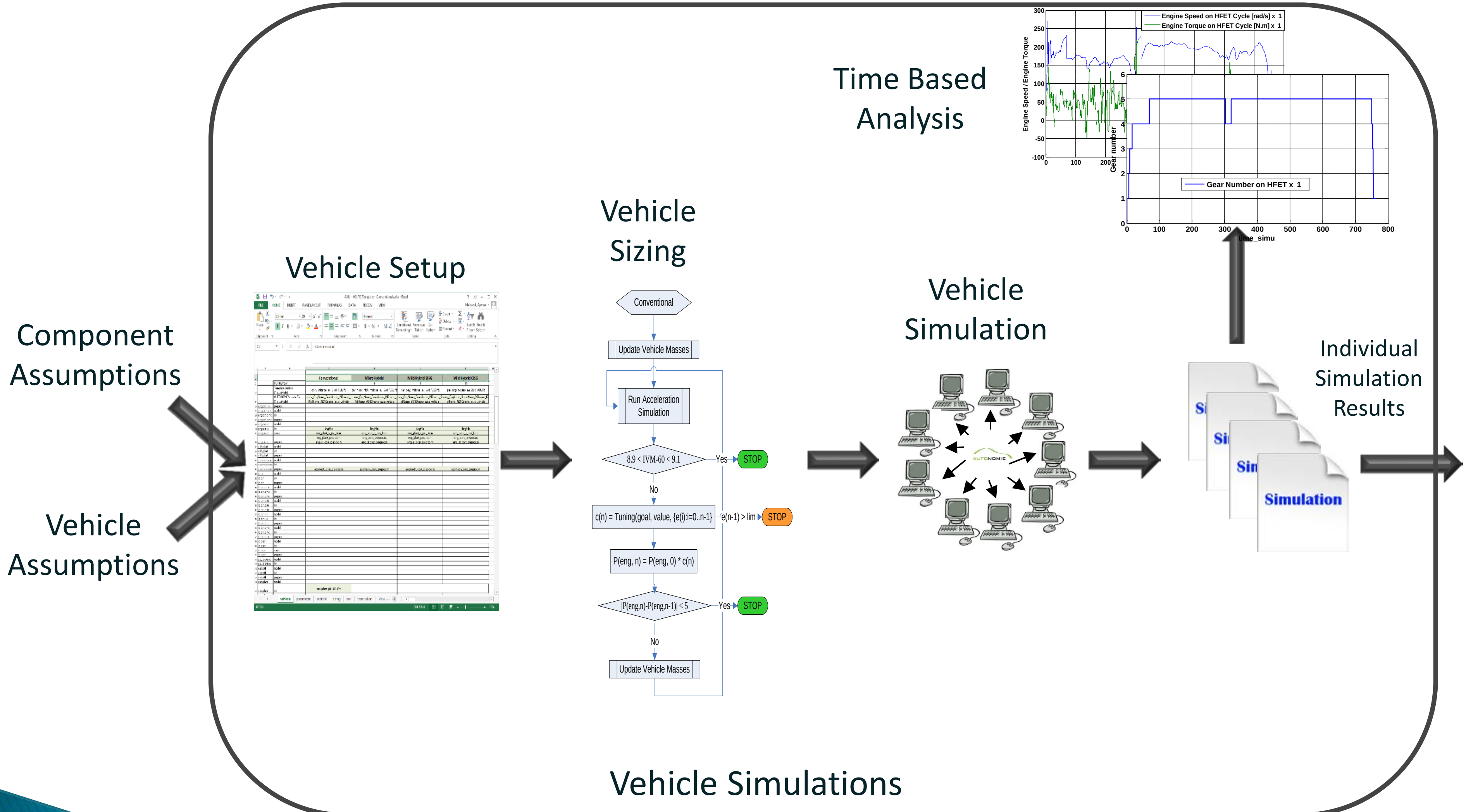
Aero Improvement

1. 0%
2. 10%
3. 20%

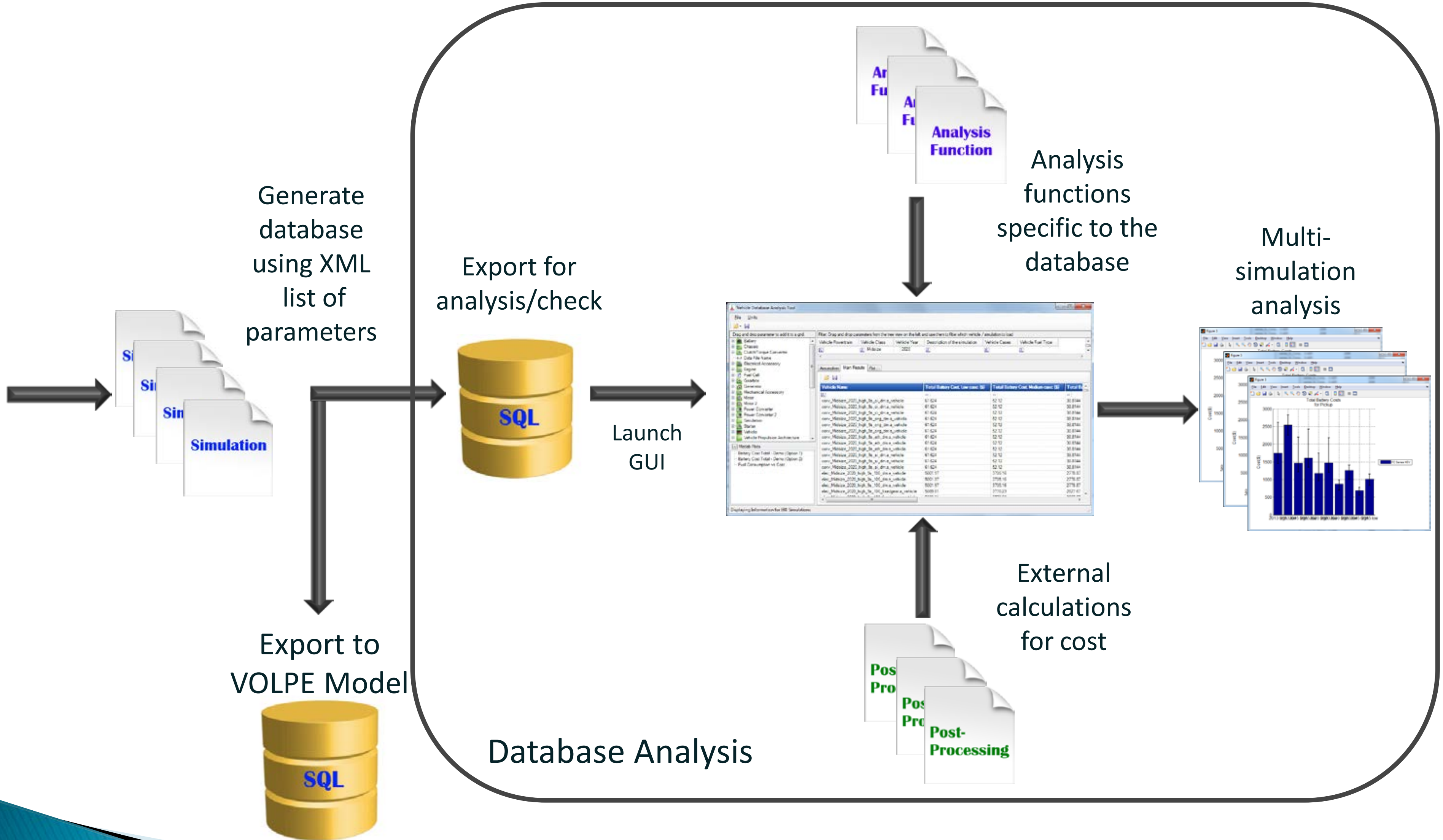
Additional Details

- Approximately 30,000 possible combinations of technology in each vehicle segment.
- 6-12 Vehicle classes → hundreds of thousands of possible technology combinations
- Exploring statistical methods to reduce number of simulations
- Developing version of Autonomie that can be run on ANL's large cluster in batch mode

ANL Mass Simulation Process Overview (1)



ANL Mass Simulation Process Overview (2)



Process Improvement

- Run some simulations using compiled models (no Matlab licenses required)
  - allows leveraging distributed computing power & significantly decreases simulation time
  - not possible when changing some parameters (e.g., gear ratios) because shift maps would need to change
- Developed algorithms that would automatically check the simulation results (i.e. number of shifting events from 0-60mph, number of shifting events per distance, number of ICE ON/OFF events, Auto vs DCT)
- Developing database analysis functions (i.e. plots, calculations)
- Investigating statistical analysis to reduce number of simulations run, and interpolation for some continuous technologies (rolling resistance, aerodynamic drag, and mass reduction)

