

# Modeling Grid-Connected Hybrid Electric Vehicles Using ADVISOR

Annual Battery Conference

Long Beach, California

January 9, 2001

Tony Markel and Keith Wipke

([ADVISOR@nrel.gov](mailto:ADVISOR@nrel.gov))

National Renewable Energy Laboratory

Golden, Colorado





## Disclaimer and Government License

This work has been authored by Midwest Research Institute (MRI) under Contract No. DE-AC36-99GO10337 with the U.S. Department of Energy (the "DOE"). The United States Government (the "Government") retains and the publisher, by accepting the work for publication, acknowledges that the Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for Government purposes.

Neither MRI, the DOE, the Government, nor any other agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the Government or any agency thereof. The views and opinions of the authors and/or presenters expressed herein do not necessarily state or reflect those of MRI, the DOE, the Government, or any agency thereof.



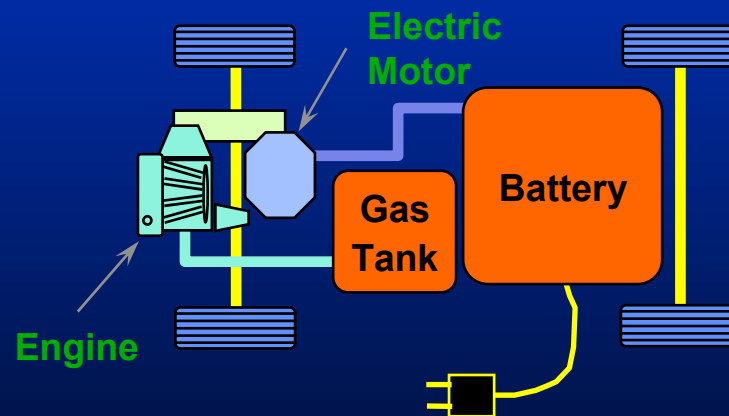
# Presentation Outline

- Grid-connected hybrid vehicle concept
- Vehicle design problem and process
- Energy management strategy parametric study
- Summary and conclusions

