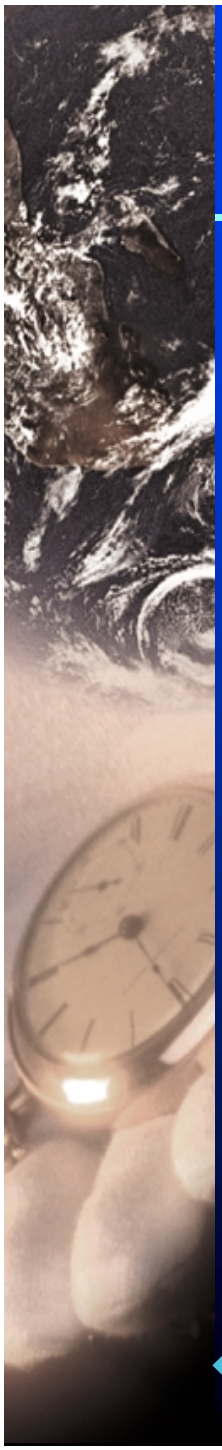
Linking ADAMS and ADVISOR for Advanced Vehicle Evaluation

by
Keith Wipke
National Renewable Energy Laboratory

ABSTRACT:

ADVISOR is an advanced vehicle simulator developed by the National Renewable Energy Laboratory, and is capable of evaluating fuel economy, emissions, and basic performance on advanced vehicle concepts. MDI and NREL have worked together to link the dynamic analysis tool ADAMS/Car to ADVISOR to allow a more complete and accurate examination of future vehicle performance. Examples of this integration will be performed with the benefits and likely applications discussed. Future improvements and modifications to the existing linkages will also be discussed. If our customers allow it, we will also discuss application of this suite of tools to a specific vehicle product.



2000 International ADAMS Users Conference

Linking ADAMS/Car and ADVISOR for Advanced Vehicle Evaluation

Keith Wipke

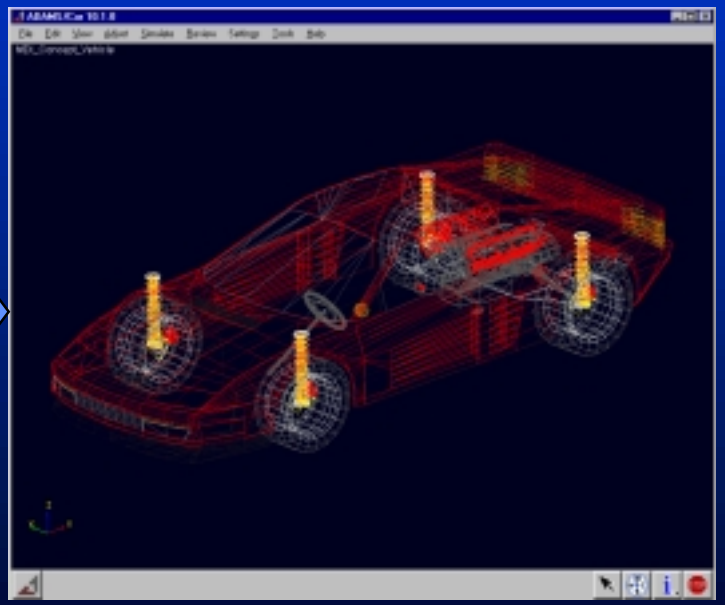
Senior Engineer, Vehicle Systems Analysis Team,
National Renewable Energy Laboratory

NREL

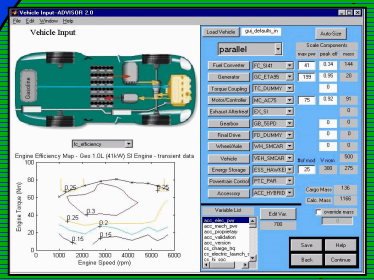
Center for Transportation Technologies and Systems

Presentation Outline

- Background and Demonstration of ADVISOR 2.2
- Objectives of linking ADVISOR and ADAMS/Car
- Details of two approaches to making linkage

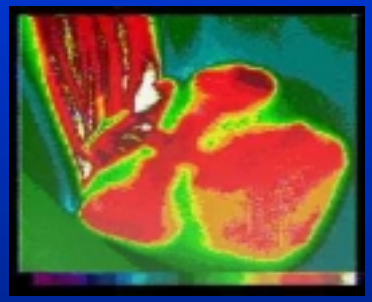


Light-Duty Hybrid Electric Vehicle Program

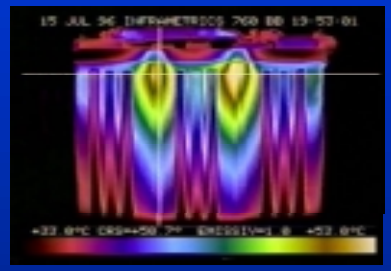


Vehicle Systems Analysis

Digital Functional Vehicle



Vehicle Climate Control



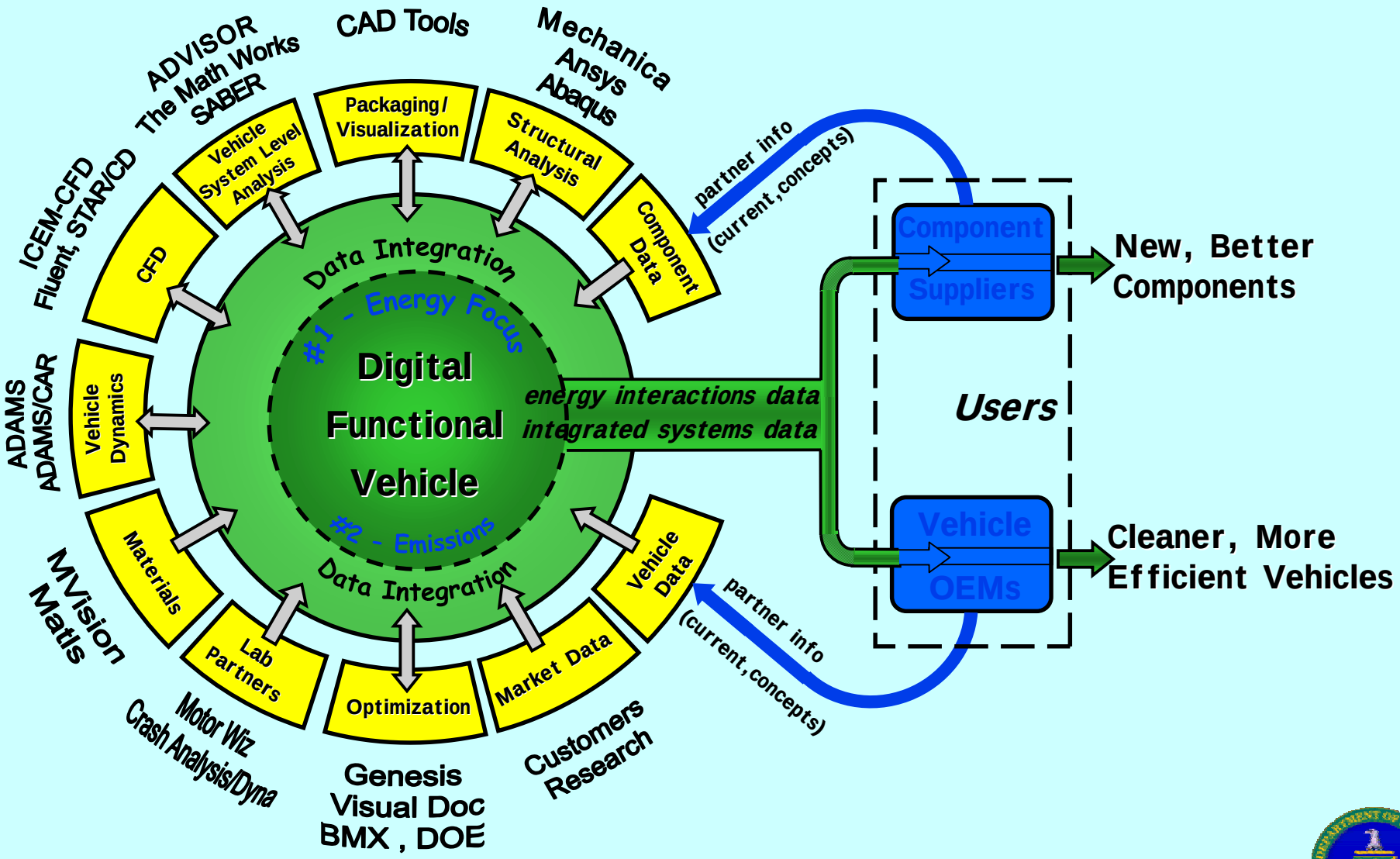
Battery Thermal Management

Big 3 Partnership
(55 mpg, mid-size vehicle)

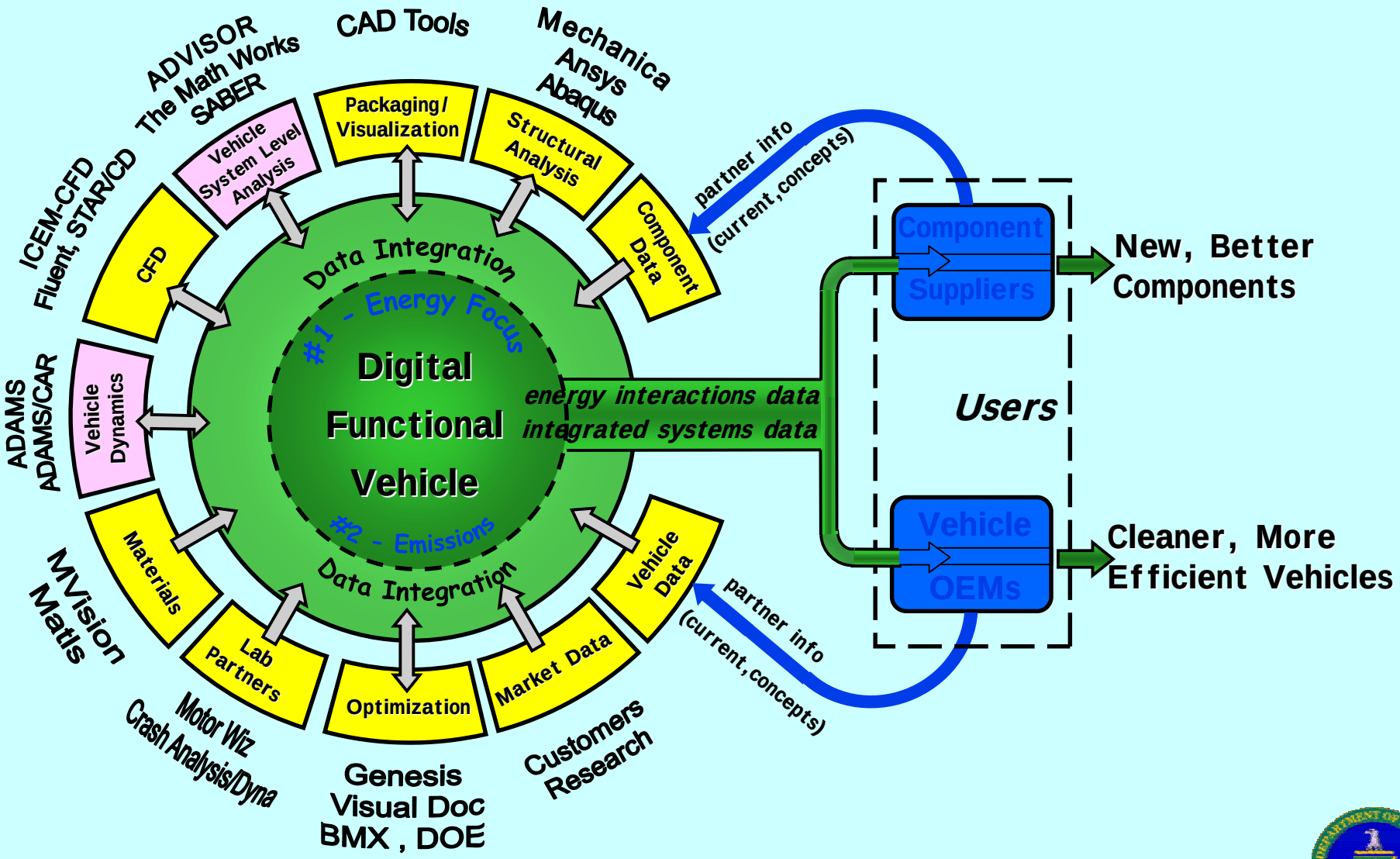
NREL

CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS

Digital Functional Vehicle Wheel

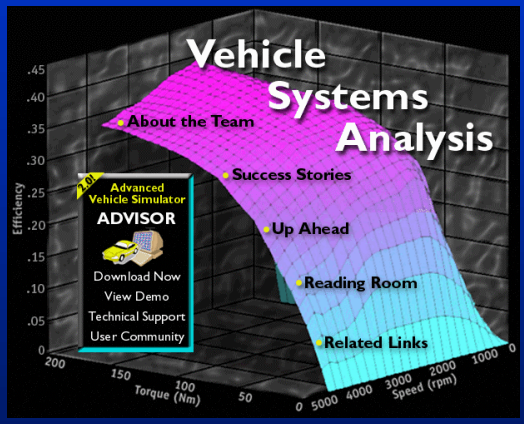


Digital Functional Vehicle Wheel: Linking Systems Level Analysis with Vehicle Dynamics



