University of Victoria

Department of Mechanical Engineering & Institute for Integrated Energy Systems

UVic Green Vehicle Research Program and Student Team Work

- Model and Optimization Based Design and Control

Dr. Zuomin Dong

MECH459 and MECH580

Advance of Hybrid Electric Powertrain Technology

Series → Parallel → Series/Parallel (THS/1-Mode) → Series/Parallel (GM/2-Mode) → Advanced Series/Parallel with Real-time Optimal Control (PHEV, EV and FCEV)

University of Victoria Green Vehicle Research & Development

Multi-Mode/Regime Real-time Optimal Control

UVic EcoCAR1 2011

Advanced Series/Parallel Real-time Optimal Control

UVic EcoCAR2 2014

Key Technology – Model Based Design, Design Optimization and Optimal Control

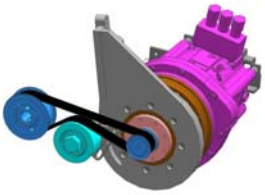
EcoCAR – Next Challenge

EcoCAR 2 – Plugging in to the Future

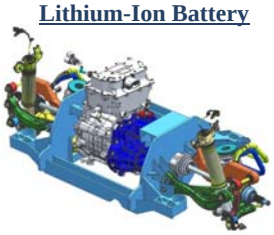
Advanced Infotainment System
Freescale In-Dash display unit

A123 6s x 3s15p
Lithium-Ion Battery

2.4L GM EcoTec LE9 Engine



TM4 80kW BAS



Magna E-Drive

Technology/Learning: Cutting Edge, Advanced, Research and Industry

University of Victoria

Major Groups

- Modeling/Simulation/System Design
- Mechanical Design, Analysis and Manufacturing
- Power Electronics and Electric Machines
- Control and Embedded System
- Programming
- CAN Bus Communication and Infotainment System
- Prototyping and Retrofitting
- Project Management
- Business Outreach

People/Experience: Multidisciplinary and Ability Training

http://www.ecocar.uvic.ca

EcoCAR and EcoCAR 2

- Government and Leading Industry Sponsored Elite Student Design Competition (15 Universities Selected in US/Canada)
- Development of Future Hybrid Electric Vehicle (HEV) Technology by Designing, Modeling, Simulating, Testing, and Retrofitting a 2013 GM Malibu with a Newly Developed Hybrid Powertrain
- Open to Both Undergraduate and Graduate Students
- Getting Training and Experiences on Advanced HEV Technology, Mechatronics and Project Management
- Working with Leading Experts Worldwide through Direct Contacts with Major Industrial Sponsors
- Closely Supervision by Faculty Members with Related Background and Interests

Why It Is Unique and Exciting?

- Urgently Needed, Advanced Technology
- Well Funded Developments:
  - Federal (US, Canadian) and Provincial Supports
  - Extremely Strong Industrial Industry Sponsorship
- Integrated to Academic Program
  - Open to Undergraduate and Graduate Students
  - 3 Year Development Program
- Advanced Research and Training

  Mechatronics, Hybrid Vehicle, Control, Modeling, System Design, Simulation, Instrumentation, Embedded Systems, CAD/CAE/CAM, Team Work, Project Management, etc.
- Hands on Experiences
  - Advanced Software Tools
  - Advanced Hardware Tools
- Great Career Opportunities in High-tech and HEV Industry

The Perks

What We Do

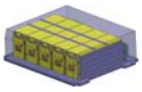
YEAR & OBJECTIVE	MECHANICAL	ELECTRICAL	CONTROLS
Year 1: Design	Lifecycle analysis, vehicle architecture selection and performance modeling		
	CAD - Component	Define Electrical Requirements	Control System Design
	CAD - Routing and Integrations	HIL Design/Setup	Simple Control and SIL/Prelim HIL
Year 2: Mule Vehicle	Finalized Component Selection		
	Vehicle Modification	Vehicle Harness/Systems Design	HIL Finalization & Communication Setup
	Component Integration	Vehicle Harness Setup	HIL Testing - Safety and Fault Mitigation Implementation
Year 3: Optimization & Refinement	Controls Integration and Vehicle Troubleshooting		
	Aero and Lightweighting, R&H, NVH	Refinement and Optimization	Refinement and Optimization
	99% Buyoff - Vehicle Ready for Production		