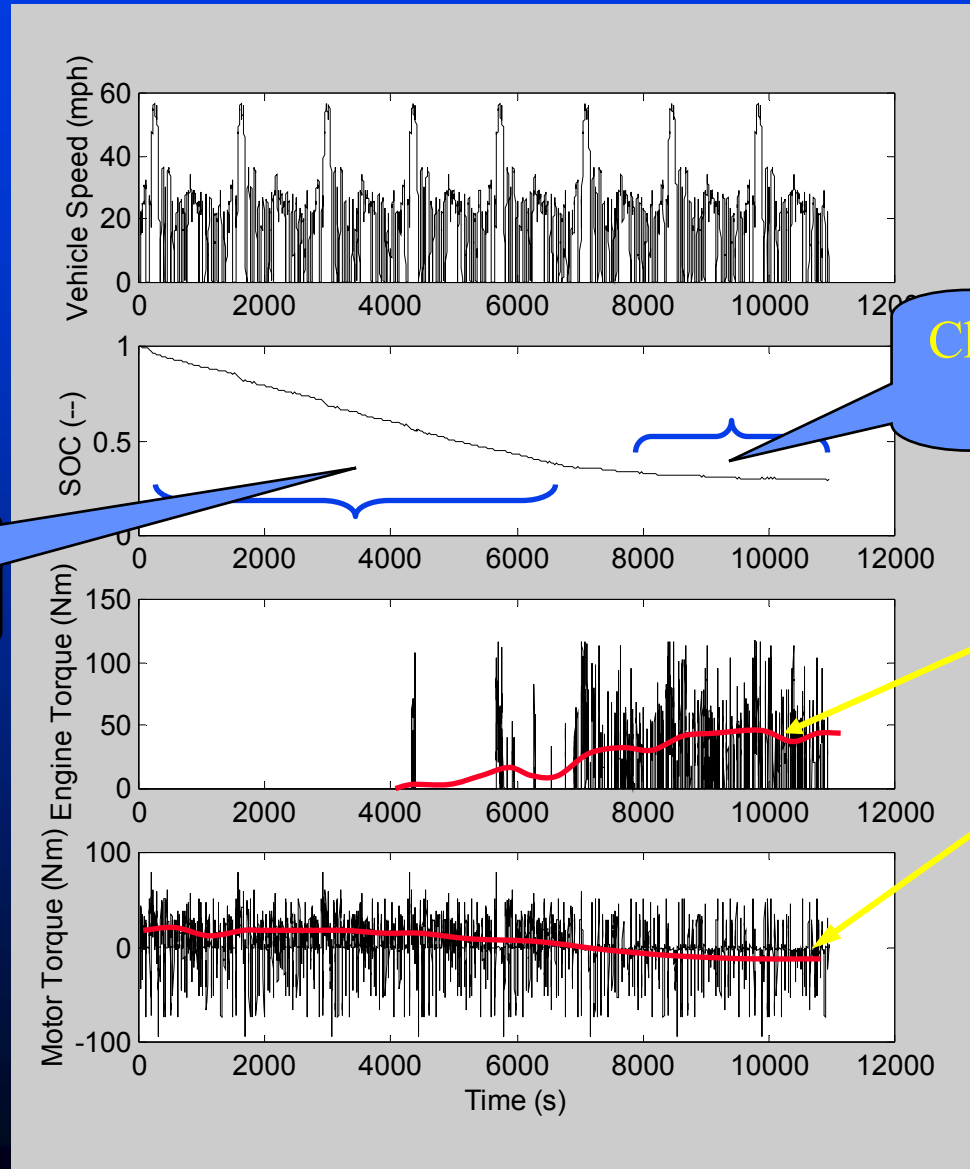


# Grid-Connected Hybrid Vehicle Concept

- EV-like vehicle
  - large battery/motor
  - small engine
  - all electric range
- Grid electricity used to offset petroleum fuel usage



