

# ROUSH®

A collage of automotive parts and components. On the left, a white truck is partially visible. In the center, there are various suspension and steering parts, including a control arm and a ball joint. On the right, there are two alloy wheels, a person wearing glasses working on an engine, and a close-up of a mechanical part.

Overview for XP Vehicles

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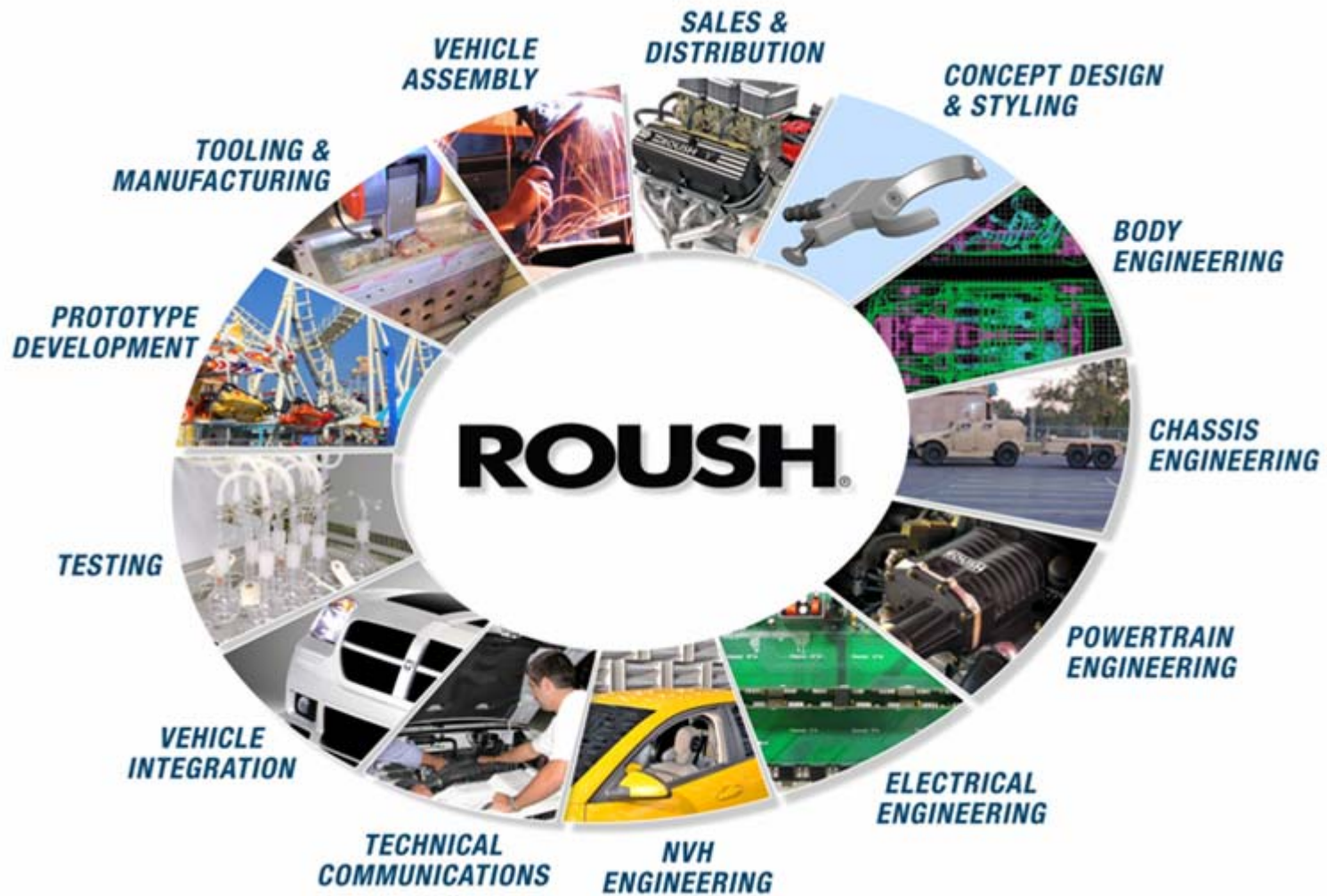
# ROUSH



- Privately Held
- Founded in 1976
- Over 2,500 employees worldwide
- Primary Activities:  
Engineering, Testing,  
Prototyping and Manufacturing



# Single Source Solution



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# Hydrogen Fuel Cell Vehicles



## Flexible Series Hybrid Edge

Plug-in Hybrid with Fuel Cell APU

**130 kW Dual Electric Drives**  
**130 kWh Li-Ion Battery**

**H<sub>2</sub> Fuel Tank**  
**30 kW Fuel Cell**

**Overall Vehicle**

Fuel Cell	30kW Fuel Cell APU
Motor	130 kW Dual Electric Drives
Hybrid Battery	130 kWh Li-Ion
Hydrogen Storage	300 bar, 4 Day/10'
Weight	2700kg
Seating	5 Passenger
Range	200 mi
0-60 Fuel Economy	27mpg

**Features**

- Slow Night Home Re-Charging (110 / 220 VAC)
- 20 Miles Range on Li-Ion Battery
- Zero Emission Hydrogen Fuel Cell APU
- 275 Miles Combined Range with Storage (1 Fuel Cell + 200 Miles other combined with 4.5kWh storage)
- Uncompromised Safety Package
- Electric APU

**How it Works**

The Flexible Series Hybrid Edge is a battery powered plug-in hybrid with a Fuel Cell that operates as an on-board charger. The vehicle operates in "battery only" mode for the first 20 miles at speeds up to 85 miles per hour. After the battery is depleted to approximately 40%, the fuel cell Auxiliary Power Unit (APU) automatically starts up and recharges the battery during the vehicle an additional 200 miles of range. The fuel cell is able to operate in a range of modes to recharge the vehicle's lithium ion battery pack as needed, allowing the break through technology to work like a substitute generator, instead of an engine, as fuel cells have the same fuel cell powered vehicle.