Related Courses and Training (Rewards)

- MECH459/558 - Fundamentals of Hybrid Vehicles (Technical Elective and Graduate Course) **5:30 - 8:20 pm; Wednesdays; ECS104**
  Instructor: Dr. Z. Dong (Open to All in the Faculty)
- MECH497 Green Vehicle Technology Project (3 Units, Crawford & Dong)
- MECH499 Design Project (ME Faculty Members)
- ECE499 Design Project (Dr. K. Li)
- ENGR466 Mechatronics System Design (Dr. D. Constantinescu)
- MECH499 Honour Thesis (3 Units, ME Fac.)
- EcoCAR 2 Co-op Terms
- EcoCAR 2 Trainings (at Sponsors' sites) and EcoCAR 2 Developments
- **Graduate Studies at M.A.Sc. And Ph.D. Levels**

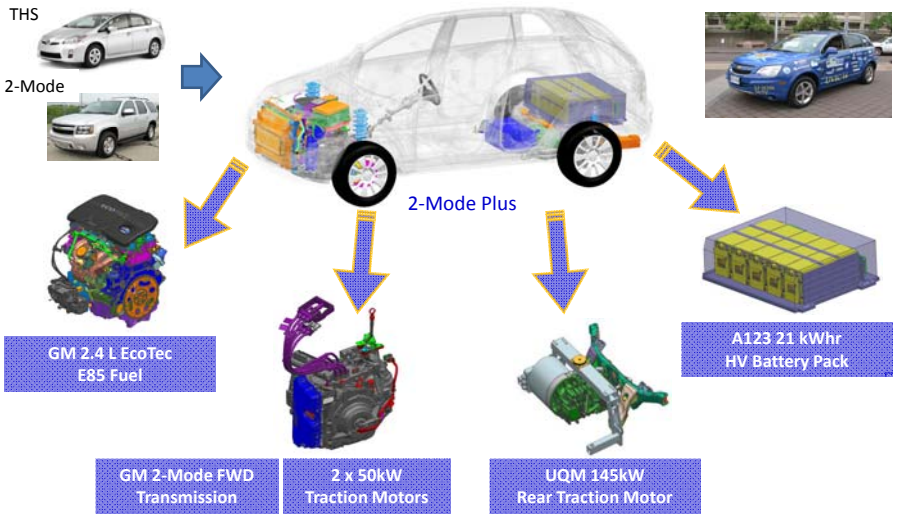
New UVic Green Vehicle Research, Testing and Training Centre

- First Class Green Vehicle Development and Testing Facilities
  - Computer Modeling, Design and Simulation
  - Hardwire in Loop Testing
  - Advanced Battery Pack Development
  - 4WD, Active Braking Enabled Chassis Dynamometer
  - Engine Dynamometer
  - Emission Measurement
- Hands on Shop
  - Automotive Shop
  - Small Machine Shop
  - Small Electronics Shop



- Team Leaders
  - Jeremy Wise and Jeffery Walden
- Faculty Advisors
  - Dr. Zuomin Dong (zdong@uvic.ca)
  - Dr. Curran Crawford (ccrawford@uvic.ca)
- **Website and contact: http://www.ecocar. uvic.ca**

UVic EcoCAR 1 – Push the HEV Technology Boundary



Results at End (2011)

