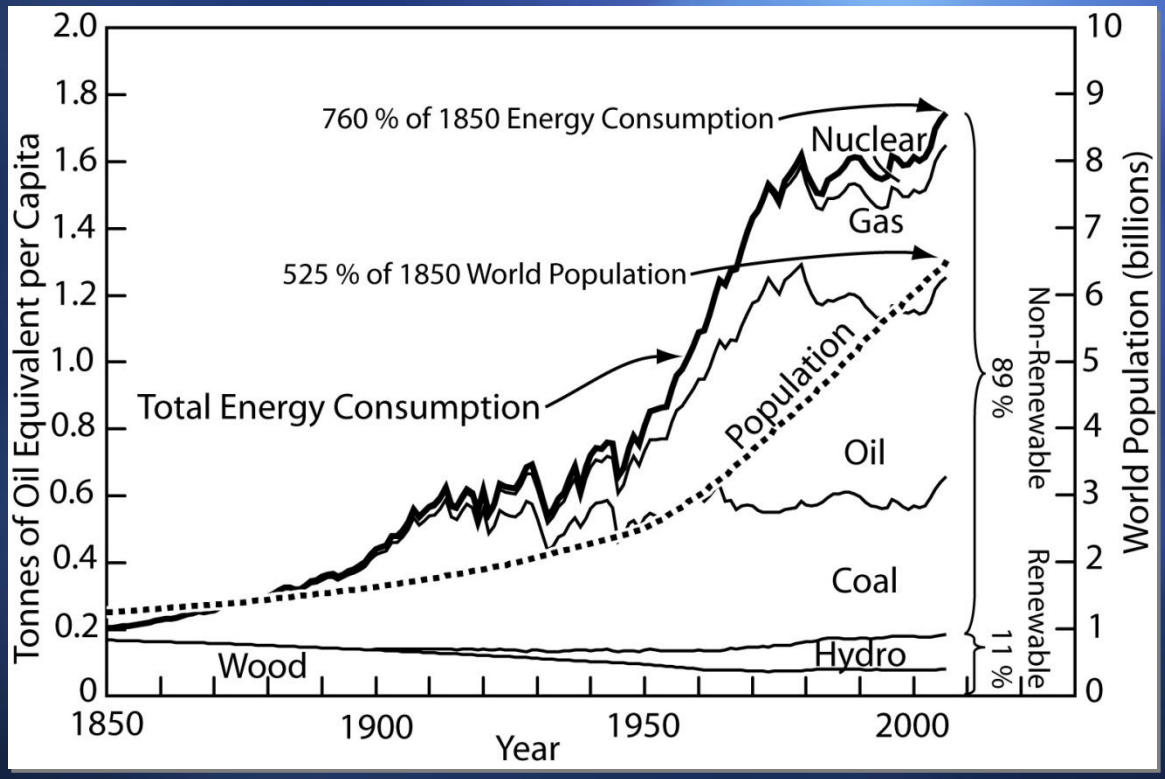
Breeding Innovaiton and Entrepreneurship: From Undergraduate to Graduate

Student Teams at Waterloo

WISE Advisory Council Meeting

Roydon A. Fraser
Mechanical & Mechatronics Engineering
April 7, 2011

To be Sustainable, What Does It Mean?