The vehicle is equipped with electrical charging and hydrogen fueling ports on the driver side of the vehicle, in the front and rear. The high voltage battery can be conveniently charged near night time homes or at work or within a 700 or 220 volt outlet. The hydrogen fuel side needs a high of hydrogen and takes about two minutes to fill. This is a zero-emission vehicle and when the fuel cell is operating, only water vapor is emitted through the exhaust system. This advanced powertrain allows an EPA combined city / highway fuel economy equivalent of 47 miles per gallon. Using the plug-in feature only the average range before refueling with hydrogen can be extended to over 400 miles giving the 20 miles per day from home recharging.

The system is a fully flexible and adaptable to other power sources, which allows for flexibility during fuel cell development and hydrogen infrastructure expansion. The benefit of this design is that it allows the flexibility to swap out the fuel cell for a small combustion engine with generator to add-on to the lithium ion battery pack. The motor / fuel tank can power the accelerator until, the fuel cell power doesn't change because of the same hybrid drive system, which is always operating in recharge mode.

**Hybrid Battery**

**Safety**

Ford's innovative hydrogen storage design is offering comfort that separates fuel tank between the frame rails and between the front and rear seats. This is an ideal location for improved weight distribution, lower center of gravity, and protection from crash intrusion.

The combination of these three features along with the uncompromised vehicle packaging makes Ford's latest powertrain "Designed Around Technology" a breakthrough in hydrogen powered vehicle safety.

**Fuel Cell Auxiliary Power Unit (APU)**

**Continued Progress of Ford Motor Company**

Continued research into hydrogen and consumer vehicles is part of Ford's overall effort to address the challenge of clean vehicles and energy independence. Ford is moving ahead with a range of technology of solutions, simultaneously, which include the Ford Focus Hybrid and Mercury Mariner Hybrid, Hydrogen Fuel Cells, Hydrogen Internal Combustion Engines (ICE), Clean Diesel and references to gasoline based powertrains and advanced transmissions.

Customers are at the intersection of our automotive and our energy and have been supportive partners. The consumer segment is expected to hit 3 million units by the end of the decade, making them an increasingly important part of Ford's business.

Note: Areas that were offering test designs will allow us to reach the customers in the competitive and regulatory segment that already belongs to Ford offering including Ford Flex Hybrid, Ford Edge APU, in time. The full size crossover based on the Flex platform.

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# Hydrogen Fuel Cell Vehicles

**207.297mph**  
**Bonneville 2007**

- Vehicle design
- Aerodynamics development
- Vehicle fabrication
- Propulsion system integration
- Race crew support



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# Plug-In Hybrid Electric Vehicles

## Ford Escape and Edge

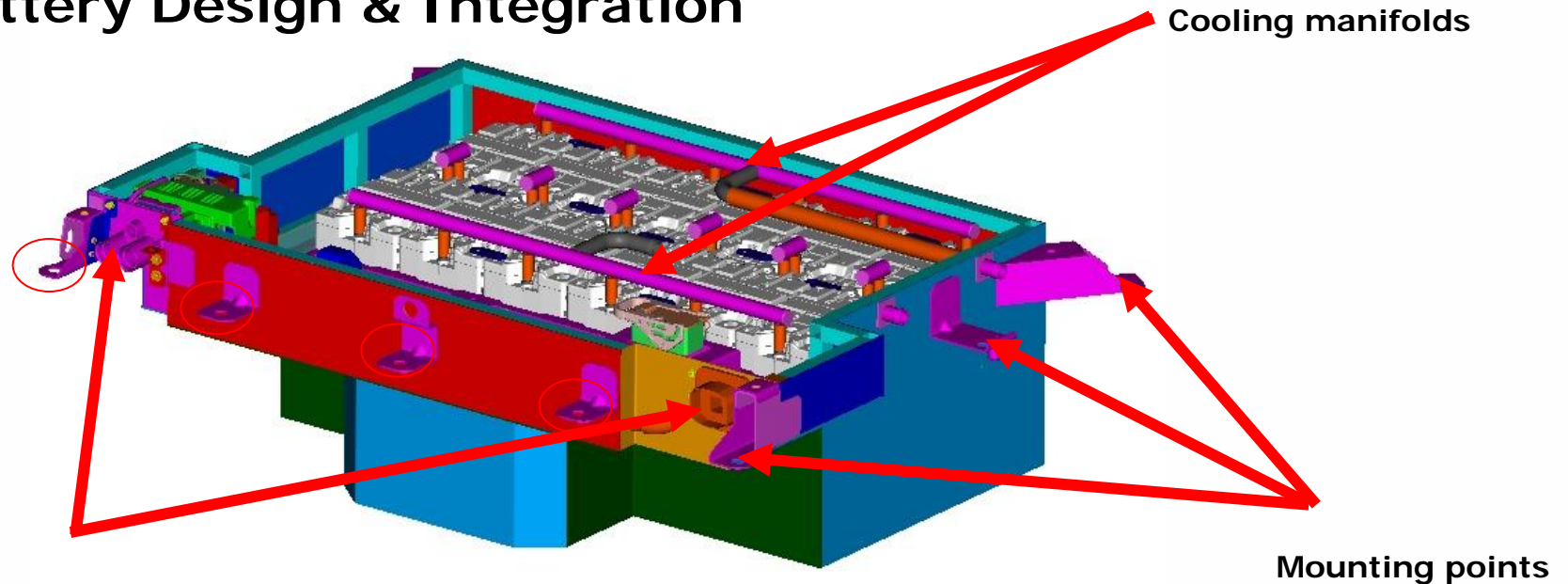
- Roush has performed all vehicle modifications to support integration of PHEV battery systems and charge capabilities.



