NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Fleet DNA











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National Renewable Energy Laboratory
2014 Annual Merit Review
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Project ID: VSS119

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Overview

Timeline

- **Project Start Date:** FY 2012
- **Project End Date:** FY 2015
- **Percent Complete:** ~60%

Barriers

- **Cost:** Reduce the cost associated with evaluating and developing vehicle components and configurations by providing public access to data reporting and analysis capabilities
- **Risk Aversion:** Address risk issues by providing easily accessible info to potential consumers
- **Computation models, design and simulation:** Accurate modeling efforts require real world data for successful development and validation

Budget

- **Total Project Funding for FY14:** $500K
  - DOE Share: $500K
  - Contractor Share: Partner cost share has been in-kind support (vehicle loans, technical support, data access and data supplied to NREL) and varies by individual partner
- **Funding Received in FY13:** $400K

Partners

Project success requires a wide range of contributing partners from industry, government, universities, and other national labs. Key past and present partners include:

- ORNL – Data collection partner
- Industry – NTEA/GTA, Cummins, PG&E, Oshkosh, Waste Management, Zonar, Parker
- Research – OSU, CSU, NC State, Calstart
- Gov./Reg. – Clean Cities, SCAQMD, CARB, EPA, ANL, City of Indianapolis
- Project Lead – NREL

Relevance

Project Objectives:

- Capture and quantify drive cycle and technology variation for the multitude of **medium- and heavy-duty** vocations
- Provide a common data storage warehouse for medium- and heavy-duty vehicle fleet data across DOE activities and labs
- Integrate existing DOE tools, models, and analyses to provide data driven decision making capabilities

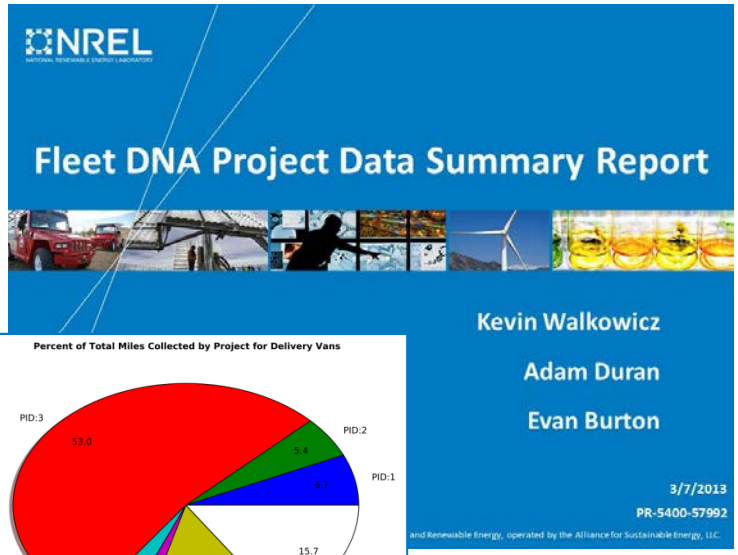
For Government : Provide in-use data for standard drive cycle development, R&D, tech targets, and rule making

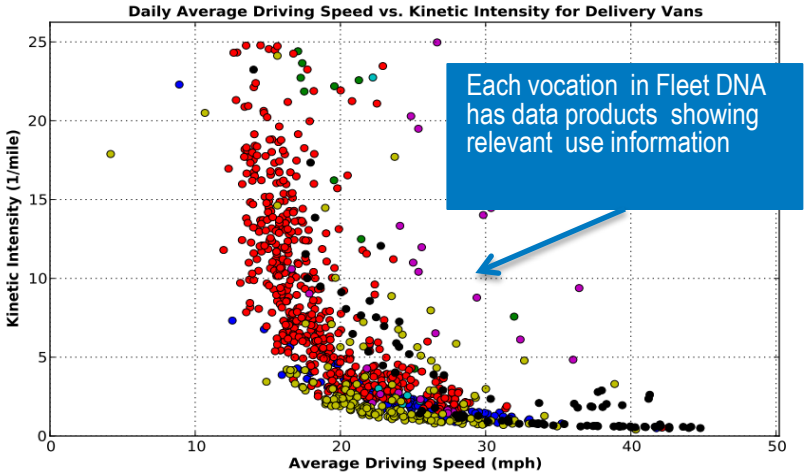
For OEMs: Real-world usage datasets provide concrete examples of customer use profiles

For Fleets: Vocational datasets help illustrate how to maximize return on technology investments

For Funding Agencies: Reveal ways to optimize impact of financial incentive offers

