Hydrogen Fleet and Infrastructure Demonstration and Validation Program: Data Analysis Overview

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Presented at the National Hydrogen Association's Annual U.S. Hydrogen Meeting and Exposition. Washington, D.C.
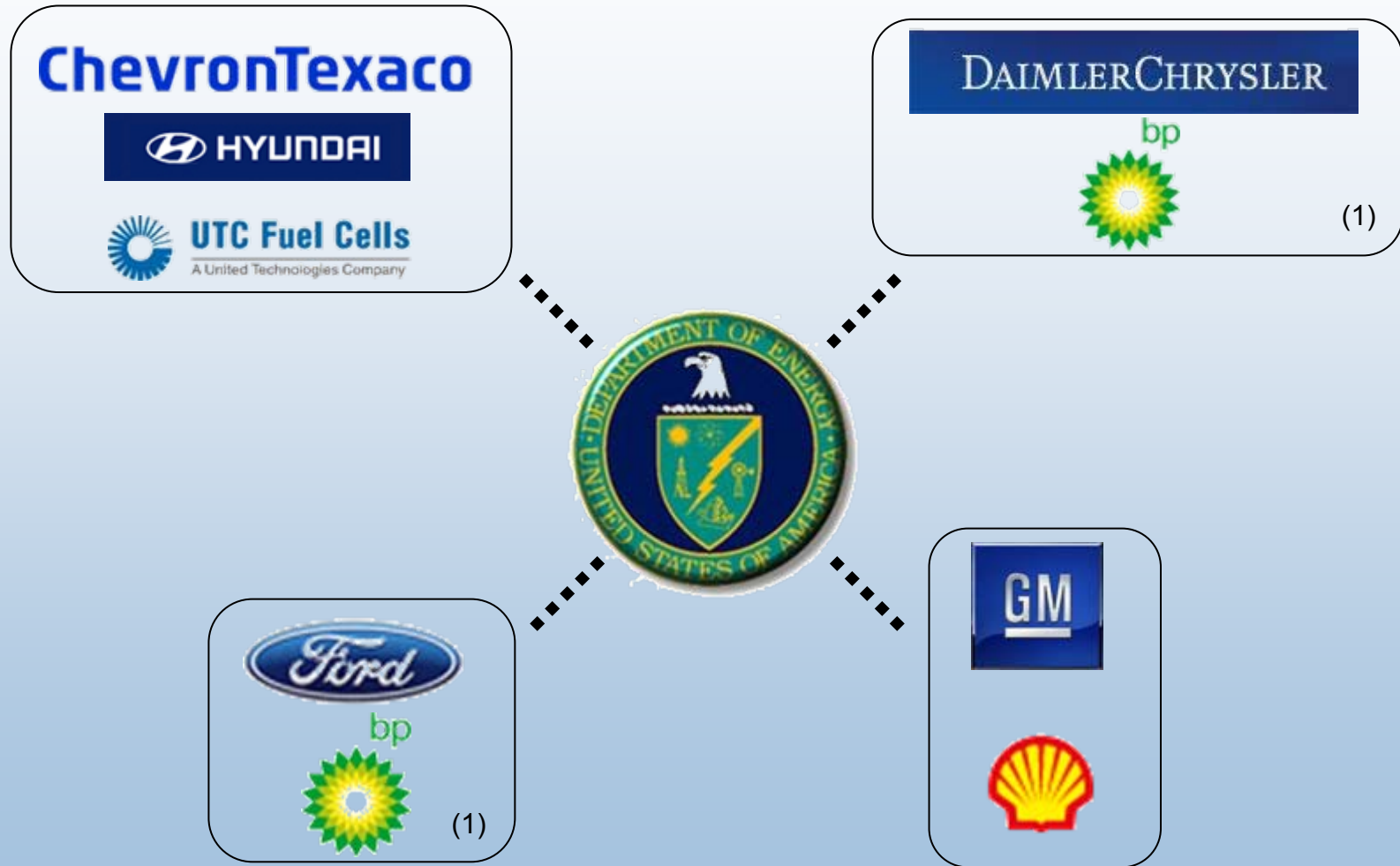March 29 - April 1, 2005