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# Plug-In Hybrid Electric Vehicles

## HV Battery Design & Integration



- Unique HV battery design and fabrication
- Maintained: production mounting points, HV connector and LV connector and locations.
- Unique Cooling manifold design



# Plug-In Hybrid Electric Vehicles

## HV Battery Design & Integration



**Final PHEV HV Battery Integrated Into vehicles**

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# Electrical System Integration

- Clean-Sheet Prototype Military Vehicles – Electrical Integration of two unique vehicles
  - Entire Electrical Architecture design and integration
  - Distributed control strategy and software algorithm design
  - Wire Harness logical and physical design
  - Multiplex communication protocol design
  - EMI, RFI analysis and testing
  - LV and HV Power Distribution
  - Diagnostics and Prognostics
  - Component Design and Sourcing
  - Instrument Cluster
  - Lighting
  - Power Generation
  - Hybrid Controls
  - Active Suspension Control
- HEV to PHEV Conversion
  - Integration of Battery module
  - Communications gateway
  - Wiring



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# Roush REV – Electric Vehicles

## Vehicle Integration and Build

- AC Motor
- Controller
- Lead Acid Gel Battery Pack
- 72-volt System
- Off road vehicle with top speed limited to 25mph
- Range 45 miles
- 1,100 lb payload capacity



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# Roush – Propane Vehicles

## Vehicle Integration and Build

- Liquid Propane Injection
- Fuel Rail
- Fuel line
- ECM modification
- Under bed/in bed fuel tank



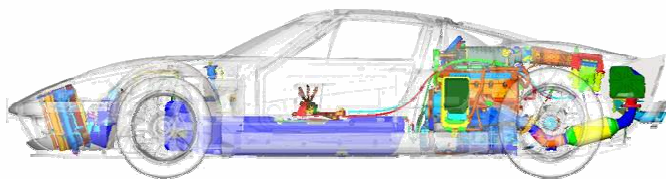
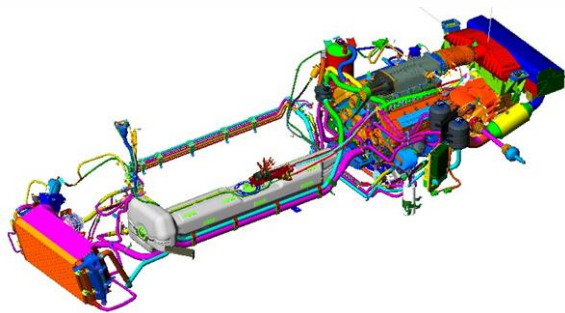
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# Ford GT Vehicle Integrator

## Powertrain Integration Engineering Role:

Engineering, Design, Development and Integration of the following:

- Base Engine
- Drivetrain
- Air Induction
- Exhaust
- Fuel System
- Engine Cooling
- HVAC System
- P/T Calibration



## Body Integration Engineering Role:

Design & Release/Supplier Management of the following:

- Instrument Panel/Door Trim/Centre Console/Headliner/NVH
- Handles, Latches & Hinges (Decklid, Hood, Doors)
- Window Regulators
- Locksets

## Vehicle Properties Produced by Roush:

- Design Aid Buck Build,
- 13 Workhorse Vehicle Carbon Bodies
- 15 Prototype Build Carbon Hood and Decklid Inner Panels

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# Concept Design & Styling

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- Sketches, Renderings & Concept Modeling
- 3,500 square foot studio
- Electronic security system
- 3-D ATOS Optical Scanner
- Norton Surface Plate
- 5-Axis Tarus Mill

