Energy Management Strategies for Fast Battery Temperature Rise and Engine Efficiency Improvement at Very Cold Conditions

2010 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

June 08, 2010

Neeraj Shidore

Argonne National Laboratory

Sponsored by Lee Slezak

Project ID # VSS014

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project Overview

Timeline

- Start : September 2009
- End : September 2010

Budget

- FY10: $250 K

Barriers

- PHEV battery power at cold temperature.
- Low engine efficiency at low temperature.

Partners

- Engine thermal model development at Argonne National Laboratory.

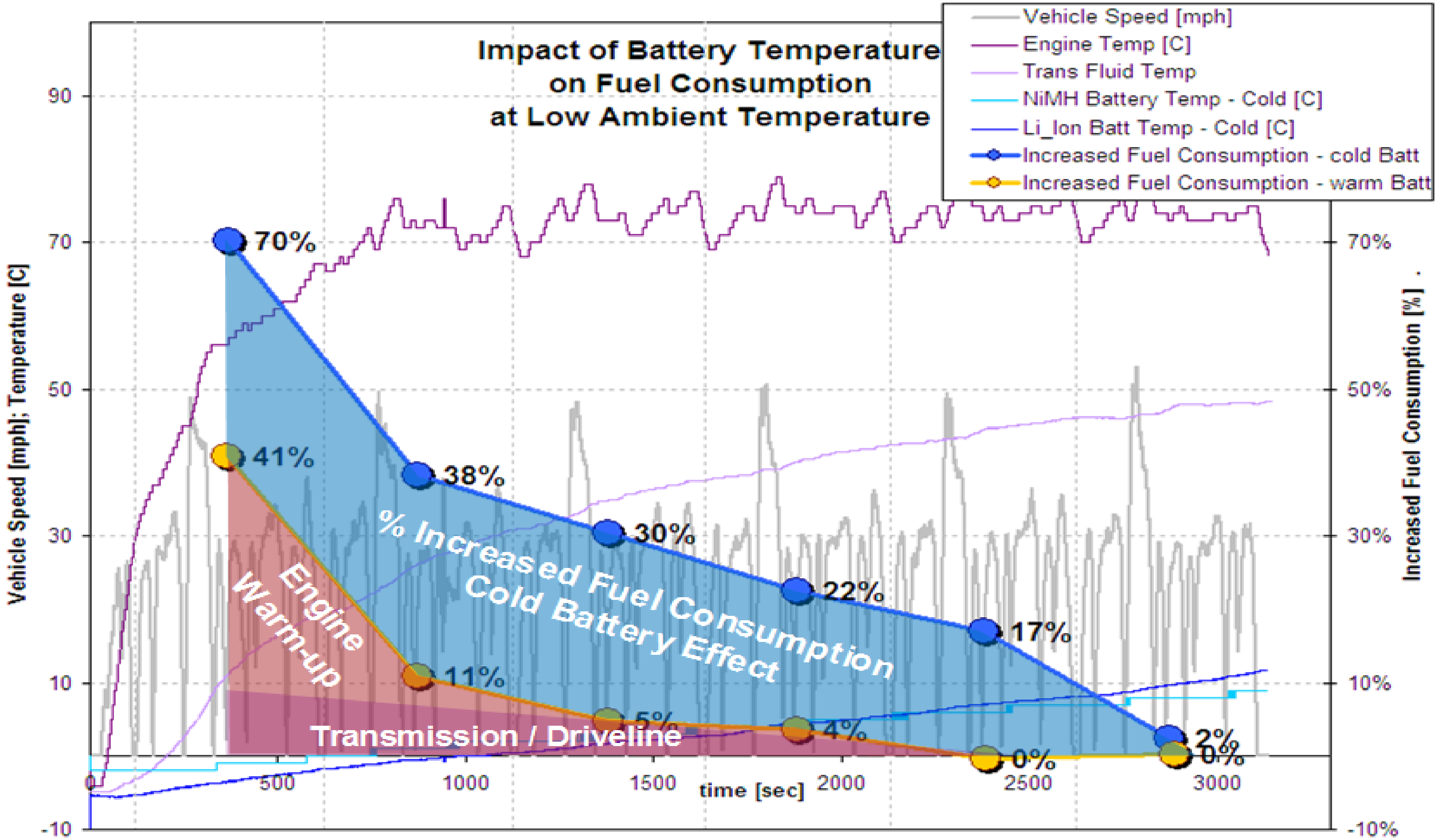
Research Objective

Evaluate various energy management strategies for fast battery temperature rise and engine efficiency improvement at cold temperatures.