Overview

- Program Objectives and Targets

- Cooperative Agreements

- Data Collection, Analysis Process

- Analysis Examples
  - "HSDC" ADVISOR Simulation
  - Stack Degradation

- Summary

Program Objectives and Targets

- Objectives
  - Demonstrate/Validate "System" Solutions
  - Identify Status of Technology
  - Re-Focus Research and Development
  - Support Commercialization Decision by 2015

- Key Targets

Performance Measure	2009*	2015**
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station	$3.00/gge	$1.50/gge
* To verify progress toward 2015 ** Subsequent projects to validate 2015 target		

Cooperative Agreements

ChevronTexaco
HYUNDAI
UTC Fuel Cells
A United Technologies Company

DAIMLERCHRYSLER
bp
(1)

Ford
bp
(1)

GM

(1) Fuel cells supplied by Ballard

Data Collection: Overview

Key Vehicle Data	Key Infrastructure Data
Stack Durability	Conversion Method
Fuel Economy (Dyno & On-Road) and Vehicle Range	Production Emissions
Fuel Cell System Efficiency	Maintenance, Safety Events
Maintenance, Safety Events	Hydrogen Purity/Impurities
Top Speed, Accel., Grade	Refueling Events, Rates
Max Pwr & Time at 40C	H_2 Production Cost
Freeze Start Ability (Time, Energy)	Conversion, Compression, Storage and Dispensing Efficiency
Continuous Voltage and Current (or Power) from Fuel Cell Stack, Motor/Generator, Battery & Key Auxiliaries: (Dyno & On-Road)	

Data Collection: Diverse Geography

Cold, Moderate, Hot/Humid, Hot/Arid Climates

Data Collection & Analysis Process

Raw Data, Reports

Hydrogen Secure Data Center (HSDC)
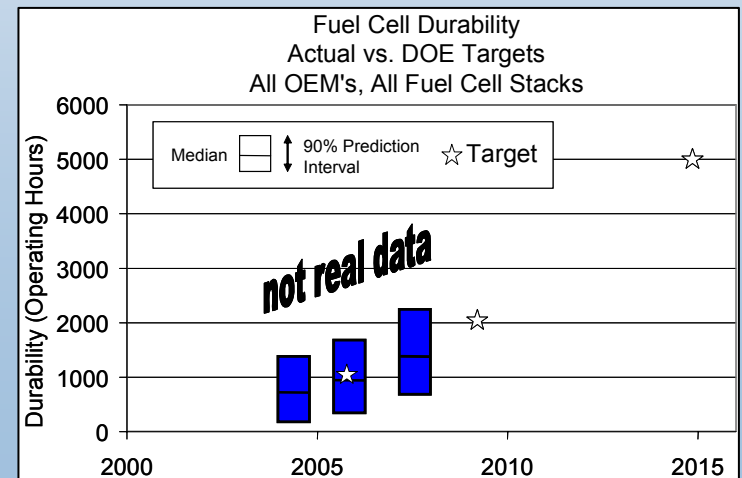
- @ NREL: Strictly Controlled Access

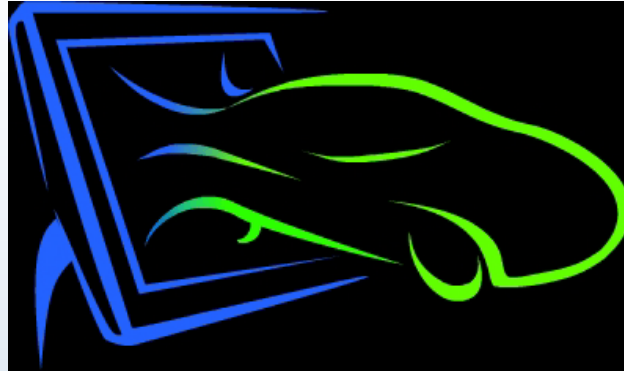- Detailed Analyses, Data Products, Internal Reports