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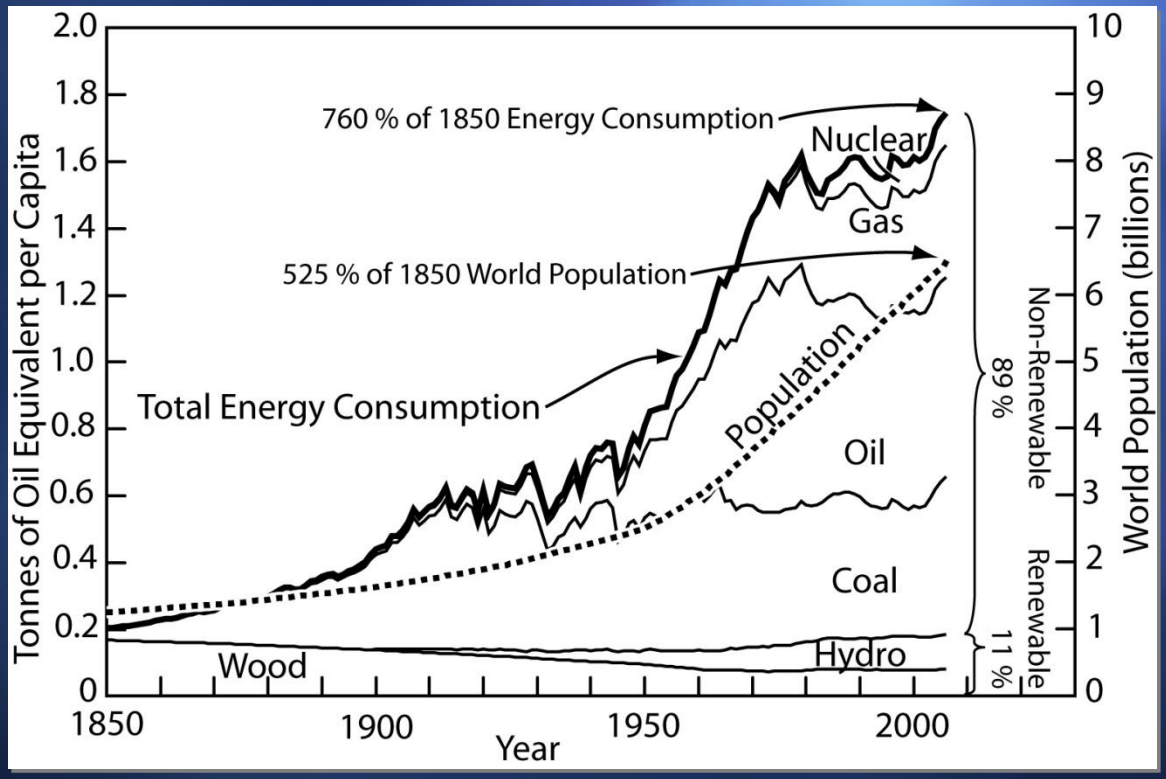
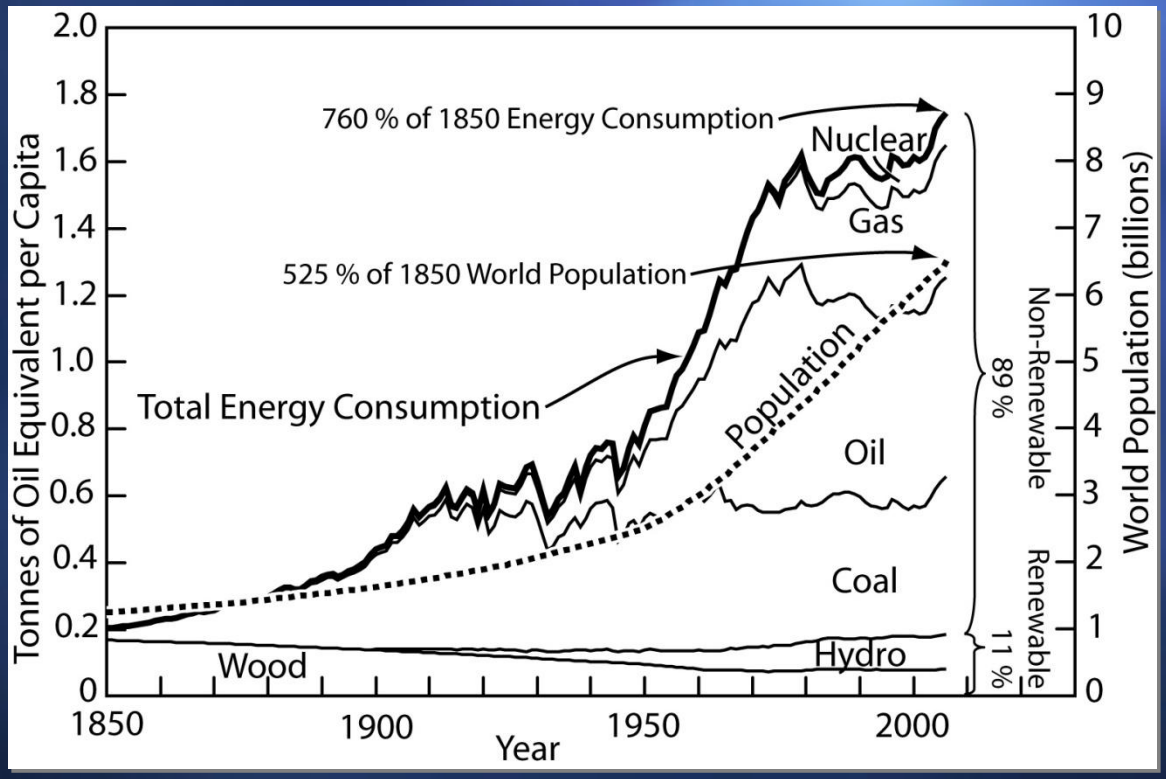


Net Energy out &
no waste.

To be Sustainable, What Does It Mean?



For Engineers it means INNOVATE and IMPLEMENT.

engineers without borders
ingénieurs sans frontières
Canada

Building a world of opportunity

Parker Mitchell

George Roter

engineers without borders
ingénieurs sans frontières
Canada

Building a world of opportunity

engineers without borders
ingénieurs sans frontières
Canada

Building a world of opportunity

K’naan

2010 FIFA World Cup Anthem

Wavin’ Flag

“When I get older I will be stronger
They'll call me freedom, just like a wavin' flag…”

engineers without borders
ingénieurs sans frontières
Canada

Building a world of opportunity

Just Prior to EWB

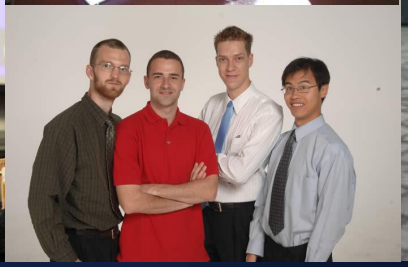
- Energy Conversion (ME459)
- Solar Water Purifier (OEC)
- Desire to ‘bend’ the official curriculum

Ontario Engineering Competition

- Engineering communications
- Innovative Design
- Parliamentary Debates
- Consulting Engineering
- Junior Design
- Senior Design







www.oec-cio.ca

Ontario Engineering Competition

OEC - CIO

Bruce Power

hydro one

CHRISTIE

RIM

The Sandford Fleming Foundation
An Organization for the Advancement of Engineering Education

