Fuel Cell Vehicle Systems Analysis

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Fuel Cell Vehicle Systems Analysis: Background

- ➢ PSAT & ADVISOR: hybrid vehicle simulation codes funded by DOE-OAAT Vehicle Systems Team.

  - ➢ **ADVISOR: quasi-steady, backward facing model**
  - ➢ **PSAT: dynamic, forward facing model, rapid prototyping, hardware in the loop capability**

- ➢ GCtool: fuel cell systems analysis tool funded by DOE-OAAT Energy Conversion Team.

  - ➢ **PEFC, SOFC, PAFC, MCFC**
  - ➢ **Fuels: H_2, CH_4, CH_3OH, C_8H_{18}, diesel, gasoline**

- ➢ GCtool has been used to generate look-up tables for PSAT and ADVISOR

  - ➢ **Steady-state results, fixed system configuration**

Objectives

- ➢ To provide a capability for simulating fuel cell drivetrains to same level of sophistication as internal combustion engines.
  - ➢ **Performance, fuel economy and emissions**
- ➢ Formulate control strategies for FC vehicles.
- ➢ Develop a software tool for constructing operating maps of FC system components from laboratory data.
- ➢ Test components, subsystems and complete systems at Argonne's Fuel Cell Test Facility and develop operating maps.

Approach

Develop engineering models of FC systems and components using GCtool architecture and link them to PSAT.

➢ GCtool models are too slow for fast transients seen in drive cycles.

➢ Incompatible philosophies

    ➢ **Vehicle codes rely on performance maps.**

    ➢ **Objective is analysis, not design or search of optimum system configuration.**

➢ Detailed information may not be available for building mechanistic models.

Engineering Models

An engineering model solves conservation equations for energy, mass, species and momentum with the source terms obtained from performance maps.

➢ ATR: Composition (P, T, GHSV, A/F, W/F)

➢ WGS: CO Conversion (P, T, GHSV, CO_{in}, H_2O/CO)

➢ PROX: CO/H_2 Conversion (P, T, GHSV, CO_{in}, O_2/CO)

➢ PEFC: V(P, T, I, CO, AB)

➢ Performance maps are design specific & become part of data library.

➢ Models are transient, can be multi-nodal and may directly interact with other components.

Linkage with PSAT

➢ Engineering models are developed on GCtool platform.

   ➢ **Flexibility in arranging components in any configuration.**

   ➢ **Some existing models easily modified.**

   ➢ **Existing utilities for math functions and gas properties.**

➢ A translator writes a MATLAB executable from GCtool driver.

➢ The executable becomes a member of the drivetrain library in PSAT.

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PSAT: PNGV System Analysis Toolkit

➢ Developed at ANL with the contributions from Ford, GM and D/C for the Partnership for New Generation of Vehicle (PNGV)

➢ Funded by USCAR and now by DOE

➢ Proprietary version available to PNGV partners, non-proprietary version to other selected users

➢ Currently ~100 active users (25 companies and universities)

➢ A powerful forward-facing modeling tool that allows the user to realistically simulate fuel consumption, exhaust emissions and performance.

