NREL/PR-540-40238

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)

National Renewable Energy Laboratory

Golden, Colorado

NREL, Center for Transportation Technologies and Systems

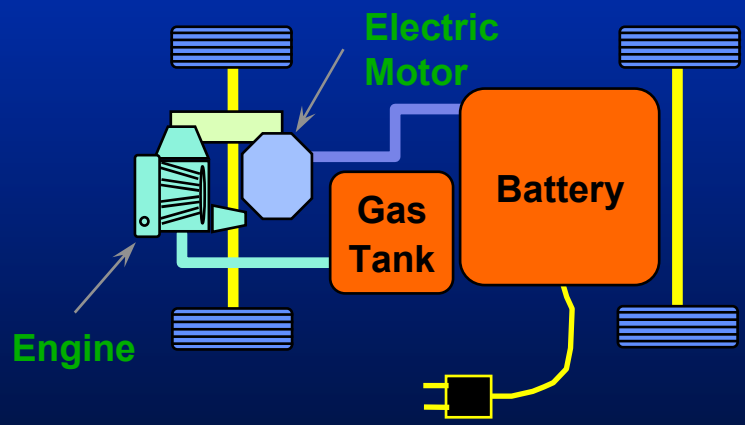
Disclaimer and Government License

Presentation Outline

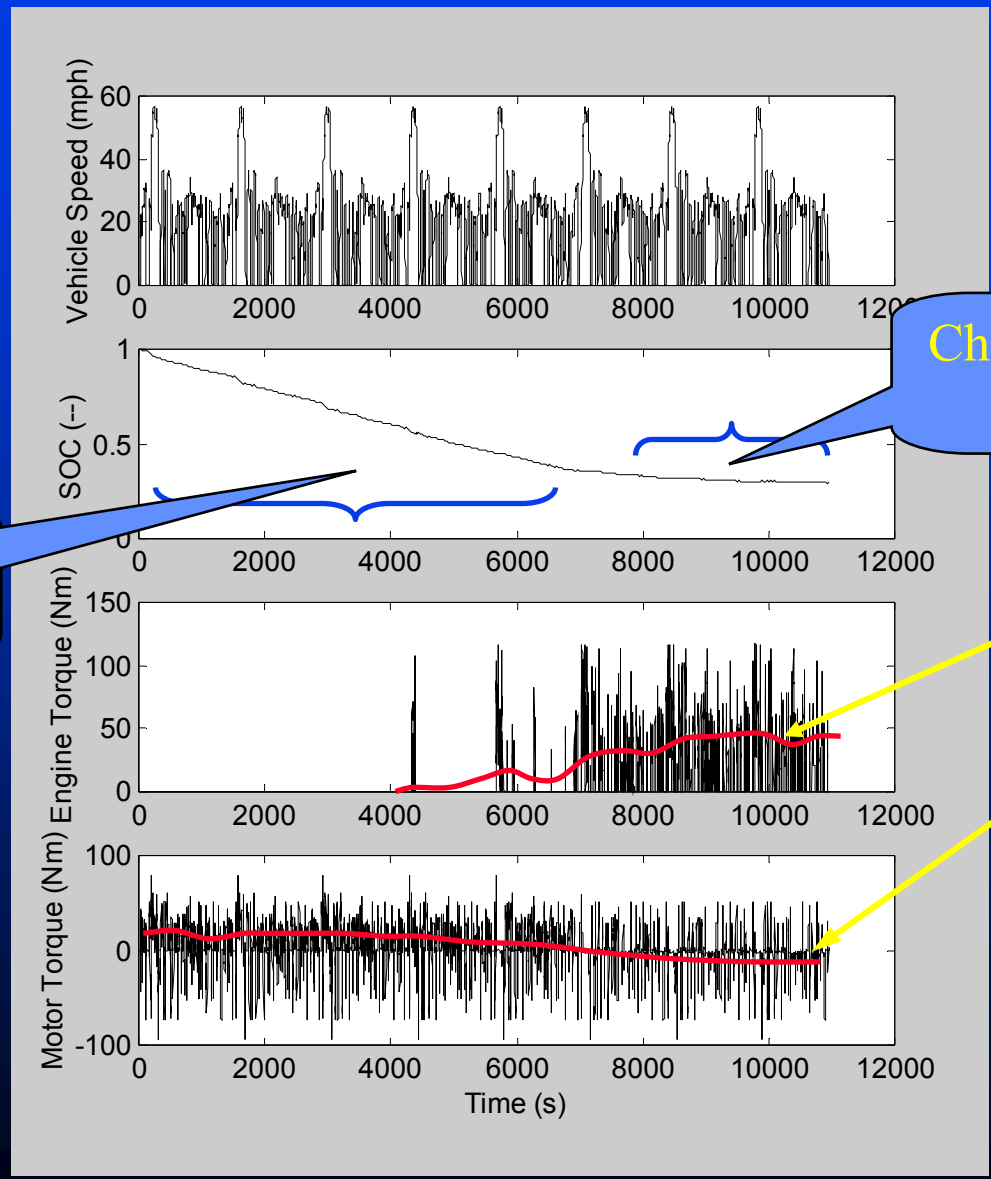
- Grid-connected hybrid vehicle concept
- Vehicle design problem and process
- Energy management strategy parametric study
- Summary and conclusions

