VEHICLE MODELING AND SIMULATION

Scott McBroom, Manager
Advanced Vehicle Technology Section
Vehicle and Driveline Research Department
Phone: (210) 522-3454   Fax: (210) 522-5720
RAPTOR™ Overview

É RAPTOR™ is a modular modeling and development simulation tool for vehicle fuel economy, performance, and emissions in both virtual and Hardware-in-the-Loop environments.

É RAPTOR™ provides an expandable environment by configuring a virtual vehicle from component and sub-component models.
RAPTOR™ Overview

RAPTOR™ is an application program written in MATLAB®/Simulink® to ensure modularity and flexibility for many vehicle configurations.
RAPTOR™ supports two different simulation methods:

* Integration Based Higher Fidelity Forward-Looking Model for:
  - Performance Studies
  - Control Algorithm Development
  - Hardware-in-the-Loop Evaluations

* Derivative Based, Corruptionally Faster Backward-Looking Model for:
  - Fuel Economy Studies
  - Component Sizing Studies
Origins of RAPTOR™:

É Vehicle System Modeling

Performance Assessment Tool for Hybrid Systems (PATHS®) (1996, 97)
Heavy-Duty & Military Vehicles

Light-Duty Passenger Vehicles

RAPTOR™
HIL, Batch Utils, Database, Modular Vehicle Construction
RAPTOR™ Overview

Major Software Elements Include:

- MATLAB®/Simulink® Model Libraries
- Advanced Graphical User Interface
- Database and Reporting Utilities
- Modular Architecture
Model Libraries: Component and Vehicle

RAPTOR™ is composed of component libraries that can be configured and stored as complete vehicles.
Model Libraries: Components

Â Vehicle
- Dynamics
- Grade
- Trailer

Â Engine
- Engine Mechanical Fuel Rate
- Turbo
- Heat Rejection
- Fuel Shut Off Control
- Emissions
- Warm-up
- Heat Rejection

Â Engine Accessories
- Air Conditioning
- Power Steering
- Alternator System
- Cooling Fan
- Generic Mechanical
- Generic Electrical
Model Libraries: Components

É Launch Device
  Â Torque Converter
  Â Clutch

É Manual or Automatic Transmission
  Â Transmission Gearbox
  Â Shift Logic

É Continuously Variable Transmission (CVT)
  Â Transmission Ratio Mechanism
  Â Ratio Scheduling

É Transfer Case
  Â Differential / Axles

É Tires
  Â Rolling Resistance
  Â Traction Coefficient
  Â Dynamic Radius
Model Libraries: Vehicle Configurations

Â Light Duty
  - 2WD Drive
    . Front wheel drive
    . Rear wheel drive
  - 4WD drive

Â Medium and Heavy Duty
  - Single Axle Trucks
  - Tandem Axle Trucks with and without Trailer
  - Buses
The GUI aids the user in Vehicle Model Construction, Data Reporting and Data Storage:

- Vehicle selection
- Powertrain Configuration
- Desired level of detail (accessories, shift schedule, etc.)
- Editing the input data
- Creating batch runs
- On-line Help
Component Access

- Select component from library menu
- Edit data fields
  - Select model and data set
  - Enter new data through fields or tables
- Plot data
- Create new versions
- View component details
- Change units
Data Modification and Display

View 2D and 3D component data before and after modification

Accept or reject changes or simulate using modifications
Example Accessory Definition Screen
Configure/Run Simulations

- Select from two Simulation Methods
  - ‘Backward’ simulation method for quick studies of data effects on fuel economy
  - ‘Forward’ simulation method for more detailed results
  - Combine the two for performance and fuel economy results
Database and Reporting

É RAPTOR™ database application performs queries regarding prior simulation jobs performed and saved to the database, data files available, job requests, etc.

É The database enables users to:
- Reproduce any simulation previously saved
- Store component models
- Securely store component model data
- Store powertrain configuration models
- Manage configurations for data and models
- Store and retrieve simulation results
Simulations and Results

Select multiple simulation drive cycles for any vehicle

- Display US or European metrics - toggle between the two
- Reset simulations displayed
Generate Standard Reports and Plot Results

- Up to four plots onscreen at once
- Preset plot styles may be applied
- Plot to new figure
- Multiple variables on a single plot with legends
- Control over line styles, colors, and markers
RAPTOR Enterprise Applications
RAPTOR Supports Real-Time Hardware-In-The-Loop and Co-Simulation of Powertrain Components

Design and Development Process

RAPTOR™ Vehicle Powertrain Simulation

Modeling and Simulation

Concept Design & Control Sys Development

Analysis

Fabrication

Testing and Calibration

Real-Time Hardware in the Loop Tools
Versatility of RAPTOR Architecture for HIL Simulation
Design Optimization

- Proprietary Genetic/Neural Network Algorithms for Optimization

- Has Been Previously Applied to:
  - Internal Combustion Engine Design
  - Transmissions Shift Logic Calibration
  - Hybrid Electric Vehicles Component Selection
Licensing

É RAPTOR™ is Being Used by:
- Daimler Chrysler Corporation
- DENSO
- U.S. Army National Automotive Center

É For Licensing Information Contact:
- Scott McBroom
- smcbroom@swri.org
- 210.522.3454
Application Example #1 - Fuel Economy and Performance

Scenario: You are a vehicle manufacturer with a wide range of engines, transmissions and vehicles. Test cells are booked around the clock, yet the total number of vehicle combinations does not come close to being tested. How can you characterize product fuel economies and emissions compliance.

Application: RAPTOR can be used to create “reference manuals” of vehicle portfolios. The database utility allows these manuals to be sorted by year, model, or major components.

Scenario: You are an engine manufacturer supplying engines to a variety of vehicle integrators (OEM’s). OEM #1 requests a modification to accommodate a new sub-system.

Application: Since it would be more cost effective to incorporate the change in all engines, RAPTOR™ can evaluate the sub-system change’s effect on your other client applications.
Supplemental Material

Application Example #2 - Full Vehicle Simulation with Legacy Models

Scenario: You are a transmission manufacturer with a wide range of engines and vehicles that your product is used in. In addition, you have a high fidelity transmission model that satisfies all of your needs (legacy code). You would like to continue use of this model, but would like the additional features of RAPTOR™ and MATLAB®/SimuLINK®.

Application: RAPTOR™ incorporates your transmission model into the existing choices for transmissions, and can now be chosen with the Vehicle Configuration GUI. Your transmission model is now in an environment that allows it to be modeled along with different engines and vehicles, within a vehicle simulation environment. In addition, vehicle configurations can be saved and recalled, and the impact of various vehicle configurations can be studied.
Supplemental Material

Application Example #3 - Development and Test Cycle

Scenario: Your company wants to develop a new engine control module.

Application: RAPTOR™ provides a virtual engine, vehicle, and test environment. For the physical model of the engine, either the standard RAPTOR™ engine model is used, or you can modify the engine model using the RAPTOR™ programmer’s guide. MATLAB®/SimulINK® is then used to develop the control algorithms for the virtual engine and vehicle.

Once the controls prototyping is accomplished, Opal RT’s RT-LAB™ (RAPTOR™ preferred Real Time operating environment) re-targets the prototype controls to a prototype controller for use on an actual engine as Hardware in the Loop (HIL). When the control algorithms have been validated, using the real engine, it is then time to place the control code into the production ECU hardware, using external production code generators.

The ECU hardware can then taken back to the original virtual engine and vehicle, for HIL validation, before the ECU is fielded for the final testing.