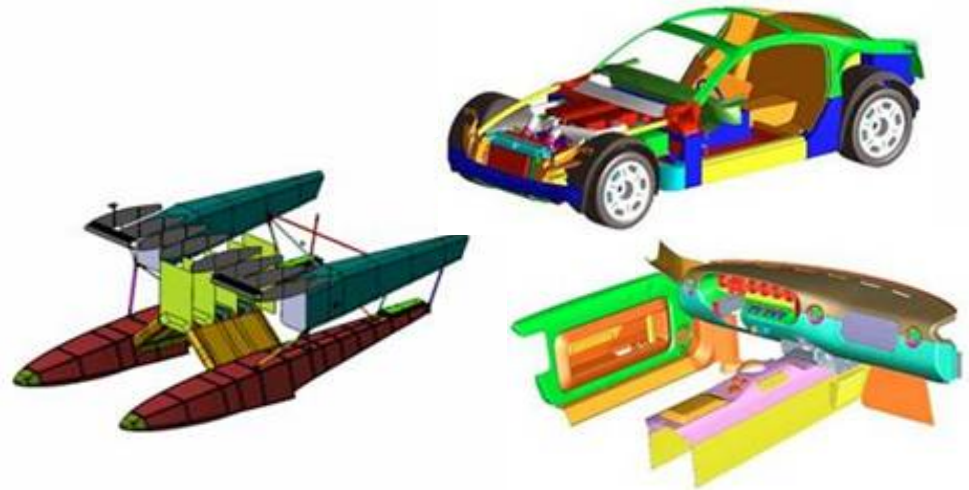


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# Body Engineering

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- Body Systems
  - Body Structures
  - Closures / Hardware
  - Exterior Ornamentation
- Interior Systems
  - Instrument Panels
  - Hard & Soft Trim
  - Consoles
  - Noise, Vibration, Harshness



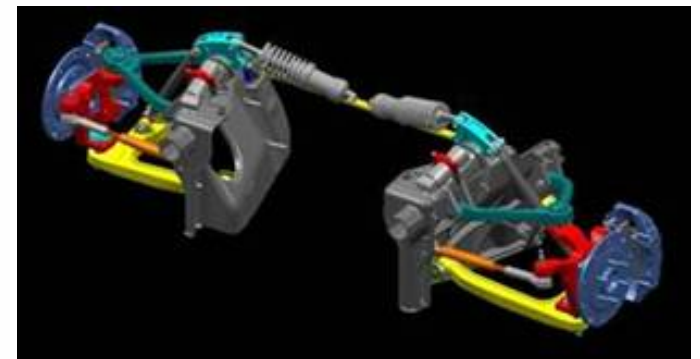
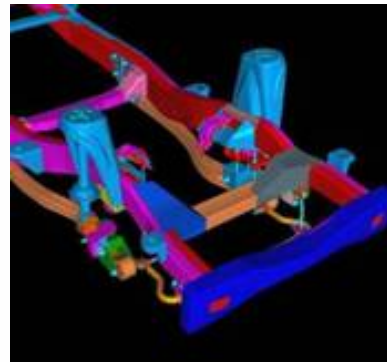
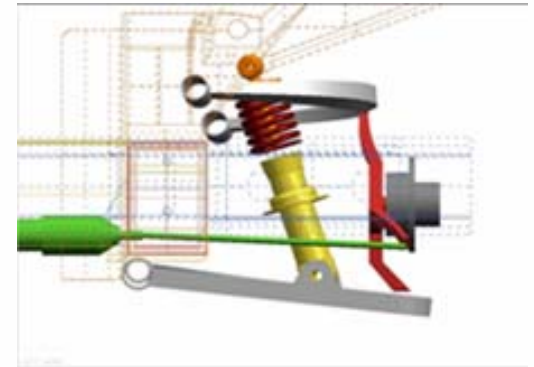
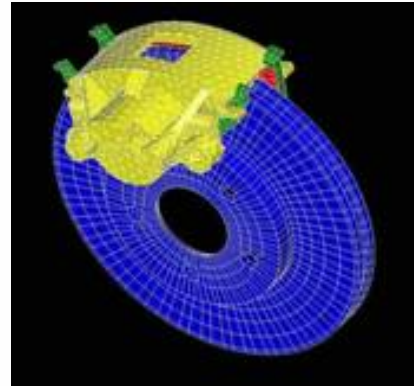
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# Chassis Engineering

## Chassis Systems Design & Development

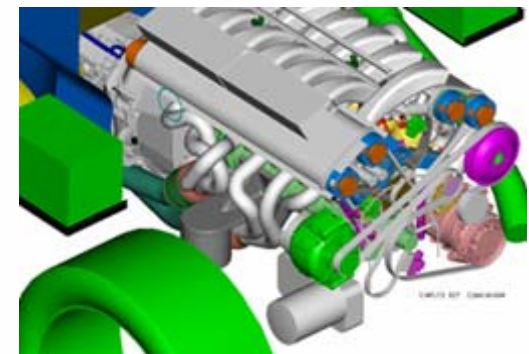
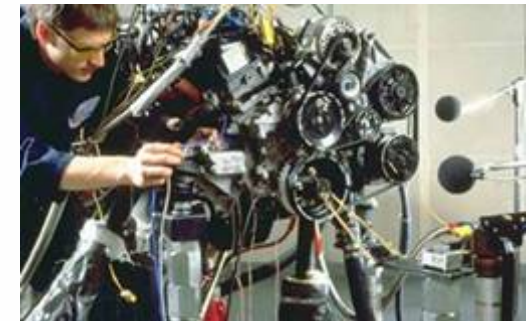
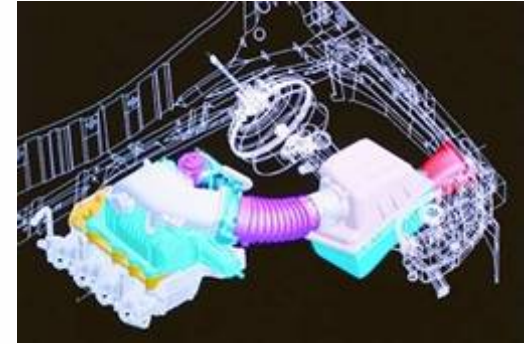
- Frame
- Braking
- Steering
- Suspension
- Ride & Handling
- Vehicle Dynamics
- Road Load Data Acquisition