For Researchers: Provides a data source for modeling and simulation

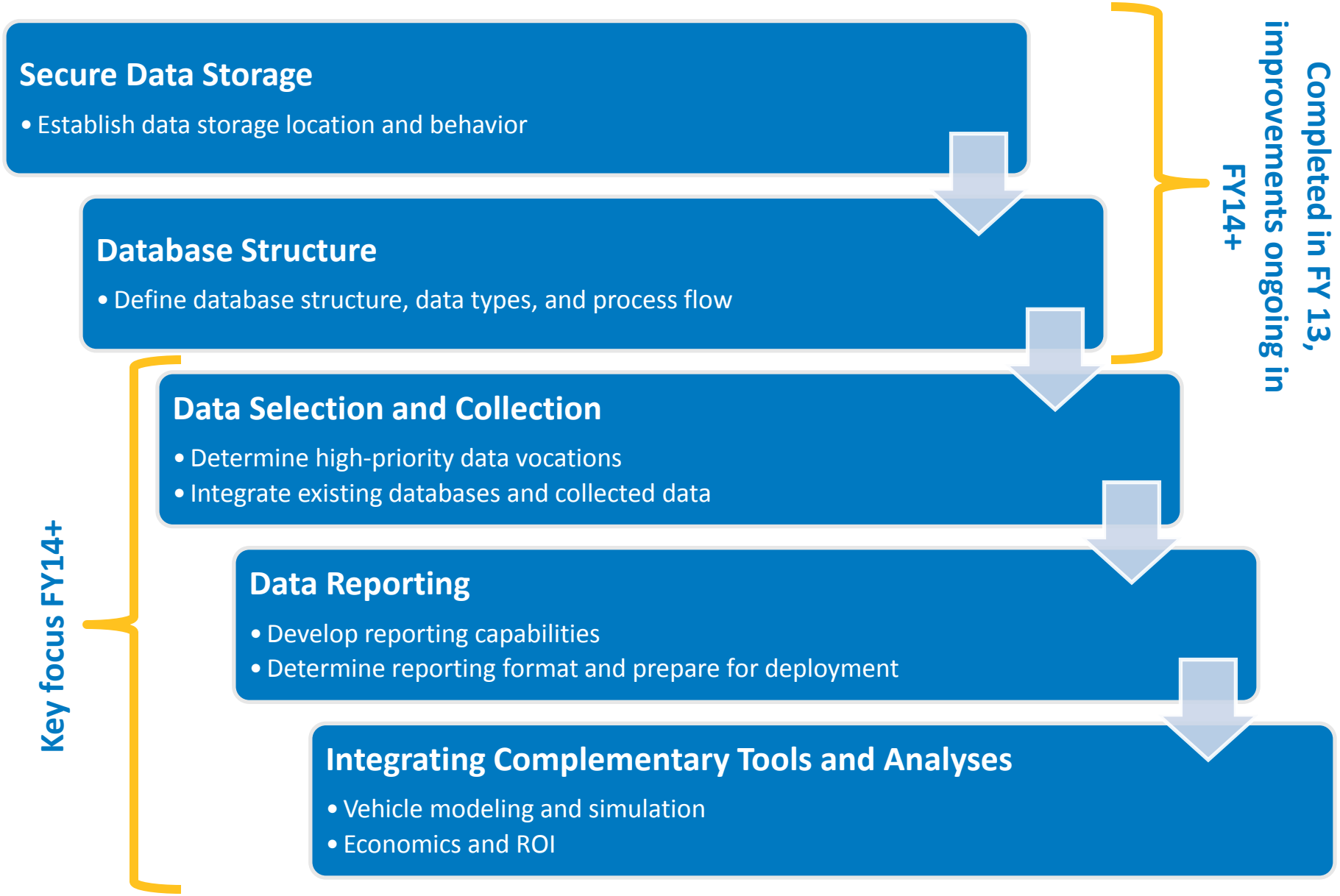




Milestones

Month/ Year	Milestone or Go/No-Go Decision	Description	Status
12/2013	Milestone report to DOE	Draft report on project status and new developments	Completed
3/2014	Milestone report to DOE	Draft report on project status and data compiled	Completed
6/2014	Milestone report to DOE	Draft report on project status and data dissemination	Pending
9/2014	Milestone report to DOE	Annual report compiled and submitted to DOE program manager on project status and deliverables	Pending

Approach – Fleet DNA Development



Approach – Secure Data Storage

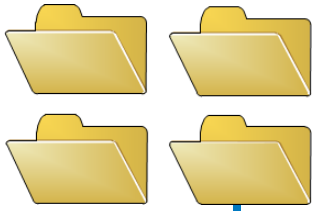
- **Data transfer/upload**
  - Data uploaded directly from ongoing VT data collection activities or from data partners via secure FTP
- **Data protection**
  - Data stored on secure raw data handling server
  - Building badge access
  - On-site security force
  - Room key access
  - Limited to data center staff
- **Data backups**
  - Data mirrored on large storage array
  - Regular tape backup
  - Fire/disaster protection for copies



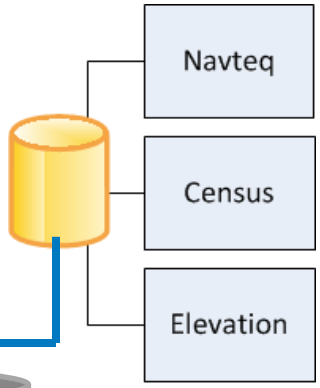
NREL Data Center
Storage Arrays
NREL PIX #18784

Approach – Database Structure

In-Use Vehicle Data Files



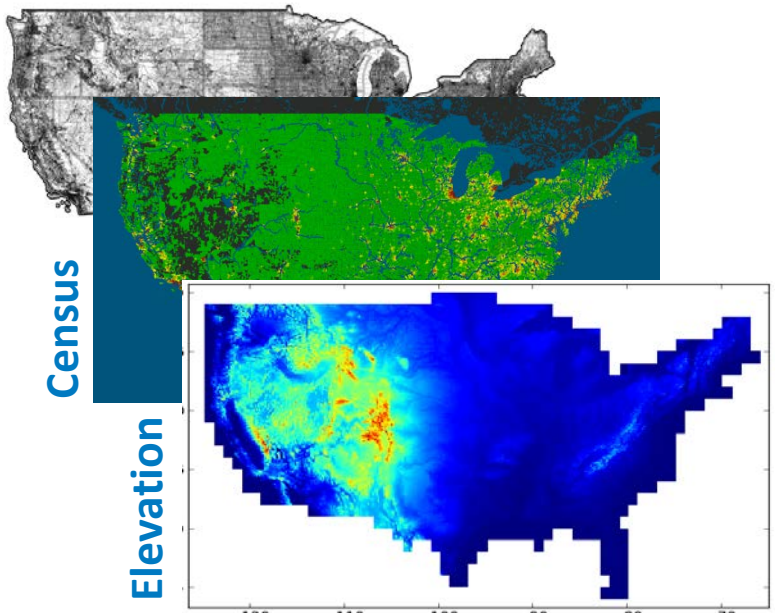
Reference Data Sets



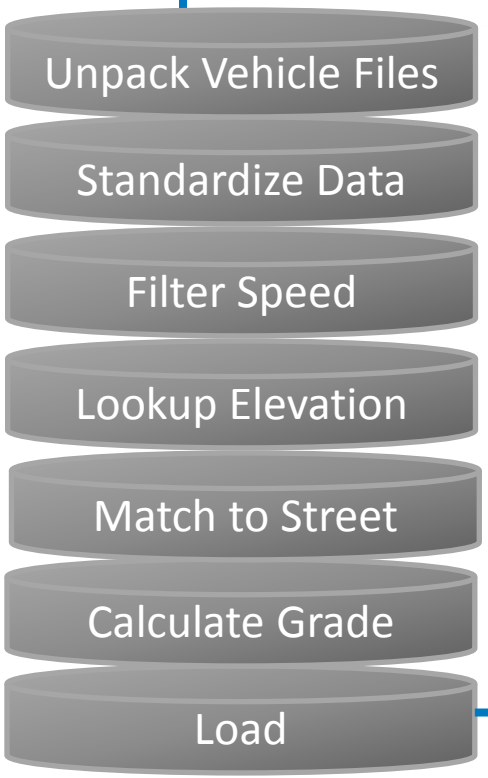
Streets (Navteq)

Census

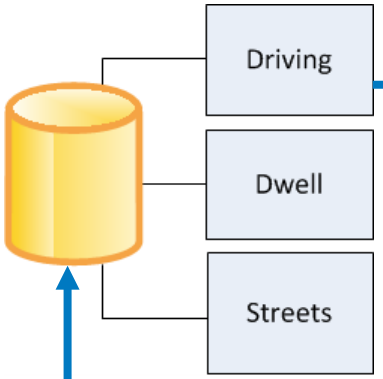
Elevation

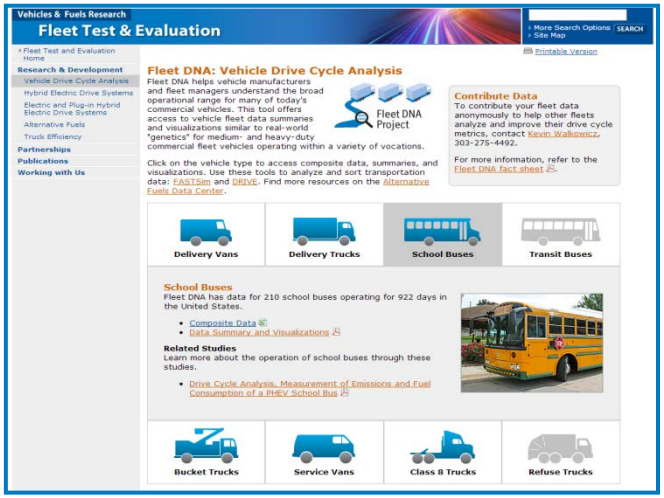


Data Processing



Analysis Results





Data Reporting

Approach – Data Selection and Collection

- The majority of fuel usage in the medium- and heavy-duty vehicle sector occurs in class 2, 3, 6, and 8 vehicles. Ongoing data collection is focused on these weight classes and associated vocations.
  - Vocations and truck types associated with weight classifications include:
    - Class 2 (Highest Priority): service van, utility van, work truck, smaller step van
    - Class 3: shuttle bus, walk-in truck, step van,
    - Class 6: transit bus, school bus, bucket truck, straight truck
    - Class 8 (Highest Priority): refuse truck, dump truck, concrete mixer, tow truck, fire truck, tractor trailers (beverage, tankers, bulk shipment, etc.)
- Growing interest in capturing CNG/LNG/LPG data in addition to existing hybrid/electric/conventional datasets