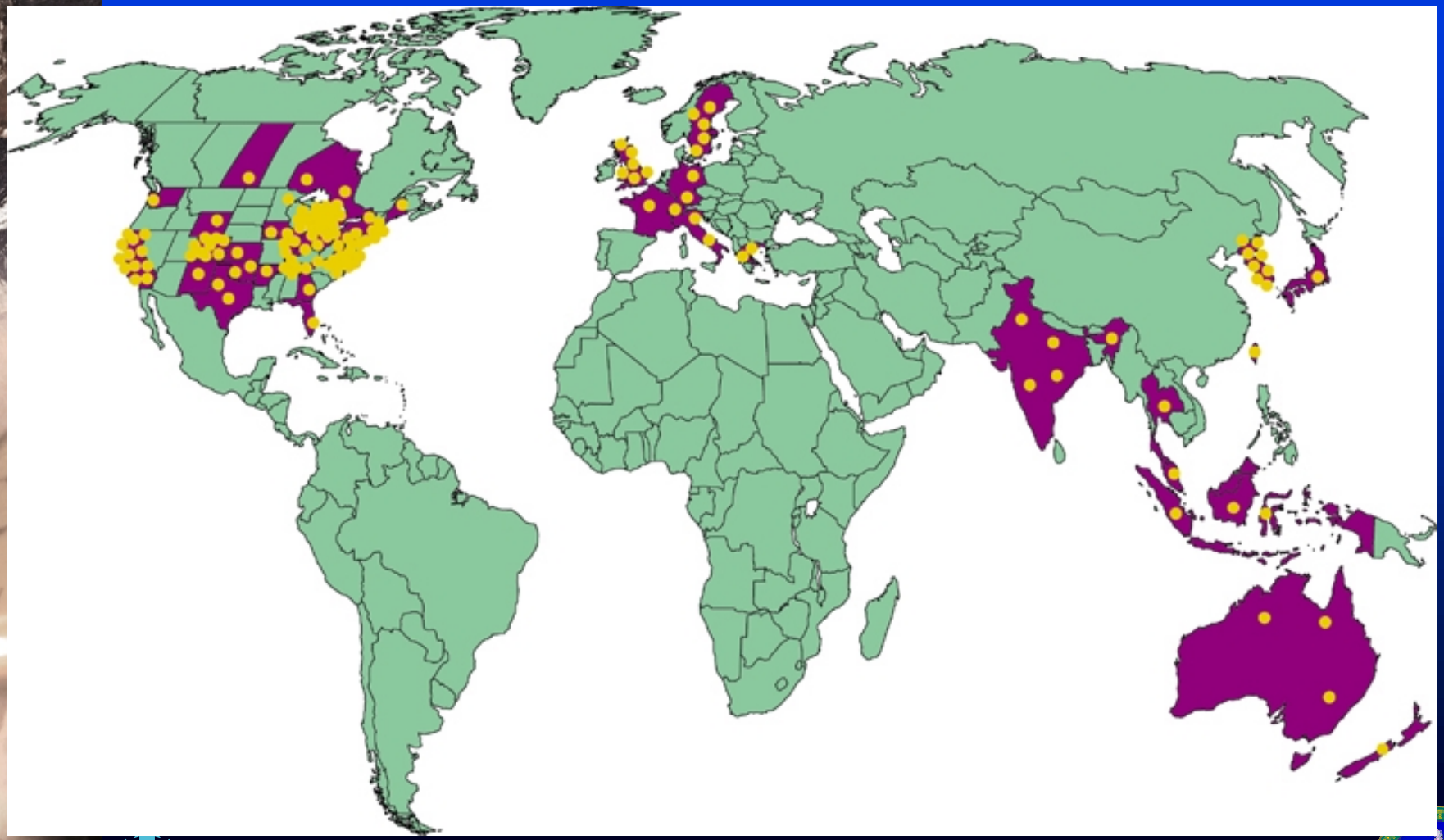
Background on ADVISOR

- ADVISOR = ADvanced VehIcle SimulatOR
  - simulates conventional, electric, or hybrid vehicles (series, parallel, or fuel cell)
- ADVISOR was created in 1994 to support DOE Hybrid Program at NREL
- Released on vehicle systems analysis web site in September, 1998

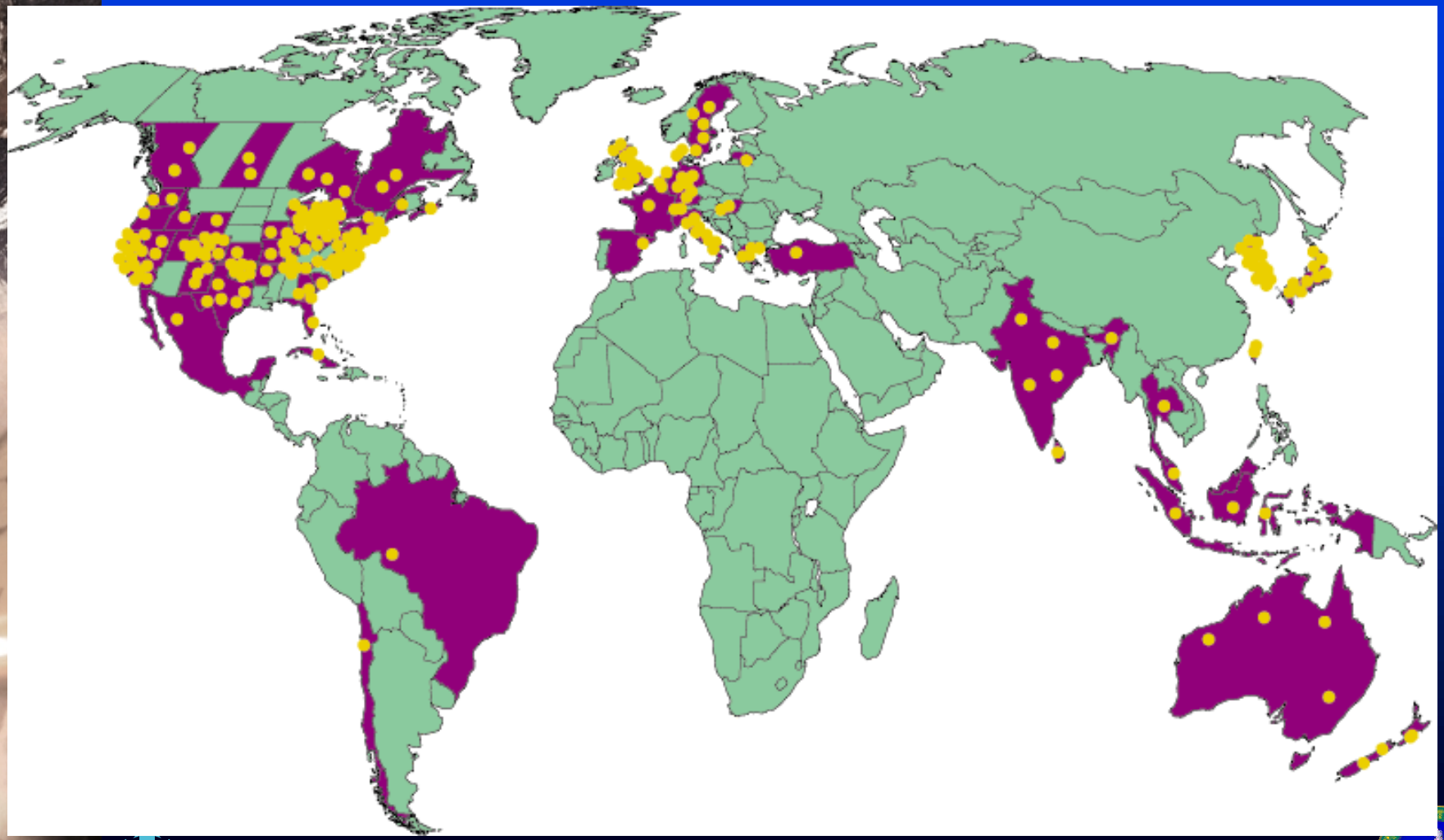


- Programmed in MATLAB/Simulink
- Downloaded by over 1700 people around world
- Users help provide component data and validation

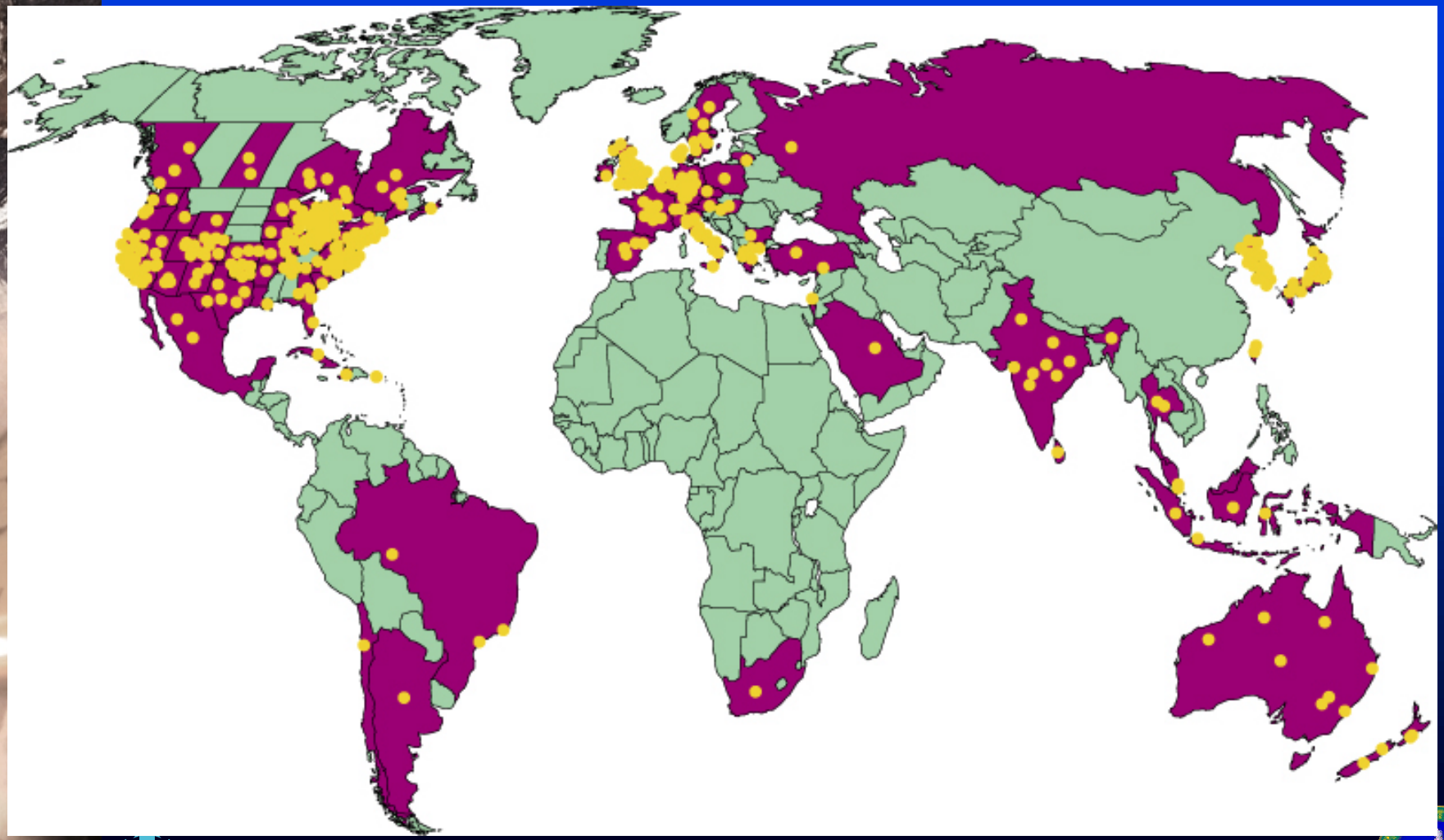
ADVISOR Being Used Globally
November 1998: ~130 users



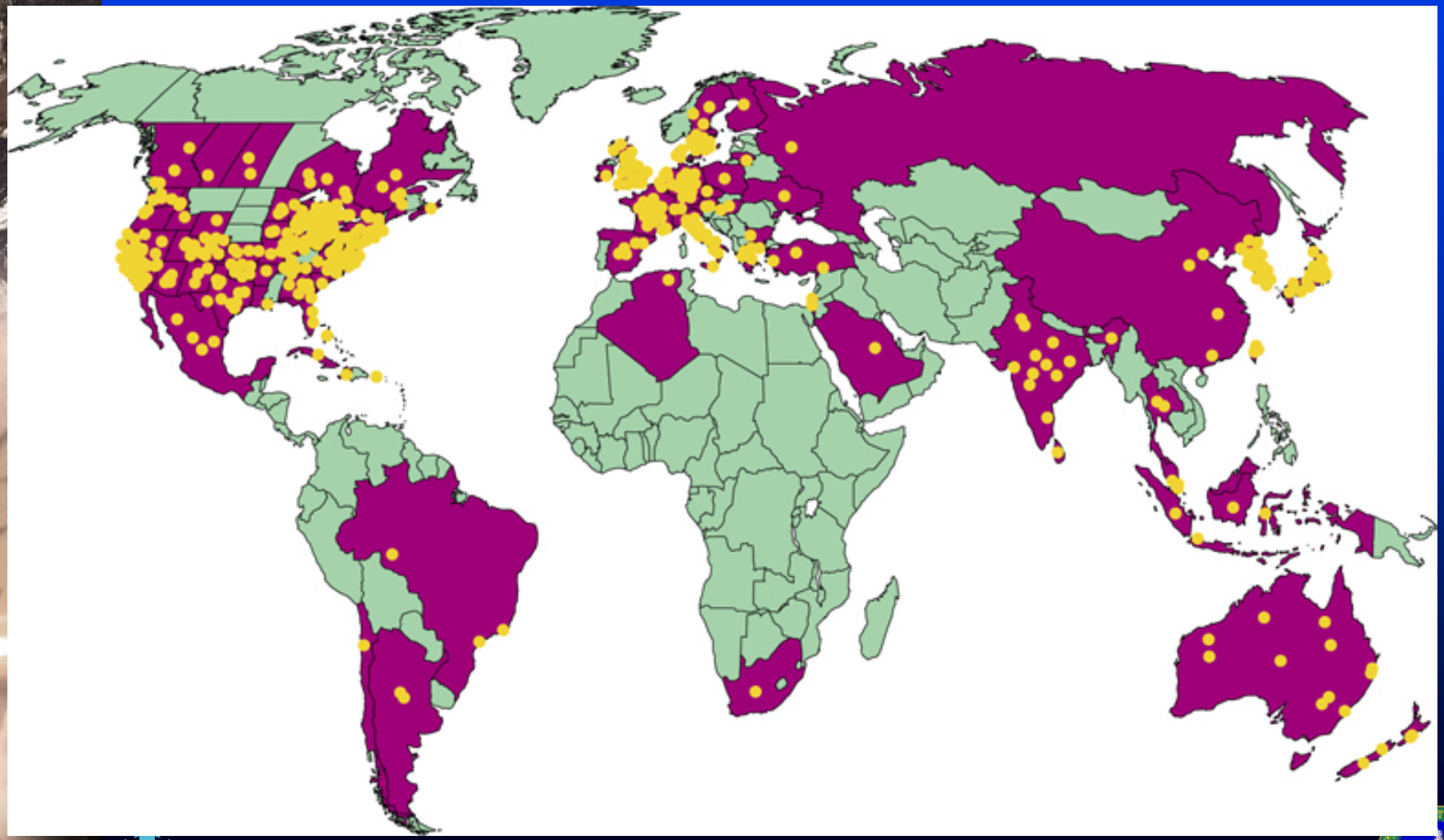
ADVISOR Being Used Globally
January 1999: ~330 users