# Typical Grid-Connected Vehicle Operation



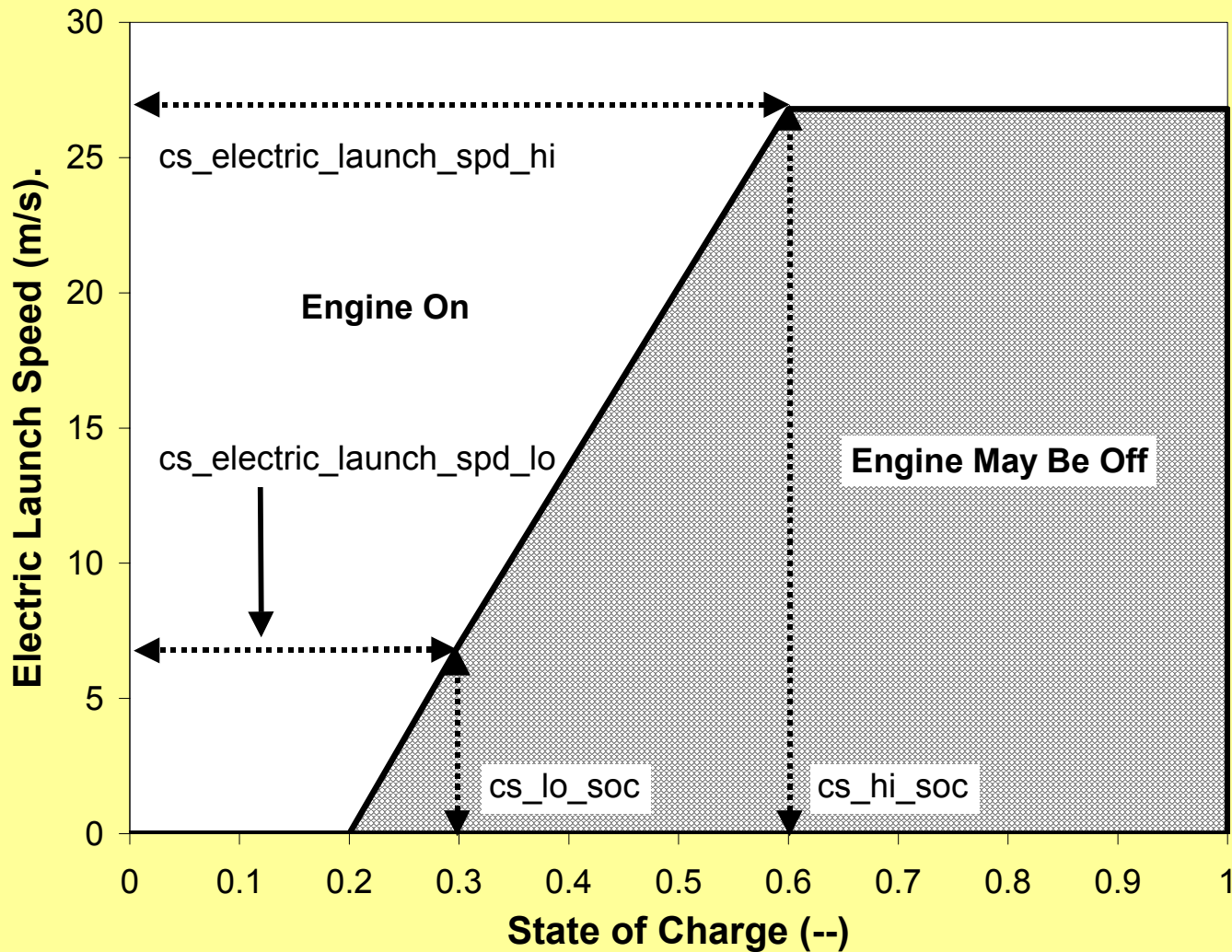
Charge-Depleting Behavior

Charge-Sustaining Behavior

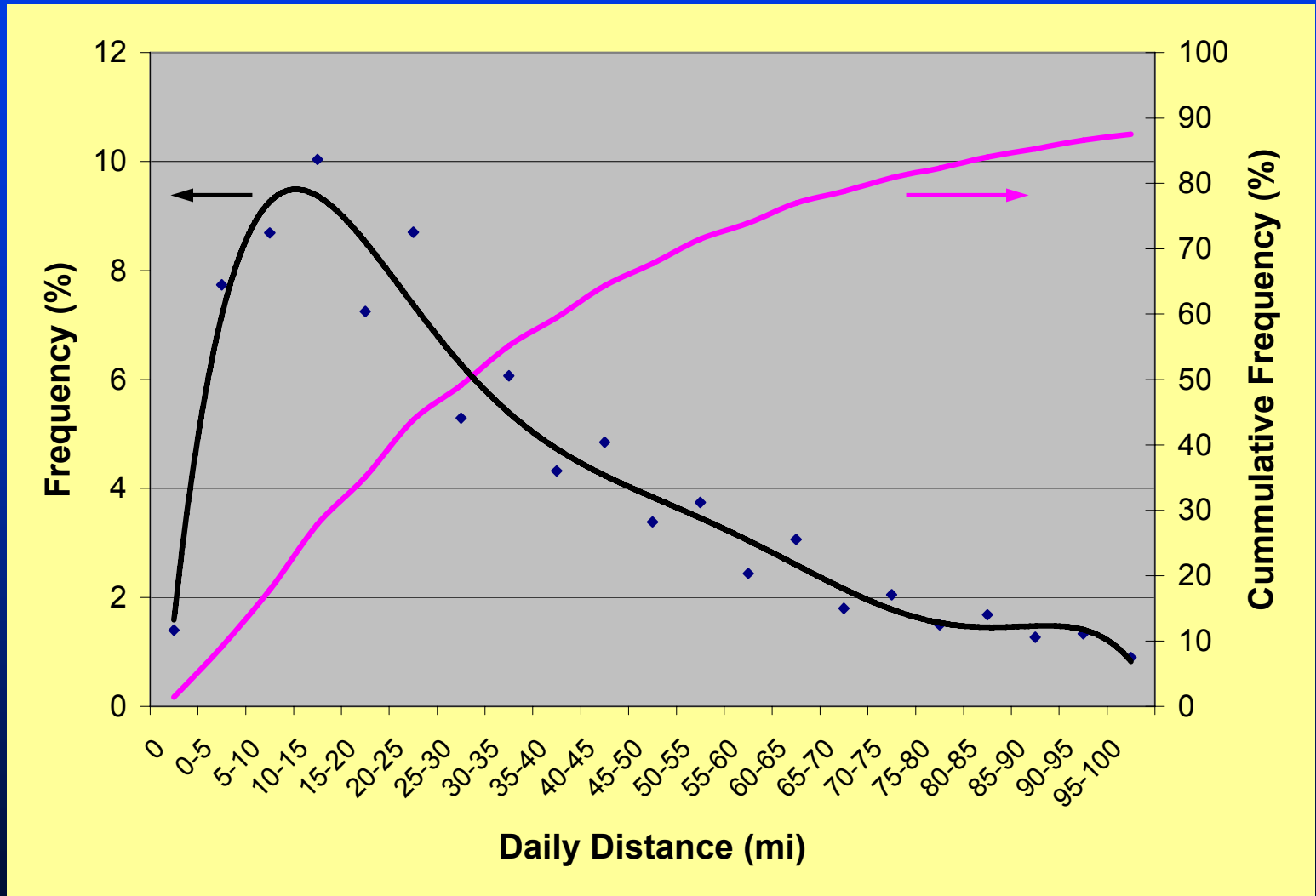
Torque Moving Average



# Engine State Based on Battery State of Charge and Vehicle Speed



# Personal Travel Characteristics Based on 1995 NPTS Data



# Grid-Connected Hybrid Vehicle Benefits

- No range penalty of EVs
  - on-board “back-up” engine
- Smaller incremental cost than pure EV
  - smaller battery pack
- Displacement of petroleum fuel
- Utility load leveling
- Possible PZEV qualification under CARB ZEV mandate





# Design Problem Constraints and Assumptions

- Constraints

- Acceleration performance
  - 0-60 mph in 9.5s
  - 50-70 mph in 5.1s
- Gradeability
  - 7.2% @ 50 mph for 15 min
  - 7.2% @ 30 mph for 30 min
- Electric range
  - 40 miles on UDDS cycle
- Drive cycle operation in “EV mode”
  - trace miss < 2 mph
- Drive cycle operation in “hybrid mode”
  - charge sustain above 20% SOC

- Assumptions

- present-day 5 passenger sedan vehicle characteristics
- permanent magnet traction motor
- nickel metal hybrid batteries
- turbo-diesel engine



# Analysis Process

- Define vehicle characteristics
- Size components for active constraints
- Perform parametric analysis of energy management parameters



# Component Sizing Results

- Engine size driven by charge-sustaining operation on drive cycle
- Motor size driven by drive cycle requirements
- Battery pack size driven by all-electric range

Parameter	Value	Units
Engine Power	38	kW
Motor Power	73.5	kW
Battery Power	88	kW
Battery Capacity	13.5	kWh
Vehicle Mass	1545	kg
Vehicle Test Weight	1681	kg

