Modeling and Control of Fuel Cell Transient Behavior

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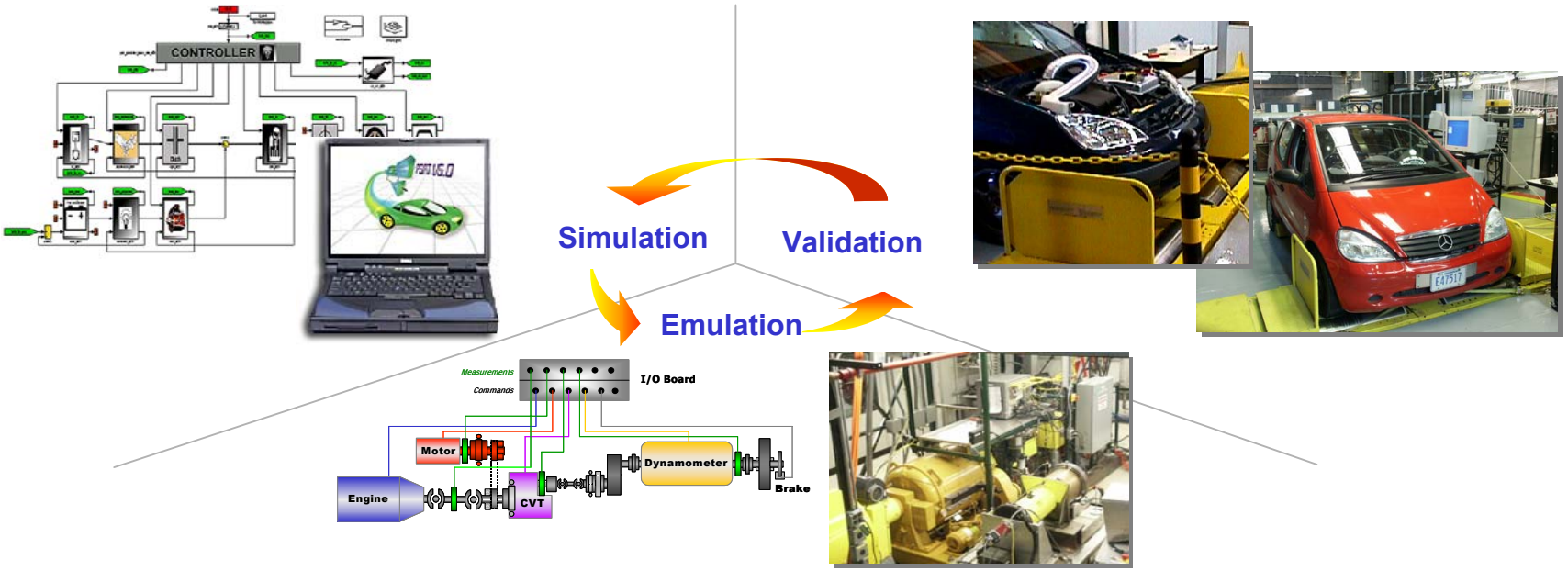
Center for Transportation Research

Transportation Technology R&D Center

Topics

- ANL modeling and development approach
- PSAT transient vehicle model
- GCTool-Eng transient fuel cell model
- Model integration
- Preliminary results with pressurized hydrogen PEM fuel cell model