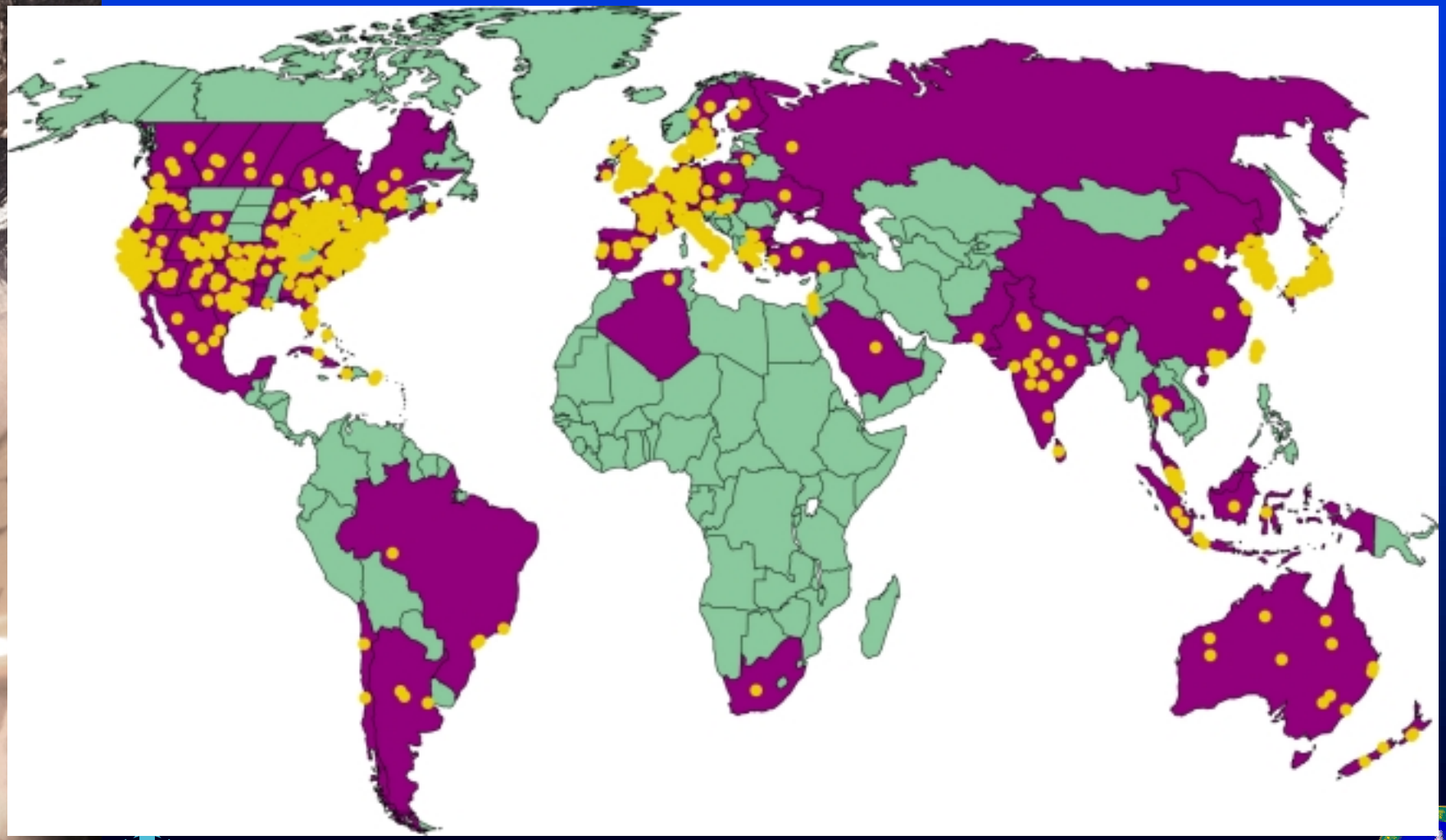
ADVISOR Being Used Globally
March 1999: ~500 users



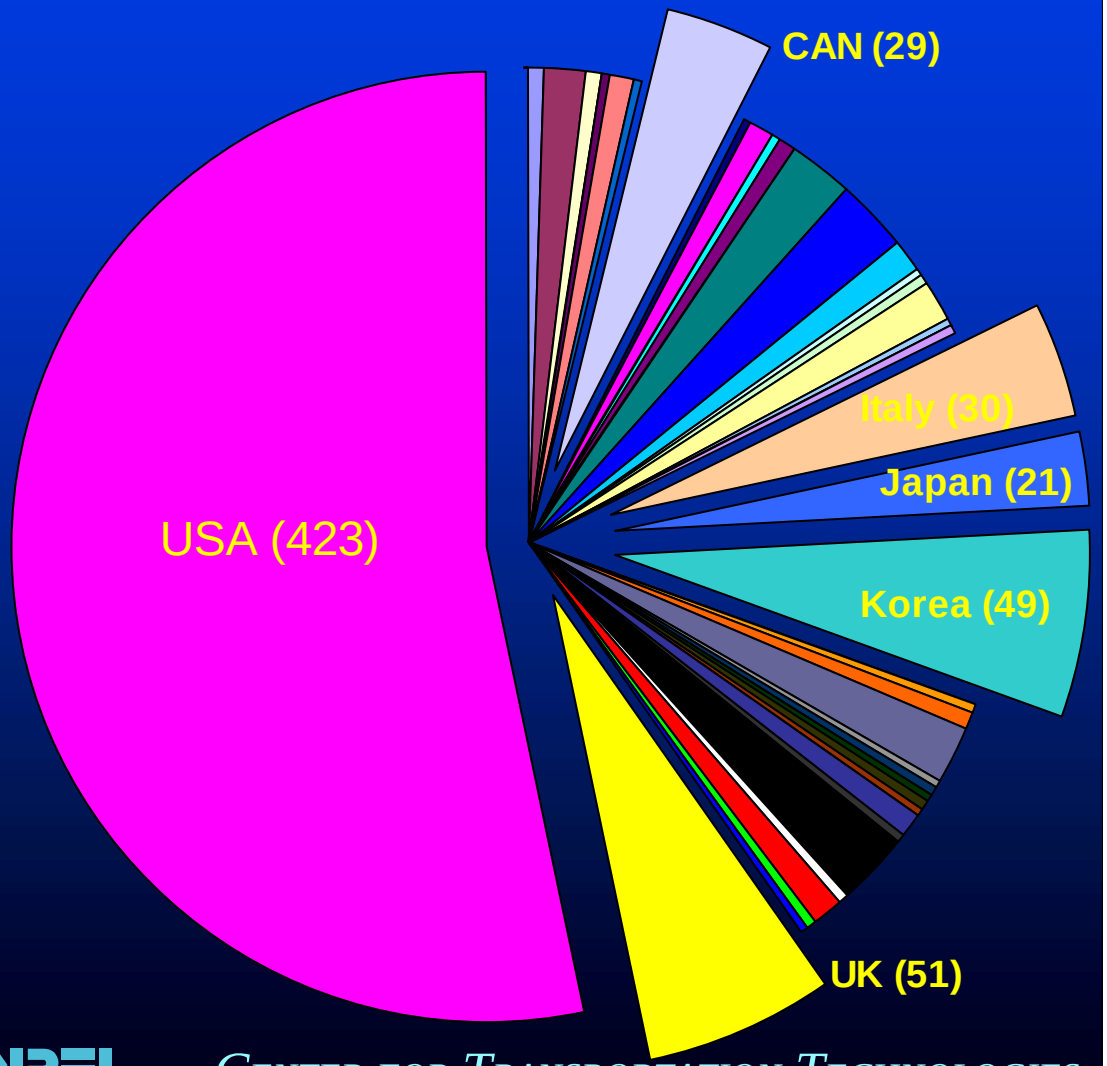
ADVISOR Being Used Globally
August 1999: ~800 users



ADVISOR Being Used Globally
June 2000: ~1700 users

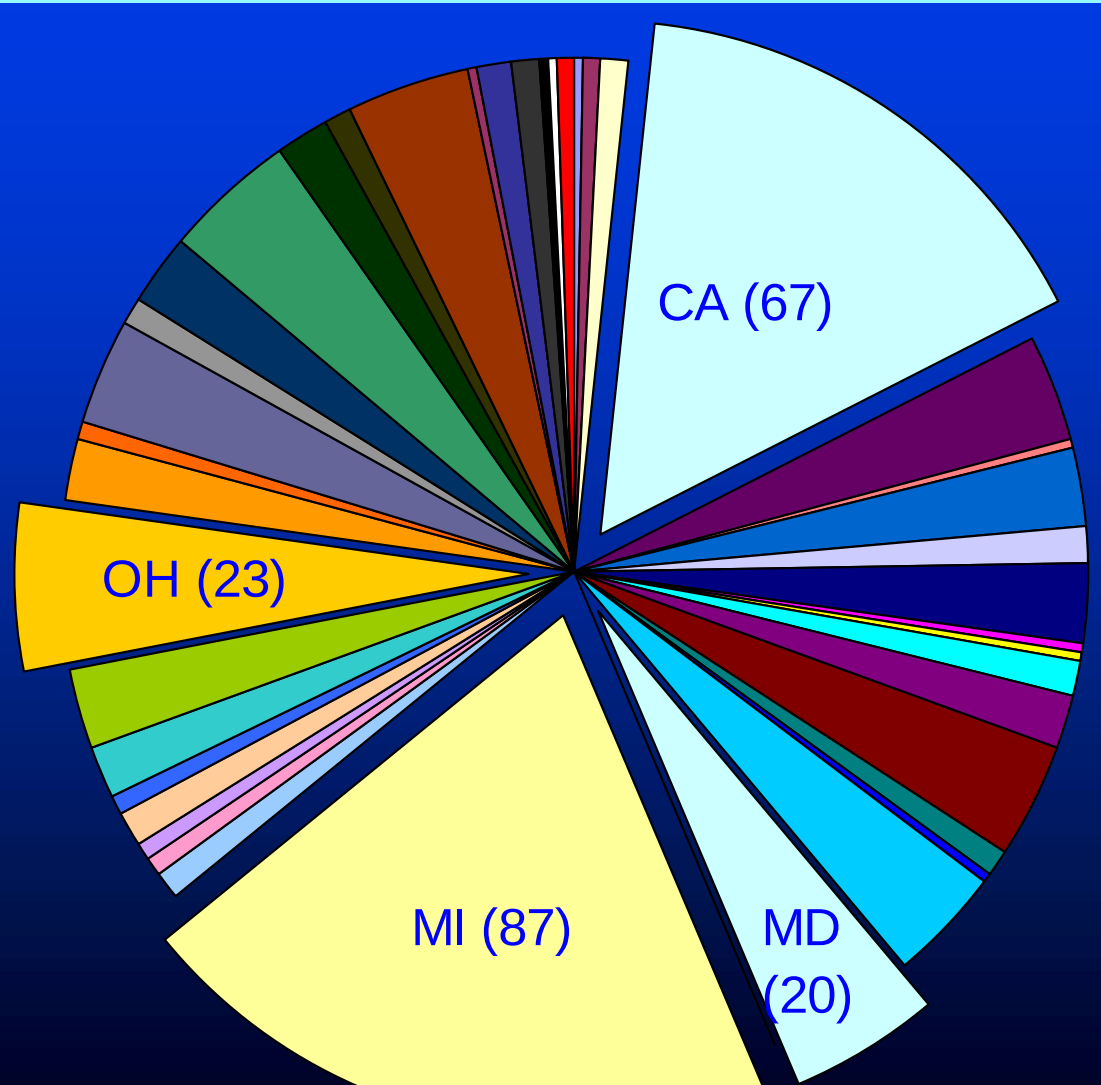


ADVISOR Users by Country (as of 8/5/99)



- Argentina
- Australia
- Austria
- (Bahamas)
- Belgium
- Brazil
- Bulgaria
- Canada
- Chile
- China
- Cyprus
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Greece
- Haiti
- Hungary
- India
- Indonesia
- Ireland
- Israel
- Italy
- Japan
- Korea
- Lithuania
- Luxembourg
- Malaysia
- Mexico
- Netherlands
- New Zealand
- Poland
- Portugal
- Russia
- Saudi Arabia
- Singapore
- South Africa
- Spain
- Sri Lanka
- Sweden
- Switzerland
- Taiwan
- Thailand
- Turkey
- United Kingdom
- United States of America

ADVISOR Users by State (as of 8/5/99)



- Alabama
- Arkansas
- Arizona
- California
- Colorado
- Connecticut
- District of Columbia
- Florida
- Georgia
- Hawaii
- Iowa
- Idaho
- Illinois
- Indiana
- Kansas
- Louisiana
- Massachusetts
- Maryland
- Maine
- Michigan
- Minnesota
- Missouri
- North Carolina
- New Jersey
- New Mexico
- Nevada
- New York
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- South Carolina
- Tennessee
- Texas
- (Unknown)
- Utah
- Virginia
- Vermont
- Washington
- Wisconsin
- West Virginia
- Wyoming
- (Puerto Rico)

Significant Usage by Industry and Others

Industry users (5 or more)	# of Users
Ford Motor Company	32
DaimlerChrysler	21
General Motors	17
Delphi	15
Fiat Auto R&D (Italy & US)	13
Volvo (Sweden)	13
Visteon Automotive Systems	13
Parametric Technology Corporation	7
AlliedSignal	6
AVL Powertrain	6
Honda R&D (USA & Japan)	6
Renault (France)	6
Denso (Japan)	5
Hino Motors Ltd. (Japan)	5
Hyundai Motor Co. (Korea)	5
Subtotal	**170**