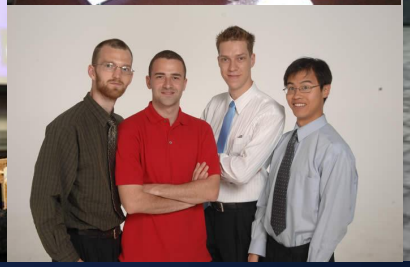
Consulting Engineers of Ontario

ONTARIO SOCIETY OF PROFESSIONAL ENGINEERS

IET

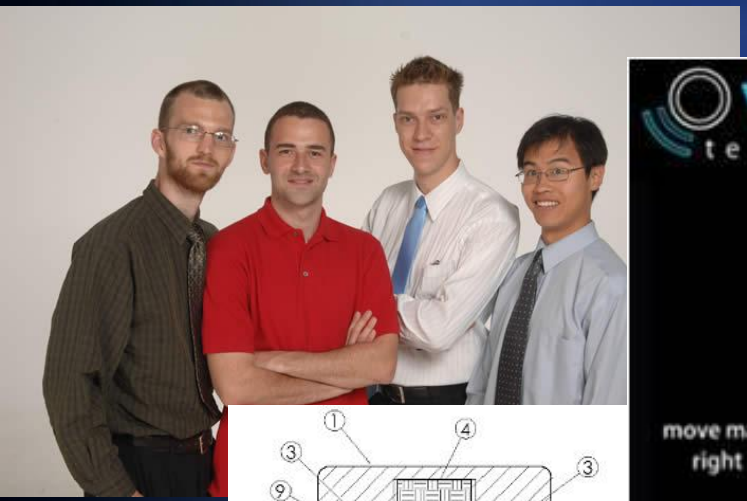
CBET the Centre for Business, Entrepreneurship and Technology at the University of Waterloo

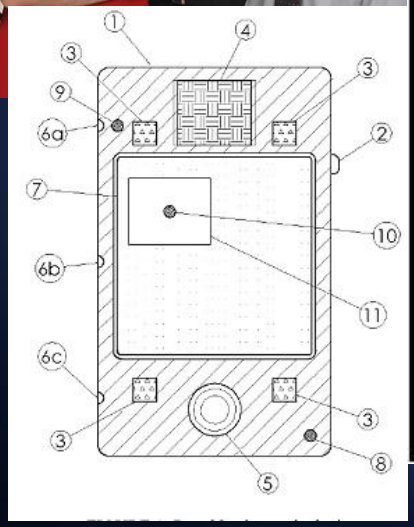
SUNCOR ENERGY

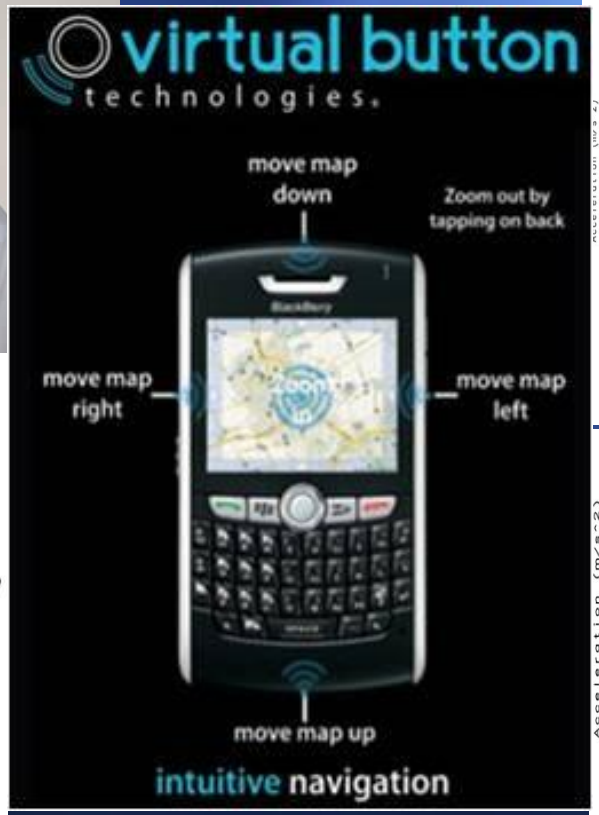


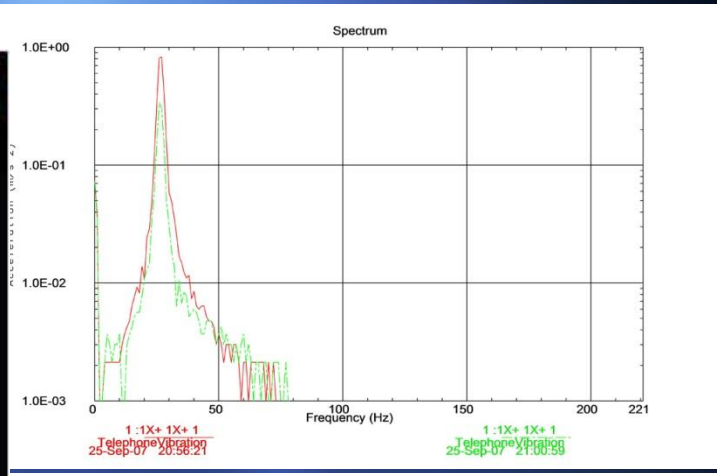
www.oec-cio.ca

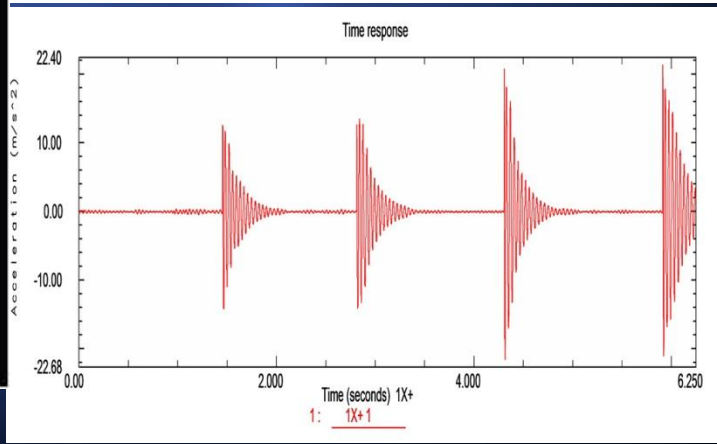
Virtual Button Technology (aka Making it Work)











Many Many Student Teams

- Solar Car
  Mini Baja
  Formula SAE
  UWAFT
  WARG
  Free-flight Glider
  UW Rocket Team
  Concrete Toboggan ..... and others ....