The research is geared towards the following vehicle systems simulation and testing strategic goals –

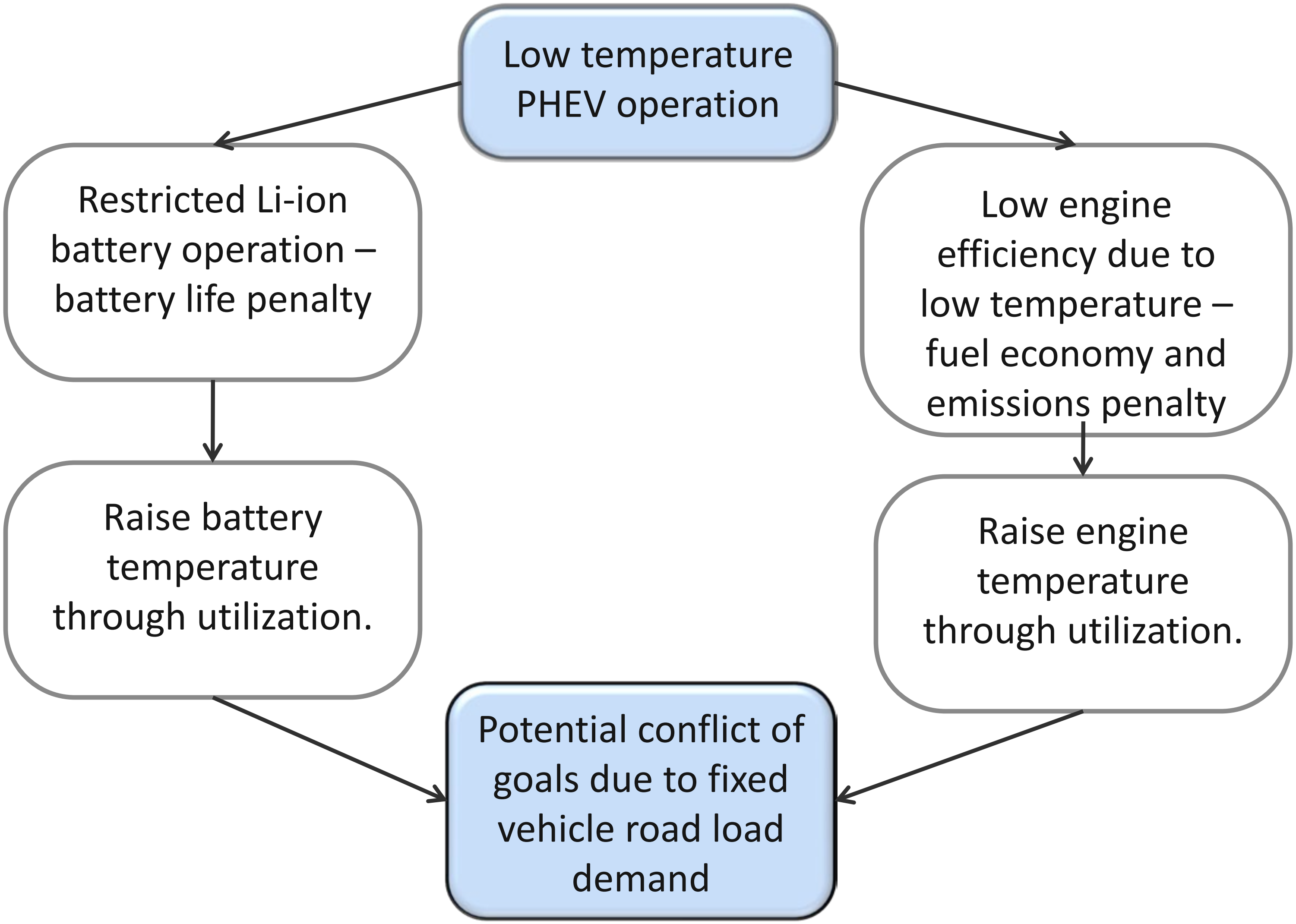
- Demonstrate market-readiness of grid connected vehicle technologies by 2015.
- Complete the successful deployment of AUTONOMIE as an industry standard advanced component and vehicle modeling and simulation tool, as well as the integration of a detailed vehicle cost model into AUTONOMIE.
- Validate, in a systems context, performance targets for deliverables from the Power Electronics and Energy Storage Technology R&D activities.
- Outcome will impact all vehicle level control strategies used to evaluate PHEV fuel consumption potential for DOE
- The higher the powertrain electrification, the more important cold start optimization becomes.