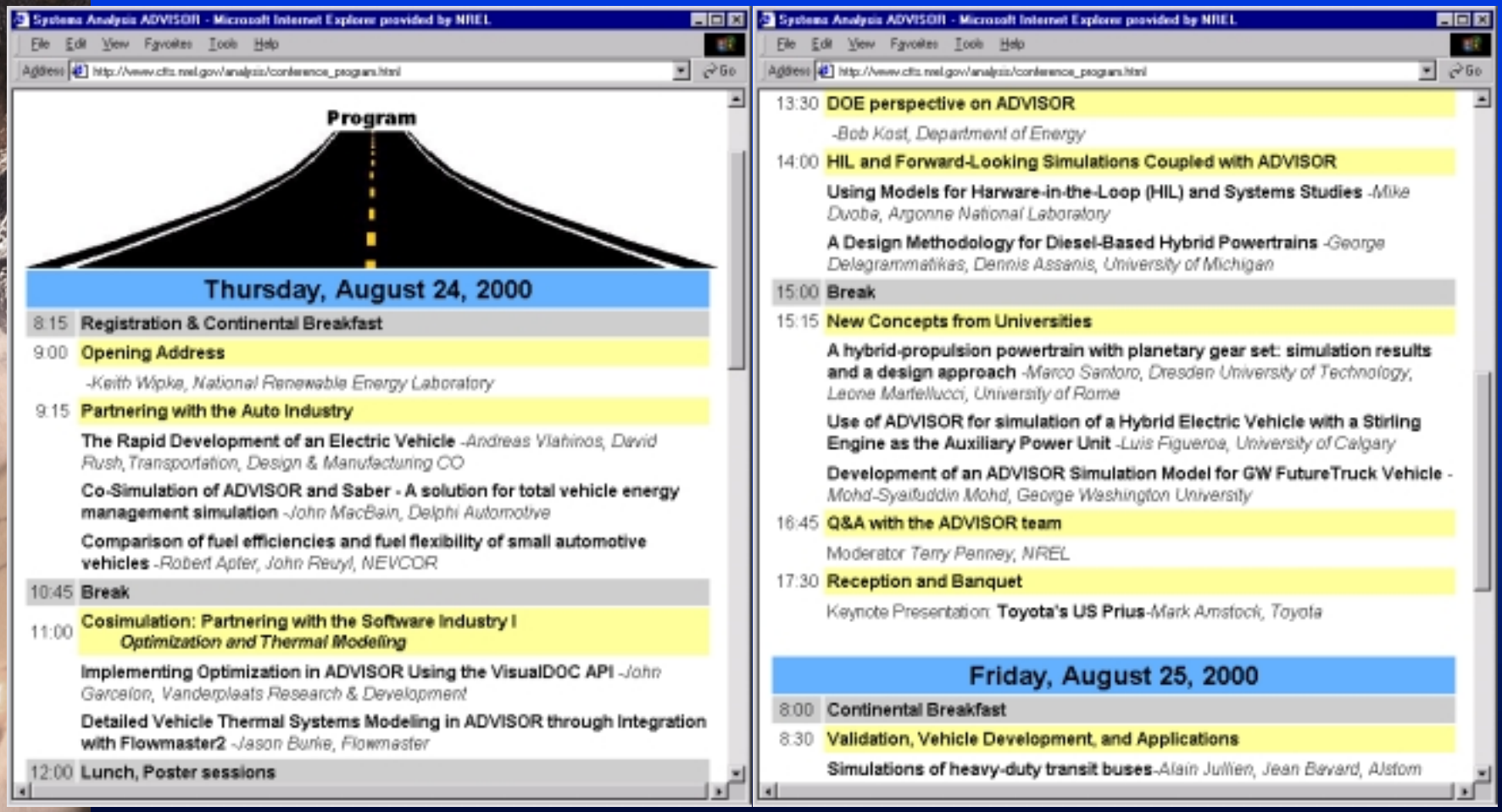
Non-industry users (6 or more)	# of Users
Ohio State University	25
University of Maryland	19
University of Michigan	14
Texas Tech University	13
University of California, Davis	13
Cornell University	9
George Washington University	9
Georgia Institute of Technology	9
University of Bath (UK)	9
Pennsylvania State University	8
Seoul National University (Korea)	7
West Virginia University	7
Argonne National Laboratory	6
NREL	6
San Diego State University	6
Texas A&M University	6
University of Tennessee	6
Subtotal	**147**

Other industry users	# of Users
Club Car, Inc.	1
Cummins Engine Co.	3
Eaton	2
Epyx Corporation	4
Mitsubishi Motors Corp. (Japan)	2
New Generation Motors	4
Nissan (Japan)	2
Ricardo	3
Rover Group Ltd. (UK)	3
Siemens AG (Germany/France)	4
Technologies M4 Inc. (Canada)	4
TNO Automotive (Netherlands)	4
Toyota Motor Corp. (Japan)	1
Volkswagen AG (Germany)	1
Subtotal	**38**

(as of 12/2/99)

ADVISOR Users Conference: August 2000

ADVISOR Users Conference: Program



Systems Analysis ADVISOR - Microsoft Internet Explorer provided by NREL

File Edit View Favorites Tools Help

Address http://www.cfts.nrel.gov/analysis/conference_program.html

Program

Thursday, August 24, 2000

8:15	**Registration & Continental Breakfast**
9:00	**Opening Address**
	-Keith Wipke, National Renewable Energy Laboratory
9:15	**Partnering with the Auto Industry**
	The Rapid Development of an Electric Vehicle *-Andreas Vlahinos, David Rush, Transportation, Design & Manufacturing CO*
	Co-Simulation of ADVISOR and Saber - A solution for total vehicle energy management simulation *-John MacBain, Delphi Automotive*
	Comparison of fuel efficiencies and fuel flexibility of small automotive vehicles *-Robert Apfer, John Reuyl, NEVCOR*
10:45	**Break**
11:00	**Cosimulation: Partnering with the Software Industry I** *Optimization and Thermal Modeling*
	Implementing Optimization in ADVISOR Using the VisualDOC API *-John Garcelon, Vanderplaats Research & Development*
	Detailed Vehicle Thermal Systems Modeling in ADVISOR through Integration with Flowmaster2 *-Jason Burke, Flowmaster*
12:00	**Lunch, Poster sessions**

Systems Analysis ADVISOR - Microsoft Internet Explorer provided by NREL

File Edit View Favorites Tools Help

Address http://www.cfts.nrel.gov/analysis/conference_program.html

13:30	**DOE perspective on ADVISOR**
	-Bob Kost, Department of Energy
14:00	**HIL and Forward-Looking Simulations Coupled with ADVISOR**
	Using Models for Harware-in-the-Loop (HIL) and Systems Studies *-Mike Duoba, Argonne National Laboratory*
	A Design Methodology for Diesel-Based Hybrid Powertrains *-George Delagrammatikas, Dennis Assanis, University of Michigan*
15:00	**Break**
15:15	**New Concepts from Universities**
	A hybrid-propulsion powertrain with planetary gear set: simulation results and a design approach *-Marco Santoro, Dresden University of Technology, Leone Marfelucci, University of Rome*
	Use of ADVISOR for simulation of a Hybrid Electric Vehicle with a Stirling Engine as the Auxiliary Power Unit *-Luis Figueroa, University of Calgary*
	Development of an ADVISOR Simulation Model for GW FutureTruck Vehicle *-Mohd-Syaifuddin Mohd, George Washington University*
16:45	**Q&A with the ADVISOR team**
	Moderator *Terry Penney, NREL*
17:30	**Reception and Banquet**
	Keynote Presentation: **Toyota's US Prius** *-Mark Amstock, Toyota*

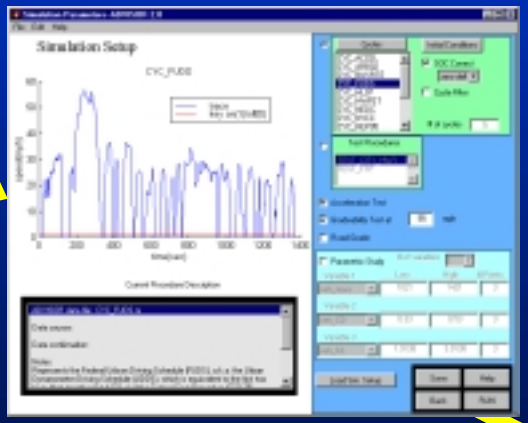
Friday, August 25, 2000

8:00	**Continental Breakfast**
8:30	**Validation, Vehicle Development, and Applications**
	Simulations of heavy-duty transit buses *-Alain Juillen, Jean Bevard, Alstom*

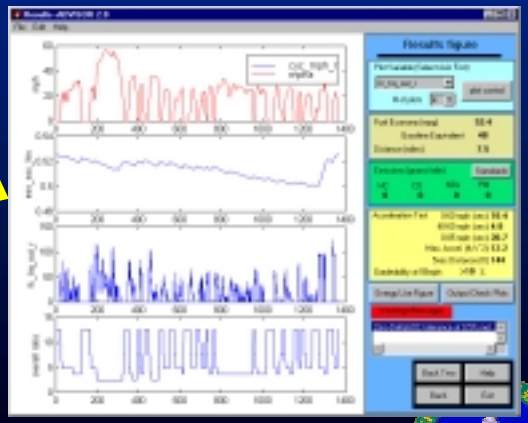
Three Main ADVISOR Screens (Roadmap)