Tools for Integrated Development

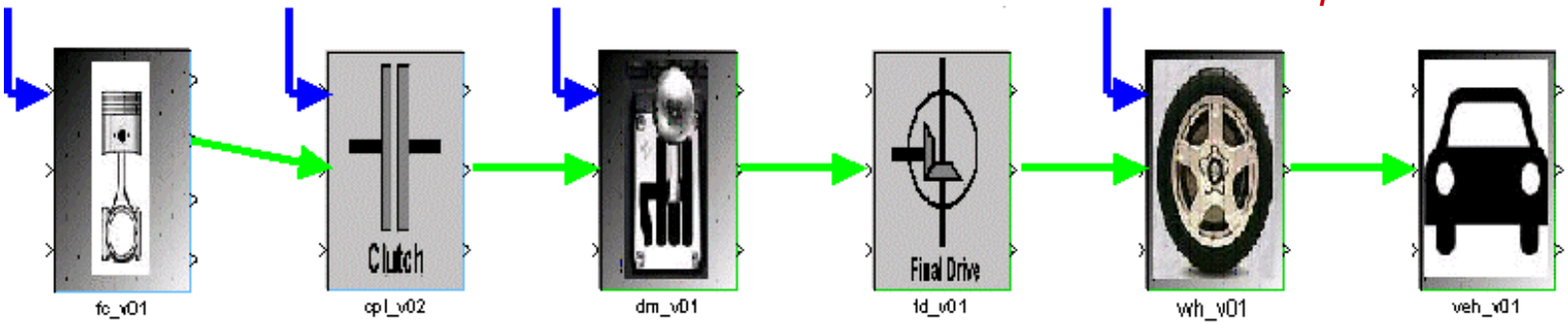


- Component/subsystem models used in vehicle simulation must be applicable to emulated and real vehicle environments
  - Forward models for realistic behavior
  - Comparable inputs/outputs to hardware
  - Validation is critical

PSAT is Control-Oriented

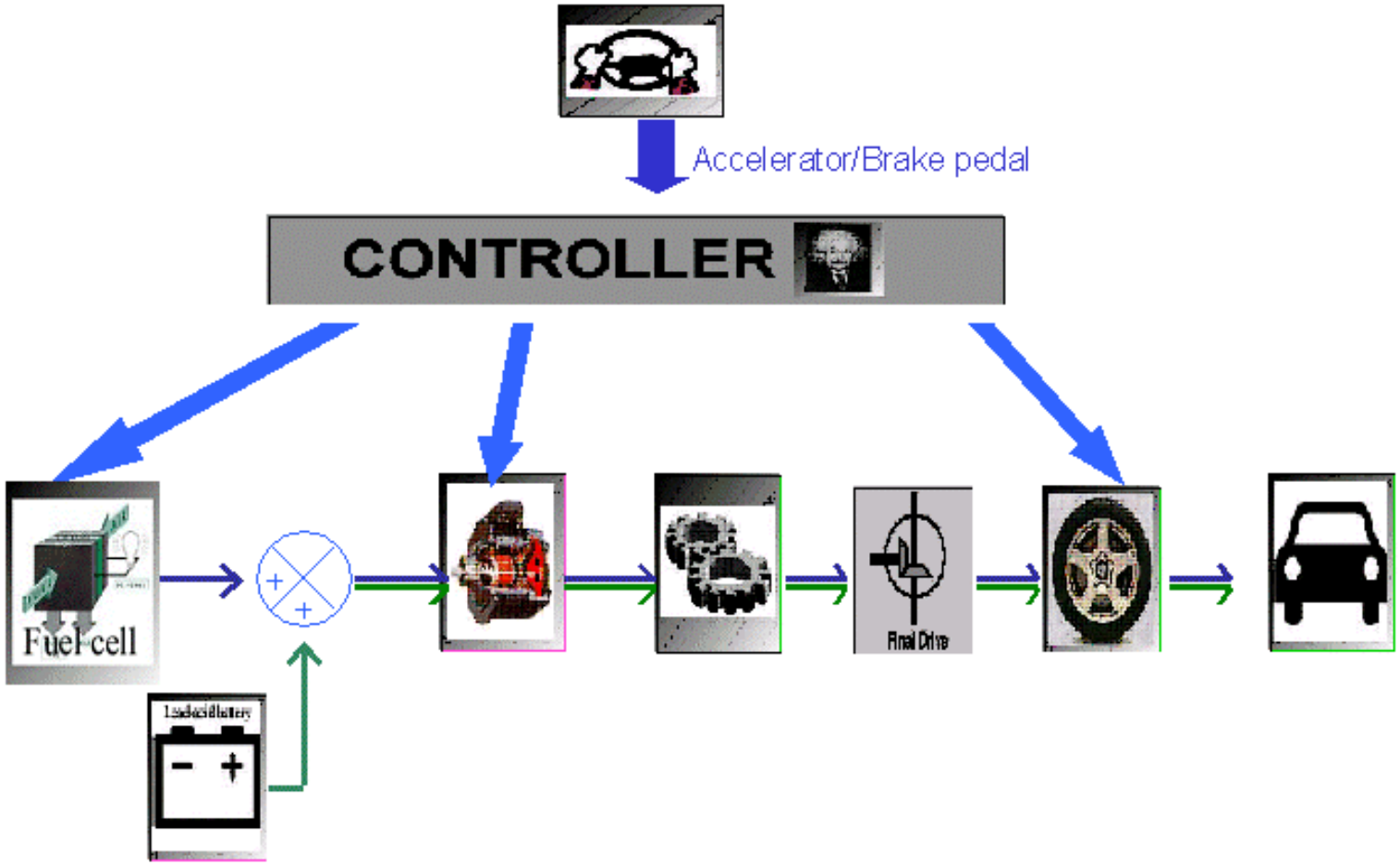
Forward modeling (driver-to-wheels) more realistically predicts system dynamics, transient component behavior and vehicle response.