Research Objective - Problem Statement - Cold Battery and Engine Result in Significant Fuel Consumption Increase

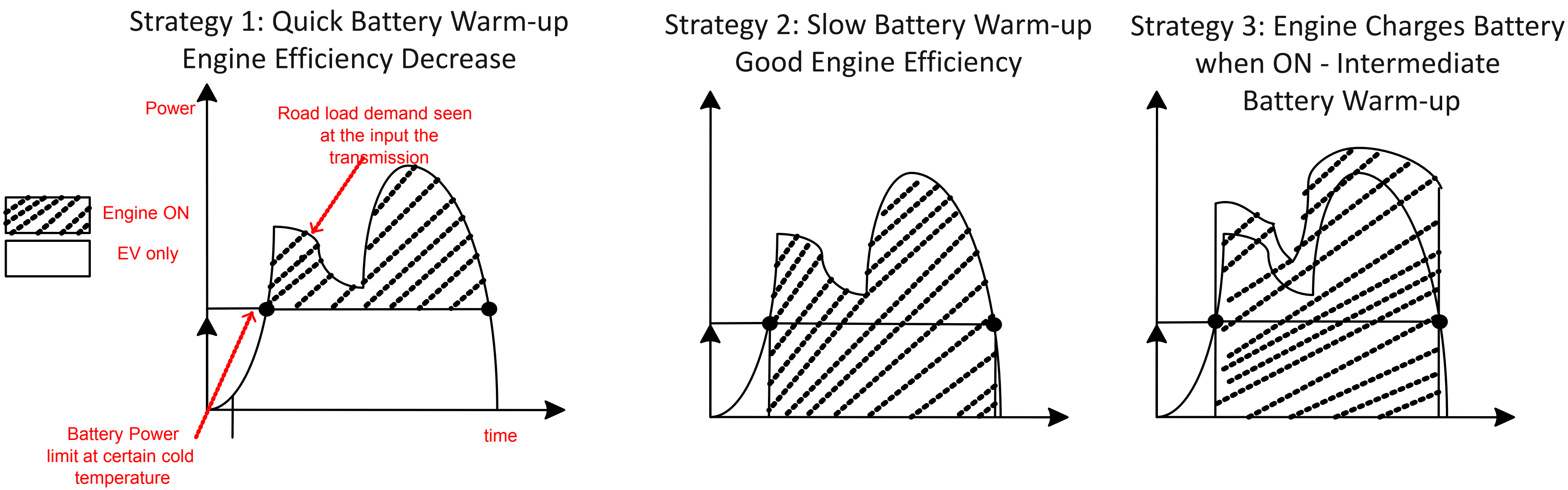


Plot from R. Carlson , et al, Hymotion PHEV Escape testing at Argonne National Laboratory

Problem Statement (Cont'd) - Increasing Battery and Engine Temperature is a Conflict for the Energy Management Strategy



Approach - Compare Different Energy Management Strategies to Quickly Raise Battery Temperature and Engine Efficiency



- Component level comparison:
  - Compare rate of temperature rise for the battery , engine.
- Vehicle level comparison:
  - Compare fuel consumption, Wh/mi , potential battery life impact (qualitatively), emissions (?) (qualitatively).
  - How strongly does the component level comparison and vehicle level comparison co-relate?

Experiment Method - Battery-in-the-Loop with Engine Thermal Model.