- HSDC ADVISOR

Composite Data Products

- Pre-Agreed Upon Aggregate Data Products

- No Confidential Information

Fuel Cell Durability
Actual vs. DOE Targets
All OEM's, All Fuel Cell Stacks

Median 90% Prediction Interval ☆ Target

not real data

Durability (Operating Hours)
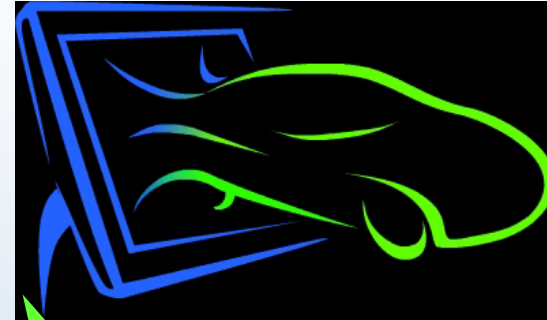
Analysis Example: HSDC ADVISOR
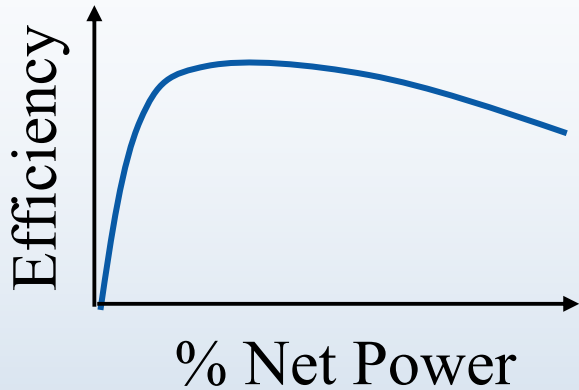

- Objectives:

  – "HSDC" ADVISOR model of each vehicle
    - Validate using real world data
    - Permits normalized comparisons of performance

  – Utilize validated models to:
    - better assess state of technology
    - inform DOE targets, trade studies, decisions
    - refocus research and development
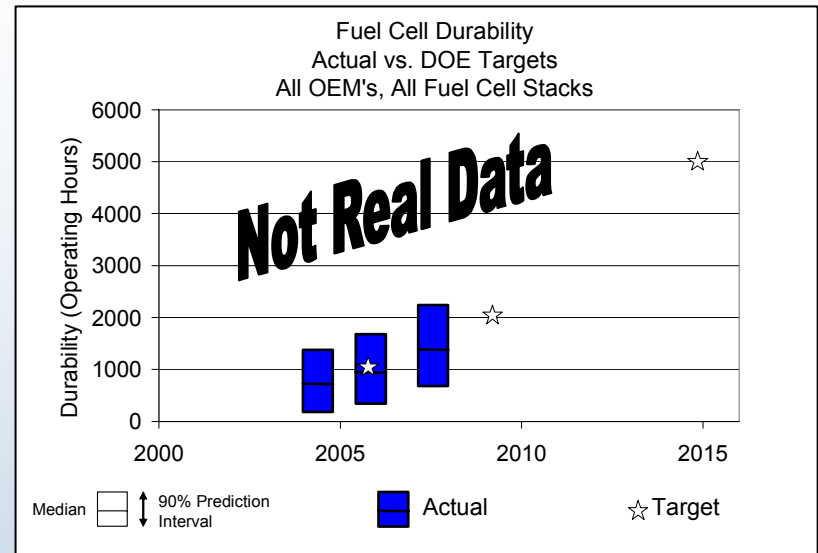
Analysis Example: ADVISOR

Vehicle, Power Plant Parameter Summary	
Include parameters for each vehicle and power plant	
Report Date	insert report date
Automaker	insert automaker
Parameter	**Units**
veh_CD [1]	dimensionless
veh_FA [1]	m2
Vehicle Mass [1]	kg
veh_front_wt_frac [1]	dimensionless
veh_cg_height [1]	m
veh_wheelbase [1]	m
Fuel Cell System	
c. Power Rating (net)	kW
Propulsion Battery or Capacitor	
c. Maximum Rated Ampere-Hour Capacity	Ampere*hrs
Electric Propulsion Motor	
b. Peak Power Rating	kW