Vehicle Input

Simulation Setup

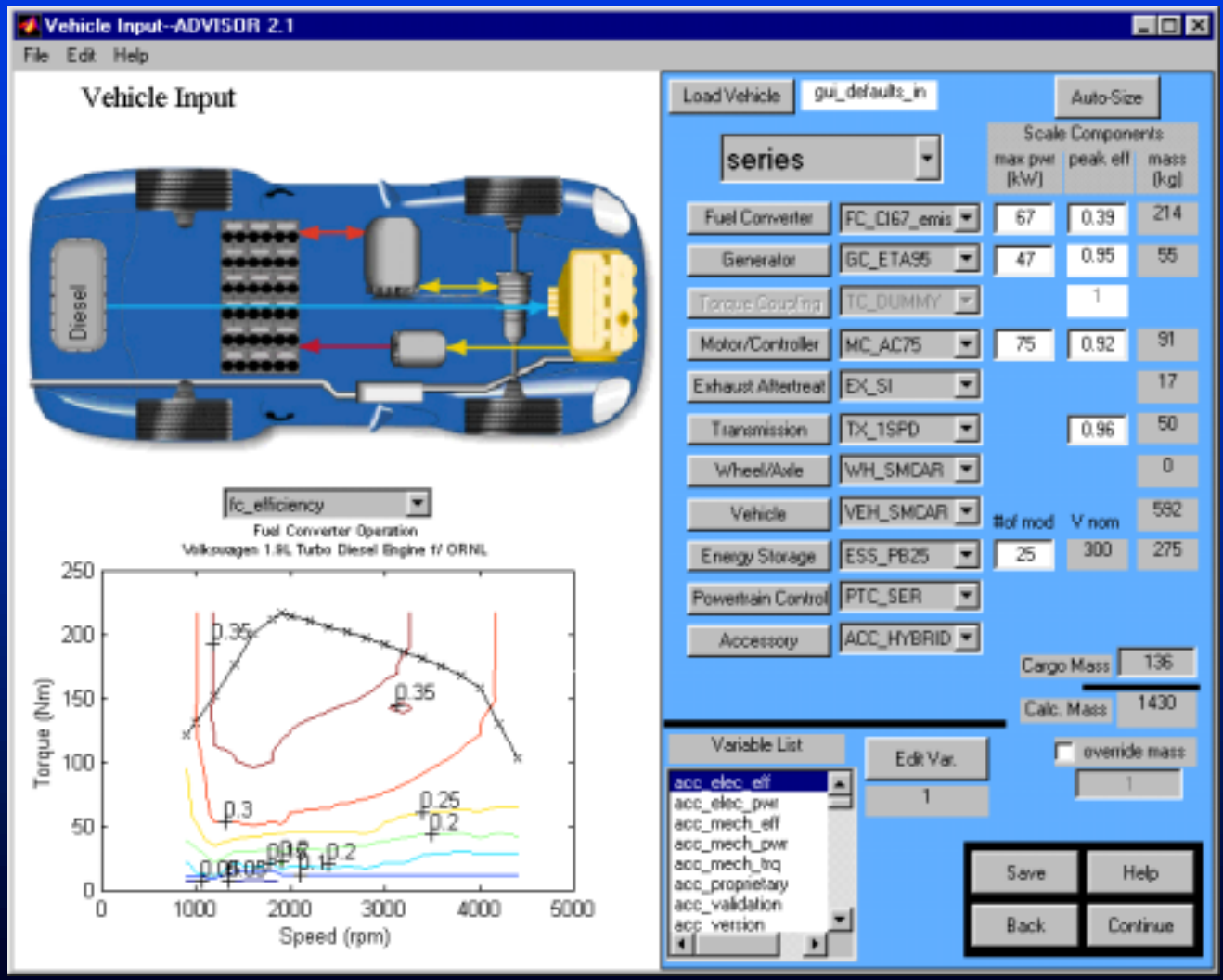


Results

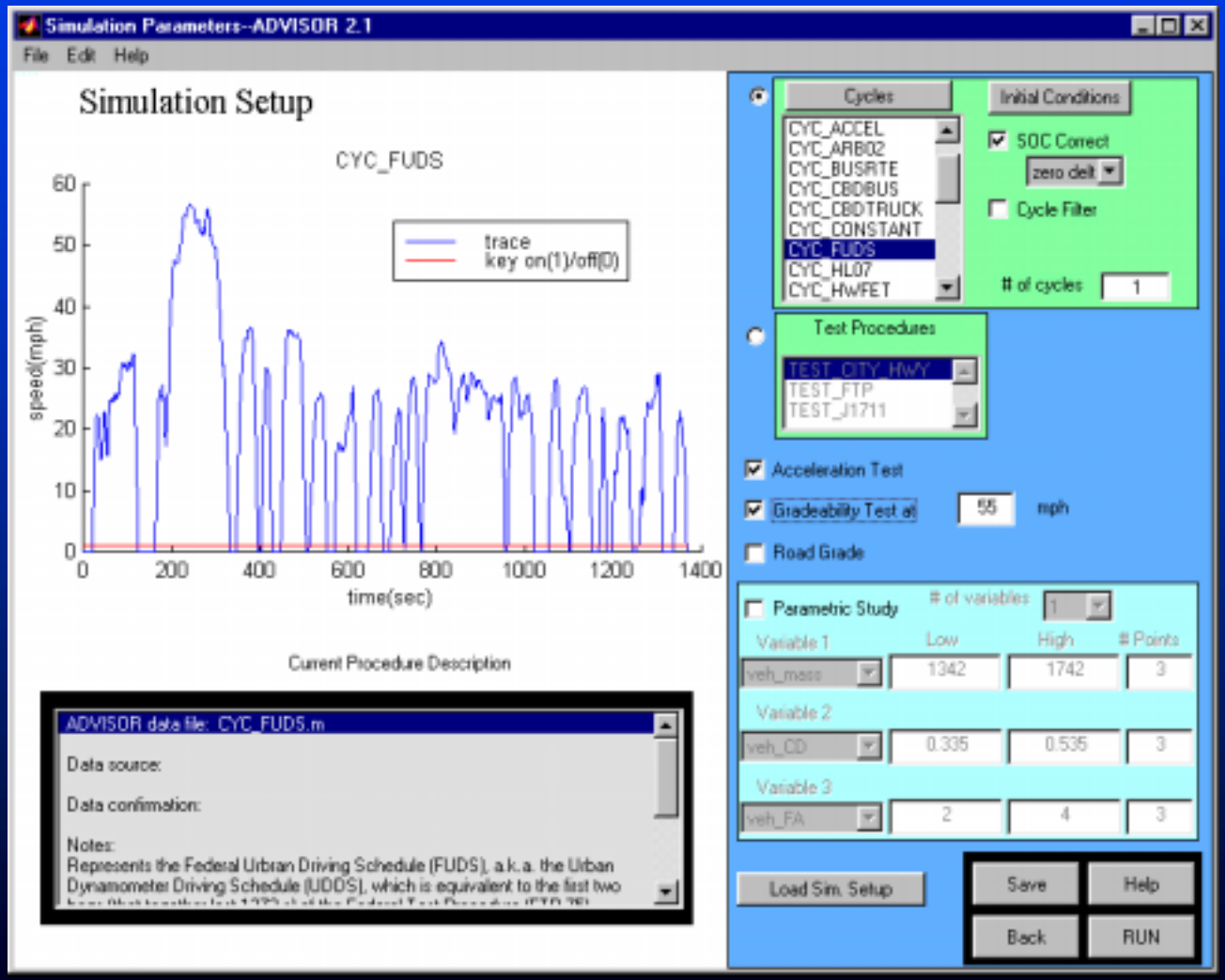


ADVISOR Demonstration

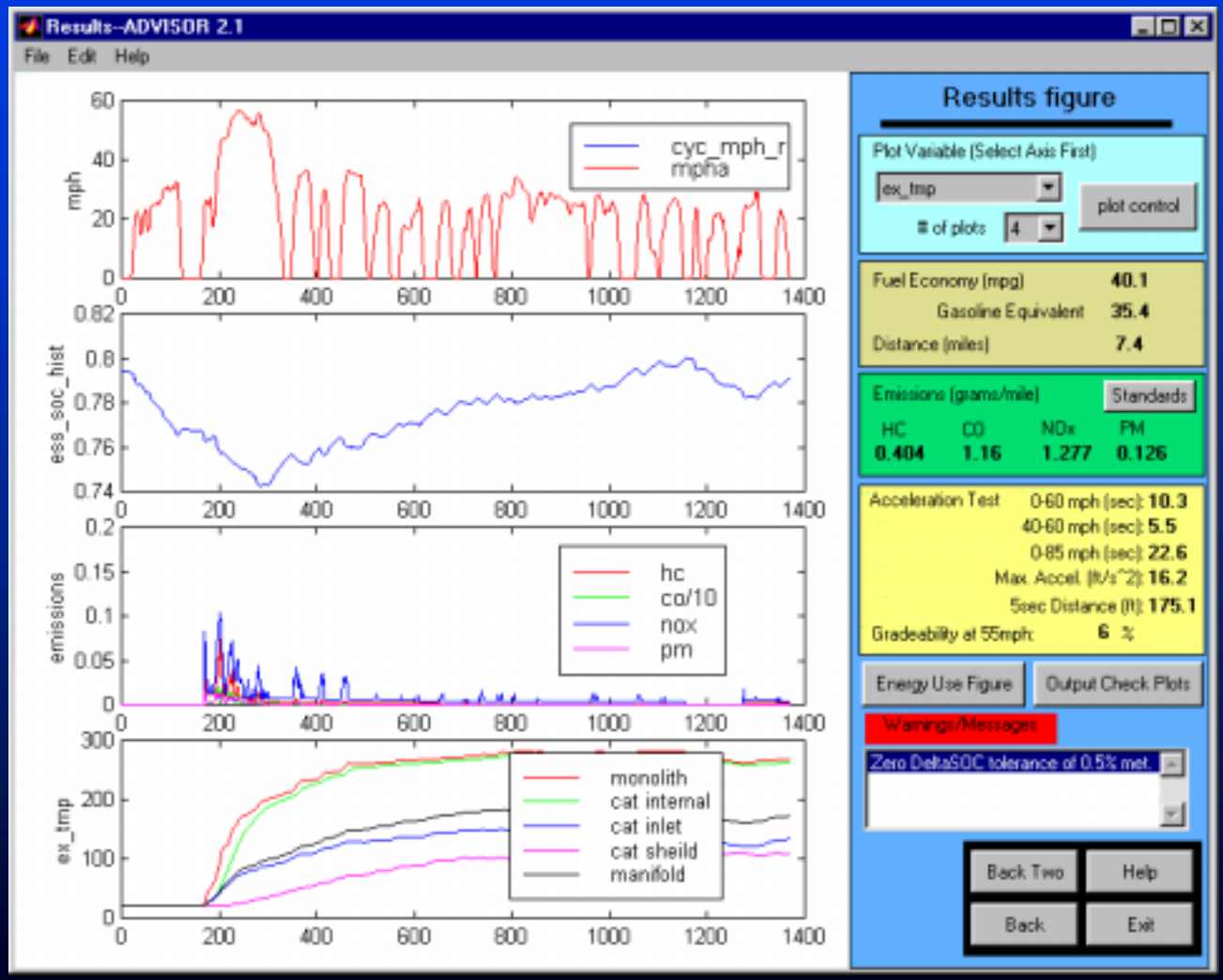
Vehicle Input Screen



Simulation Setup Screen

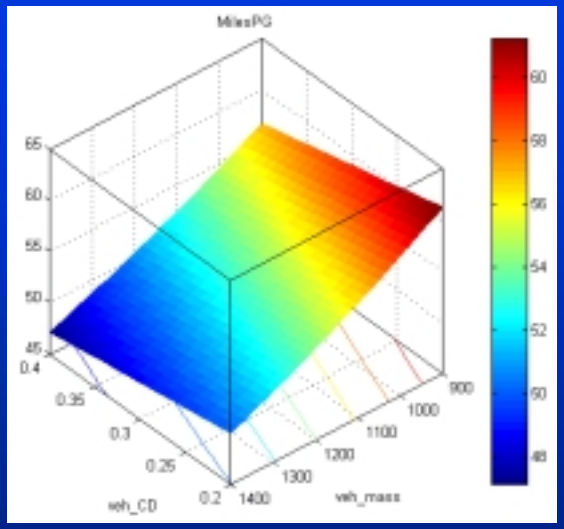


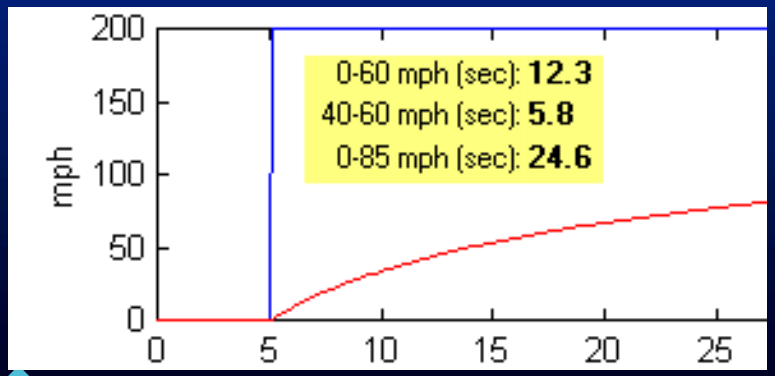
Cycle Results Screen

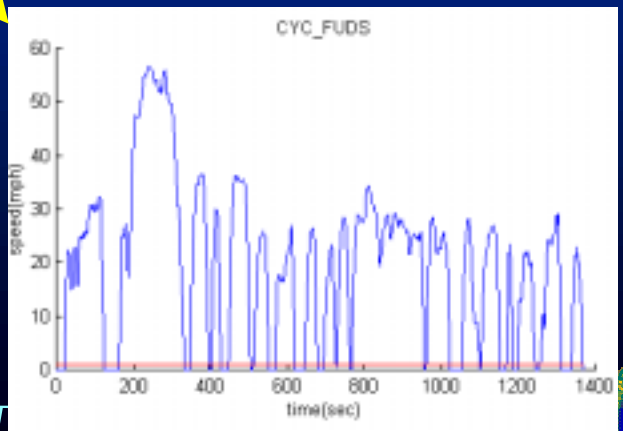


Types of Simulation Tests Possible

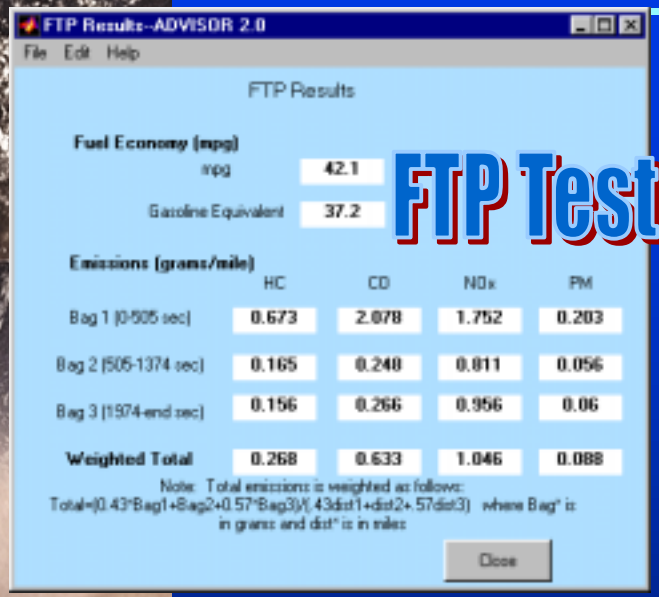
- Parametric sweeps
- Drive cycles
- Acceleration and grade tests