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



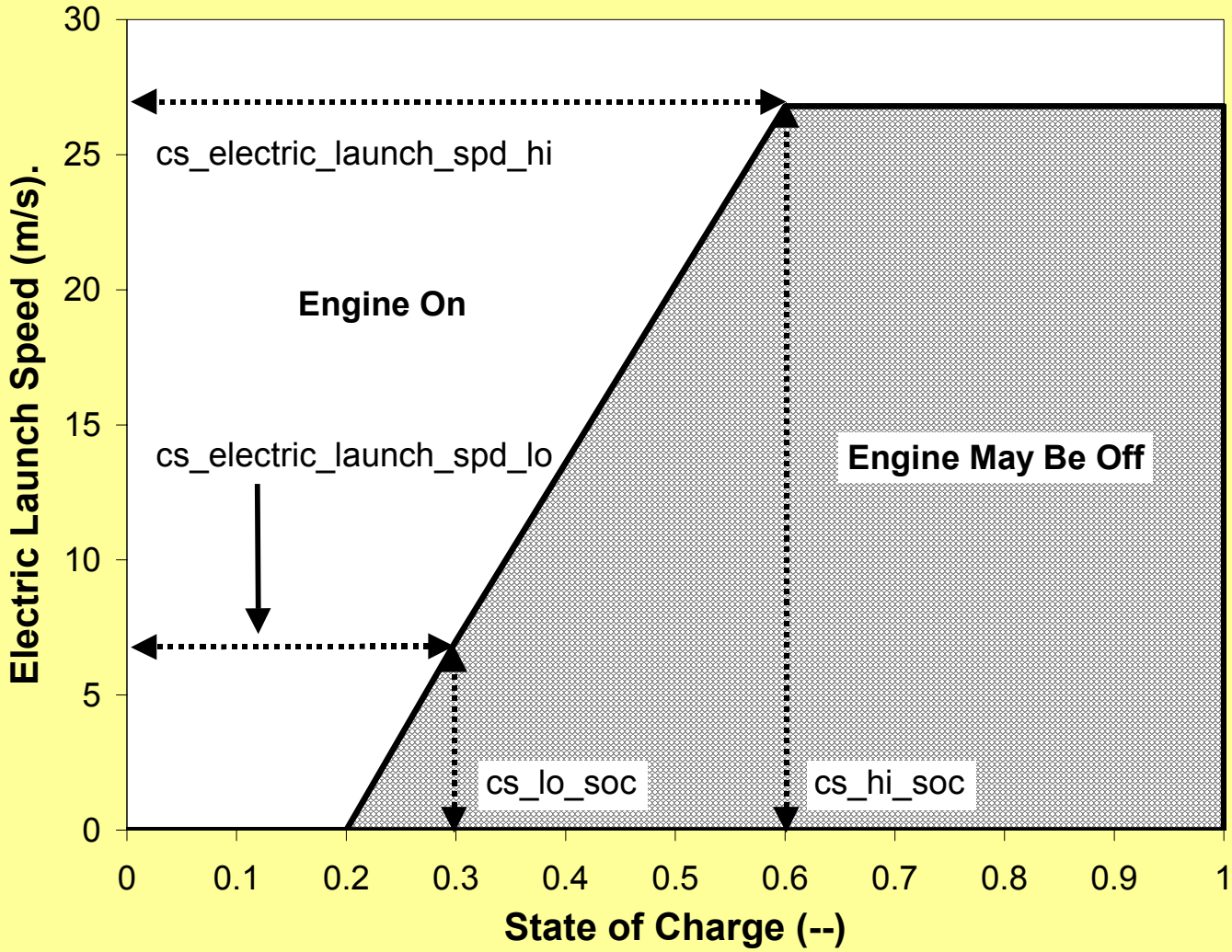
Charge-Depleting Behavior

Charge-Sustaining Behavior