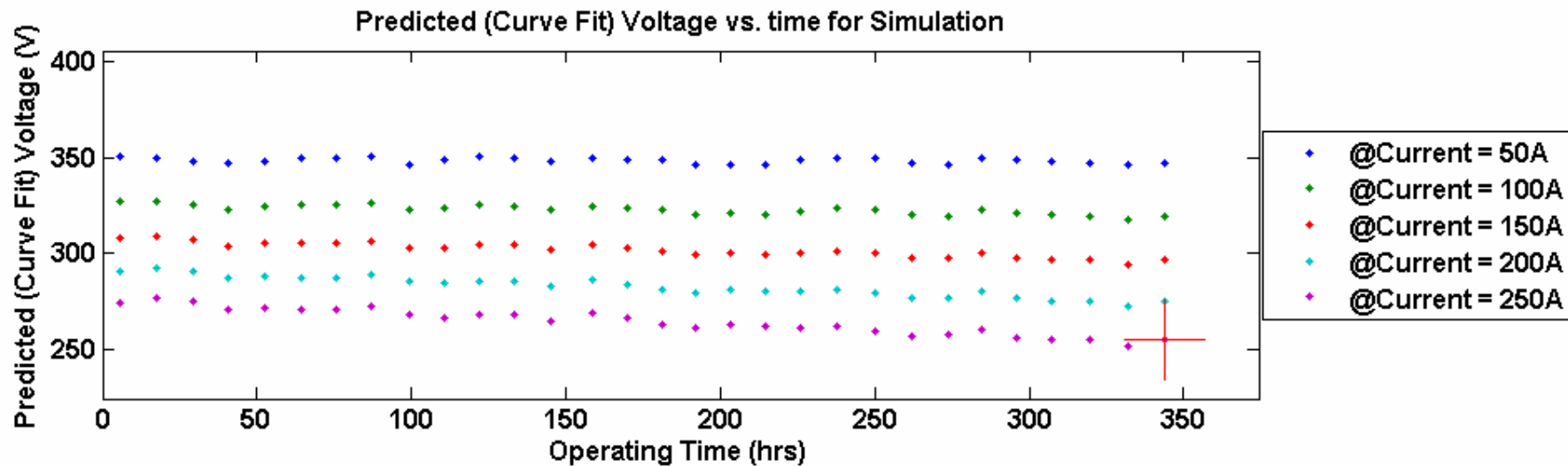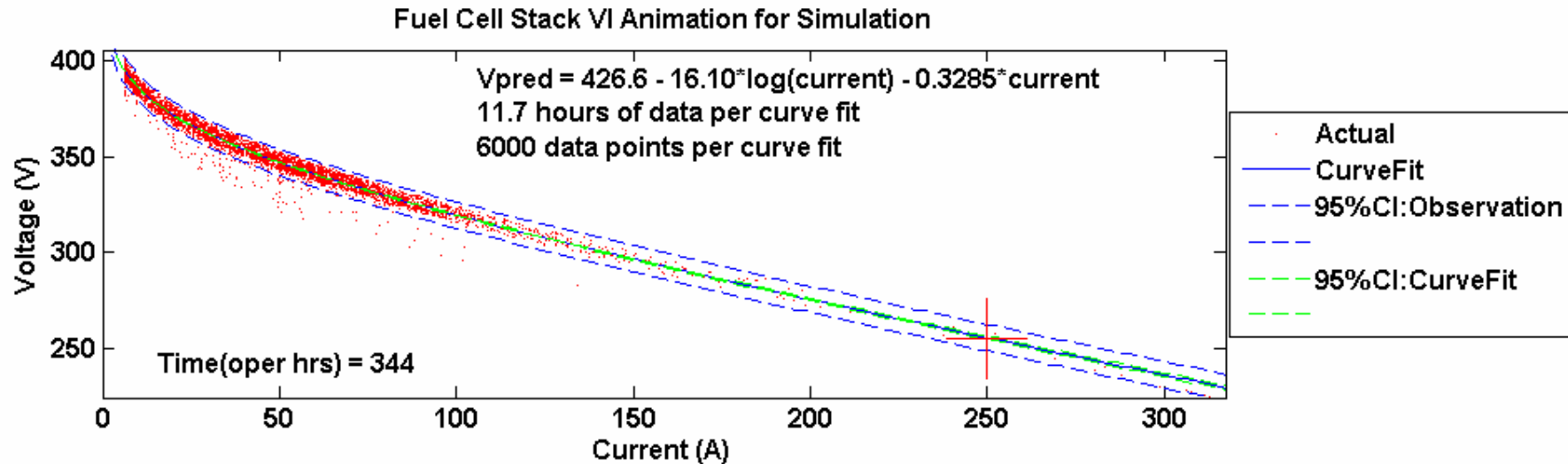ADVISOR vs. Actual Fuel Economy
(Dummy data)