Mass Reduction Studies

- Mid-Size Passenger Car Small Overlap Update
- Full-Size Pickup Truck Lightweighting Project

Mid-Size PC Small Overlap Update

- Scope of Work
  - Update the baseline Accord finite element model to correlate to IIHS small overlap test
  - Update lightweighted midsize passenger car design to achieve good rating in IIHS small overlap test
  - Estimate the amount of vehicle mass and cost change to meet the IIHS small overlap test requirement

Full Size Pickup Truck Lightweighting Project

- Objective:
  - Find the maximum feasible amount of mass reduction for a high volume production body-on-frame light duty pickup truck
  - Technology Selection Boundary:
    - Use advanced design, material and manufacturing process for MY2020-2030
    - At minimum, lightweighted pickup truck should meet the performance of the original baseline vehicle in safety, utility, manufacturability, powertrain performance, durability, NVH, serviceability
      - specific working requirements for pickup trucks
      - complexity of pickup truck configurations: cab, box, powertrain combination, driveline combination, towing and trailer package, off-road, SUV platform sharing, etc.
  - Cost boundary: control both direct and indirect cost to maintain affordability, price parity of +/- 10% of baseline vehicle

Full Size Pickup Truck Lightweighting Project

- Scope of Work
  - Phase I: Baseline Vehicle Reverse Engineering
    - Tear down a baseline vehicle
    - Reverse engineer the baseline vehicle and generate finite element analysis (FEA) and cost models
  - Phase II: Design and Optimization of the Lightweighted Pickup Truck
    - Design and optimize the lightweighted pickup truck and develop a FEA model.
    - Perform cost analysis for the optimized design.
    - Update the cost analysis for midsize passenger car study.
    - Update the mass reduction estimate for other vehicle classes done in the passenger car lightweighting project.
- Contractor: EDAG Inc.

Safety Studies

- Vehicle Fleet Simulation
- Mass-Size-Safety Statistical Analysis

Vehicle Fleet Simulation

- Phase I:
  - Report has been peer reviewed and published in the docket
- Phase II:
  - Introduce a modern design of CUV into the fleet
  - Perform lightweighted-to-lightweighted vehicle simulations
  - Update the fleet injury risk
- Potential Future Work:
  - Improve vehicle interior modeling
  - Introduce more lightweighting vehicle model
  - Introduce side impact analysis
  - Optimize restraint system for lightweighted vehicle

Mass-Size-Safety Statistical Analysis

- Update and publish safety analysis database
- Update safety analysis for midterm review

Consumer Choice Model

Why Model Consumer Choices?

- NHTSA’s regulatory analyses assume vehicle sales and market shares remain fixed with higher CAFÉ standards
- But manufacturers change MPG and other attributes (prices, performance, carrying capacity, etc.) of many models to comply with CAFE
- Some buyers respond by choosing different models, while others may postpone purchases
  - This changes the mix of new vehicle sales, which can complicate manufacturers’ compliance strategies
  - May also change fuel savings from raising CAFE
  - Changes in some attributes reduce vehicles’ utility to buyers, which imposes hidden costs