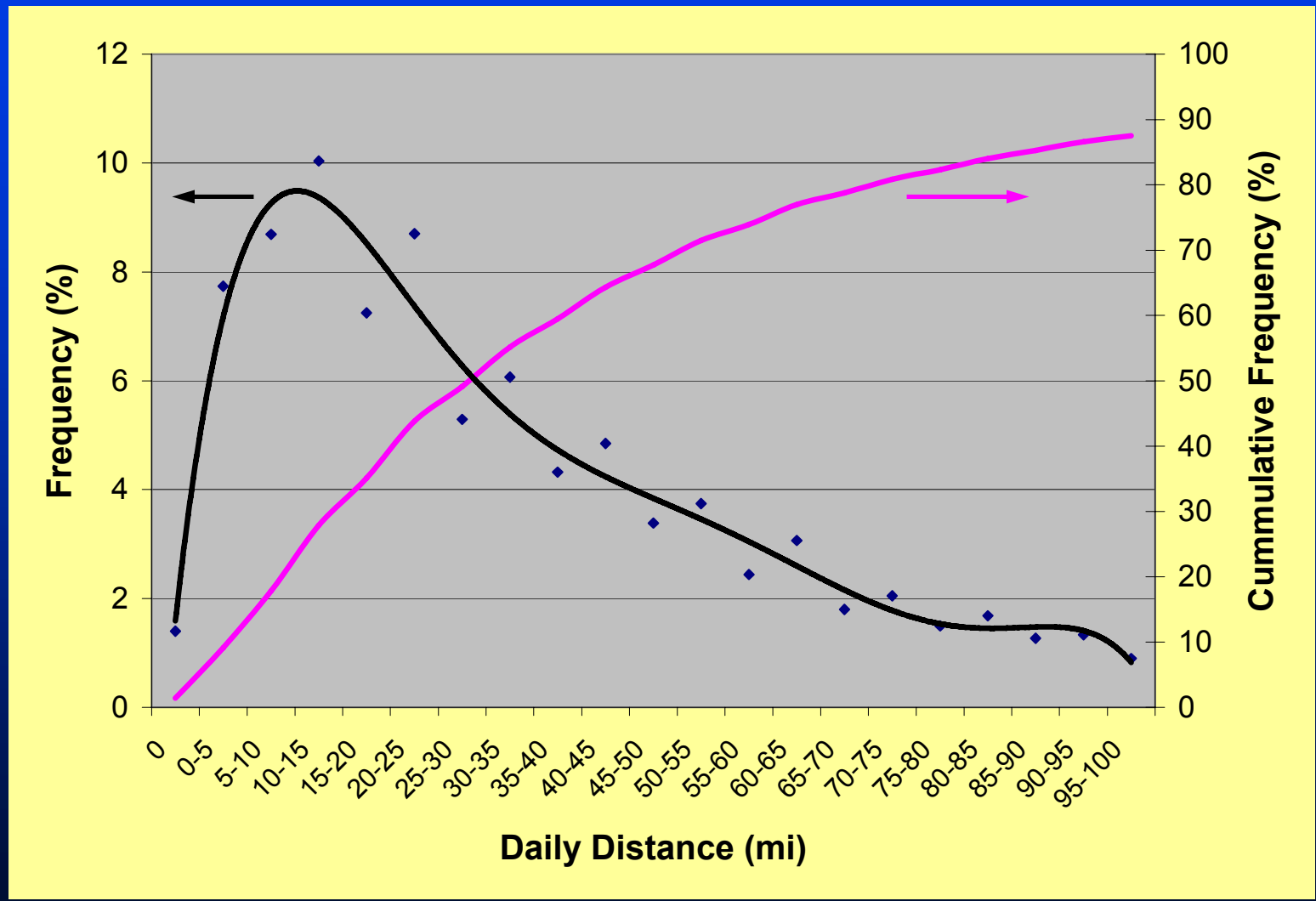
Torque Moving Average

SYSTEMS

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

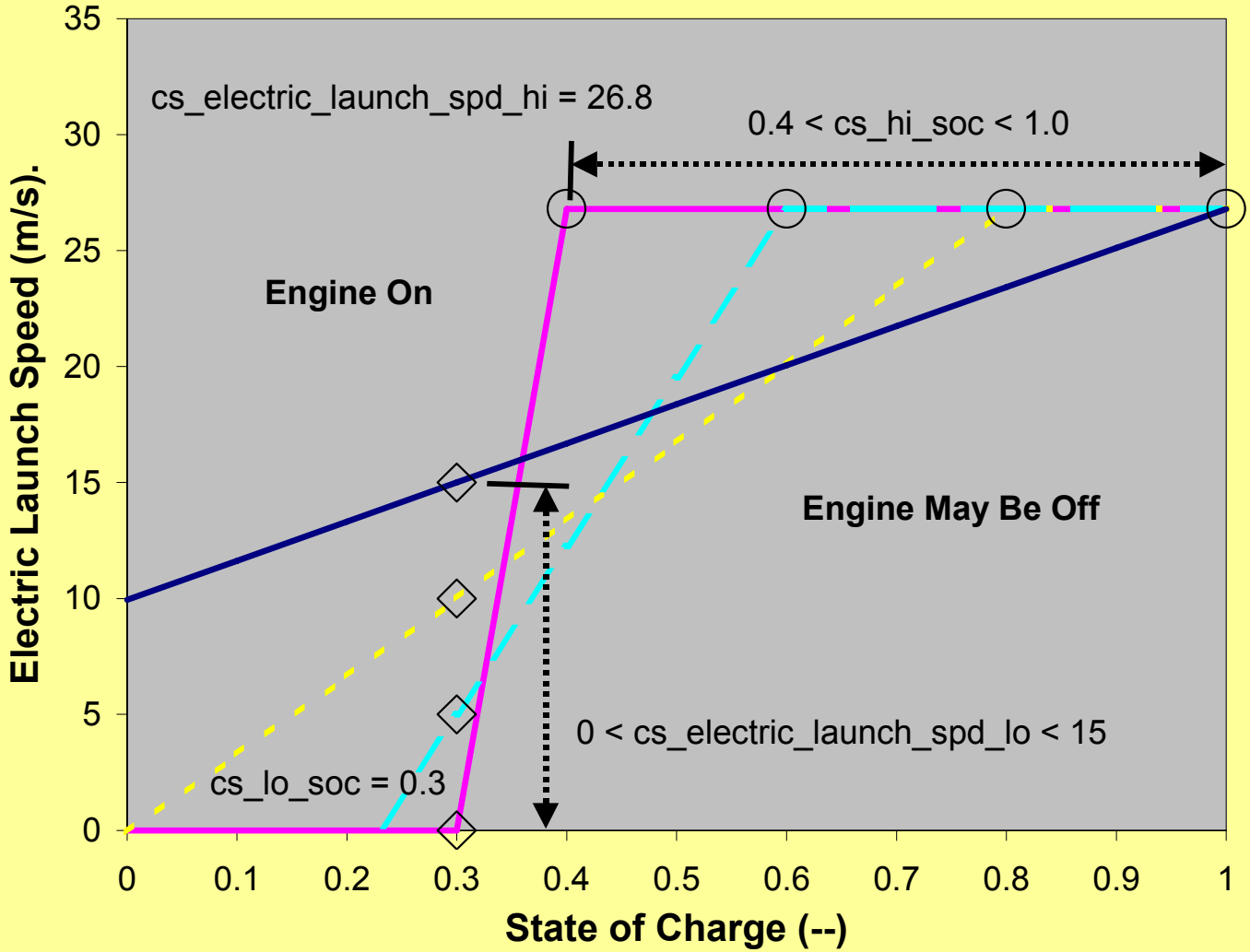
- Engine size driven by charge-sustaining operation on drive cycle
- Motor size driven by drive cycle requirements
- Battery pack size driven by all-electric range