Real Battery

AUTONOMIE

Vehicle level control
and rest of the vehicle –
Prius PHEV.
Drive cycle – LA92

Engine thermal model

F. Jehlik, E.Rask et al – Engine model
(fuel consumption, engine temperature) = f (engine speed , torque, temperature)

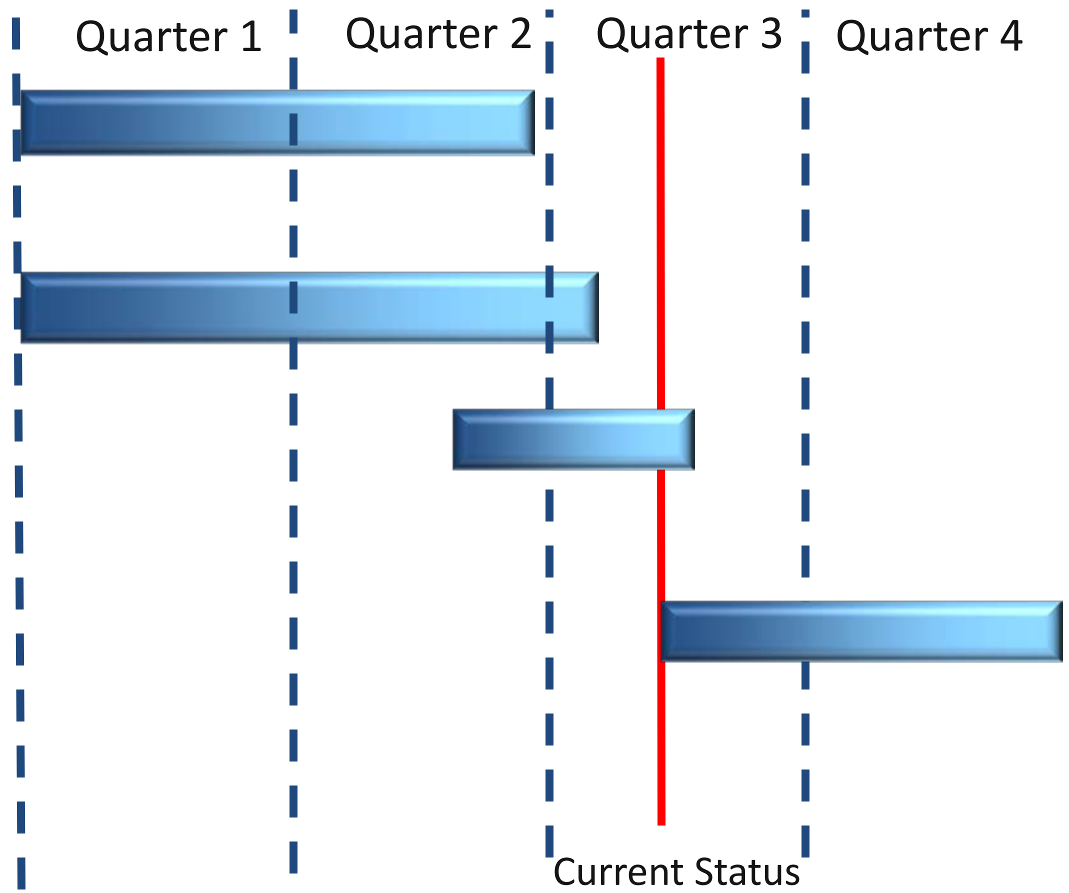
Milestones

Implement Battery in the loop in Autonomie

Development of engine thermal model (a separate project)

Integration of thermal model in Autonomie

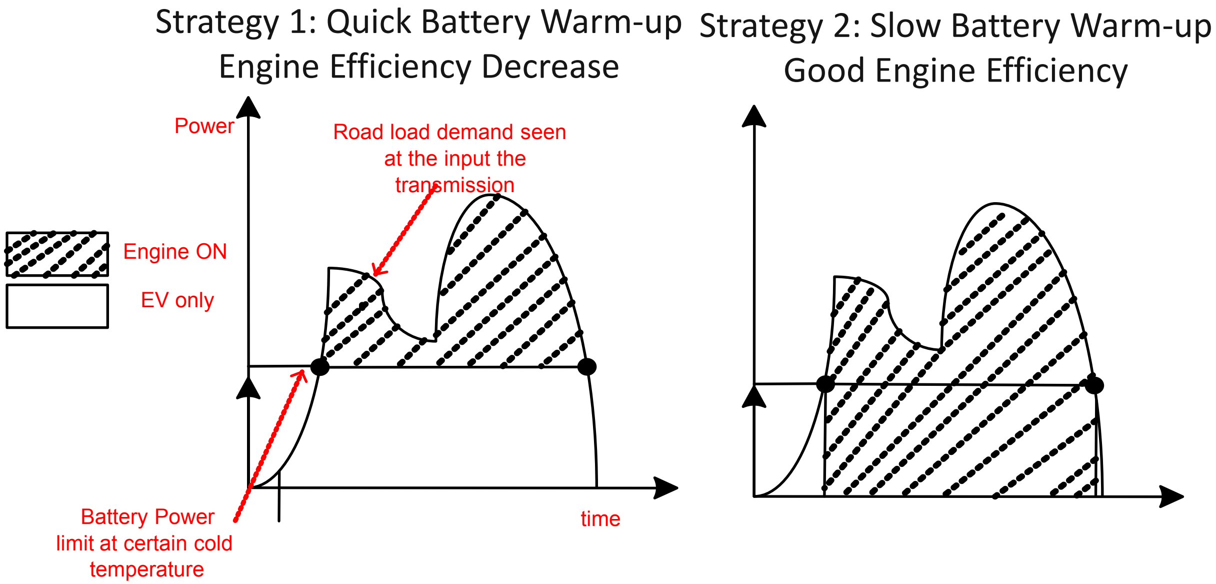
Evaluation of different energy management strategies using a real battery and the Engine model.