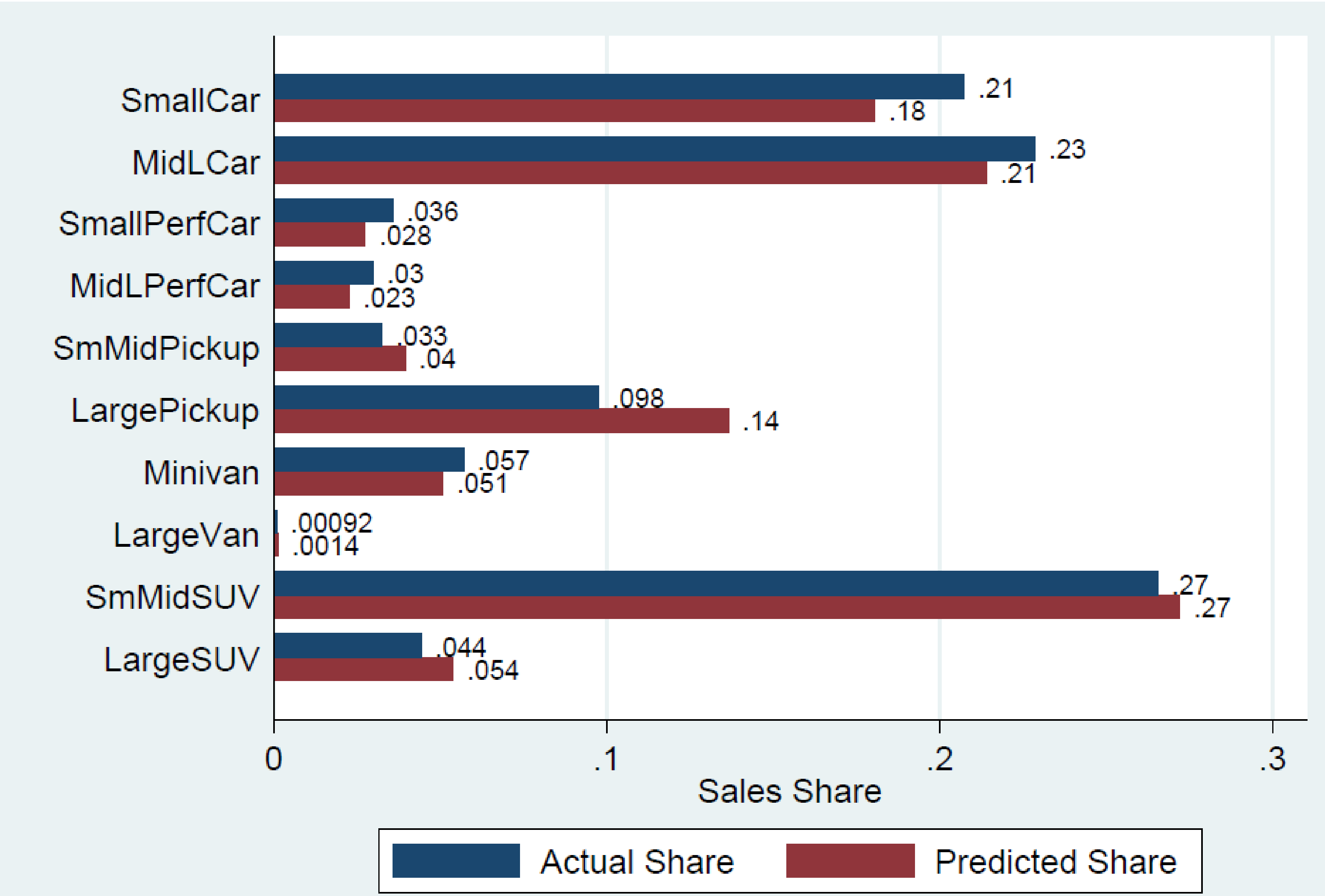
Model Development Details

- Contractor team: GRA Inc., Brookings, Univ. of California
- Vehicle purchases from 2009 National Household Travel Survey
  - Almost 17,000 households bought new vehicles, another 45,000 bought used vehicles (much larger sample than other models)
  - Survey collected detailed demographic data on all households
  - Identified make and model of all vehicles
- Detailed vehicle characteristics from NHTSA CAFE database matched to vehicle models
  - Purchase price (MSRP), fuel costs
  - Engine size, transmission type, HP, torque
  - Body type, seating capacity, interior volume, etc.
- Fuel price data from DOE matched to household location and interview date

Model Structure and Estimation

- Accounts for demographic effects on choices among models, instead of using a “representative buyer”
- Model specification (“nested logit”) reflects underlying logic of vehicle purchase decisions
  - Recognizes competition between new and used vehicles
  - Market segmented into nine categories (e.g., small auto, minivan, crossover, small SUV, large pickup)
  - Households first decide what type of vehicle to buy, then choose a specific model from that market segment
- Interactions between household demographics and broad vehicle attributes (e.g., seating capacity) determine choice of market segment
- Detailed attributes (performance, fuel costs) affect buyers’ choices among competing models within each segment

Model Performance



Note: Non-fleet vehicles only. CAFE data for model year 2008.