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

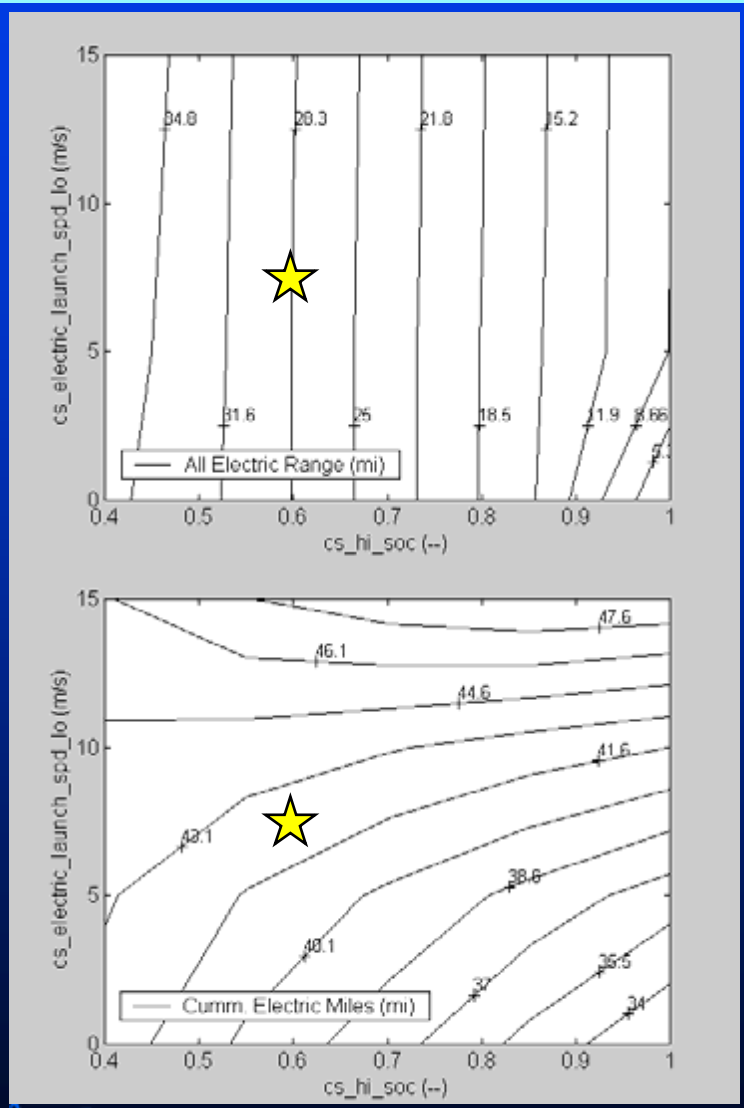
Energy Management Strategy Parametric Study