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# Powertrain Engineering

- Design
  - Base Engine & Components
  - Powertrain Systems & Components
- Development
  - Engine Management Calibration
  - Vehicle Cooling, Heat Management, Climate Control
- Computer Aided Engineering (CAE)
  - Virtual Engine Performance Simulation
  - Valvetrain / Cranktrain Dynamic Analysis
  - Induction Flow, Pressure & Velocity Distributions, Engine Cooling
  - Noise, Vibration, Harshness (NVH)
    - Stress
    - Durability

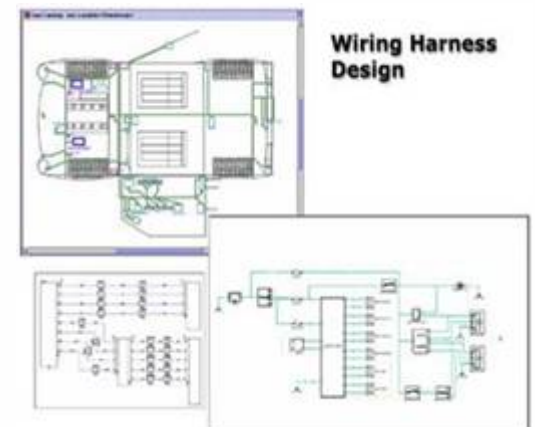


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# Electrical Systems Engineering

- Control System Development
  - Embedded Control System Software and Integration
  - Algorithm Development
  - On-board Diagnostic Development
  - Vehicle Network Communications
- Electrical Hardware Design and Development
  - Circuit Board Layout and Design
  - Prototype and Small Volume Manufacturing
- Wire Harness Design
  - Prototyping
  - Small volume production
  - Electrical system bucks
- Custom Data Acquisition and Control
  - Engineering test devices built to order

Model-Based Embedded Controls Development

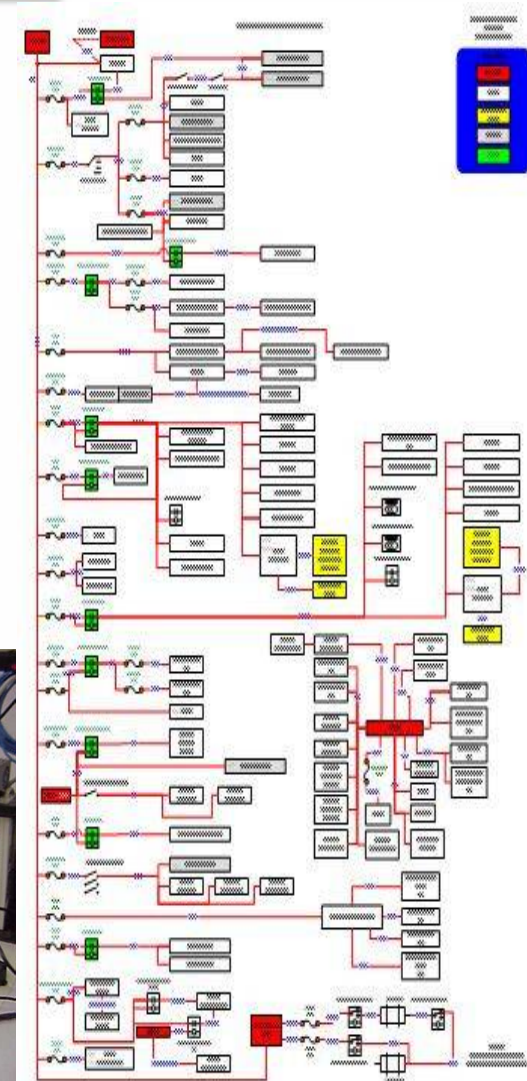
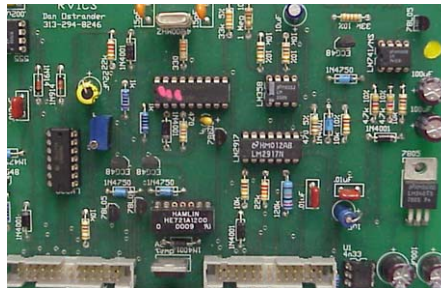


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# Automotive Wiring

- Wiring Services
  - Wire Harness Design
  - Prototype Harness Fabrication
  - Circuit Board Development
  - Load Analysis
  - Wire Gauging
  - Transmittals