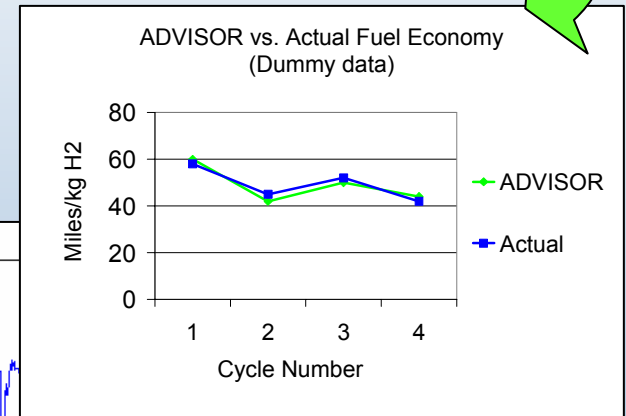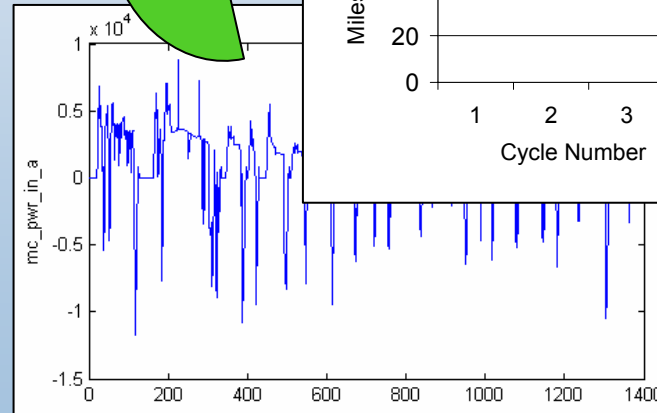
Analysis Example: Stack Degradation