Using the Model

- Suitable for short-term (2-3 model years) forecasting of market response to higher standards, but longer-term forecasts require projecting changes in joint distributions of household characteristics
- Allows valuation of loss in consumer utility from foregone improvements in performance, carrying capacity, etc., but multiple interactions between buyer demographics and vehicle attributes complicate this
- Predicting longer-term responses likely to require a simpler model
- Alternatives include adapting an “off the shelf” model, or simplifying specification of the newly developed model to reduce complexity of forecasting

Vehicle Attribute Study

Vehicle Attribute Study Objectives

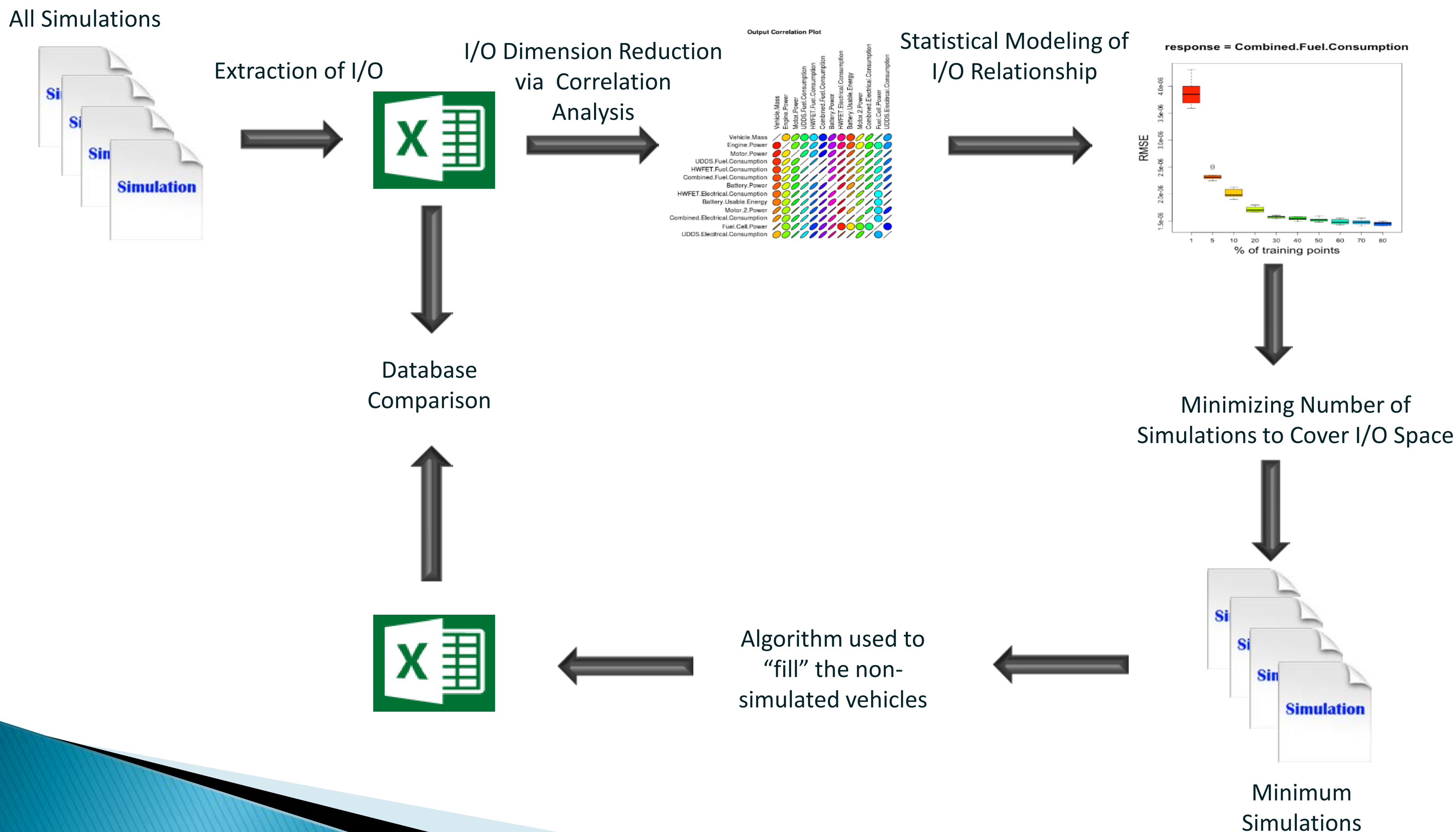
- Estimate the production cost of change to vehicle footprint
- Determine the extent to which such changes would impact weight, aerodynamic drag, fuel economy, performance and/or utility
- Evaluate potential barriers (e.g., sunk costs for tooling, part sharing between platforms, and model refresh/re-design schedules) to application of such changes