Many Many Student Teams

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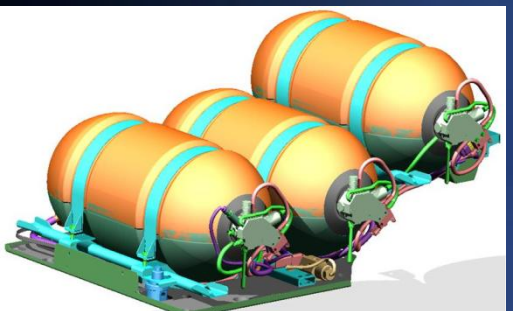
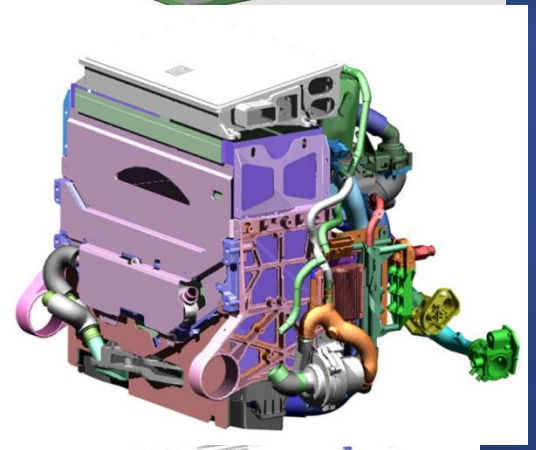
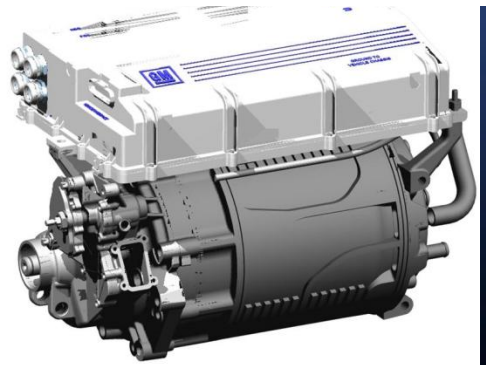
  UW Rocket Team
  Concrete Toboggan ..... and others ....