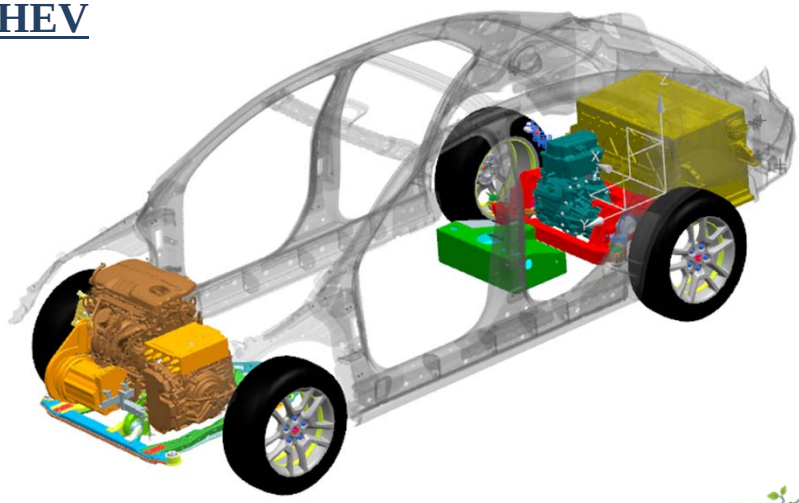
Specification	EcoCAR Competition		UVic EcoCAR1		
EcoCAR	GM Production VUE	Competition Requirements	Target VTS	Test Result Y2	Test Result
Accel 0-60	10.6 s	≤ 14 s	7.5 s	12.36 s	6.35 s
Accel 50-70	5.7 s	≤ 10 s	5 s	8.96 s	3.45 s
UF Weighted FE	8.3 L/100 km	7.4 L/100 km	2.5 L/100 km	Test Not Complete	5.88 (UDDS)
Towing Capacity	680 kg (1500lb)	≥ 680kg @ 3.5%, 20 min @ 72 km/h (45mph)	682 kg (1500lb)	≥ 680kg @ 3.5%, 20 min @ 72 km/h (45mph)	Test Not Complete
Cargo Capacity	0.83 m^3	Height: 457 mm (18") Depth: 686 mm (27") Width: 762 mm (30")	0.70 m^3	0.83 m^3	0.83 m^3
Passenger Capacity	5	≤ 4	4	5	5
Braking 60-0	38-43 m (123-140 ft)	< 51.8 m (170 ft)	48 m	42m	46m (152 ft)
Mass	1758 kg (3875 lb)	2268 kg (5000 lb)	2145 kg (4729 lb)	4916 lb	4982 lb
Starting Time	≤ 2 s	≤ 15 s	≤ 2 s	2 s	1 s
Ground Clearance	198 mm (7.8 in)	≤ 2 s	178 mm (7 in)	7 in	7 in
Range	≥ 580 km (360 mi)	≥ 320 km (200 mi)	≥ 320 km (200 mi)	Test Not Complete	Test Not Complete

University of Victoria
EcoCAR 2 – Plugging in to the Future

- Team Leaders
  - Stefan Kaban/Daniel Prescott/John Walsh/Kevin Andersen
- Faculty Advisors
  - Dr. Zuomin Dong (zdong@uvic.ca)
  - Dr. Curran Crawford (ccrawford@uvic.ca)
- **Website and contact:** http://www.ecocar.uvic.ca