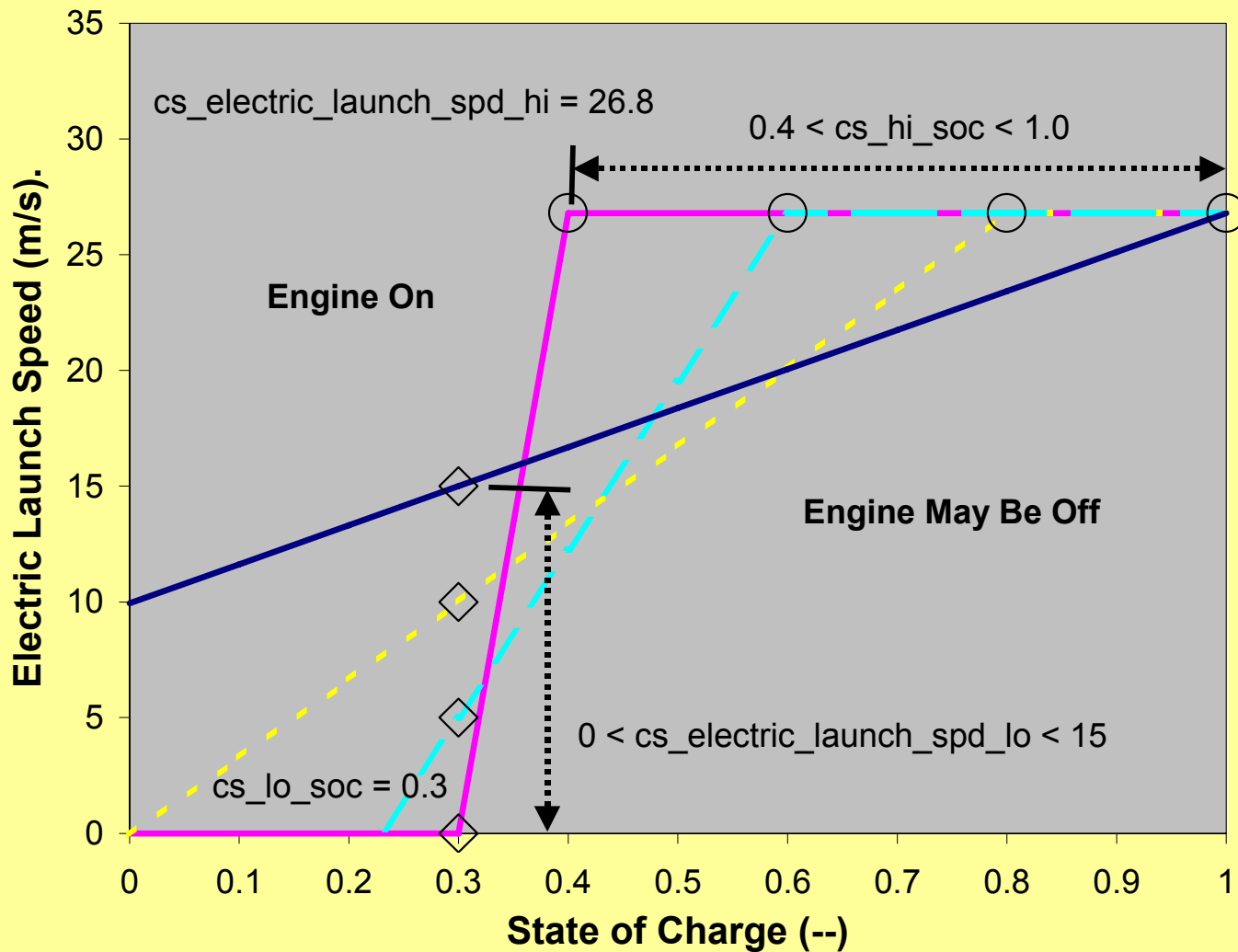


# Energy Management Strategy Parametric Study

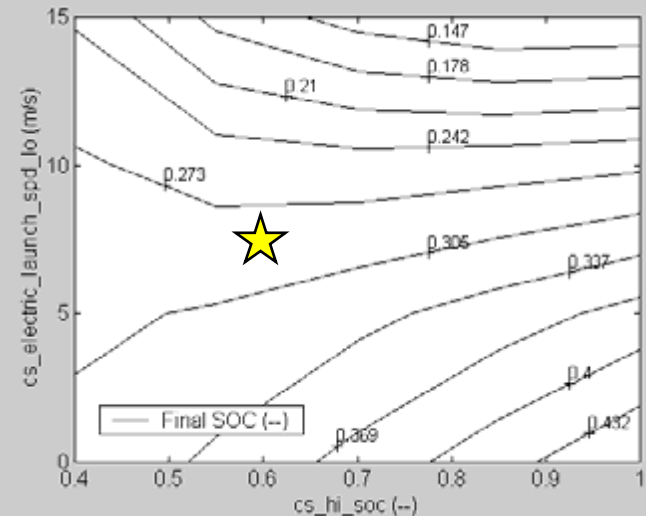
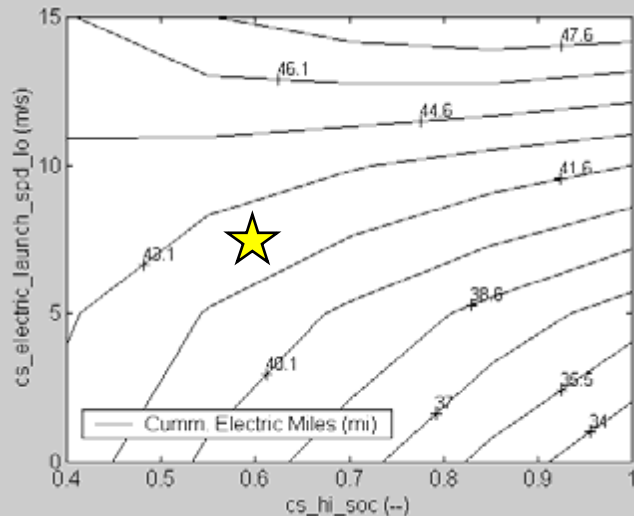
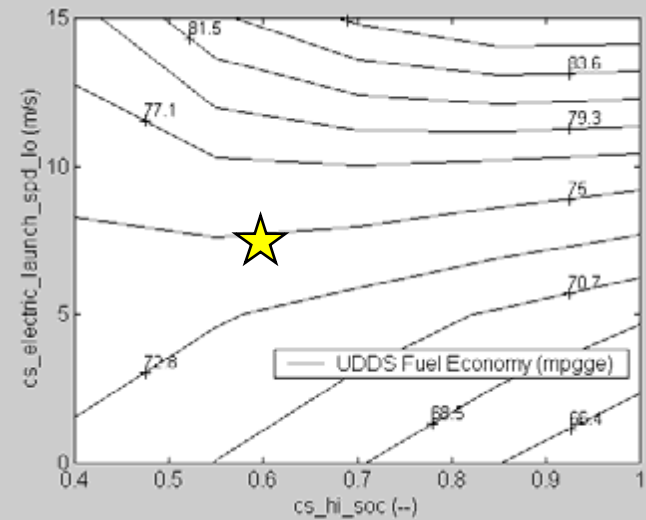