Table 5.4
Truck Statistics by Gross Vehicle Weight Class, 2002

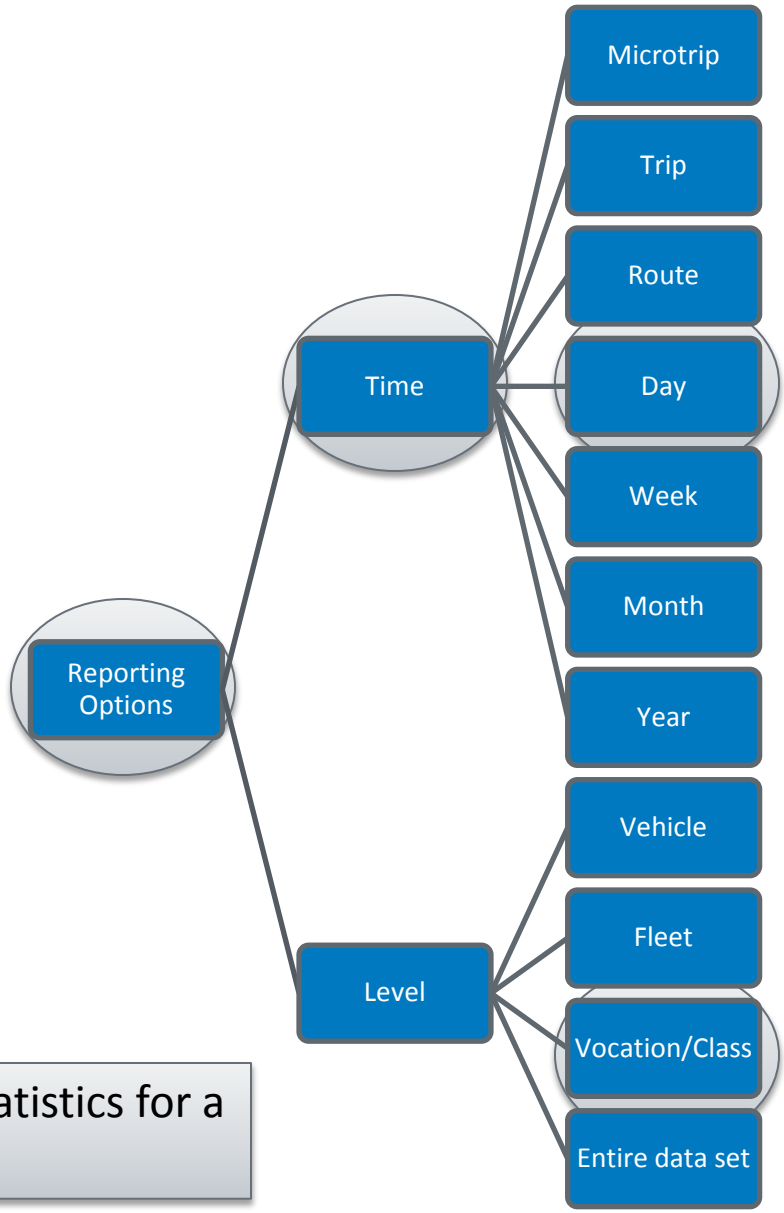
Manufacturer's gross vehicle weight class	Number of trucks	Percentage of trucks	Average annual miles per truck	Harmonic mean fuel economy	Percentage of fuel use
1) 6,000 lbs and less	51,941,389	61.0%	11,882	17.6	42.7%
2) 6,001 – 10,000 lbs	28,041,234	32.9%	12,684	14.3	30.5%
Light truck subtotal	79,982,623	93.9%	12,163	16.2	73.2%
3) 10,001 – 14,000 lbs	691,342	0.8%	14,094	10.5	1.1%
4) 14,001 – 16,000 lbs	290,980	0.3%	15,441	8.5	0.5%
5) 16,001 – 19,500 lbs	166,472	0.2%	11,645	7.9	0.3%
6) 19,501 – 26,000 lbs	1,709,574	2.0%	12,671	7.0	3.2%
Medium truck subtotal	2,858,368	3.4%	13,237	8.0	5.2%
7) 26,001 – 33,000 lbs	179,790	0.2%	30,708	6.4	0.9%
8) 33,001 lbs and up	2,153,996	2.5%	45,739	5.7	20.7%
Heavy truck subtotal	2,333,786	2.7%	44,581	5.8	21.6%
Total	85,174,776	100.0%	13,088	13.5	100.0%

Over 50% of all transportation fuel, and 75% of all medium and heavy vehicles

Sources: DOE Transportation Energy Data Book – 32nd Edition, and National Academy of Sciences report "Technologies and Approaches to Reducing Fuel Consumption of Medium- and Heavy- Duty Vehicles."

Approach – Data Reporting

- **Fleet DNA statistics are generated on multiple application levels and time scales, allowing for a wide variety of reporting**
- **Two-phase approach for public data reporting to address the interests of multiple project users/customers**
  - **Phase 1 – Static reporting website**
    - Cumulative vocational reports and source data hosted on Fleet DNA website in PDF and XLS formats
    - Provides easy access to reports and publications associated with data stored in database
    - Links to additional analysis tools and projects
  - **Phase 2 – Interactive data reporting**
    - Allows users to select, view, and download graphics and data of interest
    - Insert Fleet DNA data directly into websites and reports



*Example – Reporting daily vehicle operating statistics for a specific vehicle vocation or weight classification