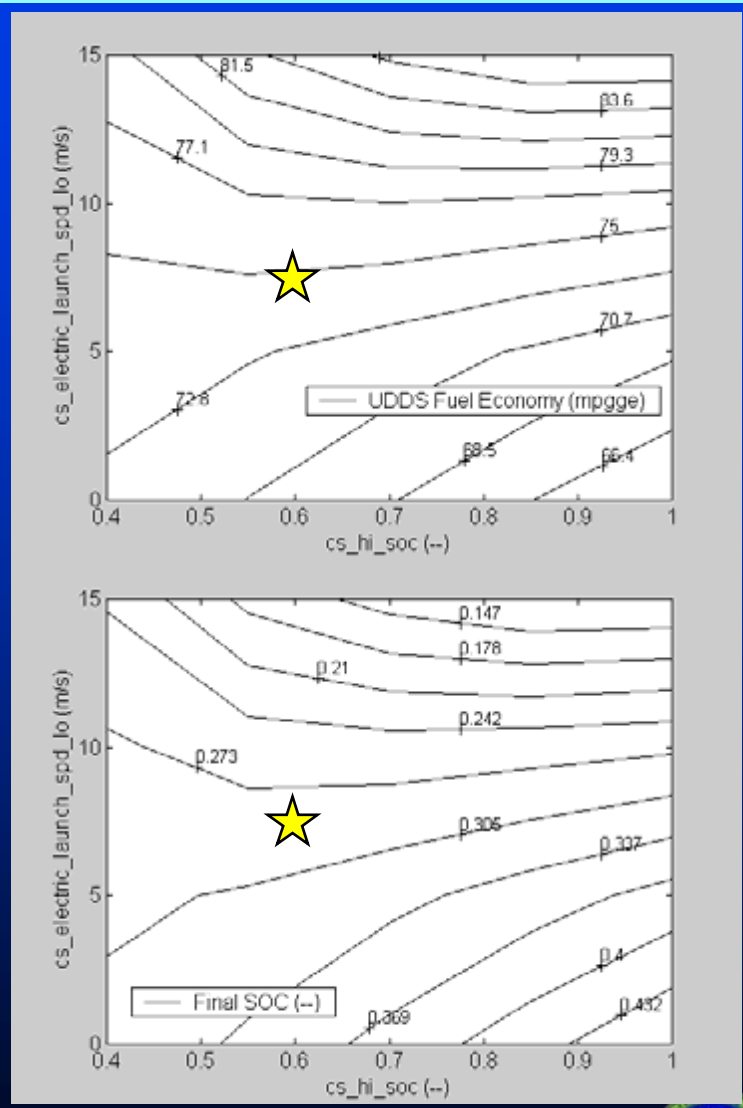
- Two design variables
  - cs_hi_soc
  - cs_electric_launch_spd_lo
- Four responses
  - All Electric Range
  - Cumulative EV Miles
  - Fuel Economy
  - Final SOC

Parametric Study Engine State Design Space



Parametric Study Results (star = design point)