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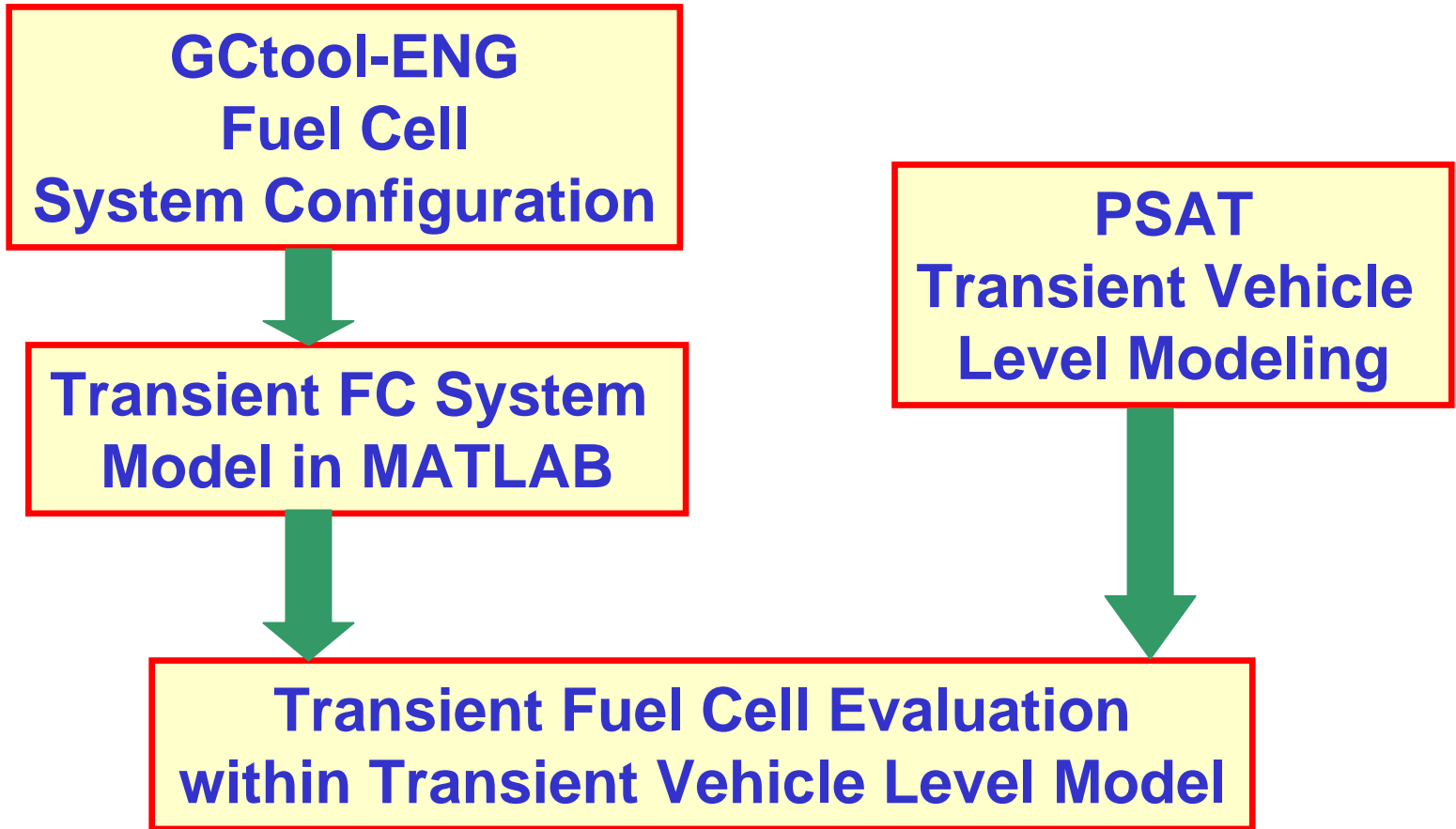of Energy**