Commands from a Powertrain Controller to obtain the desired vehicle speed



- Consistent with industry design practice
- Allows for advanced (e.g. physiological) component models
- More accurately represents component dynamics (e.g. fuel cell starting, warm-up and dynamics ...)
- Allows for the development of control strategies that can be utilized in hardware-in-the-loop or vehicle testing
- Small time steps enhance accuracy

PSAT Structure Flows Intuitively



PSAT - Gctool_ENG Integration for Fuel Cell Vehicle Analysis

- GCtool_ENG: Engineering models of FC systems based on GCtool architecture
  - Equation-based model
  - Speed and accuracy appropriate for fast transients
  - Translator to port GCtool_ENG models to MATLAB
- Applications
  - Multi-platform study
  - Fuel cell/battery/supercapacitor hybridization

Engineering Model

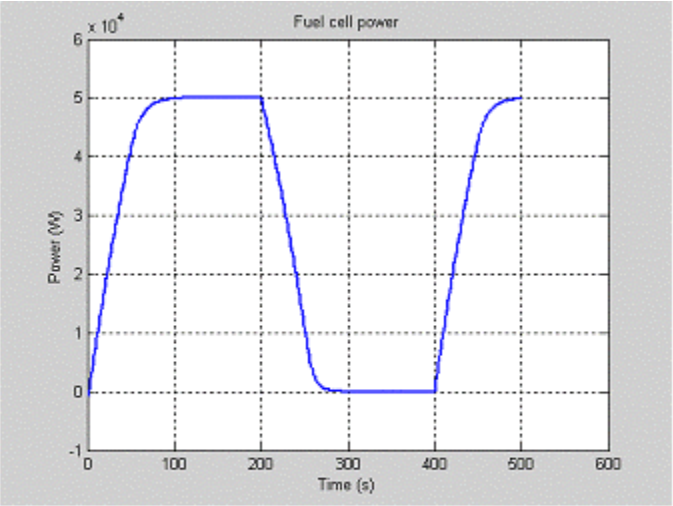
Solve conservation equations for energy, mass, species and momentum.

- ATR: Composition (P, T, GHSV, A/F, W/F)
- WGS: CO Conversion (P, T, GHSV, CO_{in}, H_2O/CO)
- PROX: CO/H_2 Conv. (P, T, GHSV, CO_{in}, O_2/CO)
- PEFC: V(P, T, I, CO, AB)
- Models are transient, can be multi-nodal and may directly interact with other components