Technical Accomplishments

Established Proof of Concept in Simulation.

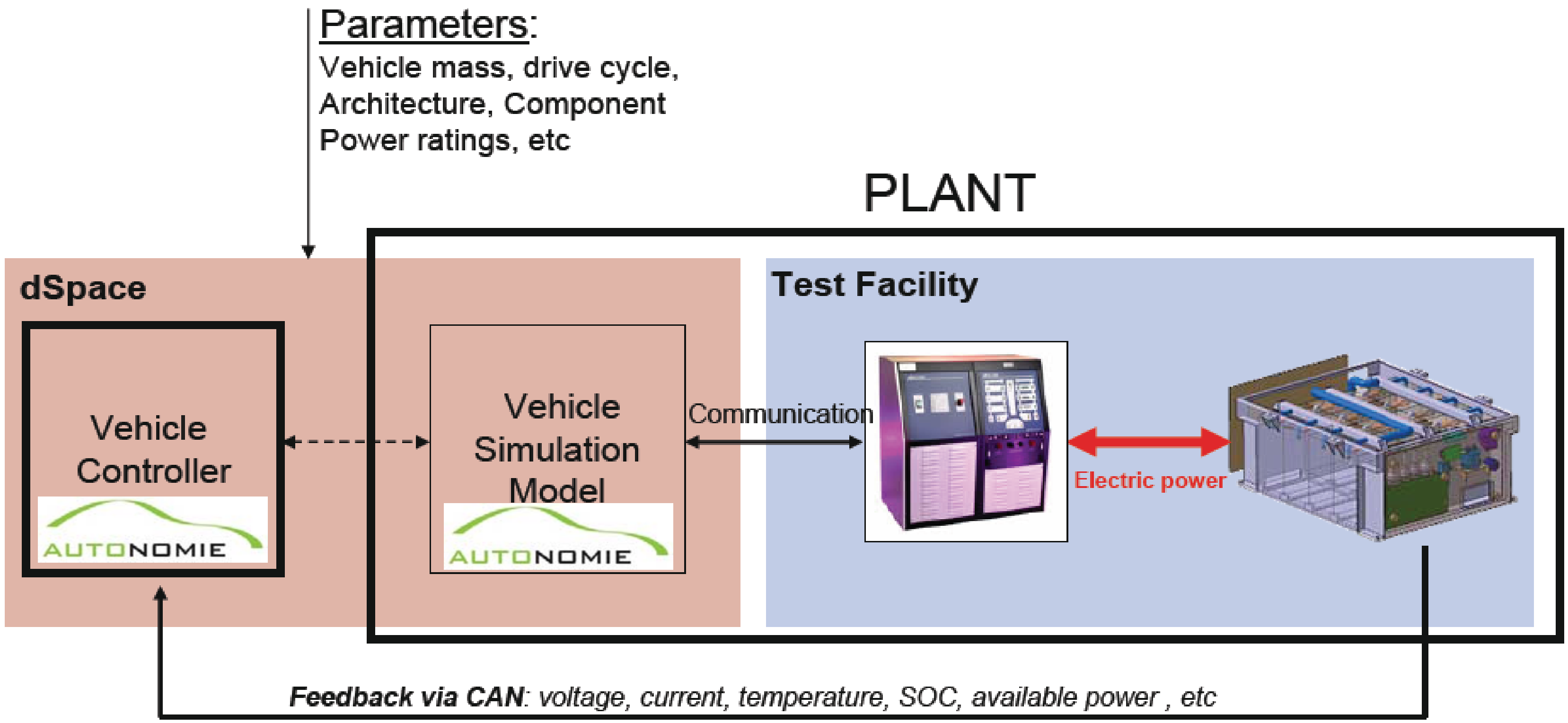
- A 505 cycle considered for comparison.
- Battery temperature remains constant over the 505 seconds, battery power restricted to 5 kW charge and discharge.
- Engine thermal effects neglected for proof of concept.