Approach – Integrating Existing Tools











Collect Lab and Field Data

Capture, Store, and Analyze

Explore & Optimize

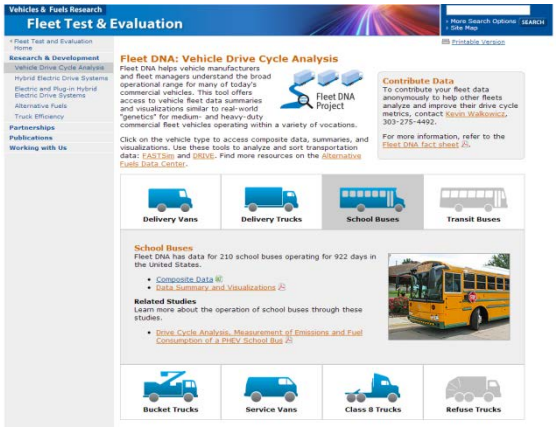
Communicate & Inform

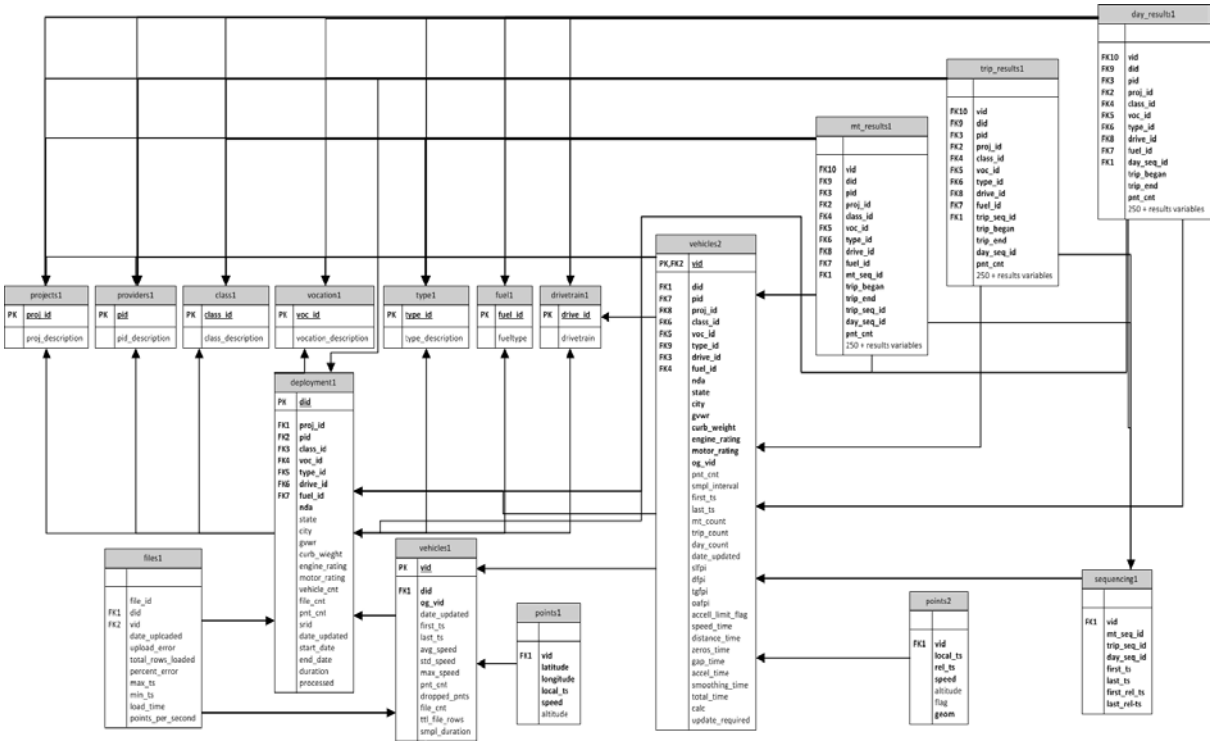
Identify Barriers, New R&D Opportunities, Validate Efforts

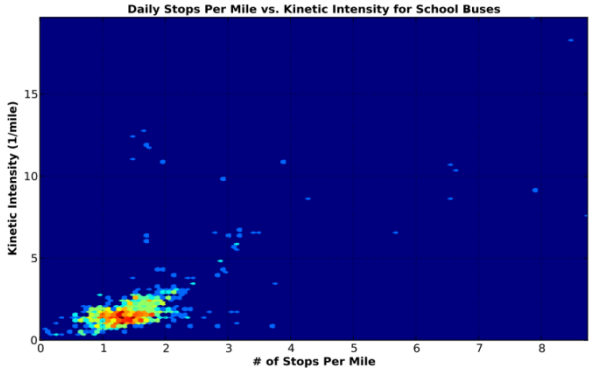
Partnership with Fleets and Technology Providers = Relevant Results & Optimized Solutions for Real World Applications

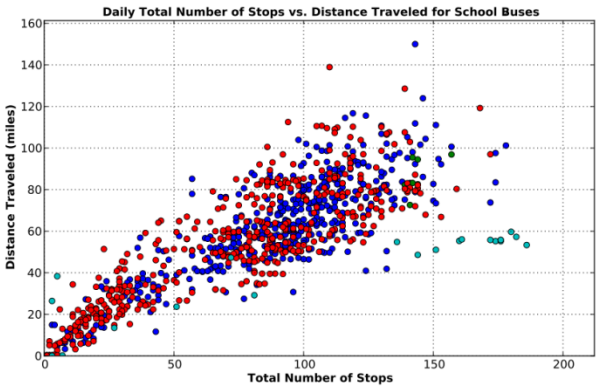
Technical Accomplishments – FY13 Review

- **Completed initial development of Fleet DNA data storage and web reporting databases**
- **Successful publication of six vocation-specific reports for major vocations of interest (delivery vans, delivery trucks, school buses, bucket trucks, service vans, and class 8 trucks)**
  - 34 unique data products per report
- **Fleet DNA website developed and deployed for public data report dissemination: www.nrel.gov/fleetdna**







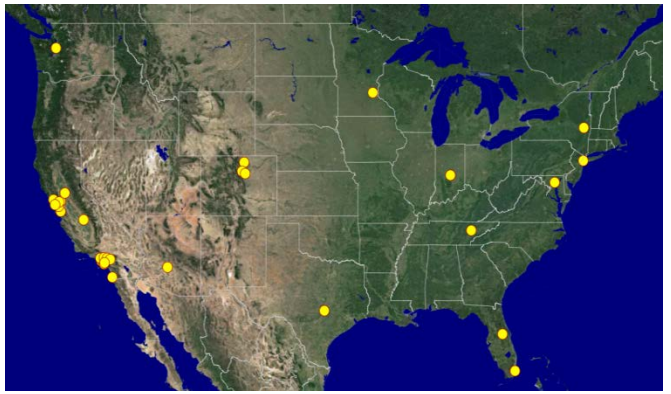


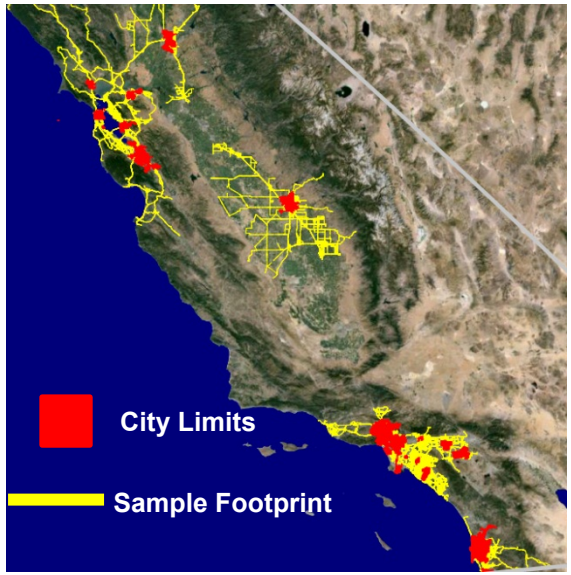
Technical Accomplishments – Data Collection

Fleet DNA Data Summary

	Vehicles	Vehicle Days	Distance	Deployments
Delivery Vans	135	1,835	93,506	42
Delivery Trucks	21	237	12,246	4
School Buses	212	368	22,223	4
Bucket Trucks	20	216	5,858	2
Service Vans	14	143	3,310	2
Class 8 trucks	185	1,368	149,854	16
Transit Buses	20	378	48,738	6
Refuse Trucks	13	142	5,140	1

Fleet DNA Locations

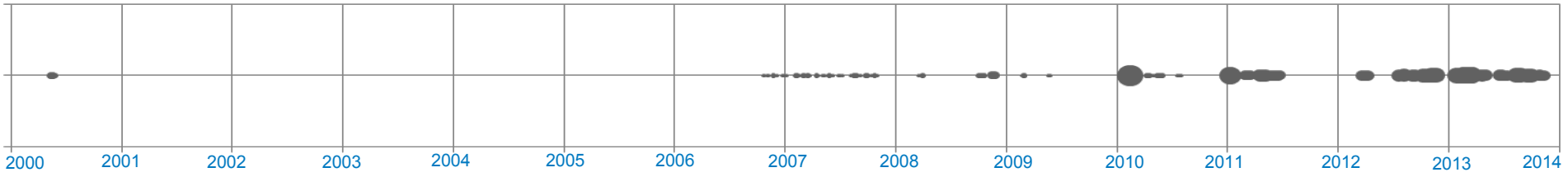




Fleet DNA Data Summary :