GCTool-ENG and PSAT Enable Transient (Realistic) Modeling

GCtool fuel cell configuration → Transient FC model in MATLAB →

PSAT transient vehicle model →



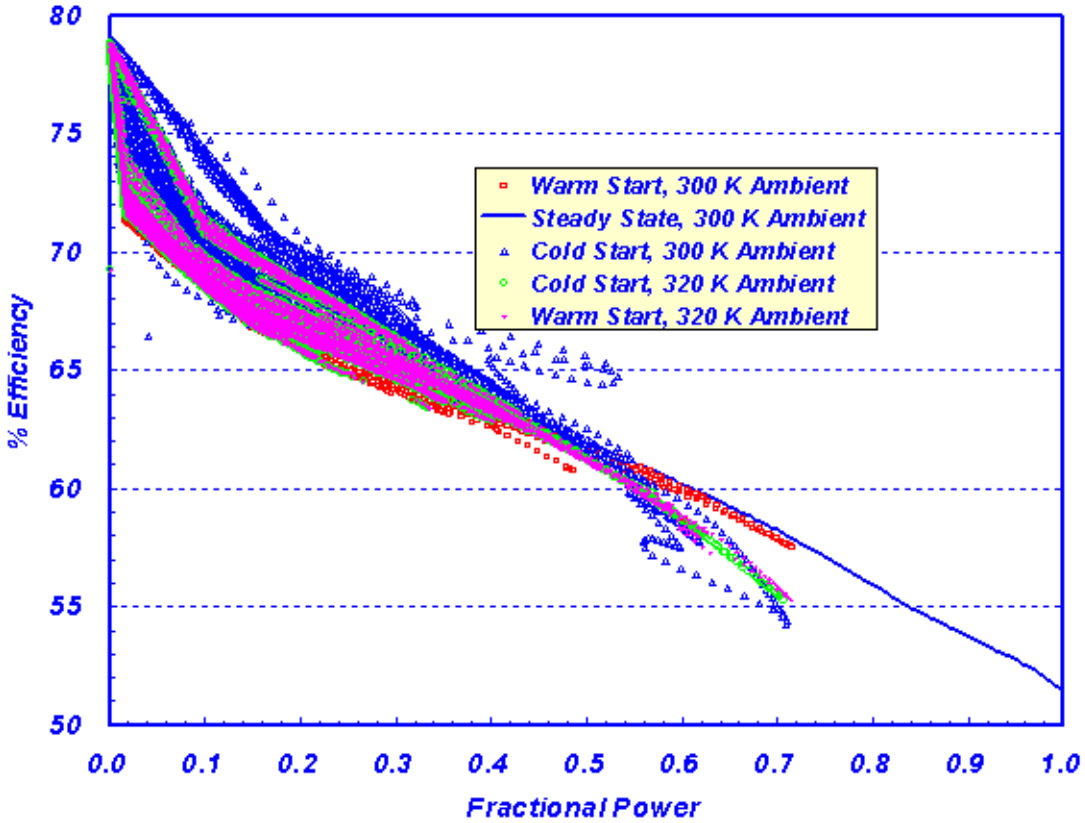
PSAT simulation of acceleration and deceleration power with direct H2 fuel cell

80-kW Direct Hydrogen System (for SUV Application)

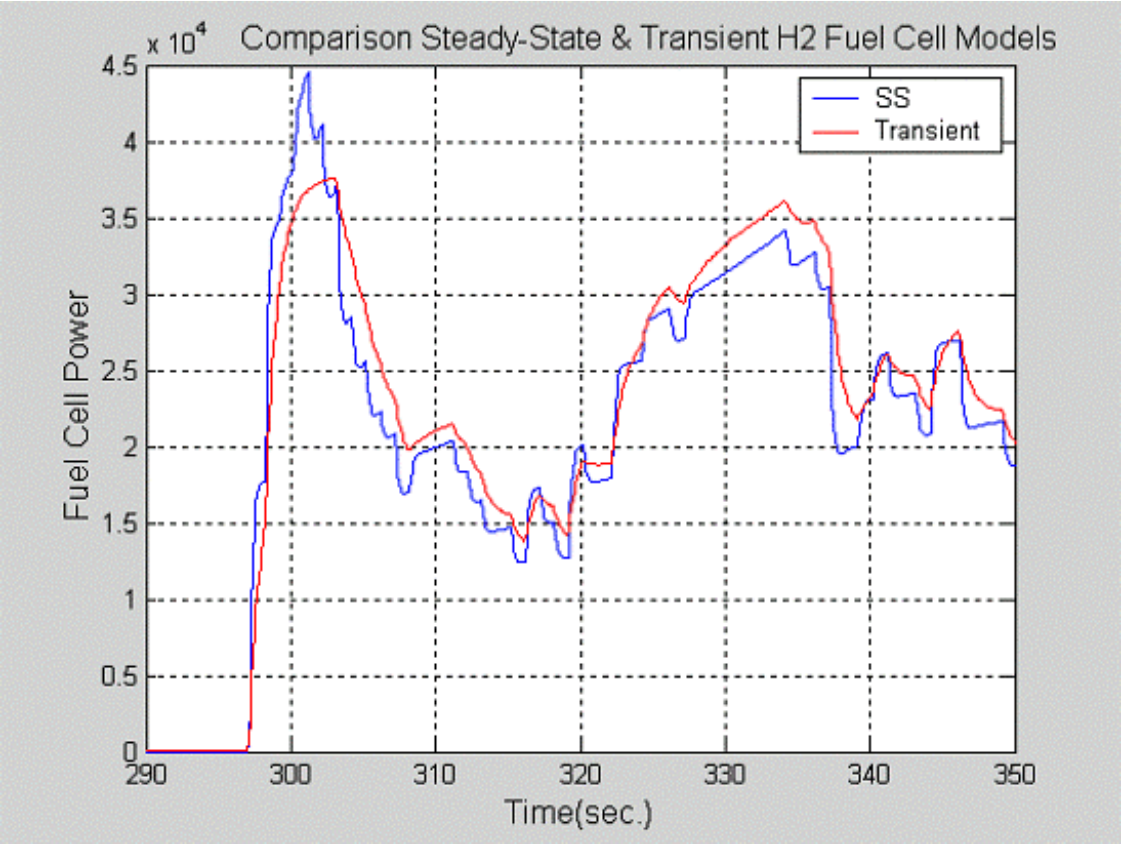
- Compressed hydrogen fuel
- CEM performance data from DOE contract
- Pressurized stack at 3 atm, 80°C, 0.7 cell potential at design point
  - Stack polarization curve from LANL and GCtool
- Anode and cathode feeds heated/cooled to 70°C, humidified to 90% at stack temperature
  - Stack coolant used for controlling anode and cathode feed temperatures
- Fuel cell – battery hybrid on SUV platform