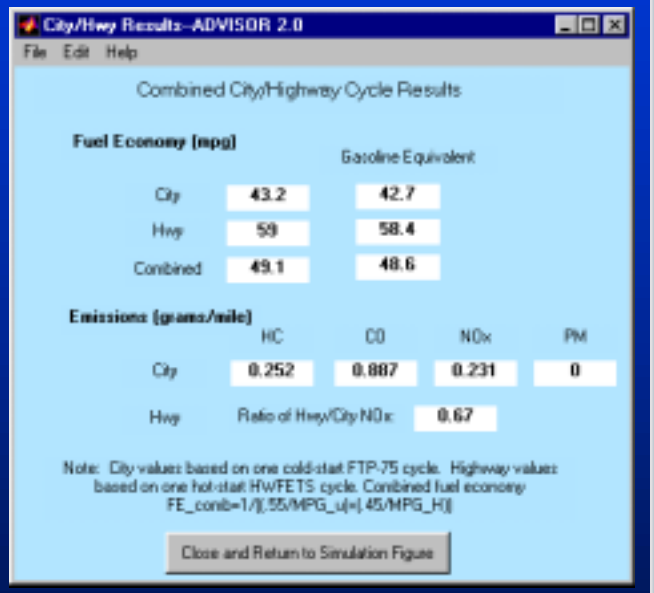


"Test Procedures" Currently Available

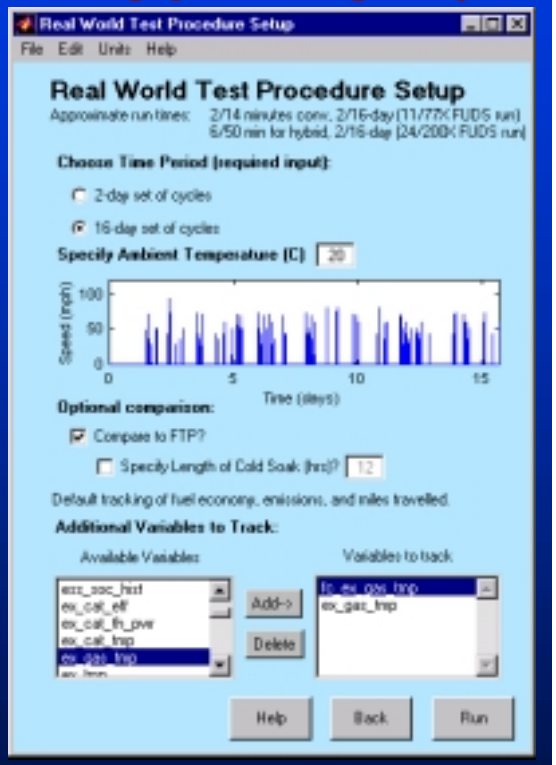


FTP Test

Combined City/Highway



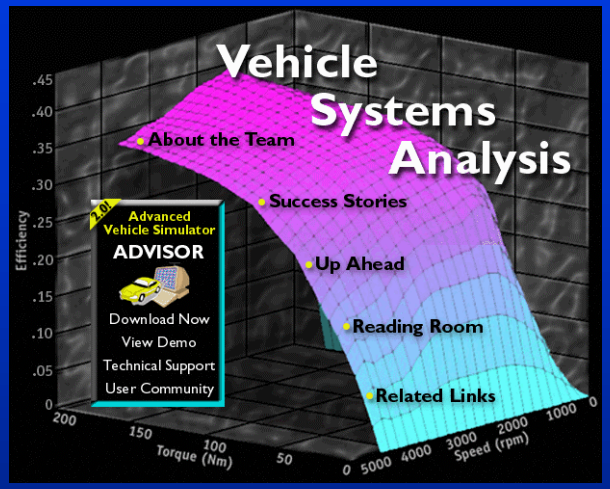
Real World



SAE J1711 HEV Test Procedure

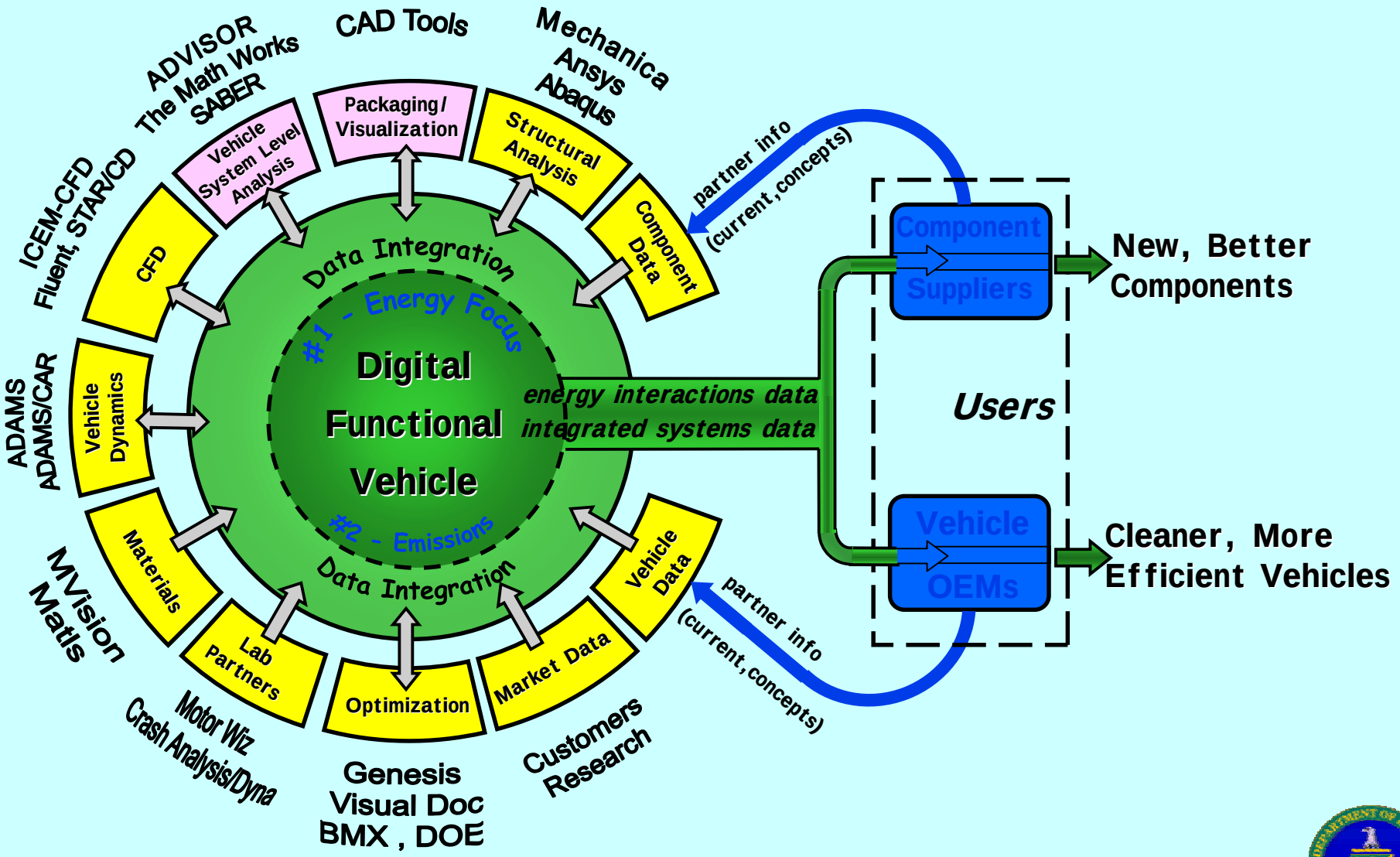
Software Availability on Web

- NREL's Vehicle Systems Analysis web site launched in September 1998
- ADVISOR 2.2 available for free after filling out simple form (incl. source code)
- 'Forum' has bulletin area for questions to be answered and files to be shared
- Documentation viewable from web site
- Reading room has all papers and presentations from team



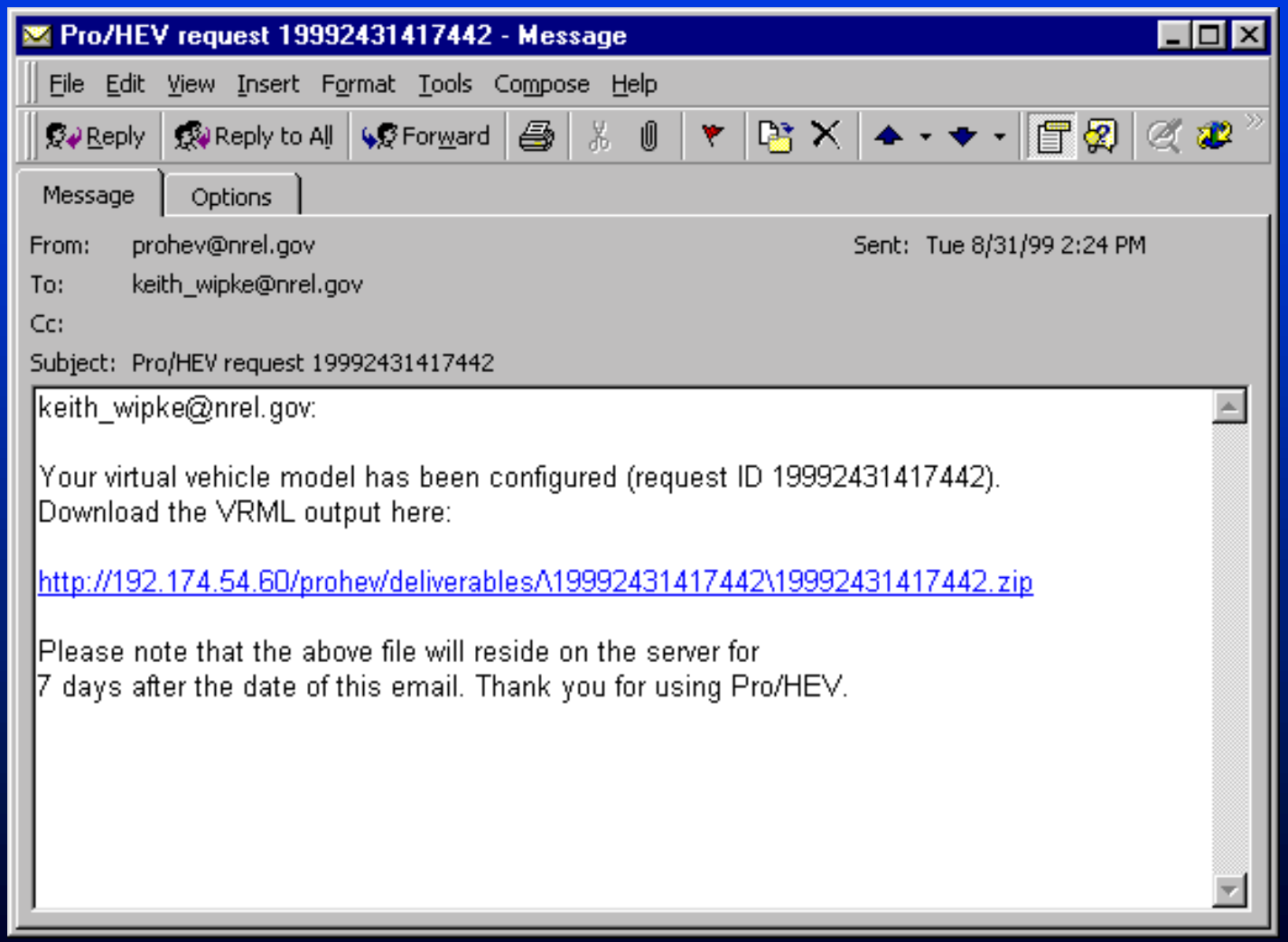
Keith Wipke, Matt Cuddy, Sam Sprik, Steve Burch, Valerie Hovland, Tony Markel.
Not pictured: Matt Keyser, Desikan Bharathan