www.uwaft.com

The parts…





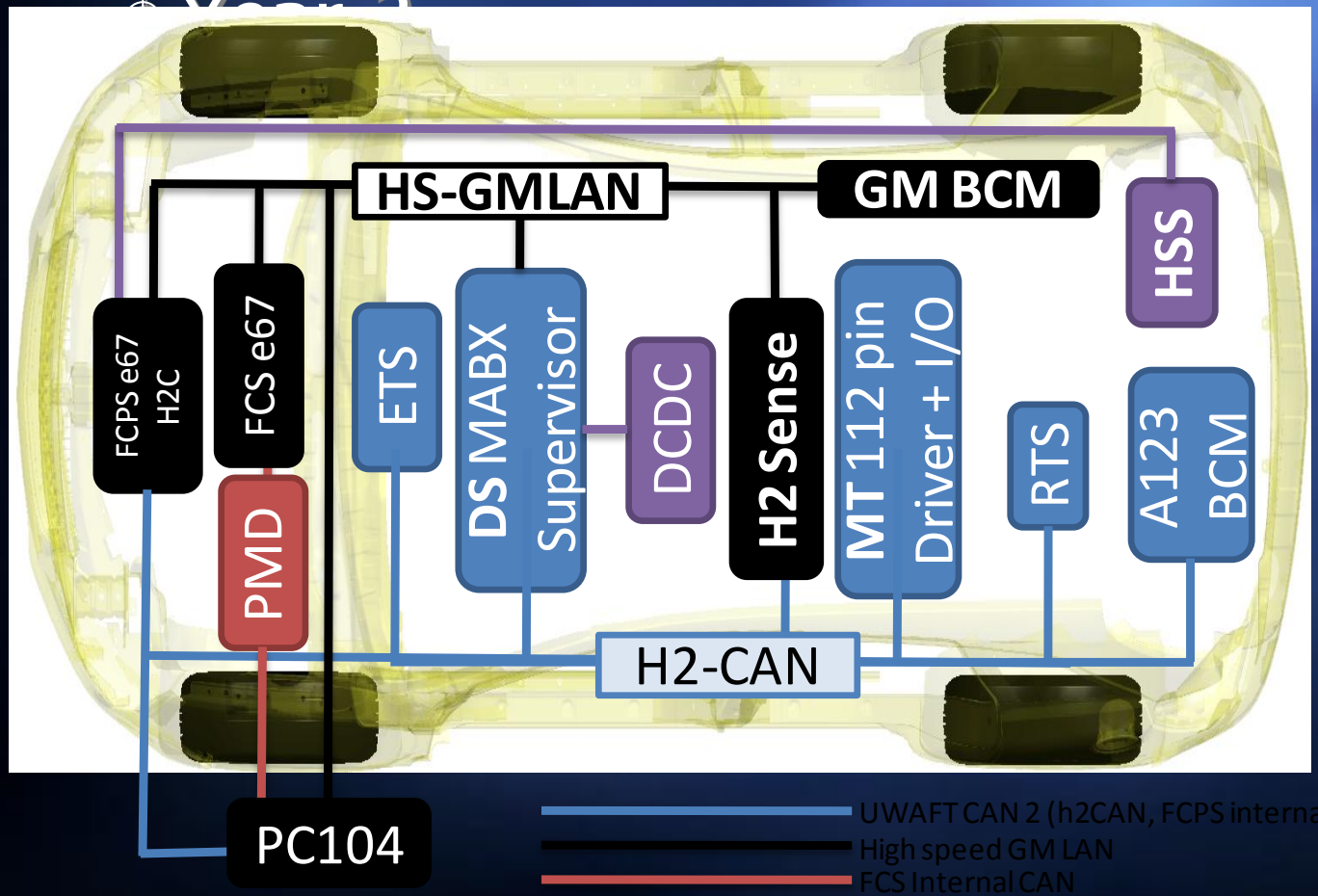


?