Dynamic Efficiency on FUDS Cycle

- Beside ambient temperature, pressure, and load, dynamic efficiency depends on the control algorithm and the state of the FC system

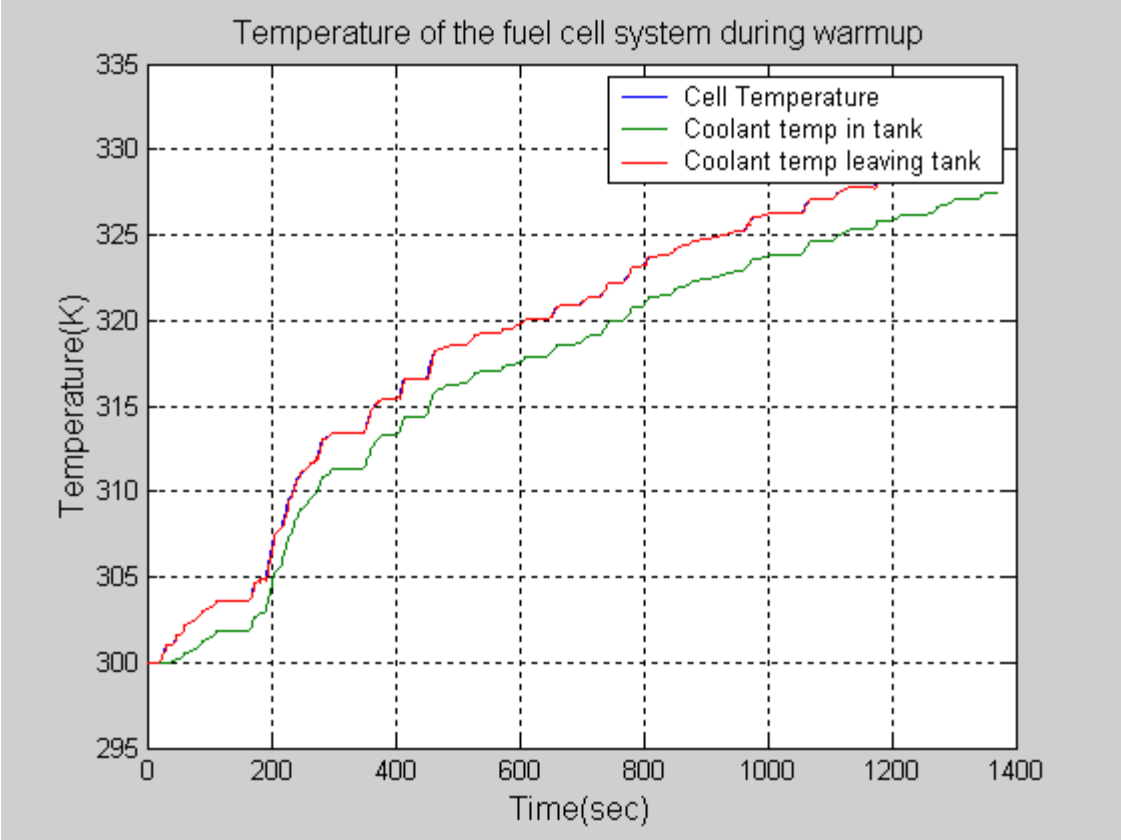


Transient Model Provides Realistic Results



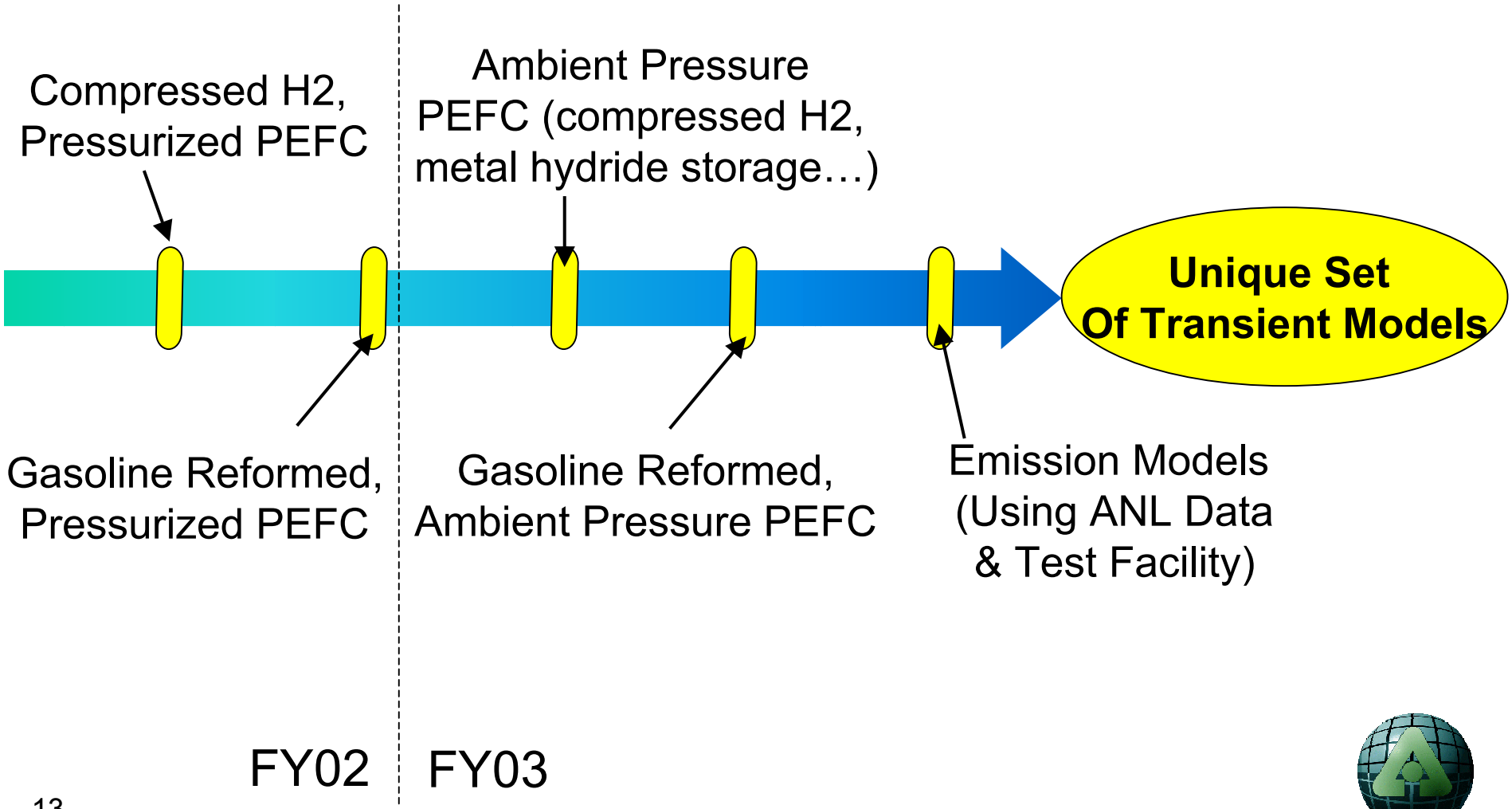
	Steady State (mpg)	Transient (mpg)
FUDS	**89.4**	**87**
FHDS	**73.9**	**70**