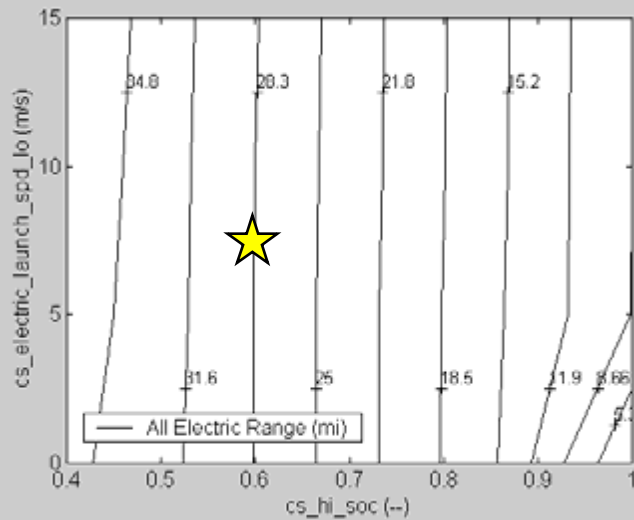
- Two design variables
  - cs\_hi\_soc
  - cs\_electric\_launch\_spd\_lo
- Four responses
  - All Electric Range
  - Cumulative EV Miles
  - Fuel Economy
  - Final SOC