EcoCAR2
PLUGGING IN TO THE FUTURE

AWD Series–Parallel PHEV



EcoCAR2
PLUGGING IN TO THE FUTURE

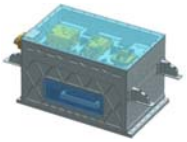
University of Victoria

Multi-Regime (Series/Parallel) AWD PHEV



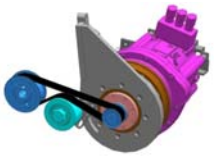


Advanced Infotainment System
Freescale In-Dash display unit



A123 6s x 3s15p
Lithium-Ion Battery

2.4L GM EcoTec LE9 Engine



TM4 80kW BAS

Magna E-Drive

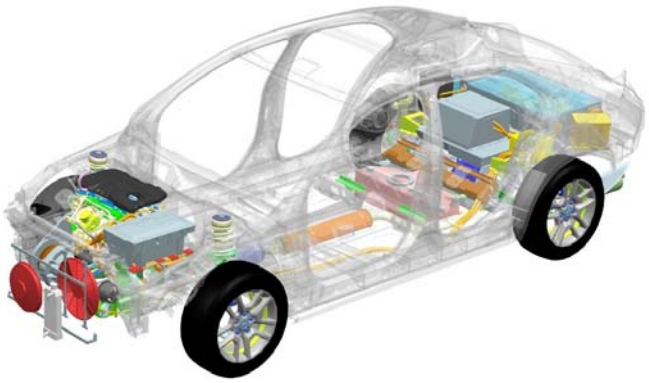
VEHICLE TECHNICAL SPECIFICATIONS

Specification	Production 2013 Malibu	UVic Series-Parallel Malibu
Acceleration 0-60mph	8.2 sec	8.5 sec
Acceleration 50-70mph	8.0 sec	3.8 sec
Braking 60-0mph	143.4 ft. (43.7 m)	142.7 ft. (43.5 m)
Highway Grade-ability (20 minutes)	10% @ 60mph	4.2% @ 60mph
Cargo Capacity	16.4 ft^3	7 ft^3
Passenger Capacity	5	5
Mass	1589.6 kg	2078 kg
Ground Clearance	155 mm	156 mm
Charge Depleting Range	N/A	83.8 km
UF-Weighted Fuel Energy Consumption	8.83 lge/100 km [787 Wh/km]	3.37 lge/100 km
Criteria Emissions	Tier 2 Bin 5	Tier 2 Bin 5

EcoCAR2 PLUGGING IN TO THE FUTURE

University of Victoria

Overall Development Plan



EcoCAR2 PLUGGING IN TO THE FUTURE

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UVic EcoCAR2 through Optimization

Goals - Minimize emissions and energy consumption (Y3 points; E&EC performance

Powertrain design and prototyping - advanced powertrain architecture, sizing and control System

- Support flexible multiple mode vehicle operations
- Enable optimal vehicle operation for different demands

Leading-edge powertrain control technology

- Real-time optimal control to maximize efficiency/performance
- Optimal/intelligent energy management (fuel economy and life)
- Integrated Infotainment system (improved utility and efficiency)

Design for low mass, manufacturing, maintenance and reliability

- Essential to have a fully functional vehicle
- Lesson from EC1

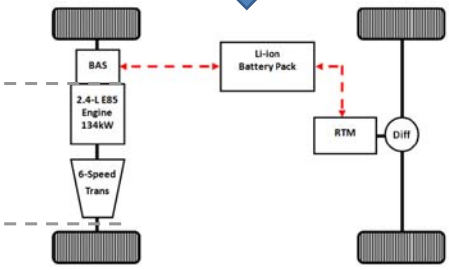
EcoCAR2 PLUGGING IN TO THE FUTURE

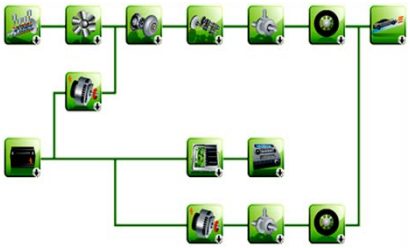
University of Victoria

An Example: What we have done in EcoCAR2 Y3

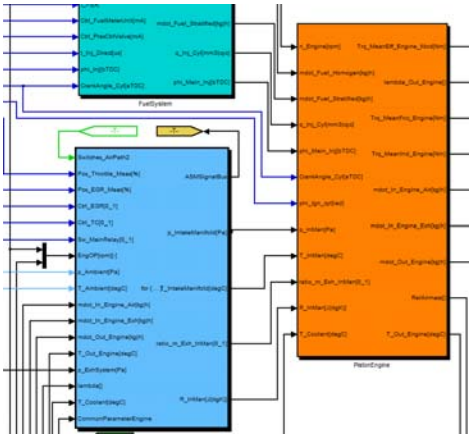
2013-2014

Hybrid Electric Powertrain Design, Modeling, and Optimization

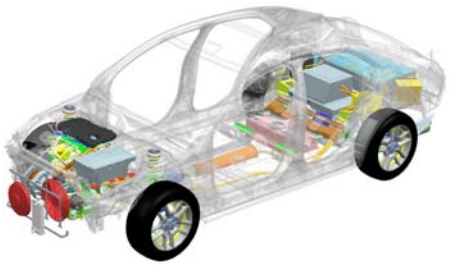


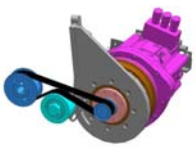


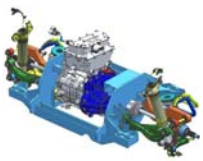
Modelling and Simulation Using dSPACE ASM