the goal…

at least part of it…

The architecture…

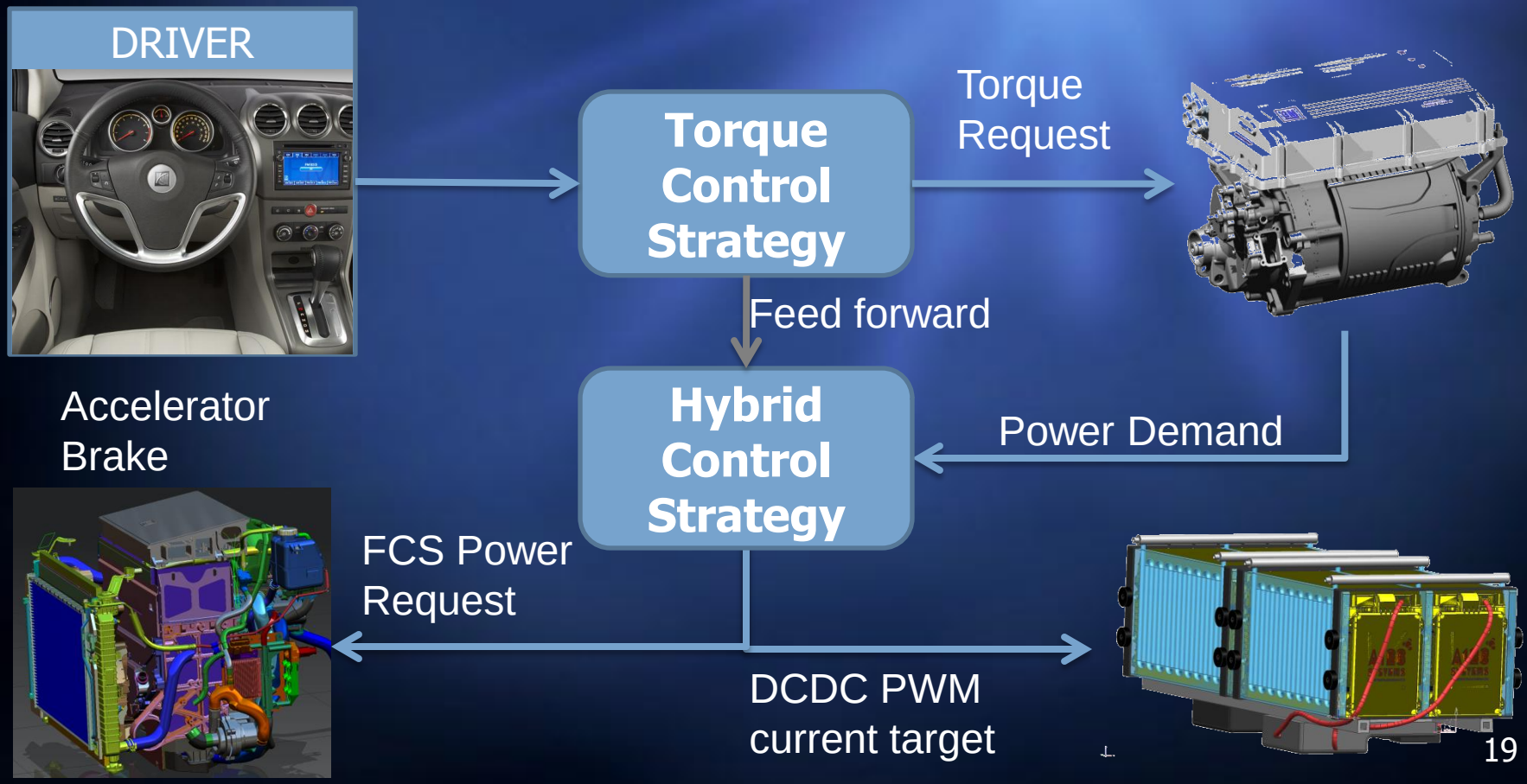


- GM101x CAN Layout
- H2 Safety
- GM101x Logging Strategy
- DCDC Control

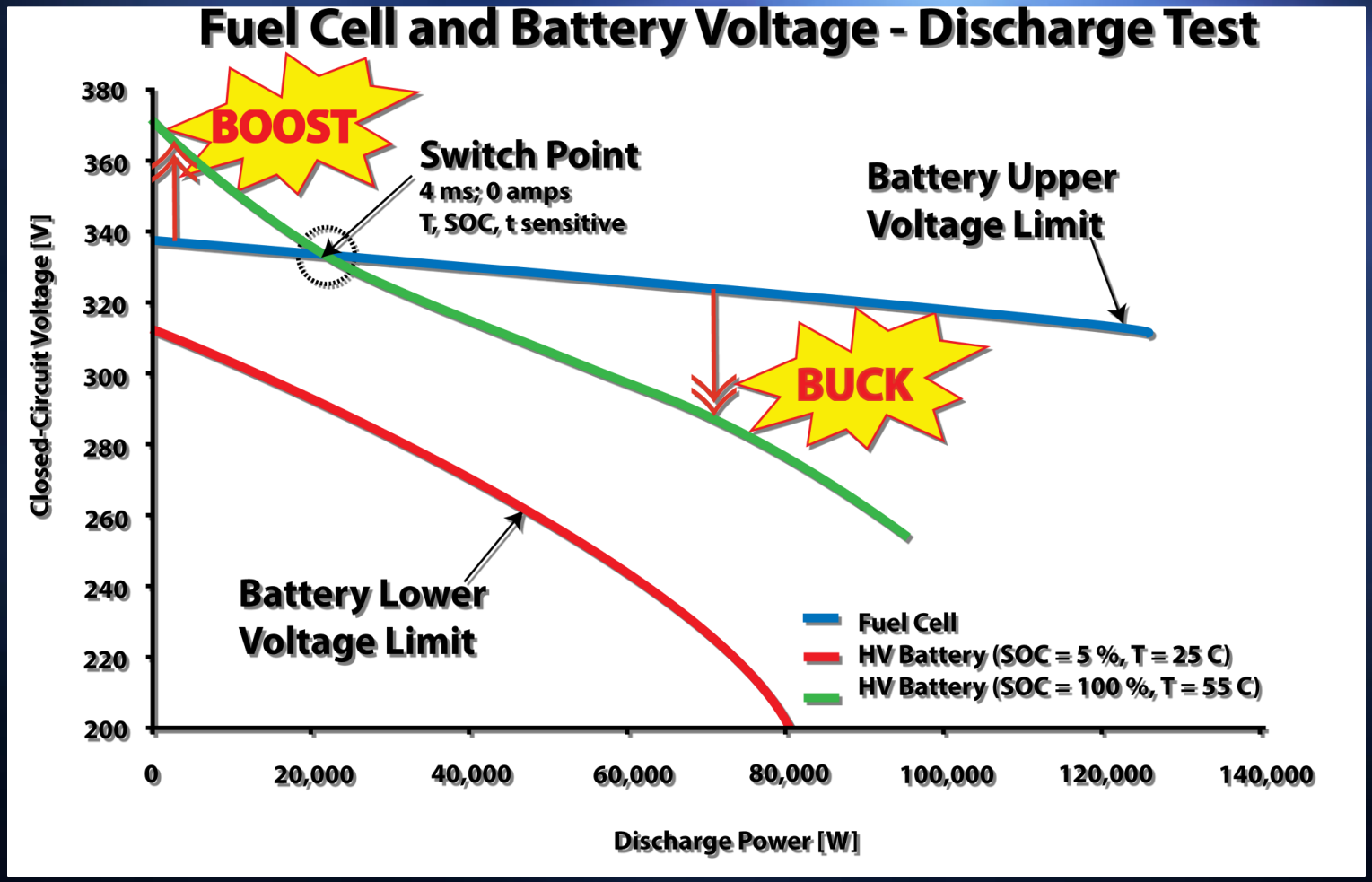
The plan…

Control strategy

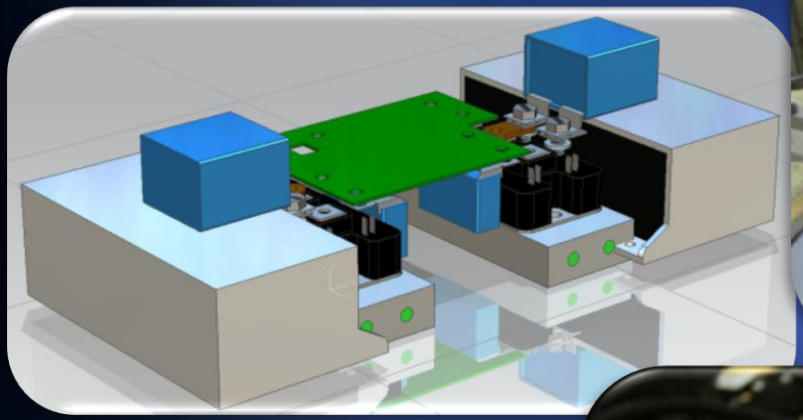
- Open loop torque control
- Feed forward to HCS for DCDC command signals