Cold Start And Altitude Effects Are Taken Into Account

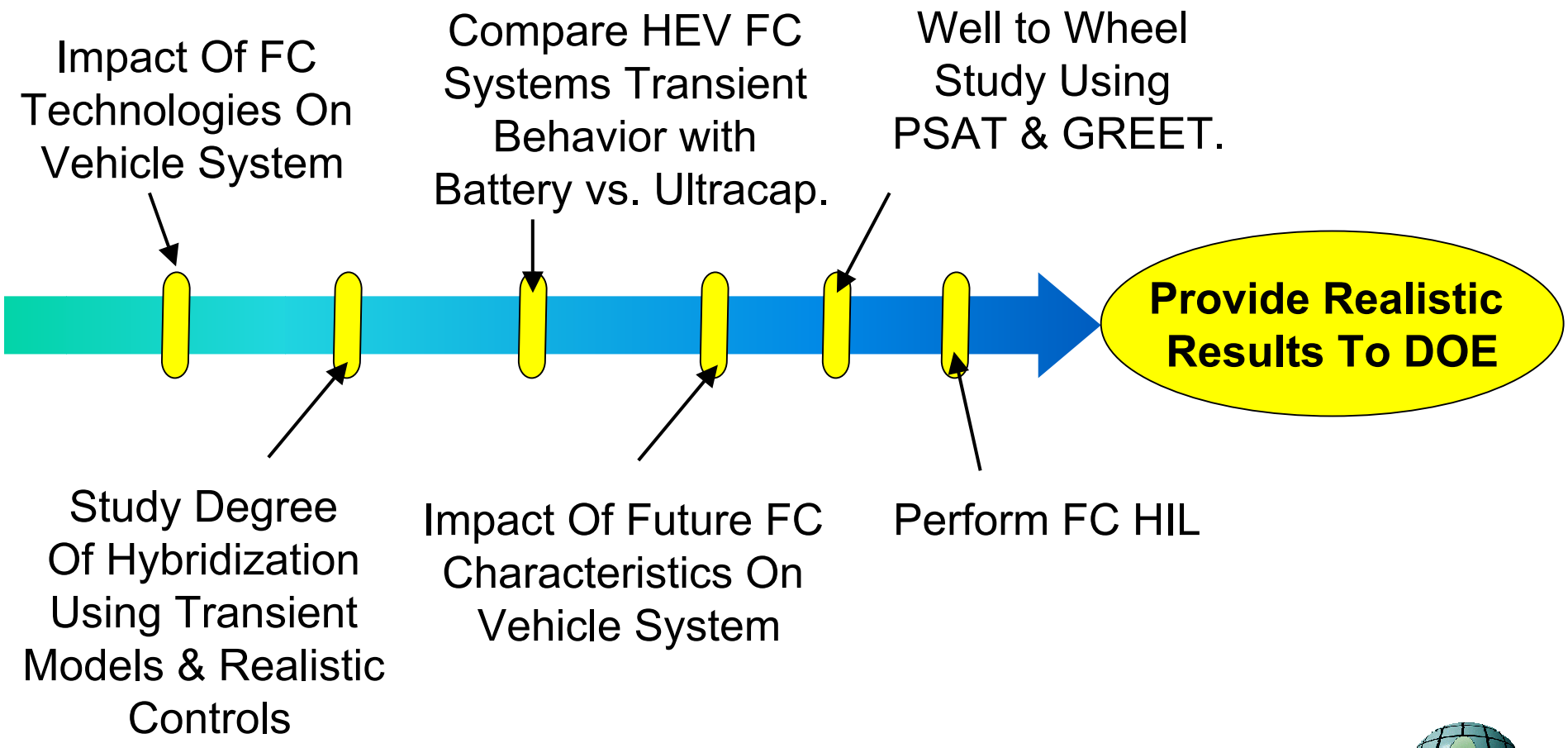


FHDS	(mpg)
hot	77.9
cold	81.6
1000m	76.1

ANL Fuel Cell Modeling Plan



ANL Fuel Cell Study Plan (FY03)



Summary

- Linking GCtool and PSAT enables detailed understanding of fuel cell drivetrain dynamics, development of control algorithms and vehicle system optimization
- Consistent analysis and development tools with hardware validation supports an efficient fuel cell technology development process.