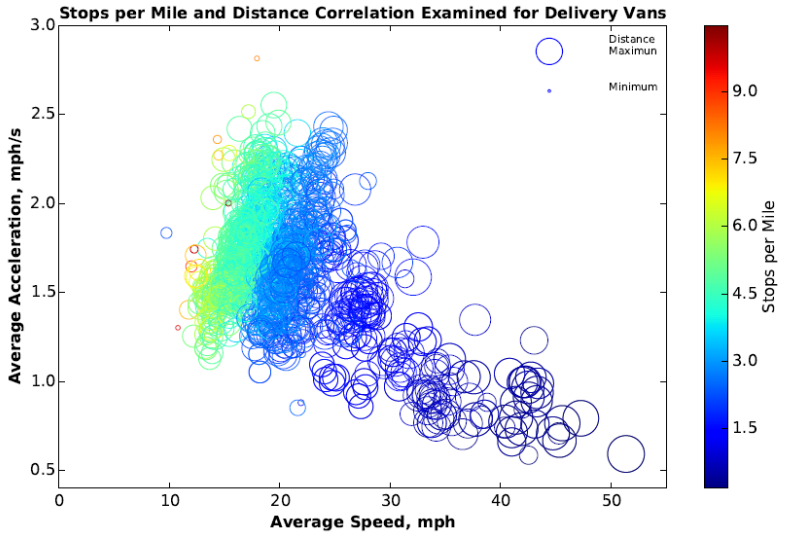
- 37 locations (FY 13 – 15 locations, ~150% growth)
- 620 vehicles (FY 13 – 334 vehicles, ~85% growth)
- 4,687 days (FY13 – 2,799 days, ~70% growth)
- 340,875 miles (FY13 – 101,794 miles, ~235% growth)
- 77 deployments (FY13 – 50 deployment, ~50% growth)

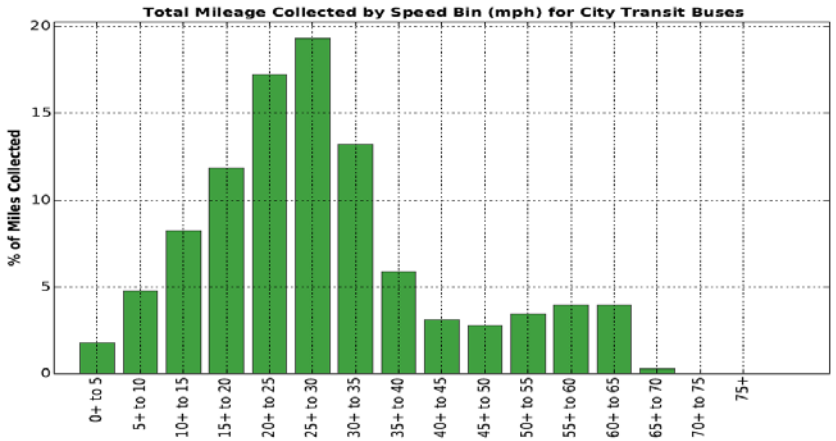
Data Collection Timeline



Technical Accomplishments – Data Reporting

- **Successful updates to phase 1 data reporting website : www.nrel.gov/fleetdna**
  - Approximately 1,000 unique visitors per month
  - 13 new unique data products added per report (total of 47, up from 34 in FY13)
    - New data products include road grade and vehicle power specific analyses
- **Successful development of new reports for major vocations of interest**
  - 2 new vocational reports developed (total of 8 currently, up from 6 in FY13)
    - Refuse trucks
    - Transit buses

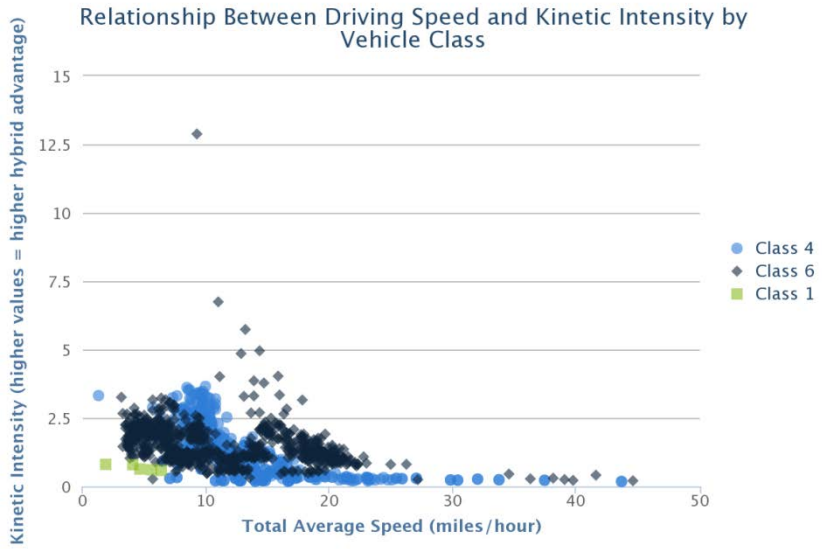


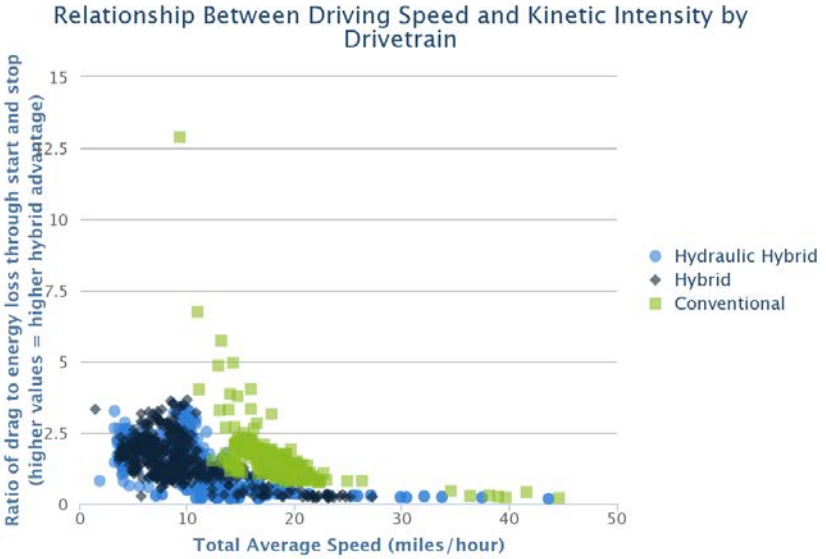




Technical Accomplishments – Data Reporting

- **Initial phase 2 interactive data reporting website developed and awaiting public deployment in Q3 FY 14**
  - Continuing to get feedback from fleet users, DOE, and other research institutions prior to full release of website
  - Ongoing development of site planned for FY15
    - Integration with DOE AFDC website
    - Addition of new charts and data
    - Continued refinement based on user feedback
  - Same vocations as static reporting website
  - Interactive graphics to be inserted into existing Fleet DNA website as widgets
- **Interactive graphics and data**
  - Phase two enables users to:
    - Download custom data and graphics
    - Insert custom charts into websites as widgets
    - Explore vocational datasets by powertrain, weight class, fuel, etc.
    - Turn data layers on and off for deeper analysis