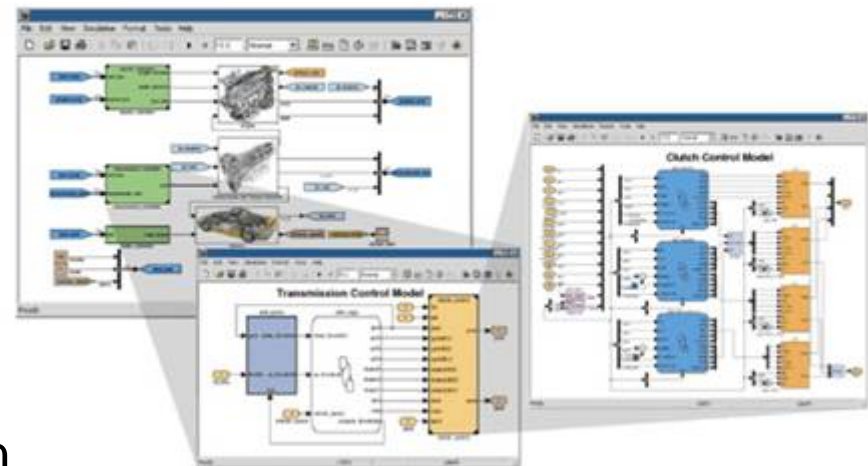


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# Software Development

- Embedded Software Design
  - System Definition
  - Requirements Capture
  - Algorithm Design and Test
  - C-programming and Code Generation
  - Legacy Code Integration
  - Validation and Verification
  - Calibration
- Test and Measurement
  - Custom Data Acquisition applications
  - Instrumentation Control
  - Data Analysis and Presentation
  - NI/LabVIEW, Visual Studio

## Model-Based Embedded Controls Development



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# Control System Development

- **Roush Embedded Control System Examples (Mototron):**

- Roush Hydrogen Internal Combustion Engine (HICE) conversion of a Chevrolet Silverado (low volume production). Key roles included:
  - Powertrain design and development
  - Creation of the entire engine and transmission control system.
  - Unique algorithm creation, testing and calibration for driveability, emissions, fuel economy, diagnostics and communications.
- Revolve HICE conversion of a European Ford Transit.
  - Similar integration as the Roush HICE Silverado



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# Control System Development

- **Additional automotive embedded control systems include (Mototron):**
  - Roush Crate Engines.
  - Supercharged Gasoline engine strategy for engine dynamometer use.
  - Direct injection diesel engine control system for engine dynamometer use.
  - Production control system for an off-highway ground support vehicle, including an OBDII scan tool interface.



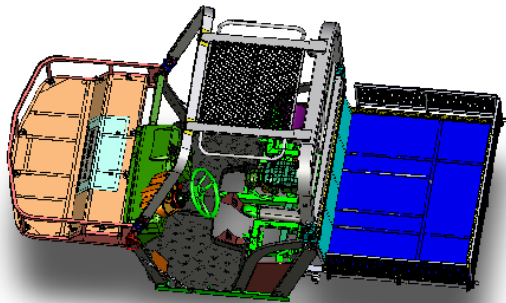
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# Computer Aided Design

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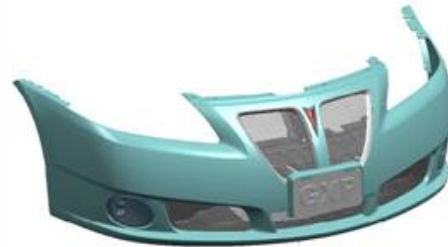
## Software

- CATIA V4 and V5
- Unigraphics NX
- PRO Engineer
- ICEM
- VIS VSA
- AutoCAD
- Product View
- VIS Mockup (digital buck)



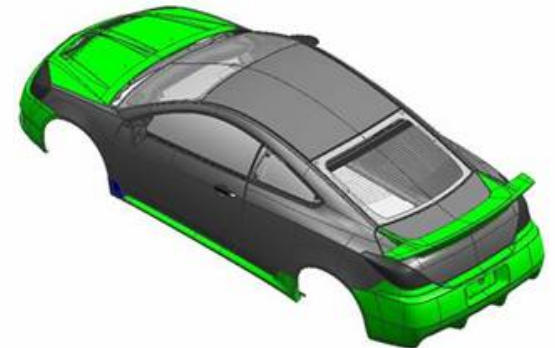
## Data Transfer

- Multiple high speed connections
- ANX/Supplier FTP
- IMI Bridge (IDEAS Metaphase)
- AUTOWEB
- Secured FTP site
- VPM
- iMAN BRIDGE
- Data Translations