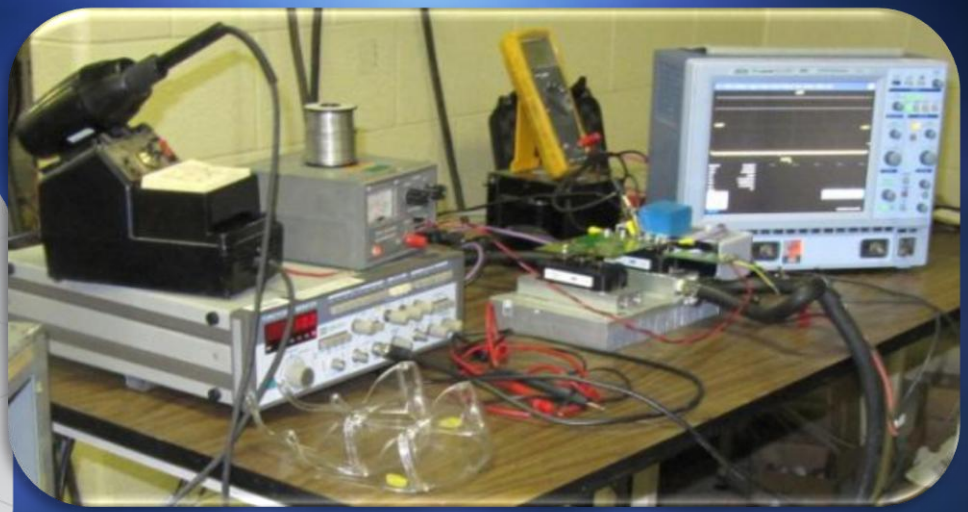


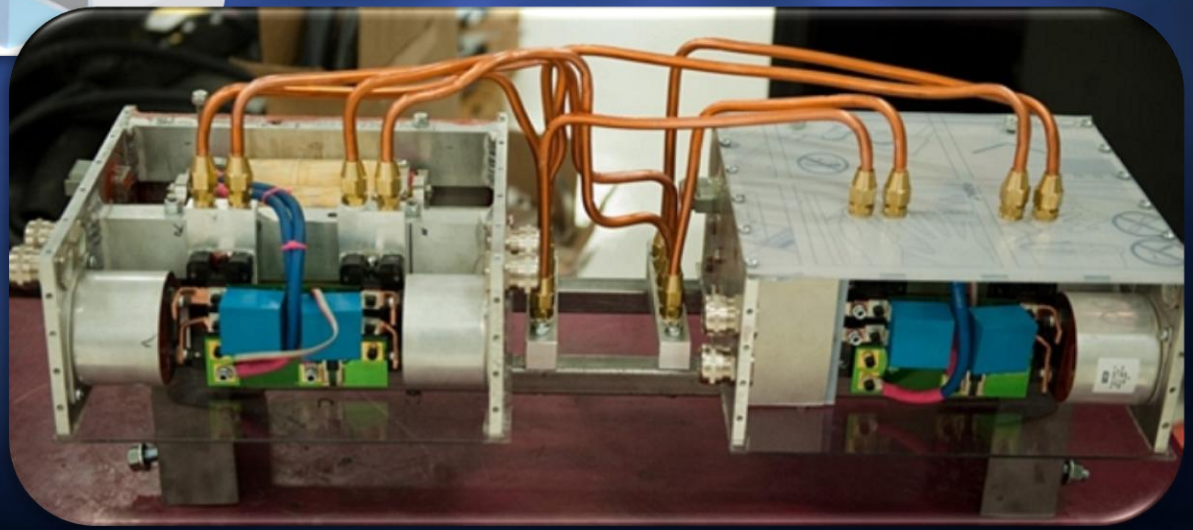
One of many problems… DC/DC Operational Modes