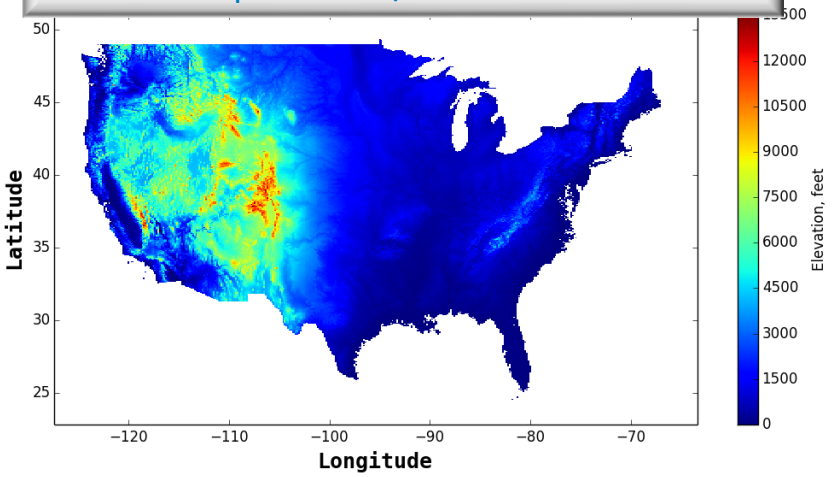




Technical Accomplishments - Road Grade

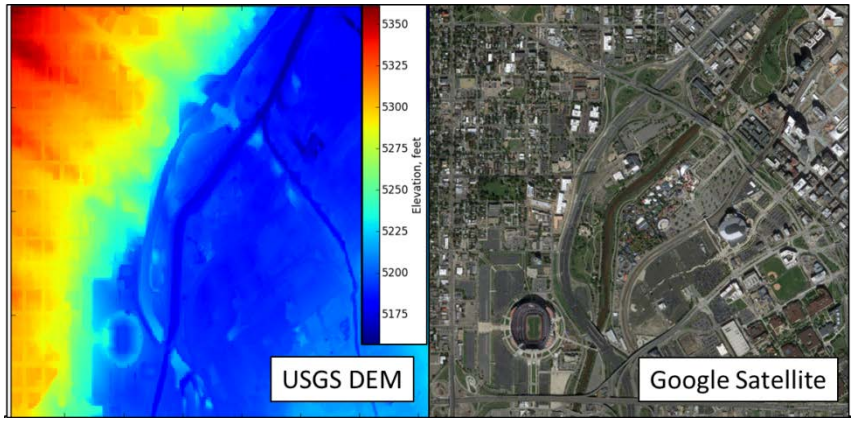
1 USGS Digital Elevation Model

>100B data points at 1/3 arc-second resolution



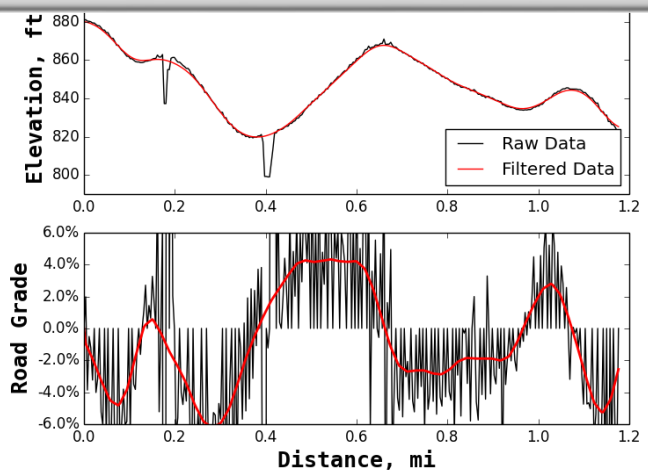
2 Match GPS Data to DEM

Raw elevation appended via spatial relation



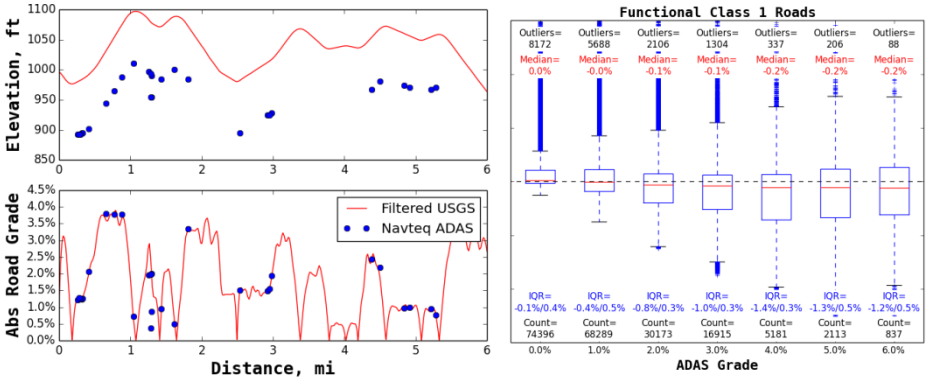
3 Filter and Smooth Raw Elevation

Remove errant data and attenuate noise from derivative



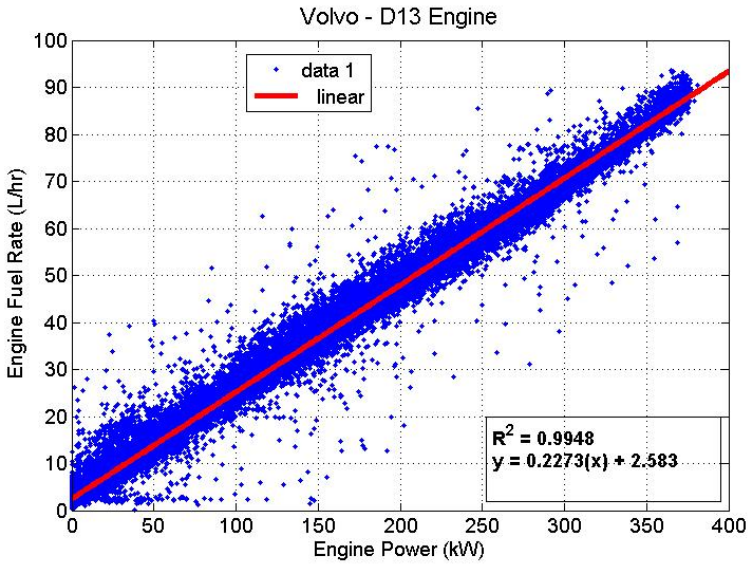
4 Validation to Navteq ADAS Data

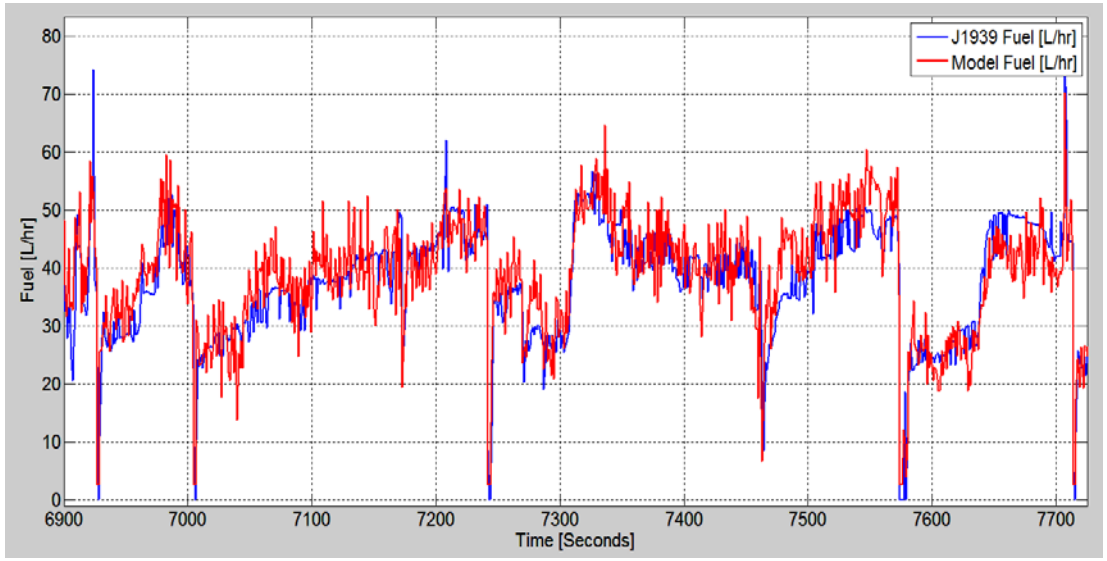
Agreement quantified over ~5M data points