# Parametric Study Engine State Design Space



# Parametric Study Results (star = design point)



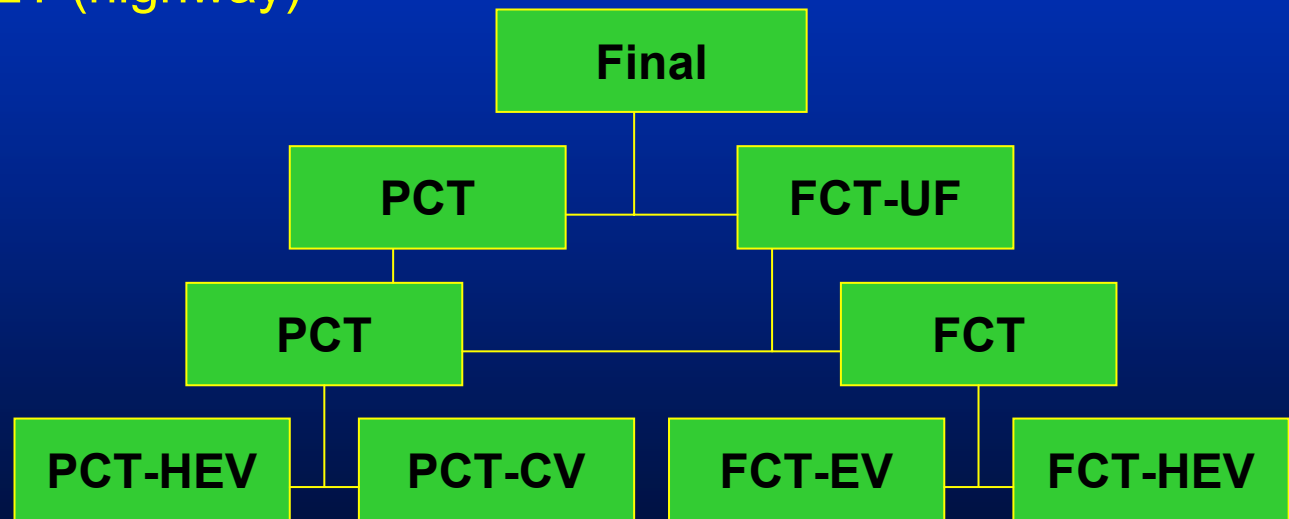
# Parametric Study Conclusions

- All electric range mainly a function of `cs_hi_soc`
- For `cs_electric_launch_spd_lo` settings greater than ~11 m/s charge-sustaining SOC falls to undesirable levels
- Equivalent fuel economy seems to be a function of cumulative EV miles and not all-electric range