## Services

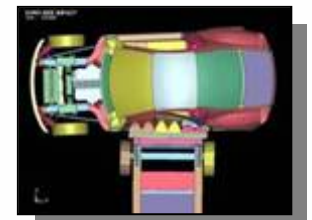
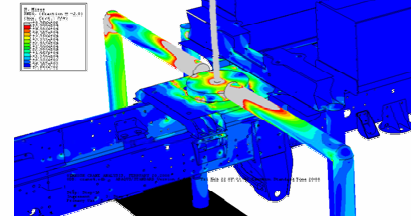
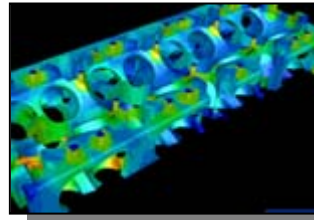
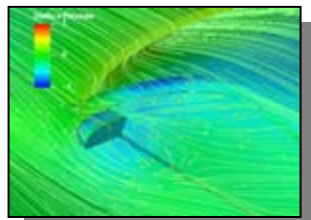
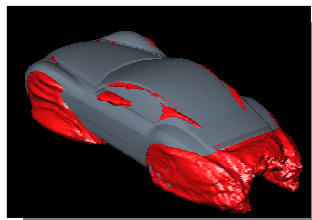
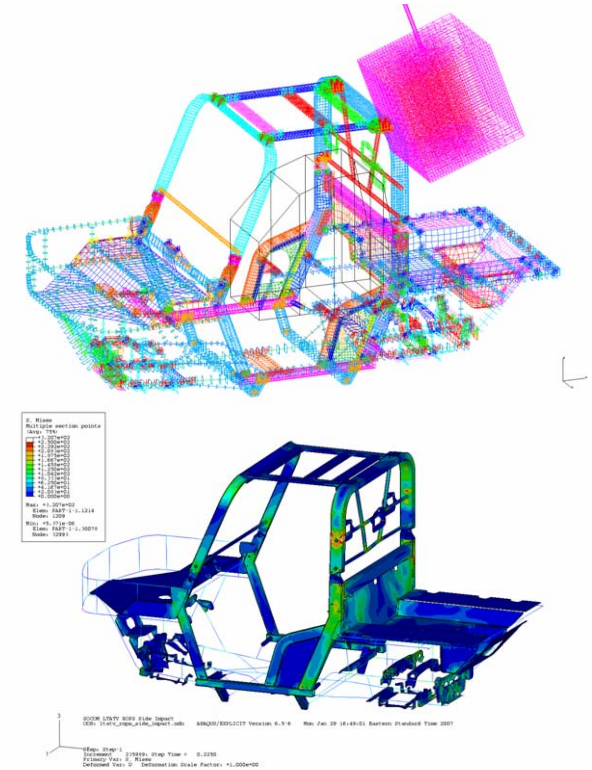
- Class A Surfacing
- Packaging/Feasibility
- 3D Solid Modeling
- 2D & 3D Tolerance Analysis
- Detailing
- Digital Buck
- Data Management



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# Computer Aided Engineering

- Finite Element Analysis
  - Predictive Failure / Modal Analysis
  - Crash and Impact Analysis
- Computational Fluid Dynamics
  - Aerodynamics / HVAC / NVH
- Kinematic and Dynamic Analysis
  - Closures / Mechanisms

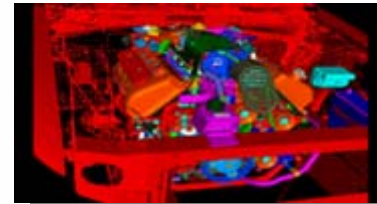
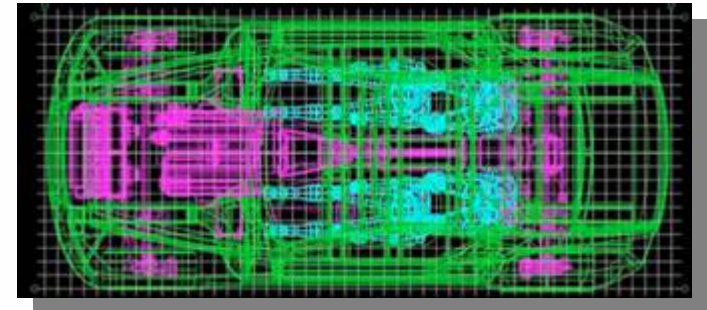
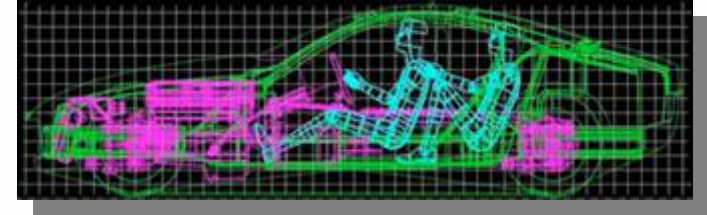


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# Packaging

- Occupant Package
  - Ingress
  - Egress
  - Safety
  - Visibility
  - Ergonomics
  - Seating Module & Restraints
- Mechanical Package
  - Chassis
  - Driveline
  - Suspension
  - Powertrain
  - Interior, Exterior & Under Hood



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# Prototype Services

- Rapid Prototyping
  - Stereolithography (SLA)
  - Selective Laser Sintering (SLS)
- Molded Components
  - Silicone Tooled Components
  - Vacuum Formed Components
- Machining Services
  - 2 Axis Laser Cutting
  - 3 & 5 Axis CNC Milling Machines
- Metal Fabrication
- Composite Lamination
  - Carbon/Kevlar
  - Reinforced Epoxy Panels



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# Vehicle Build / Mechanical Services

- Vehicle Build Programs
  - Prototype and Low Volume Production
- Mechanical Services
  - Launch Retrofit Support/Vehicle Development
  - High Volume Vehicle Assembly
- Instrumentation
  - Aerothermal Development/Road Load Data Generation



