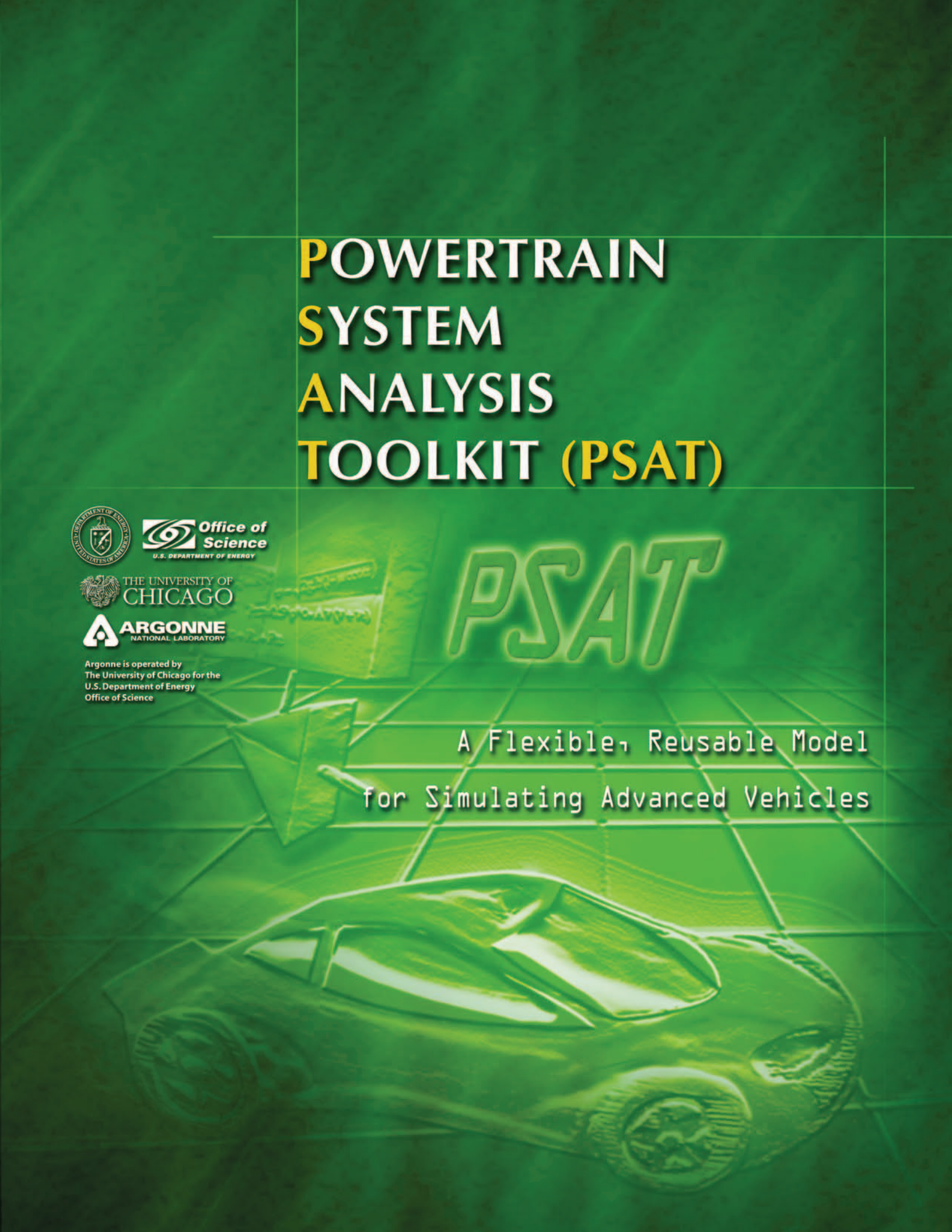
POWERTRAIN SYSTEM ANALYSIS TOOLKIT (PSAT)



Office of Science
U.S. DEPARTMENT OF ENERGY

THE UNIVERSITY OF CHICAGO

ARGONNE NATIONAL LABORATORY

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A Flexible, Reusable Model
for Simulating Advanced Vehicles

Because of the large number of possible advanced vehicle architectures, it is impossible to manually build every single powertrain configuration due to time and cost constraints. The Powertrain System Analysis Toolkit (PSAT) is a state-of-the-art flexible and reusable simulation package developed by Argonne National Laboratory and sponsored by the U.S. Department of Energy (DOE). PSAT was designed to serve as a single tool that can be used to meet the requirements of automotive engineering throughout the development process from modeling to control.

PSAT serves as a single simulation tool for building advanced vehicles.

Recognized by the Scientific Community

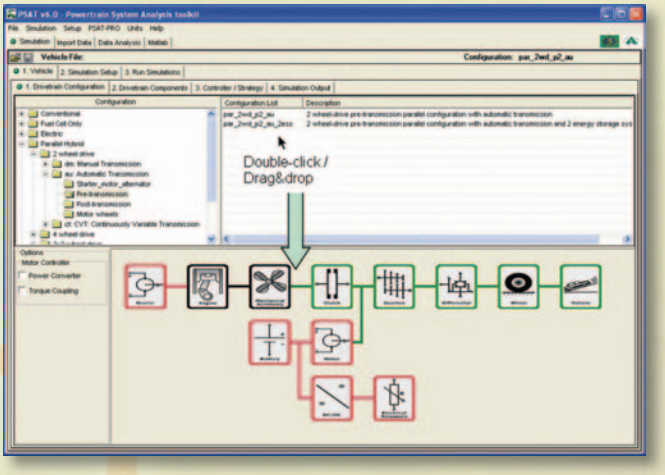
After a thorough assessment, the U.S. DOE selected PSAT as its primary vehicle simulation tool to support its FreedomCAR and Vehicle Technologies Program. PSAT has been used for numerous studies to provide U.S. government with guidance for future research orientations. Major automotive companies and suppliers are also using PSAT to support advanced vehicle development programs. Finally, as part of Challenge X, a student engineering vehicle competition organized by General Motors and DOE, 17 universities are using PSAT to select their powertrains and develop control strategies.