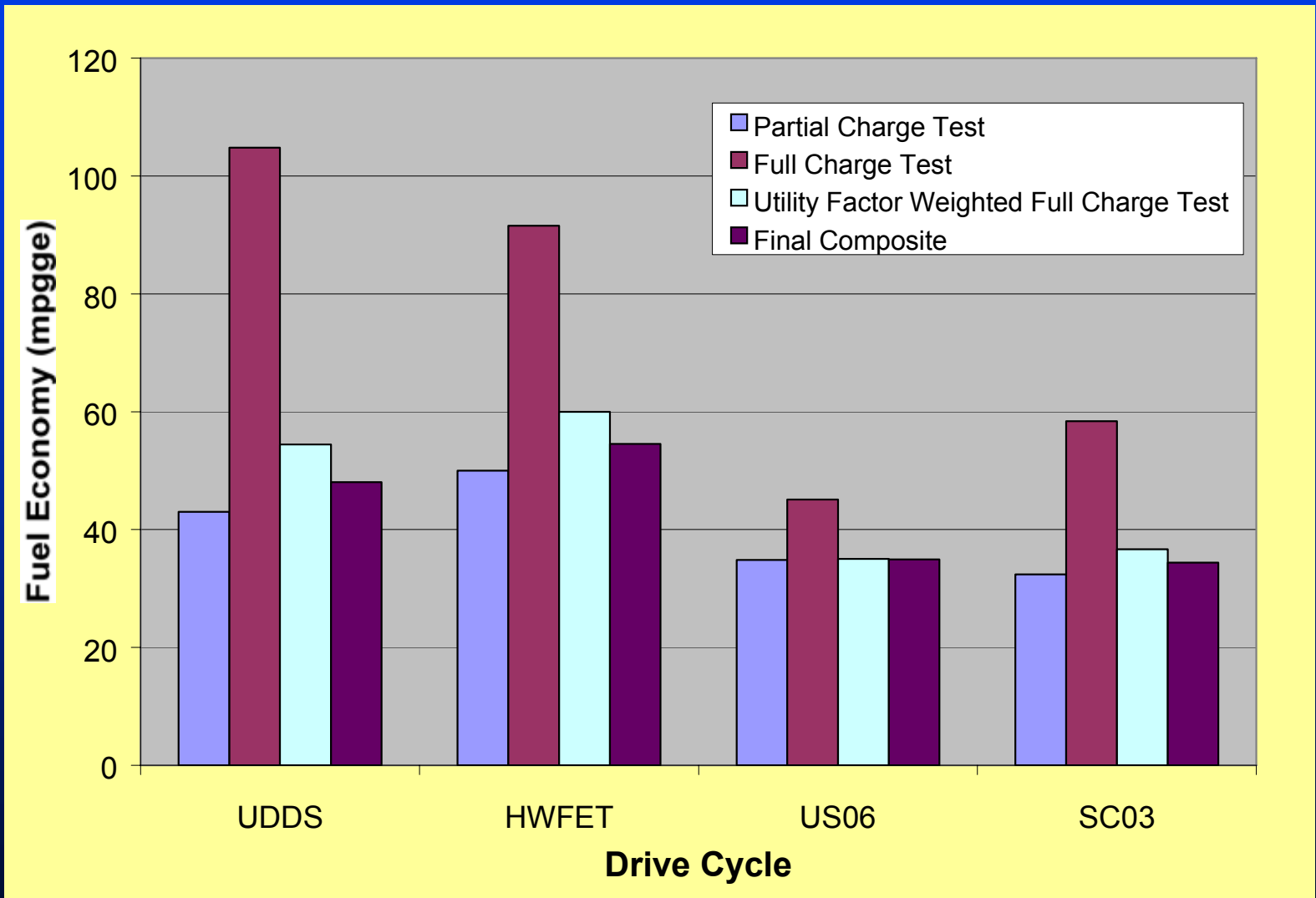
# SAE J1711 Test Procedure

- Purpose is to provide a means of comparison between various hybrid vehicle designs
- Compiles the results from four different tests performed on four different drive cycles
  - UDDS (city)
  - HWFET (highway)
  - US06
  - SC03





# SAE J1711 Fuel Economy Results



# Conclusions

- Analysis demonstrates that the grid-connected hybrid concept can help reduce consumption of petroleum
- Cost and commercialization issues not quantified in this study
- Demonstrated new capabilities in ADVISOR 3.0