Technical Accomplishments – Mass Estimation

- In FY14 a preliminary method was developed to estimate mass based on drive cycle, fuel consumption, and road grade information captured from GPS/CAN and Fleet DNA
- Mass estimation method equates collected CAN engine fueling data to a computed required engine power
- Knowing power and vehicle speed, the algorithm then performs a minimization optimization routine that isolates and returns the vehicle specific power parameters (mass, drag coefficient*Frontal Area, rolling resistance)
- Preliminary testing of method, while promising, was inconclusive due to limited "true" mass data on hand. Experiment to validate and refine method scheduled for later in FY 14
  - Using a weighted truck with known mass, collected GPS/CAN data while running on preset operating routes
  - Employ Fleet DNA's road grade determination method to determine the route geographic information
  - Test, refine, and validate existing method based on experimental data
  - Publish results of experimentation in FY 15





Technical Accomplishments – Tools

- **Integrating existing tools and capabilities**
  - Ongoing goal of the Fleet DNA project is to integrate existing and future tools and analyses to allow users to perform downstream activities using real world drive cycles and vehicle specifications
- **Drive cycle analysis – DRIVE Tool**
  - Drive cycle characterization and representative cycle generation via DRIVE. Integrated into Fleet DNA initially in FY13, with updates in FY14
- **Fuel economy modeling – FASTSim & Autonomie**
  - FASTSim provides high-level modeling capabilities to estimate fuel economy for real and hypothetical powertrain and fuel configurations. Integration with Fleet DNA completed in FY 14
  - Autonomie provides detailed modeling capabilities to estimate fuel economy, GHG and specific powertrain and component level data. Additional work planned in FY 14/15 to integrate Autonomie into Fleet DNA
- **Economics and GHG – AFLEET/GREET and AFDC Tools**
  - Fleet DNA researchers are working to ensure the database and drive cycle information are compatible with other DOE lab/program tools and models
  - Additional work planned in FY 14/15 to integrate these tools into Fleet DNA
- **Developing novel tools and capabilities**
  - In addition to incorporating existing tools, it is also the goal of Fleet DNA to develop additional capabilities which will help fully characterize medium- and heavy-duty fleet vehicle operating behavior
    - Road grade determination (FY14)
    - Vehicle mass estimation (FY14/15)







Clean Cities

AUTONOMIE

Responses to Previous Year Reviewers' Comments

Approach

"This reviewer stated that the cost and risk aversion barriers were clearly addressed by examples; however, no specific explanation of how the Computation Models, Design and Simulation barriers were addressed. The reviewer added that a few examples would be beneficial of either internal DOE or partners' use in these areas."

Fleet DNA serves as a data warehouse, storing drive cycle data for ongoing development and validation of current/future vehicle modeling software. Additionally, in FY 14 the data stored in Fleet DNA was integrated with existing vehicle modeling software (FASTSim), allowing users to perform rapid large scale modeling studies using the drive cycles stored in Fleet DNA. Having a large expanse of source data coupled with vehicle modeling software allows researchers, developers, and fleet users to explore opportunities for fuel savings in a low cost, user friendly manner.

Collaboration and coordination with other institutions

"This reviewer noted the collaboration with ORNL and preliminary industry/government/OEM partners were noted, but cautioned this database will solely have isolated consumers if collaboration and coordination is not expanded upon…"

In the last year, significant effort has been made to expand the project partnership list in all areas (industry/government/OEM). Fleet DNA has coordinated with additional industry partners (PG&E, Waste Management, Minneapolis Metro Transit, etc.) extended collaboration with other National Labs/DOE programs/government/universities (ORNL, ANL, Clean Cities, Alternative Fuels Data Center, EPA, CARB, SCAQMD, GA Tech, OSU, NC State, CSU), and reached out to strengthen ties with OEMs/Industry Groups (Cummins, Oshkosh, Odyne, Altec, Smith, Navistar, NTEA). There will be sustained effort to continue to grow the user and project partner base over the remainder of the project duration as feedback from our project partners is instrumental in guiding the ongoing development and application of the data stored in the Fleet DNA database.

Resources

"This reviewer indicated that no matter how data is drilled down, somebody will want something different or visualized differently. The reviewer went on to say that having the public data report with multiple vocations is a step in the right direction, but having access to the public database for personalized data analysis would be ideal. Additionally, the reviewer said that desktop database analytical tools are becoming more available and widespread that would allow this database more general use."

The Fleet DNA project has taken significant steps to improve the reporting and sharing of data stored within the database. As of FY14, there are currently two primary data reporting/sharing avenues available to Fleet DNA users. For higher-level data exploration, users can download static vocational data reports and source data from the Fleet DNA website. Researchers interested in analyzing second-by-second source data can access this information via an NREL-hosted controlled access portal.

Collaboration and Coordination with Other Institutions

Collaborator	Area	VT Program	Comments
ORNL	Federal Lab	Yes	Primary Data Collection Partner working with NREL
ANL	Federal Lab	Yes	Leveraging Fleet DNA for simulation work
INL	Federal Lab	Yes	Contributing Drive Cycle Data to Database
CSU, NC State, GA Tech	University	No	Leveraging Fleet DNA data for ongoing research
Calstart	Research	No	Provided Drive Cycle Data to Database. Leveraging Fleet DNA data for ongoing research
Clean Cities	DOE	Yes	Assisting with partner recruitment. Supplying Drive Cycle Data to Database
SCAQMD	Gov	No	Provided Drive Cycle Data to Database
CARB	Gov	No	Provided Drive Cycle Data to Database
EPA	Gov	No	Leveraging Fleet DNA database for regulatory work
City of Indianapolis	Gov	No	Provided Drive Cycle Data and Vehicle Access. Applied Fleet DNA to guide fleet investment
NTEA	Industry	No	Industry Project Partner – Data and Project Partner Support
GTA	Industry	No	Industry Project Partner – Data and Project Partner Support
Cummins	Industry	No	Coordinating to share data analysis approach
PG&E	Industry	No	Providing Drive Cycle Data and Vehicle Access
Waste Management	Industry	No	Provided Drive Cycle Data and Vehicle Access
Verizon	Industry	No	Applied Fleet DNA to guide fleet investment. Provided Drive Cycle Data and Vehicle Access
Many Additional Fleets	Industry	No	Provided Drive Cycle Data and Vehicle Access

Proposed Future Work – FY14/15

Data Collection and Reporting:

- Expanding data channels stored in Fleet DNA to include fueling, powertrain, and emissions data collected from CAN bus (August FY14)
- Phase 1/2 website and report development (Ongoing)
- Additional partner recruitment and data collection (Ongoing)
- Integration of results into the Alternative Fuels Data Center (FY15)

Modeling and Simulation:

- Mass estimation method validation (End of FY14)
- Integrate additional modeling software such as Autonomie with Fleet DNA database for large scale detailed modeling activities (FY 15)
- Integrate non-DOE tools, such as EPA MOVES (FY 15)
- "What if" scenarios – select drive cycles and vehicle type, evaluate potential for fuel and cost savings over range of technologies and fuels (FY 15)

High Performance Computing:

- Deploy Fleet DNA in NREL super computing environment (June FY14)

Summary

- **Fleet DNA serves as a data storage warehouse for medium- and heavy-duty vehicle fleet data**
  - Demonstration that vehicle drive cycle data can be collected and stored for large-scale analysis and modeling applications
    - Data serve as a real world data source for model development and validation
    - Storage of the results of past/present/future data collection efforts improves analysis efficiency through pooling of shared data and provides opportunity for "big data" type analyses
- **Fleet DNA shows it is possible to develop a common database structure that can store/analyze/report on data sourced from multiple parties, each with unique data formats/types**
  - Data filtration and normalization algorithms developed for the project allow for a wide range of data types and inputs, expanding the project potential
- **Fleet DNA demonstrates the power of integrating Big Data with existing and future tools and analyses**
  - Enhanced understanding and education possible when these capabilities are in place.
    - Users can explore GHG and economic opportunities via AFLEET and ADOPT modeling
    - Drive cycles can be characterized and visualized using DRIVE
    - High-level vehicle modeling can be performed using real-world drive cycles via FASTSim
    - Data reporting through Fleet DNA phase 1 and 2 websites provides external users access to analysis results and gives the opportunity to explore on their own

Acknowledgements and Contacts

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Lee Slezak
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Vehicle Technologies Office - U.S. Dept of Energy

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Technical Back-Up Slides

(Note: please include this "separator" slide if you are including back-up technical slides (maximum of five). These back-up technical slides will be available for your presentation and will be included in the DVD and Web PDF files released to the public.)

Technical Accomplishments – Applying Fleet DNA

1) Working with the NTEA, City of Indianapolis, and Greater Indianapolis Clean Cities, NREL researchers instrumented 13 rear- and side-loading refuse trucks operating within the city of Indianapolis' fleet to capture key operational data.

2) Captured data were uploaded to Fleet DNA where analysis & key metrics were produced, providing the city of Indianapolis with information to develop strategic procurement / deployment plans as well as optimize their current fleet operation.

3) To evaluate opportunities for future technology investment, existing DOE modeling software was leveraged to simulate the fuel economy of a range of possible advanced technology solutions using captured drive cycles.

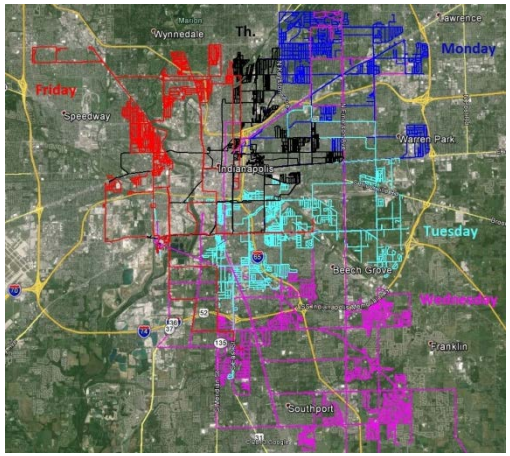
4) Based on simulated fuel economy results, worked with ANL to apply additional DOE software tools to provide rough ROI and cost-saving estimates for future planning.



NREL PIX #26732



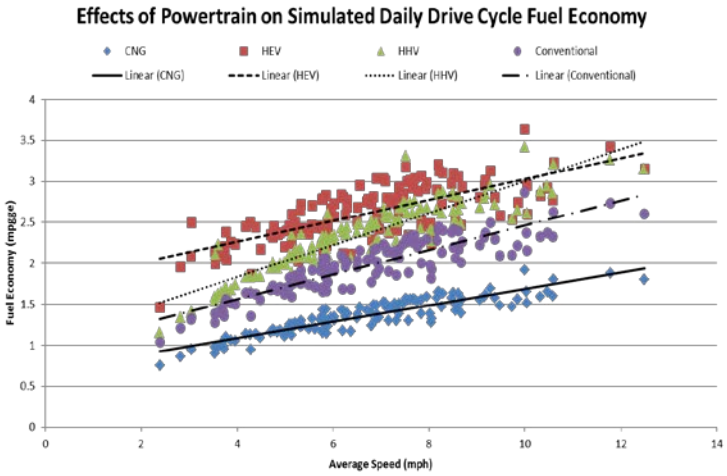
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Captured Vehicle Data



Analysis and Simulation of Data



Smart Investment and Deployment

Technical Accomplishments – Applying Fleet DNA

Used Fleet DNA's Capabilities to Support the NCFP Fleets:

- "Quick" Assessment of Fleet to Identify Best Technology for Application

1) Captured key operational data from 40 "light aerial boom trucks" and service vans operating in 3 locations within a large telecom fleet

2) Provided analysis & produced key metrics from acquired data to allow fleet to develop strategic procurement / deployment plans

3) Provided recommendation for appropriate drive cycles for analysis and testing of advanced technologies

4) Used data and analysis to simulate advanced technologies across observed drive cycles



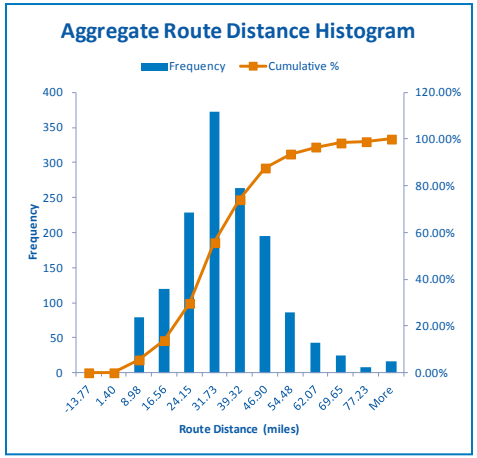
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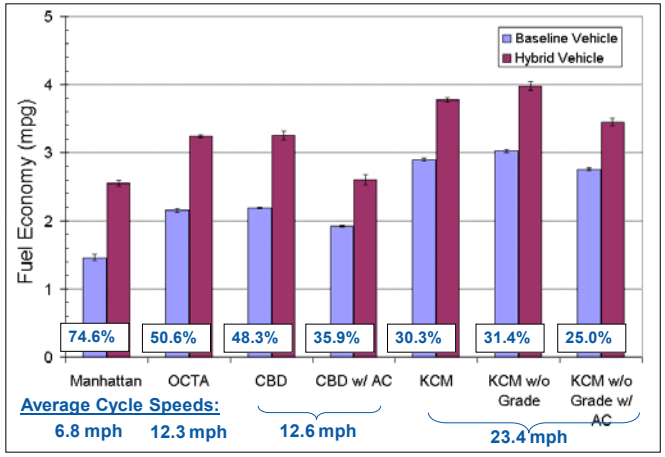
NREL PIX #18127



Captured Vehicle Data



Analysis of Data



Drive Cycle Recommendation / Smart Deployment