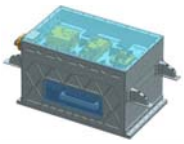


Mechanical Design, Optimization, Prototyping/Retrification/Manufacturing

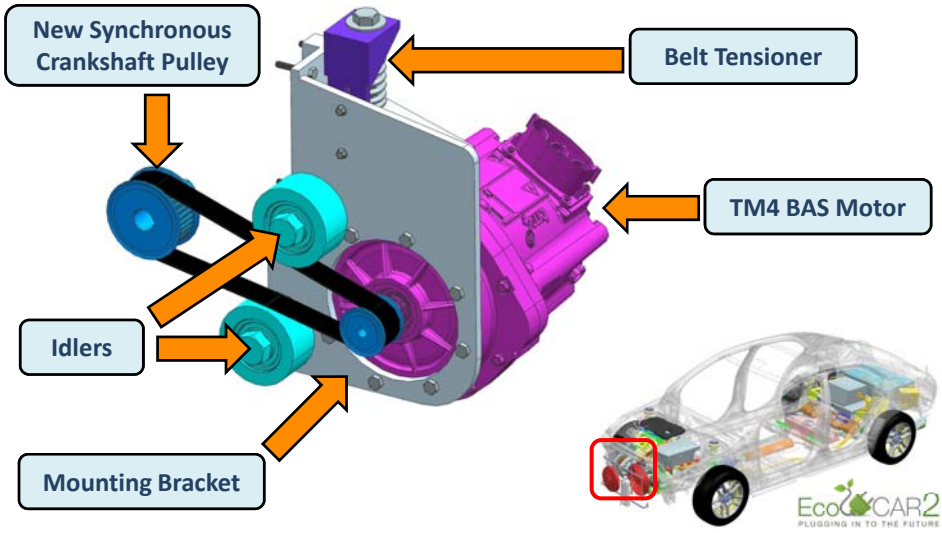








BAS Integration – Original Design



EcoCAR2 PLUGGING IN TO THE FUTURE

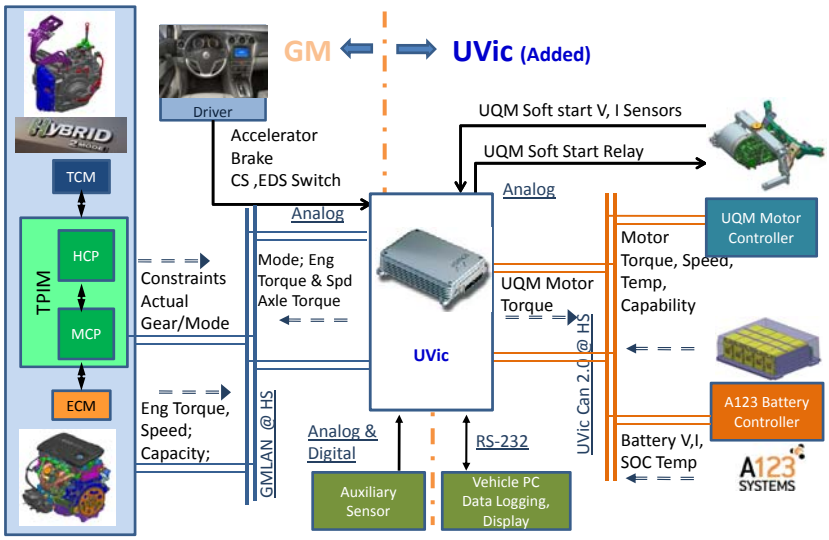
University of Victoria

BAS Integration – Bearing Idler Assembly

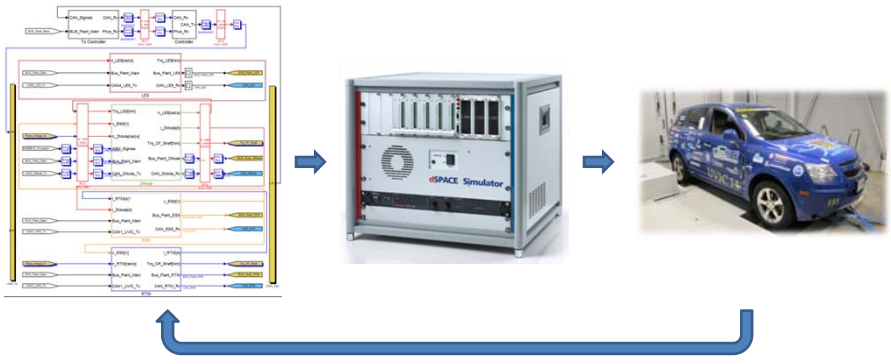
EcoCAR2 PLUGGING IN TO THE FUTURE

University of Victoria

UVic 4WD 2-Mode Plus EcoCAR Control System



Electrical/Controls/Software/Testing



Hardware in Loop (HIL) and In-Vehicle Testing under UDDS and HWFET cycles to validate of design and control system