- ## Relevant DOE Targets

  - 1000 hour lifetime in 2006
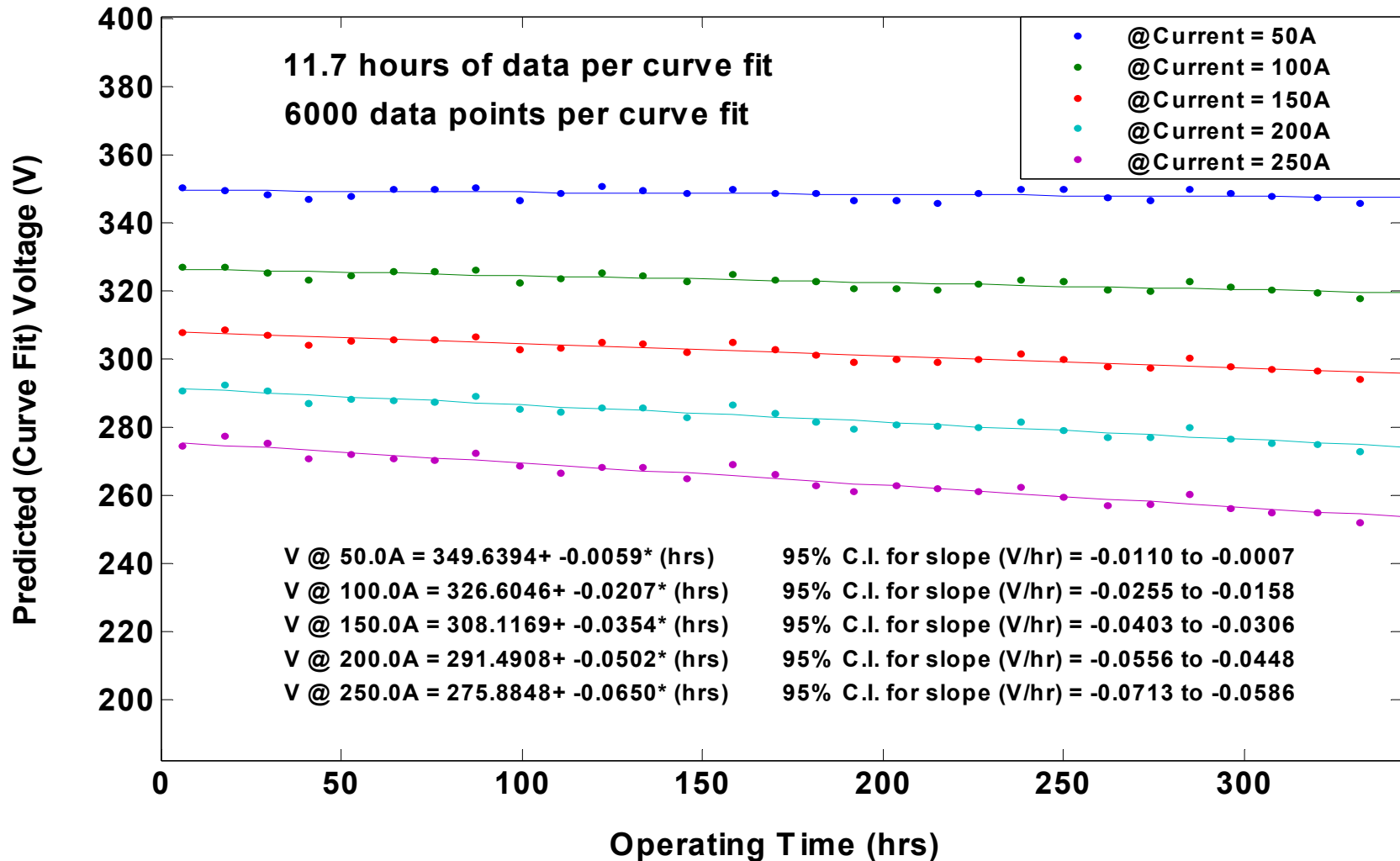 - 2000 hour lifetime in 2009
  - 5000 hour lifetime in 2015

- ## Data Collected to Quantify

  - Stack operating hours at "end of life"
  - Stack voltage and current throughout life