Example of Linkage with Packaging

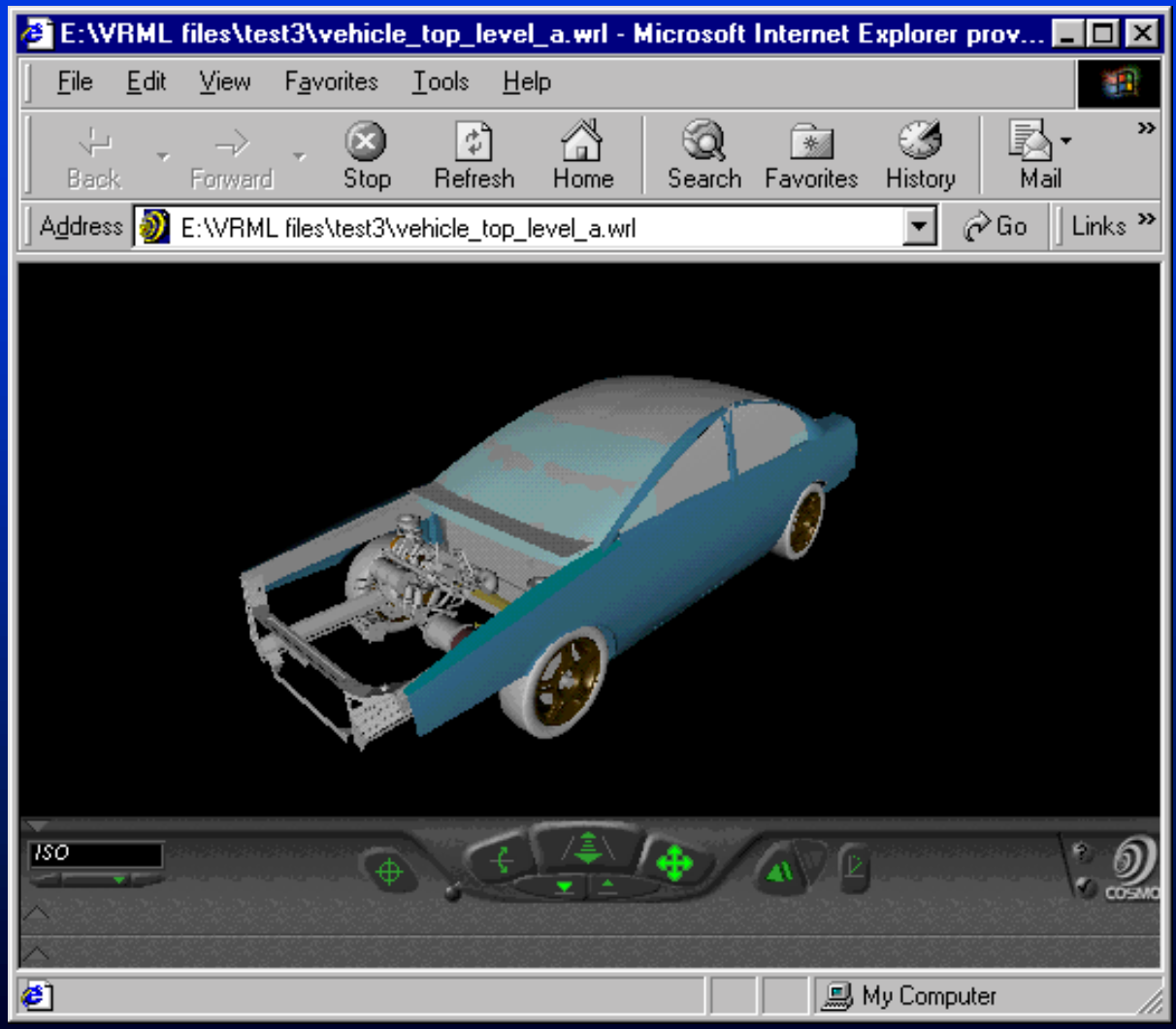


Loading ADVISOR Vehicle into Pro/HEV

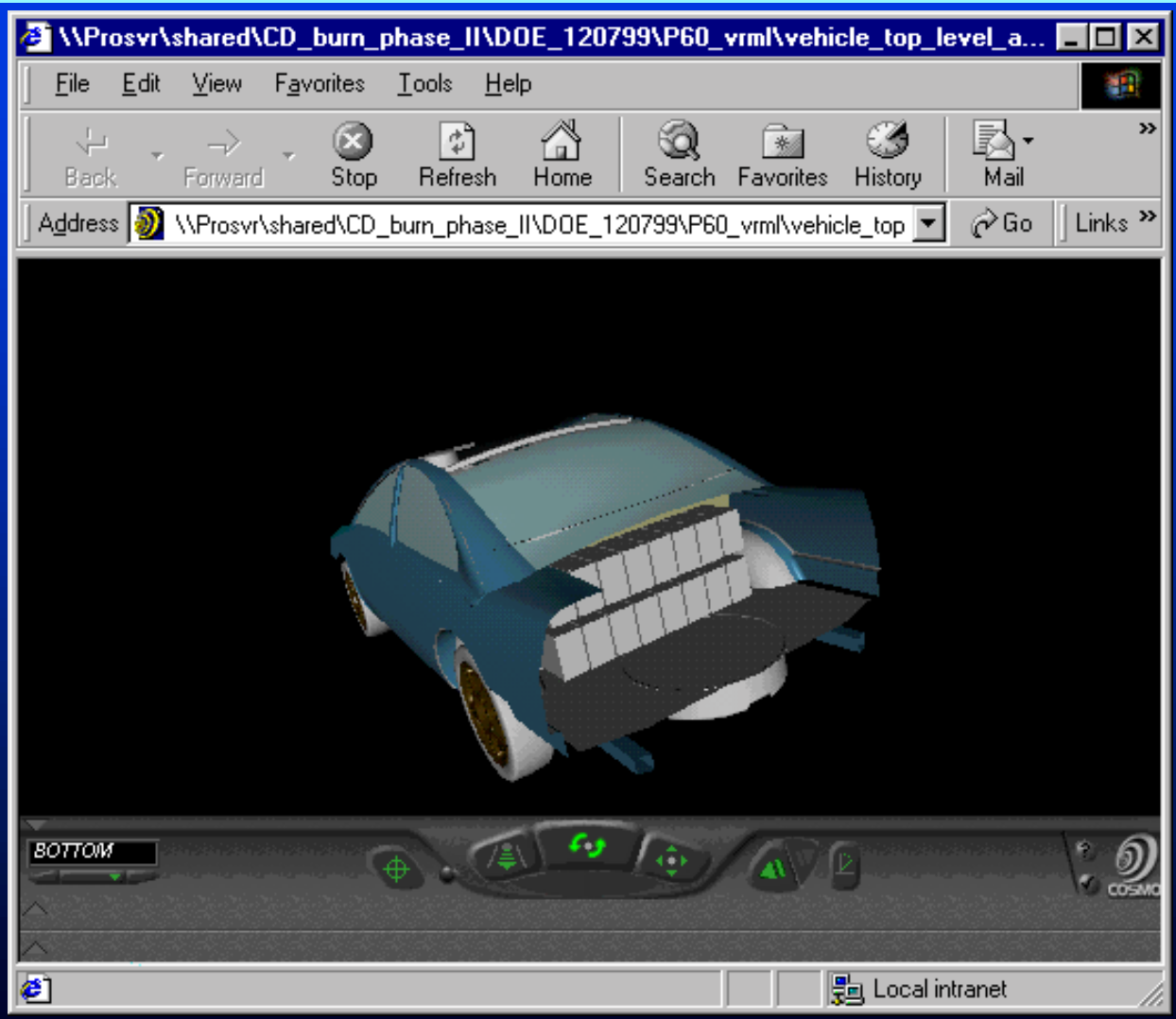
E-mail notification of VRML files



Visualizing VRML Vehicle in Browser

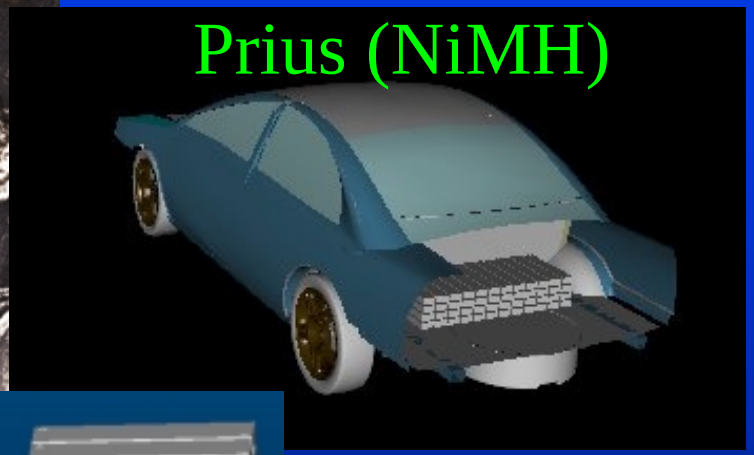


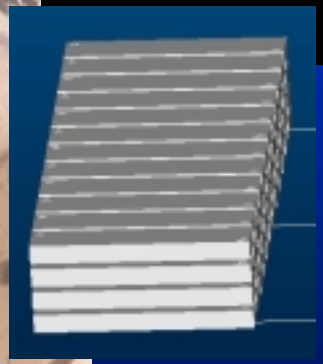
Visualizing VRML Vehicle in Browser



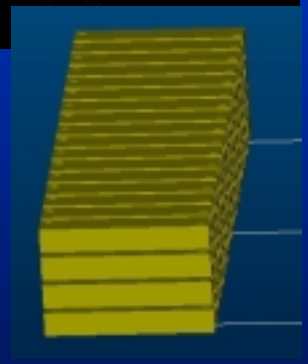
Battery Packaging Comparison from Previous Study (for illustration purposes)

Prius (NiMH)

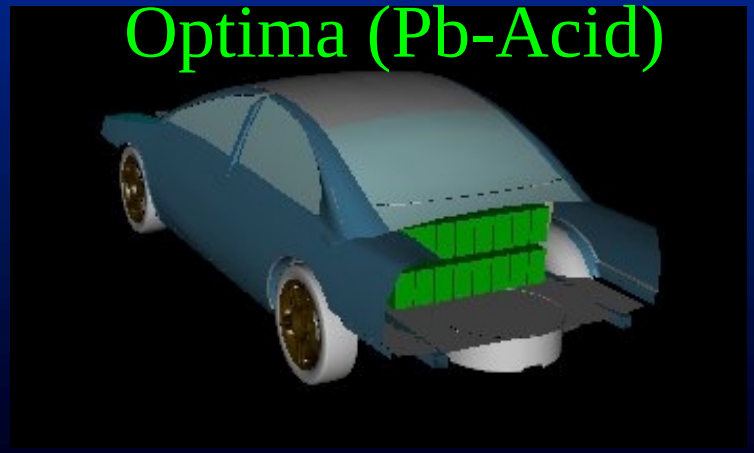




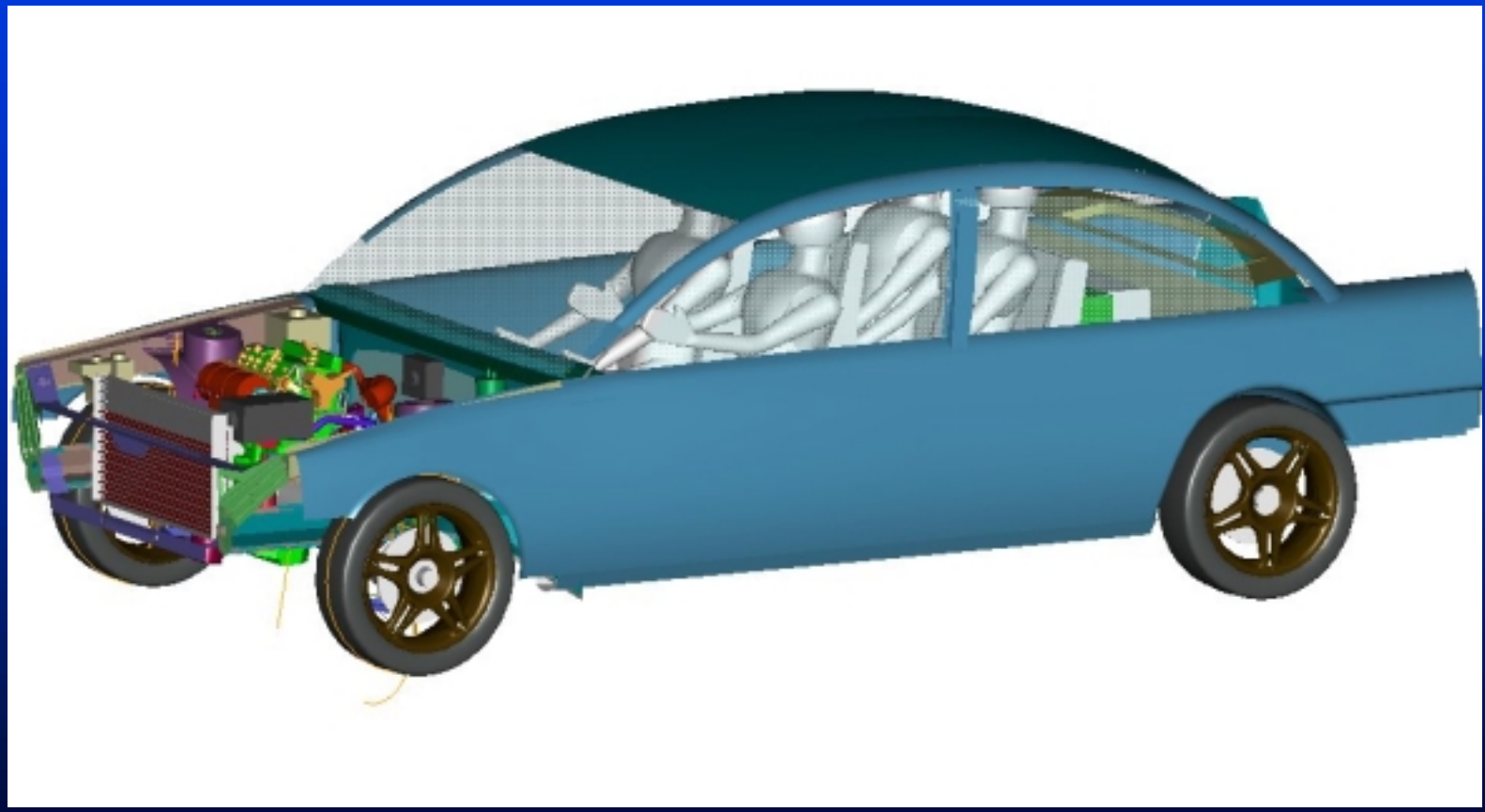
Battery “A” (Li-ion)

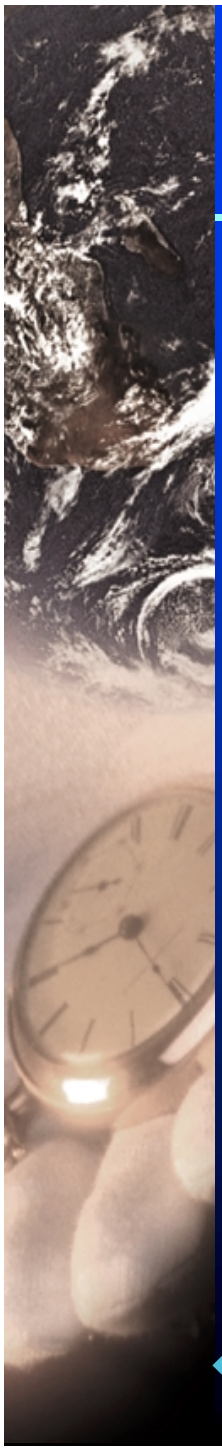


Optima (Pb-Acid)



Full Parametric Vehicle Assembly also Includes Geometry Useful for Many Groups at NREL

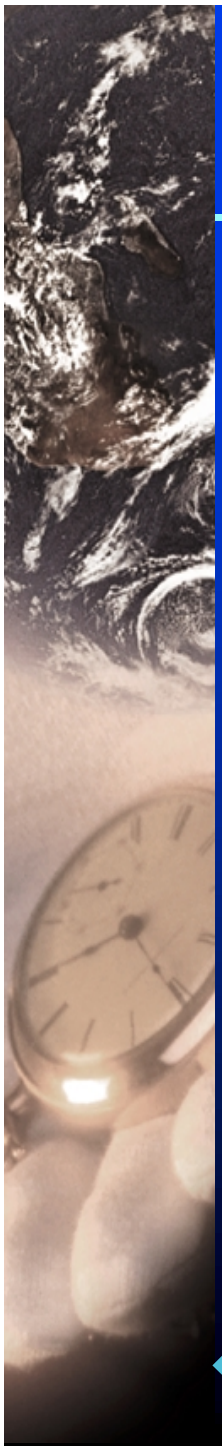




Outline:
Interfacing ADVISOR and ADAMS/Car

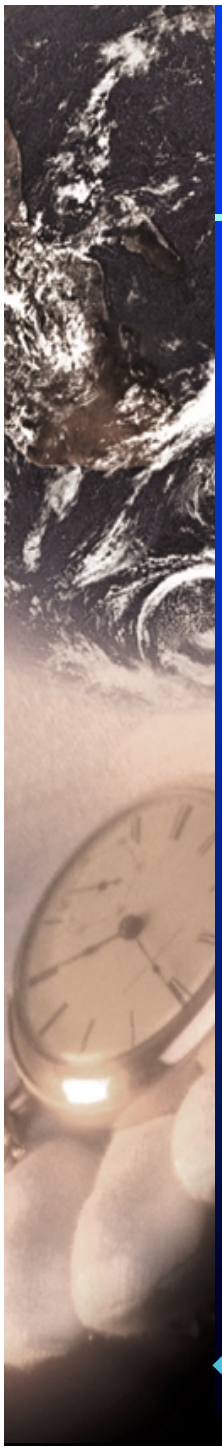
- Two interface approaches will be used:
  - ADAMS/ADVISOR Co-simulation
  - Export to ADAMS/Car

- Each approach has its own advantages and serves different simulation purposes.



ADAMS/ADVISOR Co-simulation

- What?
  - Linking ADAMS/Car full vehicle model with ADVISOR model.
  - Both ADAMS and Simulink solvers run together. Information passed back and forth between the two at each time step.
- How?
  - ADAMS/Car full vehicle model using customized powertrain template.
  - Modified ADVISOR model to work with ADAMS/Car model.

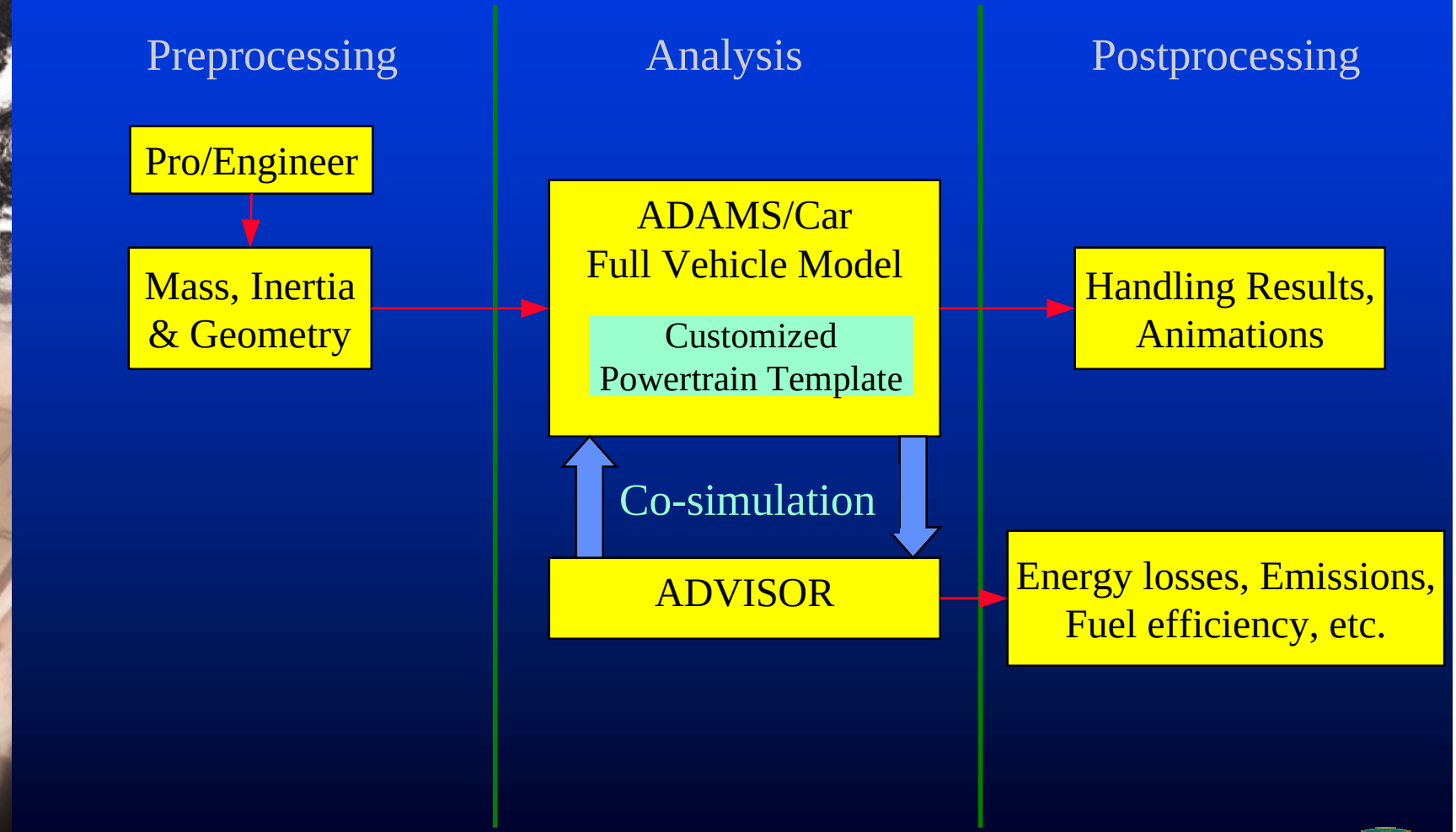


ADAMS/ADVISOR Co-simulation

- Why?
  - Simulate 4WD/AWD powertrains
    - torque split can be actively controlled by ADVISOR
  - Vehicle handling/dynamics with new CM from ADVISOR
    - Can look at stability issues relating to battery placement
  - Calculate energy losses during handling/durability events
    - useful for trying minimizing losses for maximum fuel efficiency
  - Integrate accessory loads (like electric power steering) and look at their energy impact vs. performance
  - Trade-offs to accurately assess impact of vehicle/component mass reduction and evaluating effect on dynamic performance
  - Perform anything you would normally do in ADAMS/Car, but using and advanced powertrain from ADVISOR