New to EcoCAR 2: Infotainment System

- Android and Ca-Fi: 6.2 inch touch screen LCD, powered by The Freescale™ Cartex™ A8 i.MX5x processors running at 1.2 GHz; music and other audio with output connections for camera, USB and antennas, designed to be compatible with all sorts of car.
- Mercedes-Benz A-Class concept
- Toyota Entune in-car infotainment system
- Other electronics and embedded systems: solar roof Prius, etc.

Dyno Testing

University of Victoria

UVic EcoCAR 2009 Competition Awards

- 2nd Place Overall
- 1st Place First Year Technical Reports
- 1st Place, MathWorks Modeling Award
- Best Electrical Systems Presentation
- 2nd Place, Hardware-in-Loop Evaluation
- 3rd Place, dSPACE Embedded Success Award
- Best Media Relations Program

Faculty Advisors: Zuomin Dong and Curran Crawford

UVic EcoCAR 2010 Competition Awards

- 4th Place Overall Award
- Best Technical Reports Award
- US National Science Foundation Outstanding Incoming Advisor Award (Drs. Dong and Crawford)
- Ron Stence Spirit of Challenge Award
- Dr. Don Streit Sportsmanship Award
- Modeling and Simulation (dSPACE) - 3rd Place Award
- Energy Storage System Design (A 123Systems) - 3rd Place Award
- Sprit of Outreach Award

UVic EcoCAR 2011 Competition Awards

- 1st Place MathWorks Award - Optimal Powertrain Design and Control
- 1st Place dSPACE Award - Hardwire in Loop Testing and Vehicle Dynamics Modeling
- Fastest 0-60 miles/h Acceleration (6.3 seconds)
- Fastest 50-70 miles/h Acceleration (3.5 seconds)
- Best Engineering Workmanship Award (Overall Appearance and Design for Service)
- 3rd Place A123 Workmanship Award - 21 kWh Li-ion Battery Pack Design and Prototyping
- Best EcoCAR Website Award (http://www.ecocar.uvic.ca)

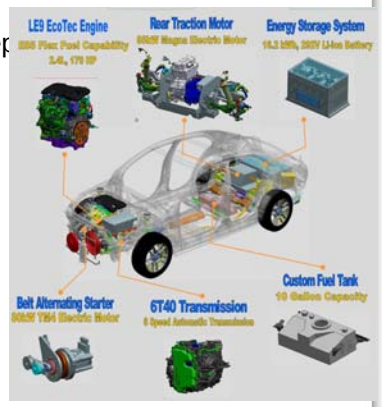
UVic EcoCAR2 2012 Competition Awards

- First Place - Mechanical Design Award
- First Place MathWorks (Modeling, Simulation and Optimization) Award
- Third Place A123 Battery System Award
- Third Place Infotainment System Award

UVic EcoCAR2 2013 Competition Awards

- First Place Award in Mechanical Design and Presentatio
- First Place Award in MATLAB Modeling and Application
- First Place Award in Infotainment System

- Highest Scores of all Year 2 Technical Rep
- Third Place in Electrical System
- Third Place in Control System
- First Place of Team Skit Video



University of Victoria | Faculty of Engineering IESVic

UVic EcoCAR2 2014 Competition Awards

- 1st Place – MathWorks – Modeling Award
- 2nd Place – *dSPACE* Embedded Success *Award*
- Dr. Donald Streit Sportsmanship Award
- 2nd Place - Controls Presentation
- 2nd Place – Business Final Presentation
- 3rd Place – Mechanical Presentation
- 2nd Place (with 5 others) – 0-60 Mile Acceleration of the Vehicle

Enhanced Curriculum at UVic

NEW COURSES INTRODUCED

- MECH459/558 - Fundamental of Hybrid Electric Vehicles (Offered in 3B) (Open to All Grad. Students)
  Instructor: Dr. Z. Dong (Open to Team Members)
- MECH497 Green Vehicle Technology Project (3 Units, Crawford & Dong)

EXTENSION OF EXISTING COURSES

- MECH499 Design Project (ME Faculty Members)
- ECE499 Design Project (Dr. K. Li)
- MECH464 Mechatronics System Design (Dr. D. Constantinescu)
- MECH498 Honour Thesis (3 Units, ME Fac.)