Transient Vehicle Model

PSAT is a forward-looking simulation package (also called driver-driven). A driver model follows any standard or custom driving cycle, sending a power demand to the vehicle controller, which, in turn, sends a demand to the propulsion components. Component models react to the demand and feed back their status to the vehicle controller, and the process iterates to achieve the desired result.

Wide Range of Powertrain Selections and Vehicle Applications

The automated powertrain configuration building is the cornerstone of PSAT's flexibility and reusability. Based on the user's selection from the graphical user interface, the entire vehicle model is built based on the powertrain, component models, initialization files, and control strategy choices. Thanks to this process, several hundred pre-defined configurations can be quickly compared, including conventional, electric, fuel cell, and hybrids (parallel, series, power split, series-parallel). Light-, medium-, and heavy-duty vehicles can be simulated using the large library of component data.



PSAT offers an easy-to-use graphical user interface with drag and drop capability.

Multiple-Option Component Model Libraries

Different component models — from steady-state to transient— can be selected based upon the simulation objectives. Each model's accuracy can be increased during the progress of the study using a single tool. PSAT also allows users to implement any proprietary component models, data sets, control strategies or drive cycle through the interactive graphical user interface. Component compatibilities are managed through a database.

Control Design for Hardware-in-the-Loop Testing

Because of its accurate dynamic component models, PSAT can be implemented directly and tested at the bench scale or in a vehicle (using its extension for prototyping, PSAT-PRO). This ability supports an ambitious development goal for PSAT — to be transportable from the virtual world of component modeling and simulation to the emulated environment of component control in hardware-in-the-loop (HIL) testing in PSAT-PRO, and then to the physical environment of full powertrain control in a vehicle.

PSAT components and controls are used to control hardware with PSAT-PRO.

Test and Simulation Data Analysis

Test and simulation data share the same post-processing tools from calculation (e.g., energy, efficiency) to results visualization. A wide range of analysis tools are available to facilitate the understanding of complex powertrains, including component operating points, Sankey diagrams, and Willens plots. In addition, a test or simulation can be replayed through animation. Using test data from Argonne's Advanced Powertrain Research Facility, conventional and mild-hybrid vehicles have been validated within 2% and full hybrid vehicles within 5% for both fuel economy and battery state-of-charge on several driving cycles.

PSAT Features

- Forward-looking model
- Written in MATLAB/Simulink/Stateflow to ensure modularity and flexibility
- Wide range of light- to heavy-duty vehicle applications
- Simulation of hydrogen-fueled vehicles
- User-friendly graphical interface
- Complete Simulink models and data sets provided
- Multiple-option component model libraries
- Designed for co-simulation environments
- Extensive HTML and PDF documentation

PSAT Applications

PSAT is used to optimize a vehicle and its components with regard to the following:

- Fuel consumption for any driving cycle or profile
- Vehicle performance, including acceleration and grade
- Drivetrain configuration
- Realistic control strategy
- Component technologies
- Component sizing
- Transmission ratios

In 2004, PSAT received an R&D 100 award, which highlights the 100 best products and technologies newly available for commercial use from around the world.

testimonials

"With its forward-looking architecture, not only does PSAT allow us to accurately model advanced vehicle components, their control strategies, and components interaction in a systems context, but it also allows us to conduct detailed laboratory benchmark testing of advanced components as they're developed by the Department's research and development activities and our industry partners. In addition, PSAT supports our student competitions, allowing college engineering students to model advanced vehicles. We're continuing to develop PSAT to meet our modeling needs as new technologies evolve and to utilize it as a tool for interactions among the various research groups within DOE and our industry partners."

Lee Slezak
Manager
Advanced Vehicle Technology Analysis and Evaluation Team
FreedomCAR and Vehicle Technologies Program
U.S. Department of Energy (DOE)

"OEMs have limited resources and research funds for new technologies. We have to pick and choose very carefully where we put our money and in what technology. In PSAT, DOE and Argonne have developed a tool that helps speed up the process and allows us to look at many different technologies much sooner than we would otherwise. We need a model that's intuitive, easy to use, and provides accurate results. PSAT gives us that."

Randy Yost
Engineering Specialist
Analytical Tool Development
General Motors Corp.

"We're using PSAT at Mississippi State University for two different activities. First, our primary application is the use of PSAT as a design and analysis tool for simulating the performance of a hybrid electric vehicle as part of the Challenge X competition. Students can select various components in the powertrain as well as the vehicle architecture. It's been an indispensable tool because it would be prohibitively expensive to physically construct several different configurations. They are also able to employ different drive cycles corresponding to various scenarios.

"In addition, I am currently instructing a course entitled Automotive Engineering that is available to all engineering majors. We have been provided with a nonproprietary version of PSAT so that students can evaluate various hybrid configurations. The software makes the application much more realistic, as it permits a quantitative evaluation of a designed vehicle."

G. Marshall Molen
DTI-Ergon Distinguished Professor of Electrical and Computer Engineering
Mississippi State University

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