	Strategy 1	Strategy 2
Battery current squared	188	140
Engine Energy (Wh)	553	751

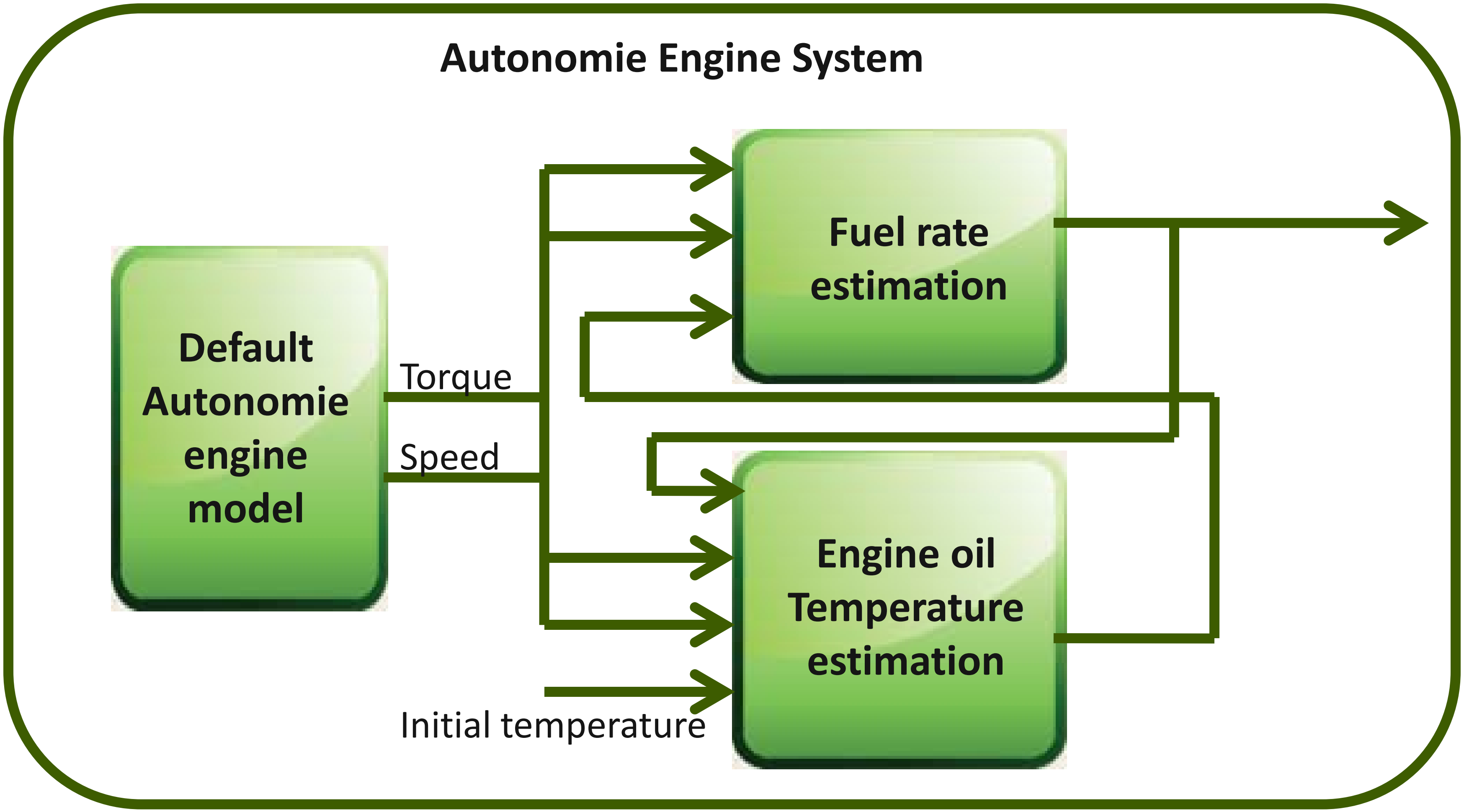
Technical Accomplishments

Battery-in-the-Loop Operational in Autonomie



Technical Accomplishments

Ongoing work – Integration of Engine Thermal Behavior Model* in Autonomie



*F. Jehlik, ' ANL_PHEV_thermal_analysis_development' presentation to VSATT on 01_06_10

Future Work

- Perform testing using Battery in the Loop technique.
- Incorporate detailed accessory load models into the study.
- Engine coolant temperature has direct impact on passenger comfort ; therefore, different energy management strategies could be evaluated with a better model of cabin temperature.
- Evaluate the impact of different powertrain configurations and sizing.
- Ultra-capacitor battery combination can be evaluated to compare against ‘battery only’ energy storage systems.

Collaboration

- Forrest Jehlik, Eric Rask – Argonne Advanced Power train Research Facility - engine thermal behavior modeling.