ECOCAR 2 CO-OP TERMS

- EcoCAR 2 Trainings (at Sponsors' sites) and EcoCAR 2 Developments

GRADUATE STUDIES AT M.A.SC. AND PH.D. LEVELS

Advanced Industrial Training

TRAININJG AT MAJOR SPONSORS' FACILITIES (5-12 team members)

- **Computer Modeling**
  - MathWorks MATLAB/Simulink Multi-physics Modeling Tool ($1.5M)
    Headquarter (Boston) & Workshop/Seminars at UVic (Fall and Spring)
  - Siemens NX Computer Aided Design and Engineering Software Tools ($50M)
  - US Argonne National Lab (ANL)'s Advanced Vehicle Powertrain Modeling Tools ($50K)
- **Automotive**
  - GM Research Center (MI) and Vehicle Proofing Grounds (MI & AZ)
  - US EPA Vehicle Testing Facilities (MI)
- **Electronics**
  - dSPACE (ANL) Hardware in Loop Tech/Equipment & Vehicle Dynamics Modeling ($400K)
  - Freescale Microcontrollers
- **Energy Storage and Battery System**
  - A123 High Power Battery Modules and Technical Supports (MA, $70K)

FULL TECHNICAL SUPPORTS AND TUTORING (Mentors / Team Technical Support Staffs)

- GM, Siemens, dSPACE, A123, Freescale, etc.

CO-OP TERMS

- EcoCAR 2 Related Trainings (at Sponsors' sites) and UVic EcoCAR Co-op Terms

Formula Hybrid

http://students.sae.org/competitions/formulaseries/hybrid/

- 2014 Competition:
  - April 28 - May 1, 2014
    New Hampshire International Speedway, Loudon, NH
  - Registration Fee: $1,750.00
    Registration Limit:35 teams
    Registration Opens:
  - For Hybrid category on Monday, October 7, 2013 10:00 AM EDT
  - For Electric category on Wednesday, October 9, 2013 10:00 AM EDT
  - For entry of a 2nd team vehicle on Monday, November 4, 2013 10:00 AM EST

Formula Hybrid Contact

- **Doug Fraser**
  Director, Formula Hybrid
  603.646.3522
- **Amy Keeler**
  Coordinating Manager
  603.646.6580
- **Formula Hybrid**
  Thayer School of Engineering at Dartmouth
  14 Engineering Drive
  Hanover, NH 03755
- Email: info@formula-hybrid.org
- For rules questions, visit the Formula Hybrid Support Center.
- To submit required documents, visit the Formula Hybrid Document Upload Page.

What is Formula Hybrid?

- Formula Hybrid™ is a design and engineering challenge for undergraduate and graduate college and university students. They must design, build, and compete an open-wheel, single-seat racecar. This car must conform to a formula which emphasizes drive train innovation and fuel efficiency in a high-performance application.
- Formula Hybrid builds on the Formula SAE program and takes it to the next level. It adds a new layer of complexity and provides an additional technical challenge to student teams. We expect that one path of entry to the Formula Hybrid competition will be to construct the vehicle and develop the chassis and related systems in the Formula SAE program and then replace the IC engine with a hybrid drive train the following year for the Formula Hybrid competition, resulting in a two-year design cycle.

Competition Information

- Rules and Important Documents
- Register
- Online Registration Guide*
- Registered Teams
- Event Website
- International students will need to download and complete the International Student Registration form and submit to CDS staff for use during onsite registration at event.