Footprint Attribute Tasks

- Literature review
- Statistical analysis of historical data to identify vehicle design changes that are required to increase vehicle footprint
- Detailed engineering cost analysis to estimate the cost of design changes
- Detailed engineering analysis to estimate the resulting changes in vehicle curb weight and other vehicle characteristics resulting from footprint changes
- Identify of any limitations associated with increases of a particular size (e.g., sunk costs for tooling, part sharing between platforms, and model refresh/re-design schedules).
- Conduct for each of the 12 CAFE vehicle model classes

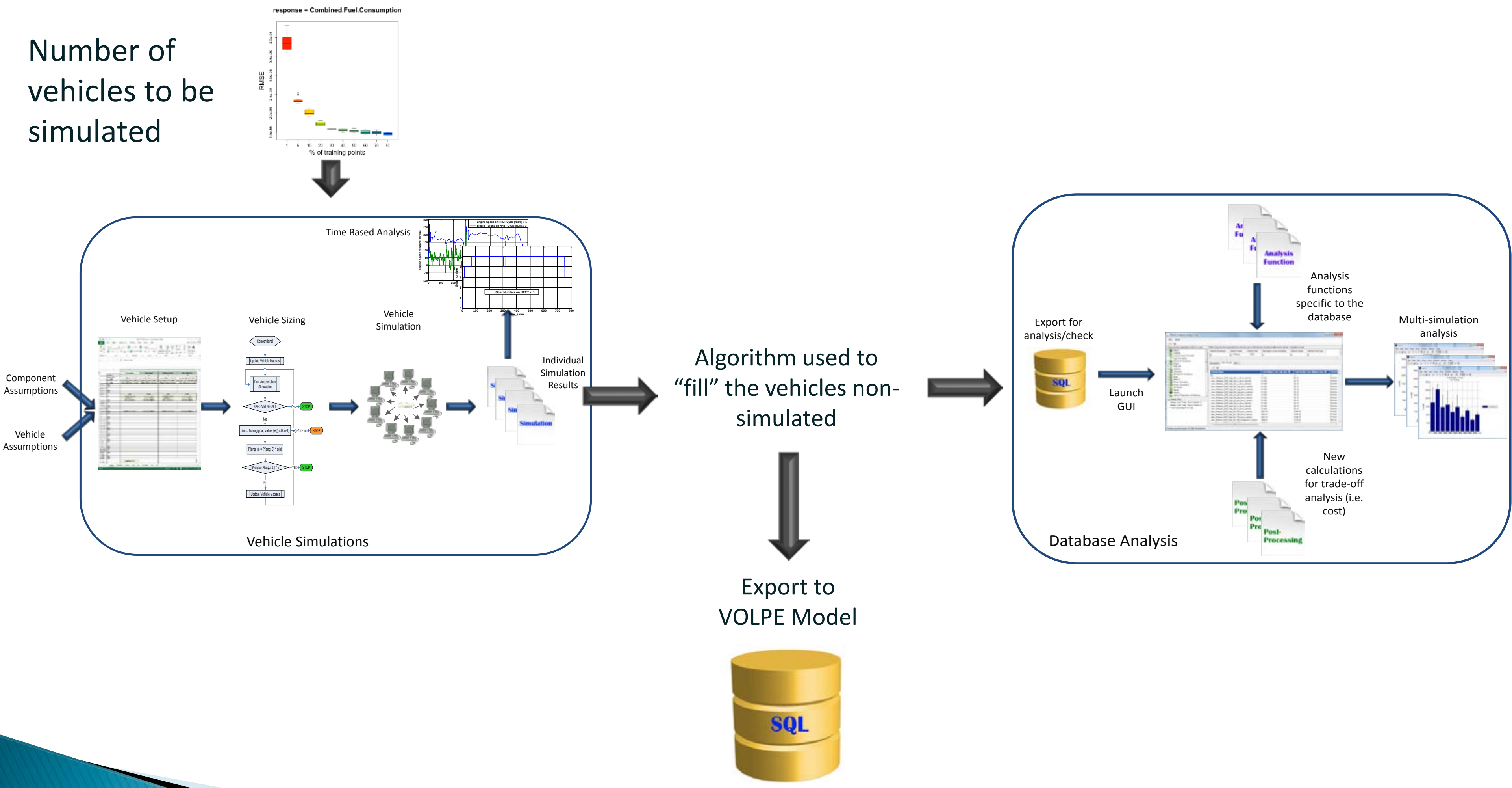
APPENDIX for CAFE Model Simulation Approach