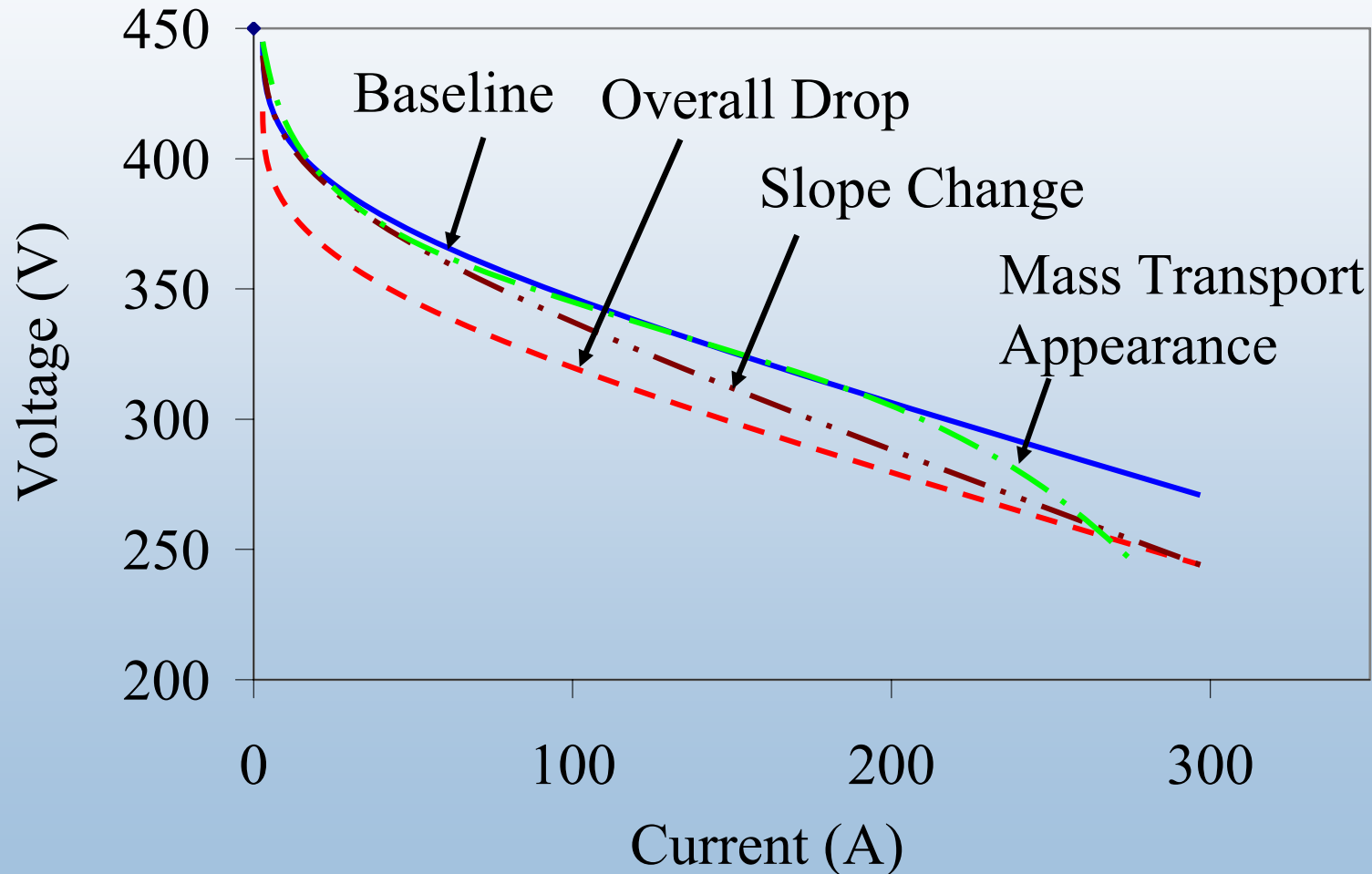# Analysis Example: Stack Degradation

Analysis Example: Stack Degradation

Predicted (Curve Fit) Voltage vs. time for Simulation

11.7 hours of data per curve fit

6000 data points per curve fit

- @Current = 50A
- @Current = 100A
- @Current = 150A
- @Current = 200A
- @Current = 250A

V @ 50.0A = 349.6394+ -0.0059* (hrs)   95% C.I. for slope (V/hr) = -0.0110 to -0.0007
V @ 100.0A = 326.6046+ -0.0207* (hrs)   95% C.I. for slope (V/hr) = -0.0255 to -0.0158
V @ 150.0A = 308.1169+ -0.0354* (hrs)   95% C.I. for slope (V/hr) = -0.0403 to -0.0306
V @ 200.0A = 291.4908+ -0.0502* (hrs)   95% C.I. for slope (V/hr) = -0.0556 to -0.0448
V @ 250.0A = 275.8848+ -0.0650* (hrs)   95% C.I. for slope (V/hr) = -0.0713 to -0.0586

Predicted (Curve Fit) Voltage (V)

Operating Time (hrs)

Analysis Example: Stack Degradation

Various Fuel Cell Polarization Curve Changes

Analysis Example: Stack Degradation

– *In-situ* quantification of on-road stack degradation
  - *Early indication of status vs. targets*

– Automated analyses: MATLAB environment

– Supplements/complements Partner analyses

– Inform DOE/Partner R&D decisions
  - *e.g., polarization curve "shape change" could shed light on dominant decay mechanisms on which to focus*

Summary

- **Objectives**
  - Demonstrate/Validate "System" Solutions
  - Identify Status of Technology
  - Re-Focus Research and Development
  - Support Commercialization Decision by 2015

- **Program Well Underway**
  - 4 Cooperative Agreements Awarded
  - Detailed vs. Composite Data
  - Data Analysis Begun
    - Current ADVISOR modeling encouraging
    - Stack degradation analysis promising