2014 Formula Hybrid Teams

029	Atilim University
016	Carnegie Mellon Univ
021	Dartmouth College
023	Delhi Technological University
005	Embry-Riddle Aero Univ
028	Ferris State University
025	Georgia Institute of Technology
020	Illinois Inst of Tech
002	Lawrence Technological Univ
003	McMaster Univ
011	Middle Tennessee State Univ
022	Milwaukee School of Engrg

027	Nitte Meenakshi Inst of Tech
017	Princeton Univ
024	Rensselaer Polytechnic Inst
013	RV College of Engineering
018	Tufts Univ
015	Univ of Akron
026	Univ of Houston - Houston
014	Univ of Idaho
004	Univ of Michigan - Ann Arbor
012	Univ of Waterloo
019	University of Vermont
001	Yale Univ

Major Sponsors

- Platinum Sponsors
- Gold Sponsors
- Silver Sponsors
- Friends of Formula Hybrid
- Team Sponsors
- Additional Sponsors
- UVic Sponsors

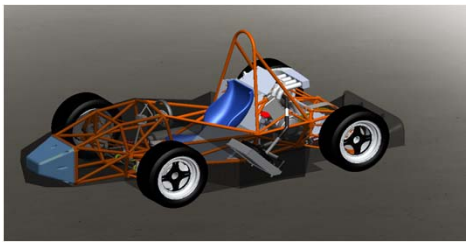
Event points breakdown for 2014 Formula Hybrid event

Static Events		Hybrid
	Presentation	100
	Engineering Design	200
Dynamic Events		
	Acceleration - Electric	75
	Acceleration - Unrestricted	75
	Autocross	150
	Endurance	400
Total Points		1000

2014 Formula Hybrid™ Summary Score Sheet

Line No.	Car No.	Team Name	Presentation	Design	Acceleration - Electric	Acceleration - Unrestricted	Autocross	Endurance	Total Penalties Assessed	Total Score	Position in Class
			100	200	75	75 (1)	150	400		1000H / 925E	
		HYBRID DRIVE CLASS									
1	1	Yale University	85.40	142.94			0.00	0.81		229.15	4
2	2	Lawrence Technological University	56.19	148.95			0.00	48.48		253.63	2
3	3	McMaster University	96.61	200.00			0.00	0.00	-100.00	196.61	7
4	4	University of Michigan	93.35	51.35			0.00	75.33		220.03	5
5	5	Embry-Riddle Aeronautical University	100.00	151.35			0.00	0.00		251.35	3
6	12	University of Waterloo	76.27	0.00			0.00	0.24		76.51	10
7	13	RV College & Nitte Meenakshi Institute	73.01	68.47			0.00	0.00		141.48	9
8	14	University of Idaho	83.44	178.17			0.00	0.08		261.70	1
9	22	Milwaukee School of Engineering	56.32	128.53			0.00	0.00		184.85	8
10	24	Rensselaer Polytechnic Institute	90.48	109.31			0.00	0.00		199.79	6
11	28	Ferris State University	0.00	0.00			0.00	0.00		0.00	11
12	29	Atilim University	0.00	0.00			0.00	0.00		0.00	11
13											

UVic "Traditional" Formula SAE Team



Competition information at Formula Hybrid website

most commonly used student resources located under the 'Students' tab

- Anticipating a fantastic competition next year with between 25 and 35 international teams represented.
- **Start a Team** – outlines suggestions for getting started
- **Forum** – have team leaders sign on to keep up-to-date with rules updates, etc.
- **Rules and Deadlines** - Read the **2014 Rules** – the 2015 Rules are expected to release on September 1, major changes are currently posted under the Announcements page. **Action deadlines** for 2015 will be similar to those outlined for this year (some dates will be earlier)
- **Announcements** – outlines updates over the past year
- **Components** - **supplier sponsored** (free or heavily discounted parts) and **recommended components** (recommended by FH staff and alums)
- **Schedule and Program** (2014) – Read this to become familiar with the track layout, schedule of events, daily operations, etc.
- **Tech Support and References** – When your team runs into technical questions you can submit a ticket with the FH Support Center. The Document Upload Page is where you'll submit action deadlines. 2014 Action Deadlines can be viewed for reference. Some of these will be updated in 2015.
- Follow the event on Facebook (Formula Hybrid) and Twitter (@Formula_Hybrid).
- Registration will open in early October. (anticipate the registration fee increasing to $2,100 USD and the cap on registration is 35 teams, with hybrids receiving priority registration (a few days earlier than electrics).
- One of the most significant changes this year - updating the business presentation to a project management presentation.

Formula Hybrid Management

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Weekly Team Meeting: Tue 5:00 pm Q-Hut

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Reception and Open House at "Q-Hut"