PSAT: A Forward Facing Model

➢ The driver input creates the vehicle response

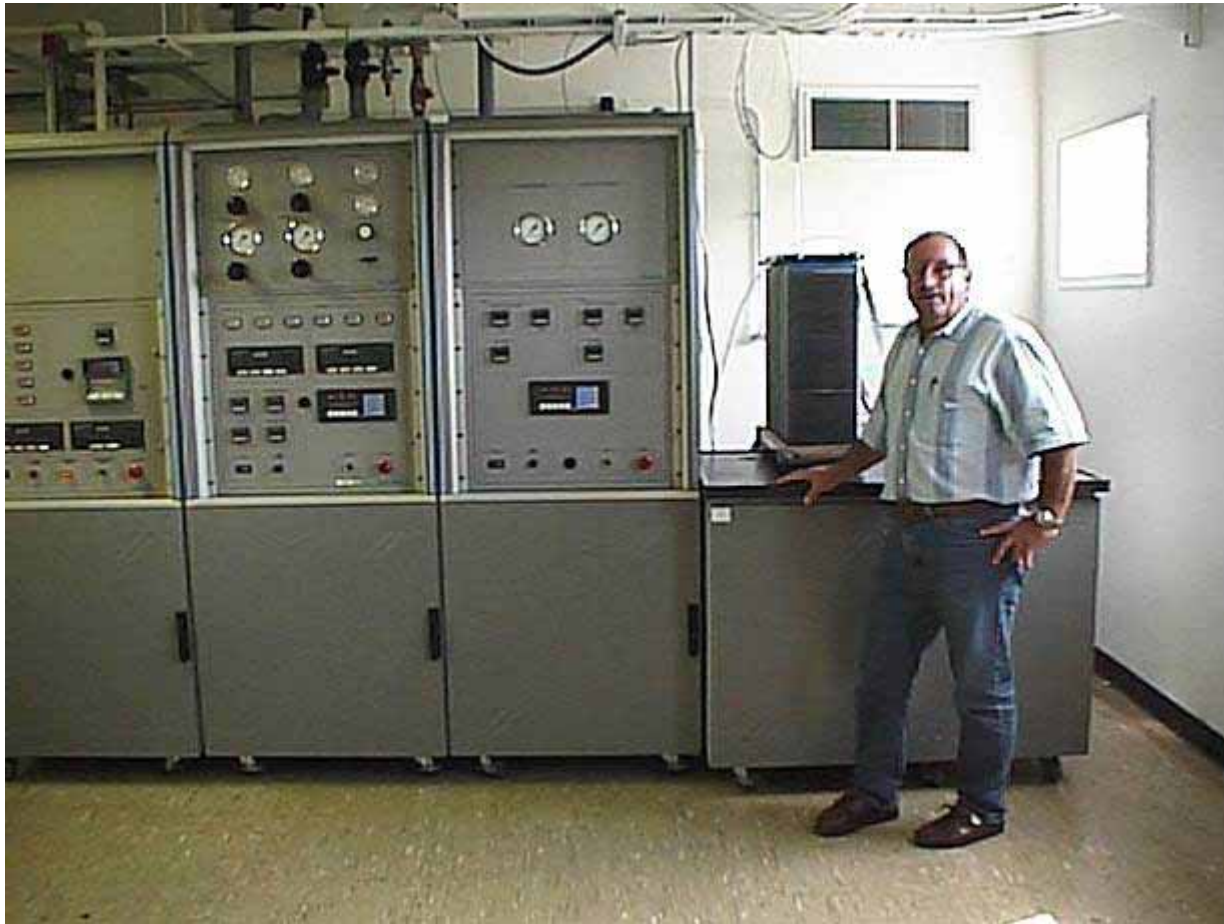**Commands from a Powertrain Controller to obtain the desired vehicle speed**
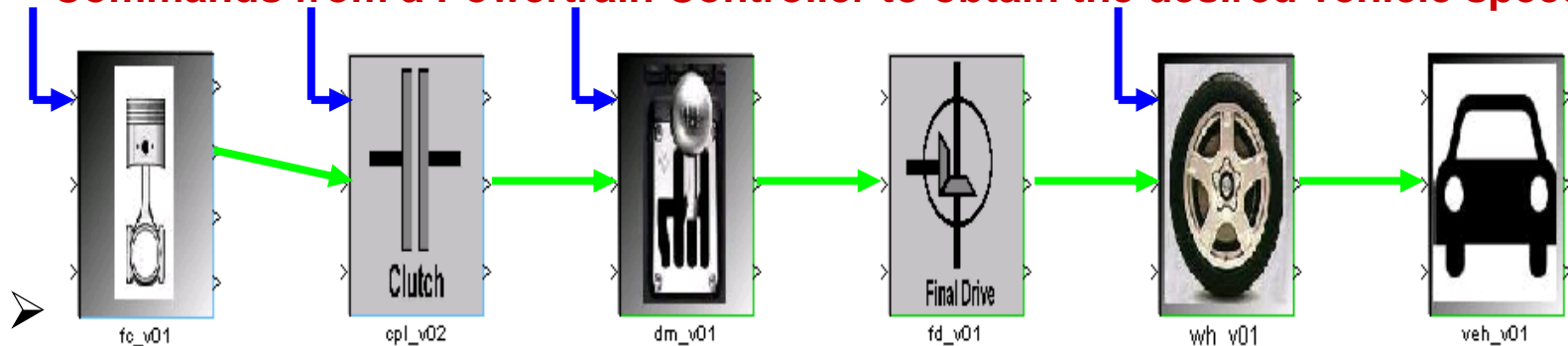
➢
➢ Accurate representation of a dynamic system (fuel cell starting, shifting, clutch engagement / disengagement…)
➢ Develop control strategies that can be later tested on a bench or in a vehicle
➢ Small time step (needed for accuracy)

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GCtool-ENG PSAT Integration

GCtool-ENG
Fuel Cell
System Configuration

Transient FC System
Model in MATLAB

PSAT
Transient Vehicle
Level Modeling

Transient Fuel Cell Evaluation
within Transient Vehicle Level Model

Fuel Cell Test Facility

- Computer-controlled, simulated testing

- Consists of a gas mixer, test station and humidifier

- Can use with many fuels

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Status and Future Work

➢ Transient FC system models being developed on GCtool platform.

  ➢ **Component maps from detailed GCtool models or test data.**

  ➢ **Argonne's Fuel Cell Test Facility being commissioned for testing components, subsystems and complete systems.**

➢ Seamless link between GCtool and PSAT will allow comparison between different fuel cell drivetrains.

➢ PSAT architecture will facilitate development of control algorithms for fuel cell drivetrains and vehicle system optimization.