THE UNIVERSITY of TENNESSEE Challenge X Program

PRESENTERS
Scott Curran
Shaun Hinds
Courtney Lindwurm
Sean Peterson
Outline

• Challenge X program
• Stock Equinox
• Physics
• Hybrid types
• Tour of Vehicle
What is Challenge X

- Minimize Energy Consumption
- Reduce Emissions
- Maintain/Exceed Vehicle Performance

Competition

- Year 1 – Modeling, Simulation, Powertrain testing
- Year 2 – Integrate & Develop Powertrain
- Year 3 – 99% Buy-Off
- Year 4 – Detroit - DC
Stock Vehicle

- 2005 Chevy Equinox with 3.4 L V6 and AWD
Stock Specs

- **3.4L V6 Engine**
  - 185 hp and 210 lb.-ft. of torque

- **EPA estimated MPG**
  - 19 city, 26 highway

- **Time for 0-60 mph**
  - 10.94 seconds

- **EPA Emissions Level**
  - LEV
Physics

• Thermodynamics
  – Engine Efficiency
  – Combustion

• Electricity and Magnetism
  – Electric motors
  – Hi Voltage System
  – Batteries and Energy Storage

• Dynamics
  – Power and Energy
  – Vehicle Handling
  – Newton's Laws
Focus on Hybrids

• Q. Why does a Hybrid get better fuel economy than a regular car?

A. Less Wasted Power
Forces

- Newton's Laws
Power

\[ \text{Power} = \text{Force} \times \text{Velocity} \]

\[ P = F \times V \]

\[ P_{\text{dw}} = P_{\text{roll}} + P_{\text{aero}} + P_{\text{grade}} + P_{\text{accel}} \]
Fuel Mileage

- City Driving - FUDS

Positive Power
Negative Power

Power Required to propel
Vehicle speed

Federal Urban Driving Schedule

Drive Wheel Power (kW)
Vehicle Speed (mph)

Time (sec)
Fuel Mileage

- Highway Driving - HFET
Regenerative Power

- Kinetic Energy = ½ M*V^2
Hybrid Electric Vehicles

- A vehicle that operates using two or more energy sources
- Current marketed vehicles have gasoline engine and electric motor

More information:
www.howstuffworks.com
Energy Sources

- Engine
- Fuel Cells
- Flywheel
- Ultracapacitors
- Electric Machine

- Fuel Types
  - Gasoline
  - Diesel
  - Biodiesel
  - Ethanol
  - Hydrogen
Series

**Advantages**
- No mechanical coupling between engine and wheels
- Engine always operates at most efficient point
- Regenerative braking

**Disadvantages**
- Needs two electric machines
- Expensive
- Heavy

*Honda Insight*
Parallel

- Advantages
  - Regenerative braking
  - Engine can charge battery
  - Optimize performance of engine and motor
  - Only need one electric machine

- Disadvantages
  - No stationary charging
  - Engine must always be running

Chevrolet Silverado
Pre-Transmission Parallel
Post-Transmission Parallel
Thru-the-road Parallel

- **Advantages**
  - Complete redundancy
  - Simple to implement
  - Engine and motor are only connect thru the road
  - Only one electric machine needed

- **Disadvantages**
  - No stationary charging
  - Engine must always be running

University of Tennessee Equinox
Thru-the-road Parallel
Series-Parallel

- Advantages
  - Can run on pure electric mode
  - Regenerative braking
  - Engine can run more efficiently

- Disadvantages
  - Complex to implement
  - Two electric machines needed

Toyota Prius
Series-Parallel

- FUEL
- ENGINE
- GENERATOR
- POWER SPLIT DEVICE
- MOTOR
- POWER ELECTRONICS
- BATTERIES
- WHEEL
- WHEEL
Not Stock

- Equinox with 1.9 L Turbo Diesel and AWD Parallel HEV
Through the Road Hybrid

Internal Combustion Engine Powered Front Wheels

Electrically Powered Rear wheels

Provides System Redundancy
Hybrid Components

- 1.9 L Turbo Diesel running biodiesel
- 336 V NiMH Battery Pack
- 60 kW Motor
Modes of Operation

- **Full Hybrid mode**

  Both CI engine and IPT provide the traction power for the vehicle.

  Battery Charging Occurs at Vehicle Cruising speeds when the CI engine can provide excess power to do so.
Modes of Operation

- **Limp-Home Mode**

System redundancy & segregation provides the ability for limited vehicle operation should either the CI engine or the High-voltage systems fail.
Modes of Operation

- Series Regenerative Braking
Component Layout

View From Above
- 1.9L GM Turbo Diesel Engine
- Competition Fuel Tank

View From Below
- Cobasys 336 Volt NiMH Battery Pack
- IPT Controller
- Ballard IPT

Logos:
- Ballard
- GM
- Cobasys
- TN engineering
Packaging Continued

Trouble Areas for THRU-the-Road

Battery Pack Compartment Modification

IPT interference with sub-frame

Rear Sub frame

Component to Frame Interfaces

Rear Seat and Floor
## Design Goals

- Increase fuel economy
- Maintain performance and utility
- Reduce emissions
- Noise considerations

### New Specs

<table>
<thead>
<tr>
<th>Description</th>
<th>Goals</th>
<th>UT Hybrid</th>
<th>Stock Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-60 MPH</td>
<td>≤9.5 sec</td>
<td>23.59</td>
<td>10.94</td>
</tr>
<tr>
<td>50-70 MPH</td>
<td>≤7.3 sec</td>
<td>23.21</td>
<td>7.49</td>
</tr>
<tr>
<td>Vehicle Mass</td>
<td>≤4200 lbs</td>
<td>4312</td>
<td>3791</td>
</tr>
<tr>
<td>MPG Combined EPA</td>
<td>≥32.0 mpg</td>
<td>20.39*</td>
<td>15.27*</td>
</tr>
<tr>
<td>Highway Range</td>
<td>≥200 mi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger Capacity</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Trailing Capacity</td>
<td>2500 lbs</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>Cargo Capacity</td>
<td>60 Cu. Ft.</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Starting Time</td>
<td>&lt;5.0 sec</td>
<td>7-8 sec</td>
<td>1.5 sec</td>
</tr>
<tr>
<td>Noise Emission</td>
<td>&lt;75 dbA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>