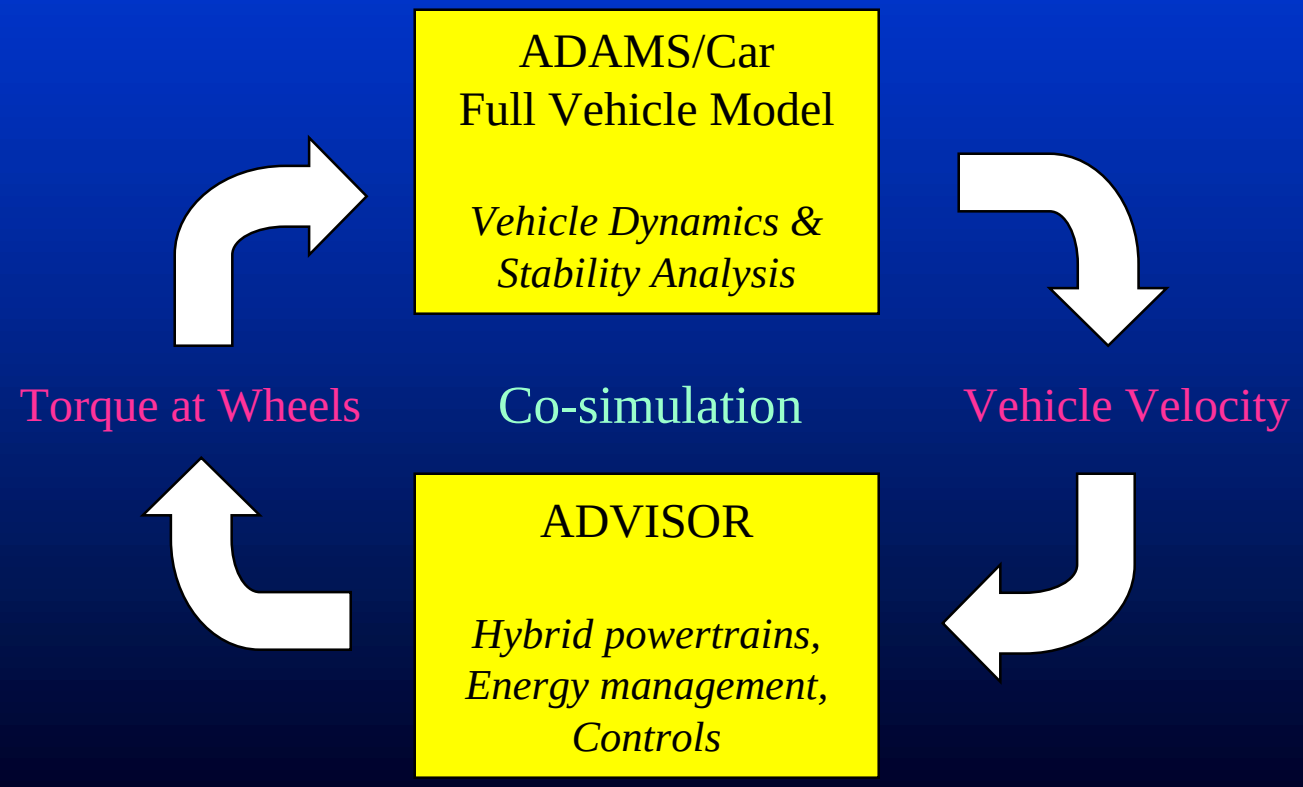
ADAMS/ADVISOR Co-simulation

- Overview



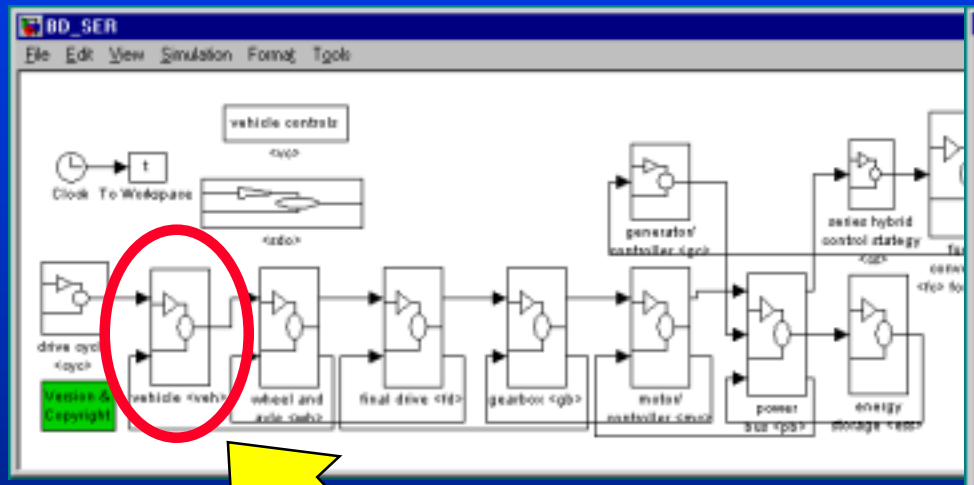
ADAMS/ADVISOR Co-simulation

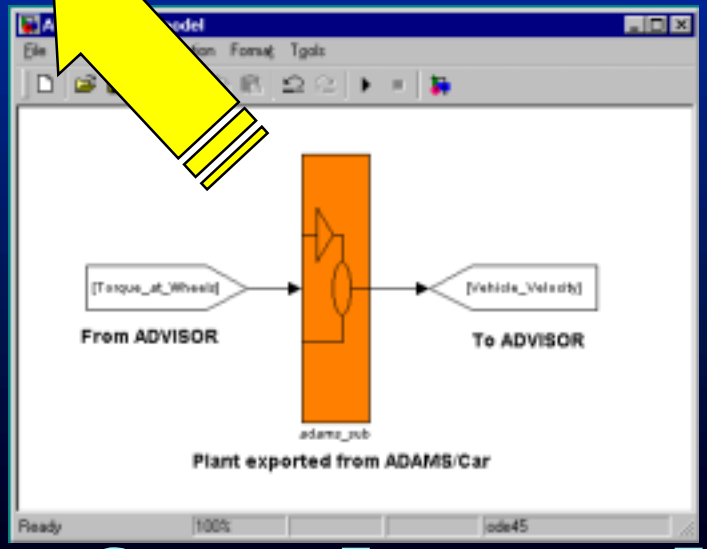
- Information Flow
  - The major variables exchanged are shown below. Additional information will also be exchanged.

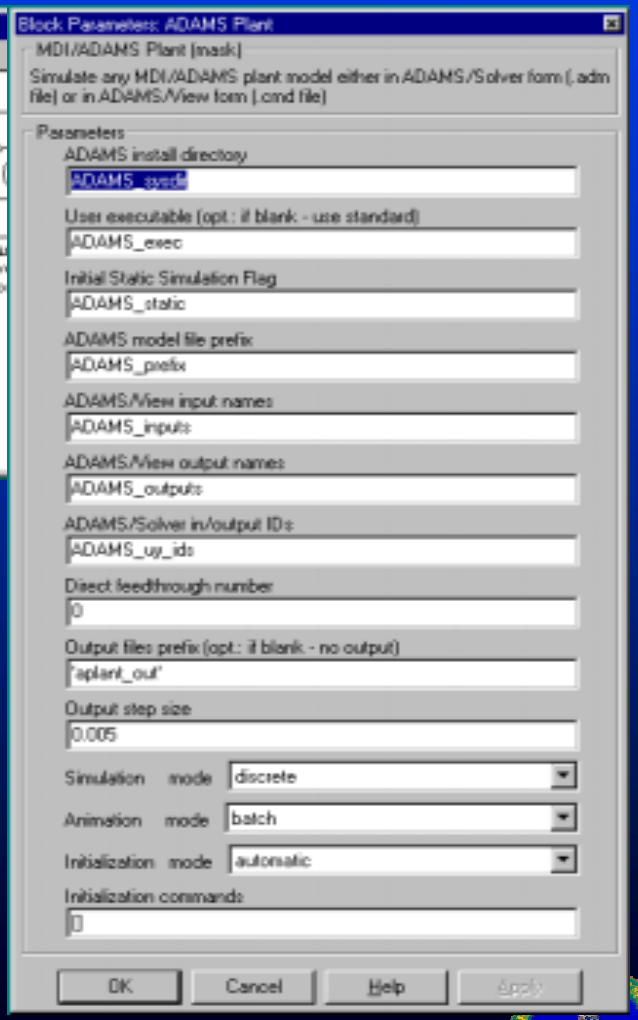


ADAMS/ADVISOR Co-simulation

- Exporting ADAMS/Car Plant to Simulink





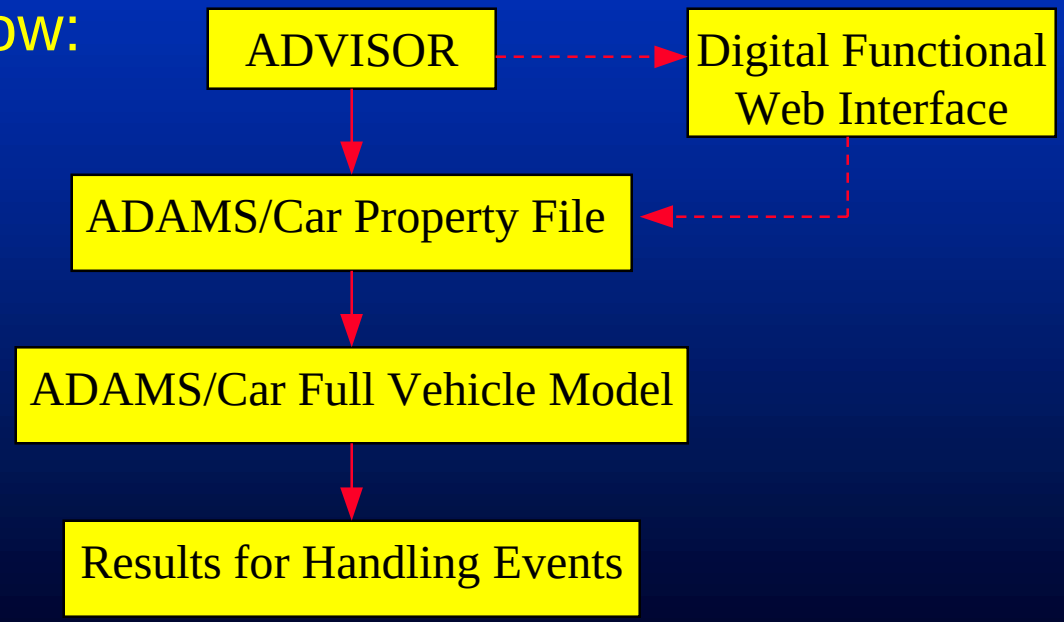


Export to ADAMS/Car

- What?
  - ADAMS/Car full vehicle model with mass and inertia properties exported from ADVISOR
  - One way information flow to ADAMS/Car
- How?
  - Output mass and inertia properties from ADVISOR to ADAMS/Car.
    - Optionally, geometry may be specified in web interface
  - Run standard handling maneuvers in ADAMS/Car.

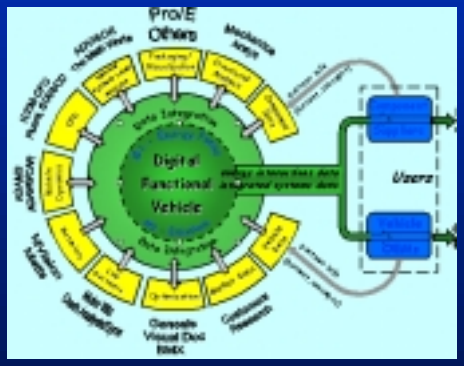
Export to ADAMS/Car

- Why?
  - Faster simulations
  - Quick estimate of handling performance of hybrid vehicle
    - Example: allows analysis of battery pack location (often a large mass) and effect on handling
- Information flow:



Conclusions

- ADVISOR 2.2 is a user-friendly simulation tool available to the public through the web
  - www.nrel.gov/transportation/analysis
- Widespread usage of the model globally has led to a large database of components and vehicles
- NREL is working with industry to link ADVISOR up to tools they use, such as:
  - Pro/E (visualization, packaging)
  - Visual-Doc (Optimization)
  - SABER (electrical)
  - ADAMS/Car (vehicle dynamics)



- Looking for input from active ADAMS users on how they might benefit from and guide this linkage with our advanced powertrain modeling linkage (ADVISOR)