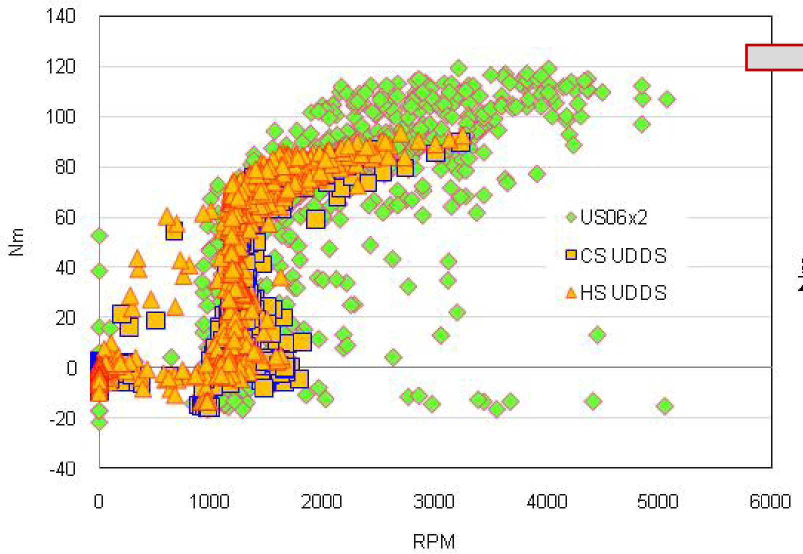
Summary

- Cold battery and engine temperature have a significant negative impact on fuel consumption.
- Cold start optimization is important for electrified powertrains.
- Different energy management strategies will be compared for their ability to warm-up the battery and raise engine efficiency.
- Engine thermal behavior model developed at Argonne will be used as part of the ‘battery in the loop’ concept.
- Proof of concept has been established with simulation
- Integration of engine model into Autonomie is in progress.
- Battery in the Loop testing will be conducted in the last quarter.