Simulation Reduction Through Statistical Analysis



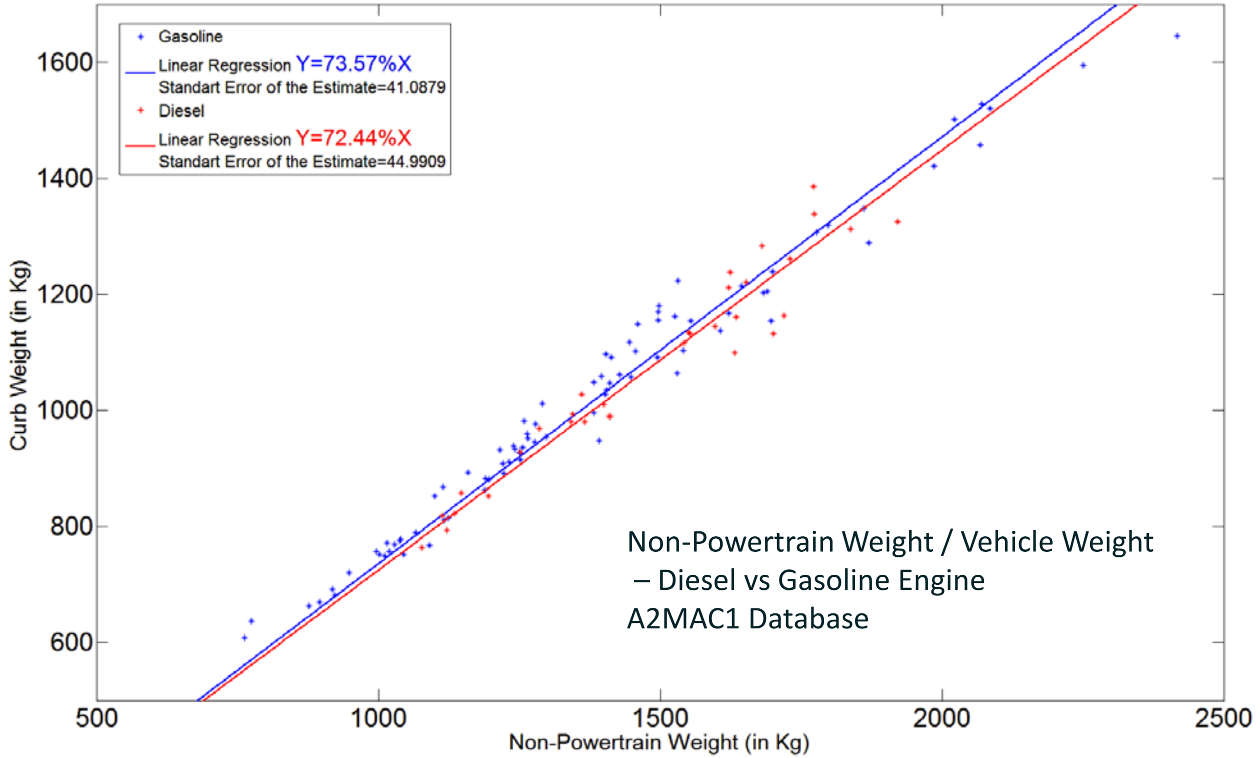
Final Process Overview

Simulation Reduction Through Statistical Analysis



Updated Assumptions

- Added relationship between glider & powertrain weight during sizing algorithm



- Evaluate impact of “platform” on component sizing (i.e. limited number of engines)
- Optimize transmission ratios based on component and powertrain
- Run heuristic optimization on control calibration