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# Testing

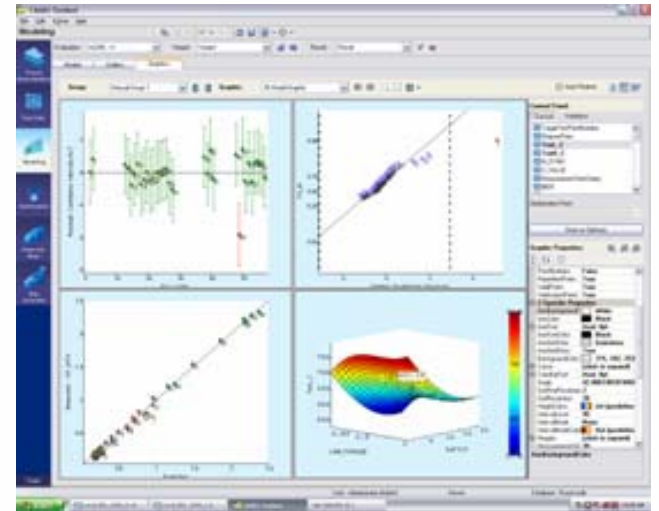
- Vehicle Emissions
  - Tailpipe and Evaporative Testing (LEVII)
  - Electric Range Testing
  - Net Energy Usage Determination
- Powertrain Test Cells
  - 25 Durability & 24 Development
  - Gasoline / LPG / CNG / Diesel Fuels
  - Emissions & In Cylinder Combustion Analysis
  - Deep Thermal Shock
- Brake Testing & Analysis
  - On Road
  - Environmental Dynamometer
- Mileage Accumulation
  - California, Colorado, Florida, Minnesota



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# Transient & Climatic Dynamometer Testing

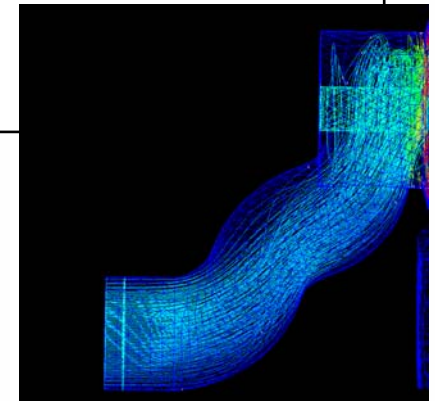
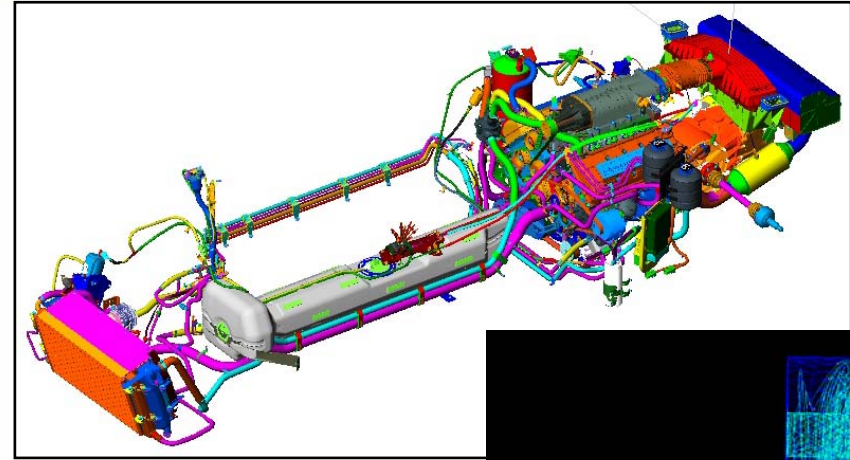
- Complete Drive Cycle Simulation
- Configurations
  - Engine only
  - Engine with Transmission
  - Hybrid Powertrain configuration
- Climatic Testing from  $-40^{\circ}\text{C}$  to  $90^{\circ}\text{C}$  with Rapid Engine Cooling
- 16 Channel Combustion Analysis
- Combustion Air and Fuel Conditioning
- Emissions, Drivability & Cold Start Performance
- Calibration Optimization



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# Thermal Systems Engineering



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# Noise, Vibration, Harshness (NVH)

- CAE Noise Analysis
  - Statistical Energy Analysis
  - Finite Element Analysis (FEA)
- Vehicle Sound Package Optimization
- Materials Testing
- Testing Resources
  - 9 Hemi-Anechoic test cells for:
    - Powertrain
    - Vehicle
    - Brakes
    - Accessories
  - Reverberant Chamber (sound absorption)
  - Sound Quality Listening Room
  - Vibration / Durability Shakers



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# In Summary

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- Powertrain Development & Testing is a Core Competency
  - Vehicle Integration is Roush's Specialty
  - Extensive Range of Local Services to Provide Support for Specific Needs
  - Personnel, facilities and support are available in one organization
  - Passion to deliver to our customers on time and within budget
    - Over 32 years of experience
- “Putting Product in the Market Place”

**ROUSH**

The image features a collage of grayscale industrial and automotive components, including gears, pistons, and wheels, serving as a background. The word "ROUSH" is prominently displayed in a large, bold, blue, sans-serif font with a white outline and a registered trademark symbol (®) to its right. Below the logo, the tagline "Focused. Driven. Committed." is written in a white, bold, sans-serif font, with a blue horizontal line underlining the word "Committed."

# ROUSH®

**Focused. Driven. Committed.**

**For more information or questions, please contact:**

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