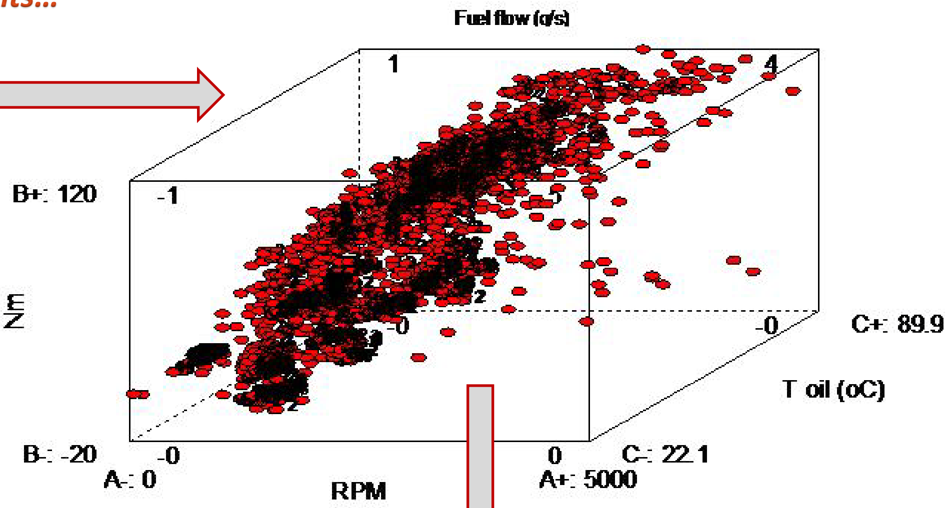
Additional Slides

From F. Jehlik: Technique: Response Surface Modeling of Experimental Data

1. Experimental speed/load points…



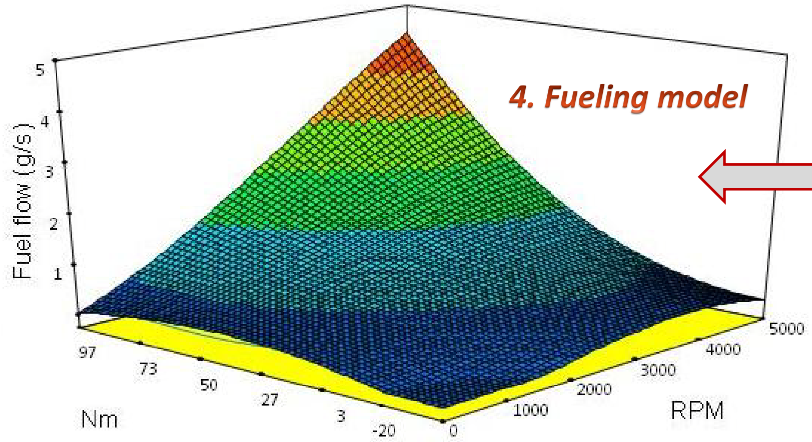
2. Design points…



3. Model inputs…

1) **RPM**
2) ***Nm***
3) ***Engine oil/coolant temp***

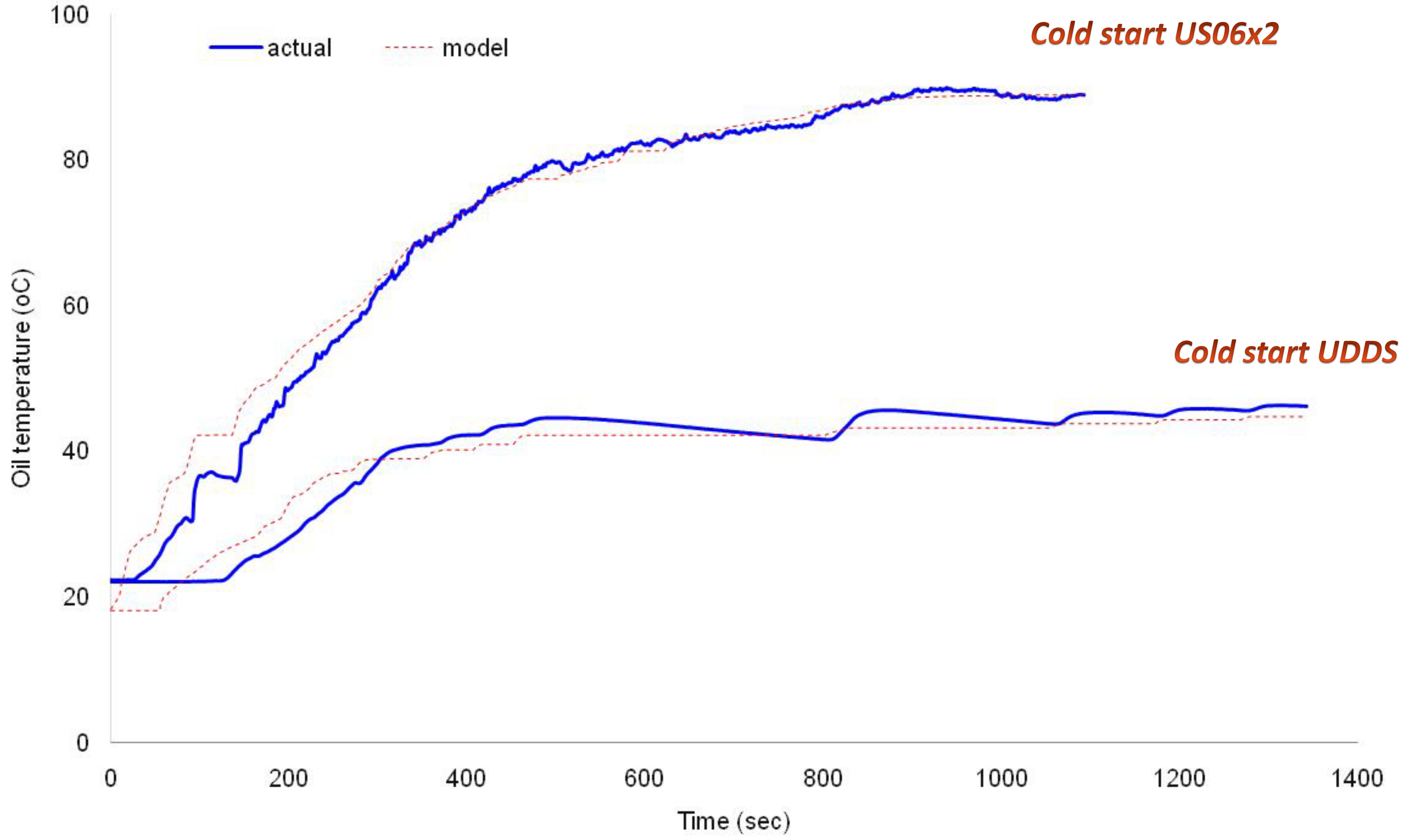
4. Fueling model



Methodology only requires experimental speed/load and initial engine temperature points as input

Applying statistical techniques to experimental data to develop predictive fueling model as a function of engine temperature

From F.Jehlik: Response Surface Temperature Models: Predicted Vs. Actual Results: 22°C Ambient Start



Application of statistical modeling technique to develop predictive oil temperature model.
This, coupled with fueling model, allows for predictive modeling of engine efficiency across operating temperatures.