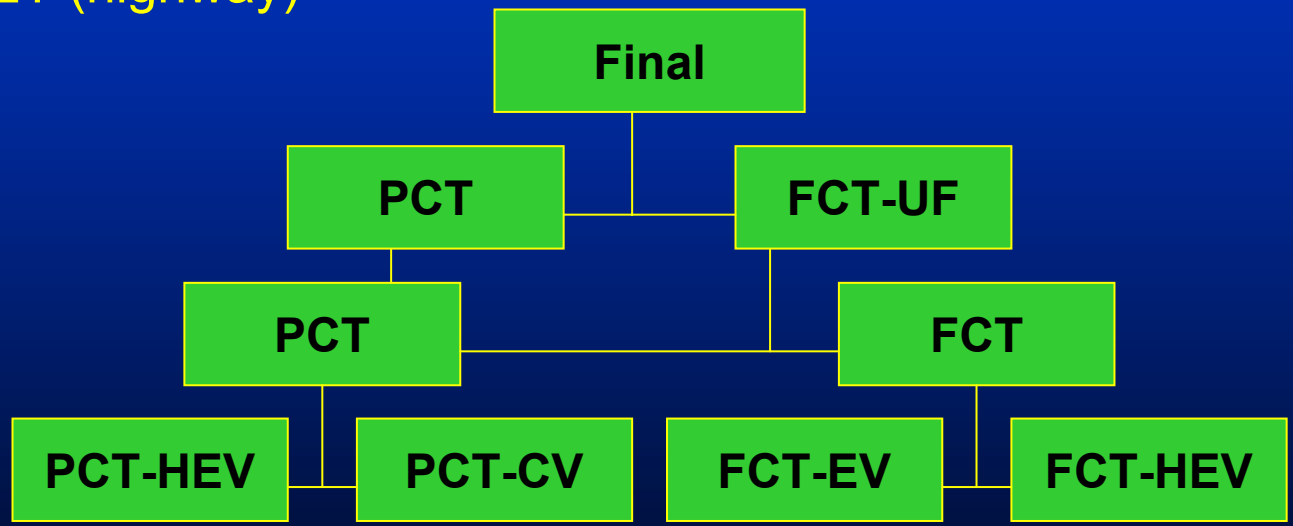


Parametric Study Conclusions

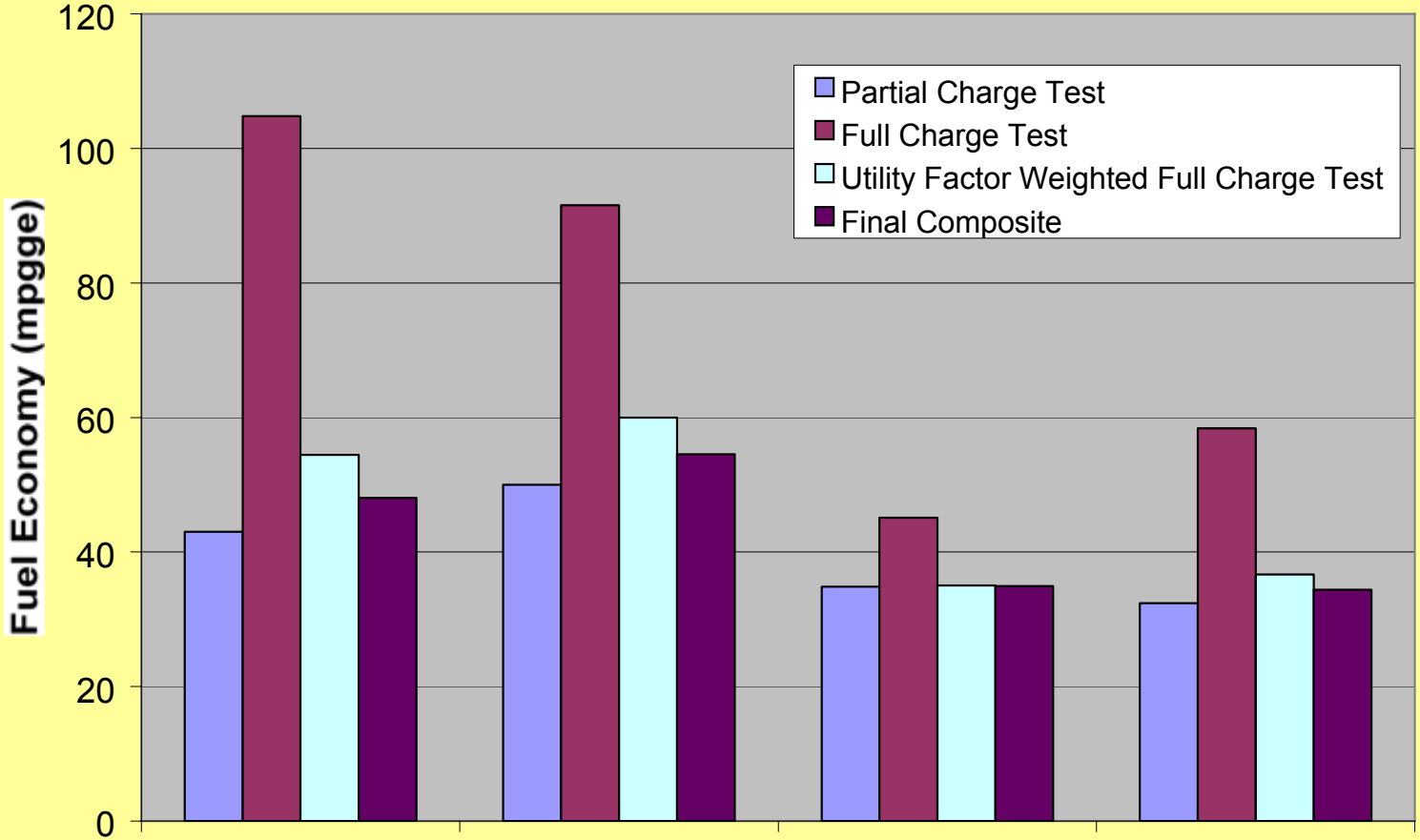
- All electric range mainly a function of cs_hi_soc
- For cs_electric_launch_spd_lo settings greater than ~11 m/s charge-sustaining SOC falls to undesirable levels
- Equivalent fuel economy seems to be a function of cumulative EV miles and not all-electric range

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