Design to build

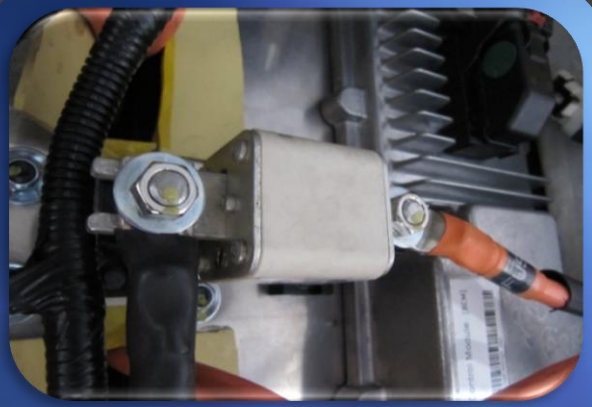






A danger controlled ....
Li-Ion Battery Pack HV Safety

Incidental contact protection

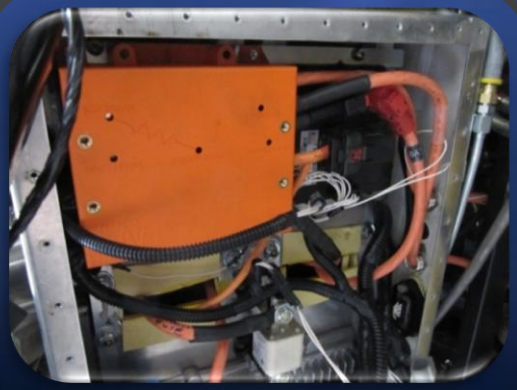


315A fuse recessed terminals

Liquid sensor

Cover HVIL

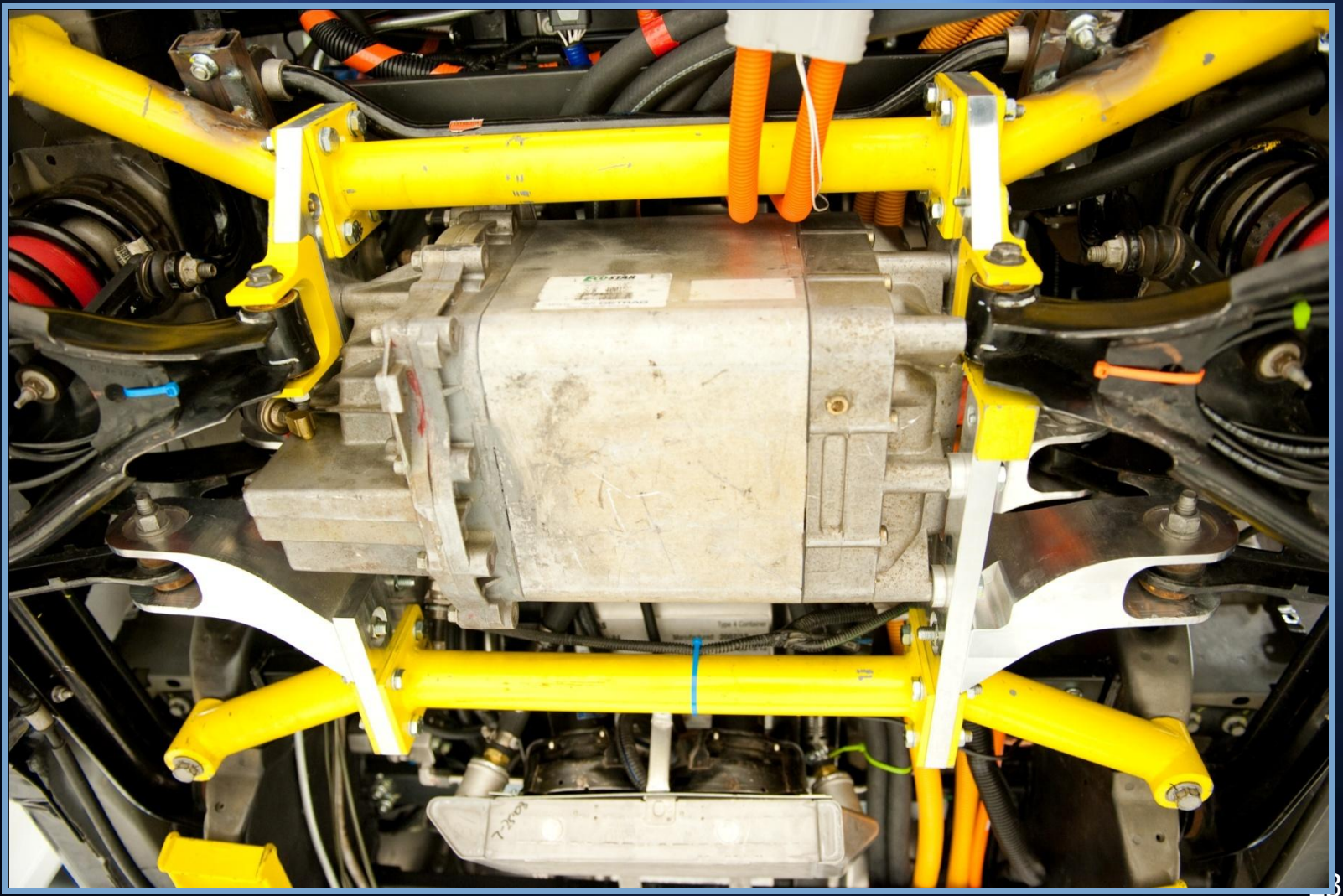
Manual safety disconnect



HV terminals protected

Ground fault indicator

Quality Accomplishment….



The experience…

Rick Wagoner
(past) Chairman & CEO of General Motors

Public Relations and Outreach …

Outreach


University of Waterloo
Ethanol
WATERLOO
FUELS TEAM
Eco-friend

Discovery Channel

Video

What is learned….
Head fake – What UWAFT teaches

Thought I was going to learn	What I spent most my time learning
• Batteries • Fuel cells • Hybrid controls • Vehicle design • Modeling • Integration	• Logistics • Team Management • Sponsorship • Media/PR • Border Crossing • Motivation/Passion

Chris Lawrence

Electrical lead

Hybrid Vehicle Engineer @ GM

Joining Waterloo's Alt. Fuels Team to participate in ChallengeX was one of the best decisions I ever made. It was the learning experience of a lifetime

ChallengeX was the reason I'm now working for GM on its Hybrid vehicle projects.

Master's
Electrical Engineering

Chris Haliburton

team captain & controls lead

Hybrid Vehicle Engineer @ GM

Working with Challenge X I was able to take my skills and apply them to problems that I felt would **improve** and maintain the **environment** for future generations.

I just graduated from Mechanical Engineering with an option in Mechatronics from Waterloo, **but** it might be more fitting that I graduated from Challenge X with a degree in hybrid engineering

Bachelor's
Mechanical Engineering

Chris Mendes

team captain & mechanical lead

Co-Founder and Partner @ CrossChasm

...working with the incredible group of organizers and sponsors was what made Challenge X as enriching as it was.

... it is because of Challenge X and the skills that it allowed me to develop that I feel ready to start my own company.

Master's
Mechanical Engineering

Matthew Stevens

team captain & controls lead

Co-Founder and Partner @ CrossChasm

...Challenge X has been a truly inspiring experience for me. Having the chance to work with so many **dedicated and passionate people** in this important area of work has been a privilege.

It is a, incredible example of what government, industry, and academia can achieve through **collaboration**.

PhD
Chemical Engineering

Jennifer Bauman

electrical lead

CrossChasm Newest Team Member

... I am so **grateful** to have had the **opportunity** to participate in Challenge X.

I learned more about vehicle design, power electronics, **teamwork**, and project management than I could have ever hoped to while at university. I will always be thankful for this **life-changing** opportunity.

PhD
Electrical Engineering

One more outcome…

www.crosschasm.com

Experience Backed
Innovative Design Integration

TEST, TEST, TEST

Experience Backed
Innovative Design Integration

TEST, TEST, TEST

One cannot skip RE-Design

VIEWPOINT

- In my opinion, from a teaching perspective, and an entrepreneurial perspective, it is imperative that IIT Rajasthan work hard towards a

VIEWPOINT

- In my opinion, from a teaching perspective, and an entrepreneurial perspective, it is imperative that IIT Rajasthan work hard towards a

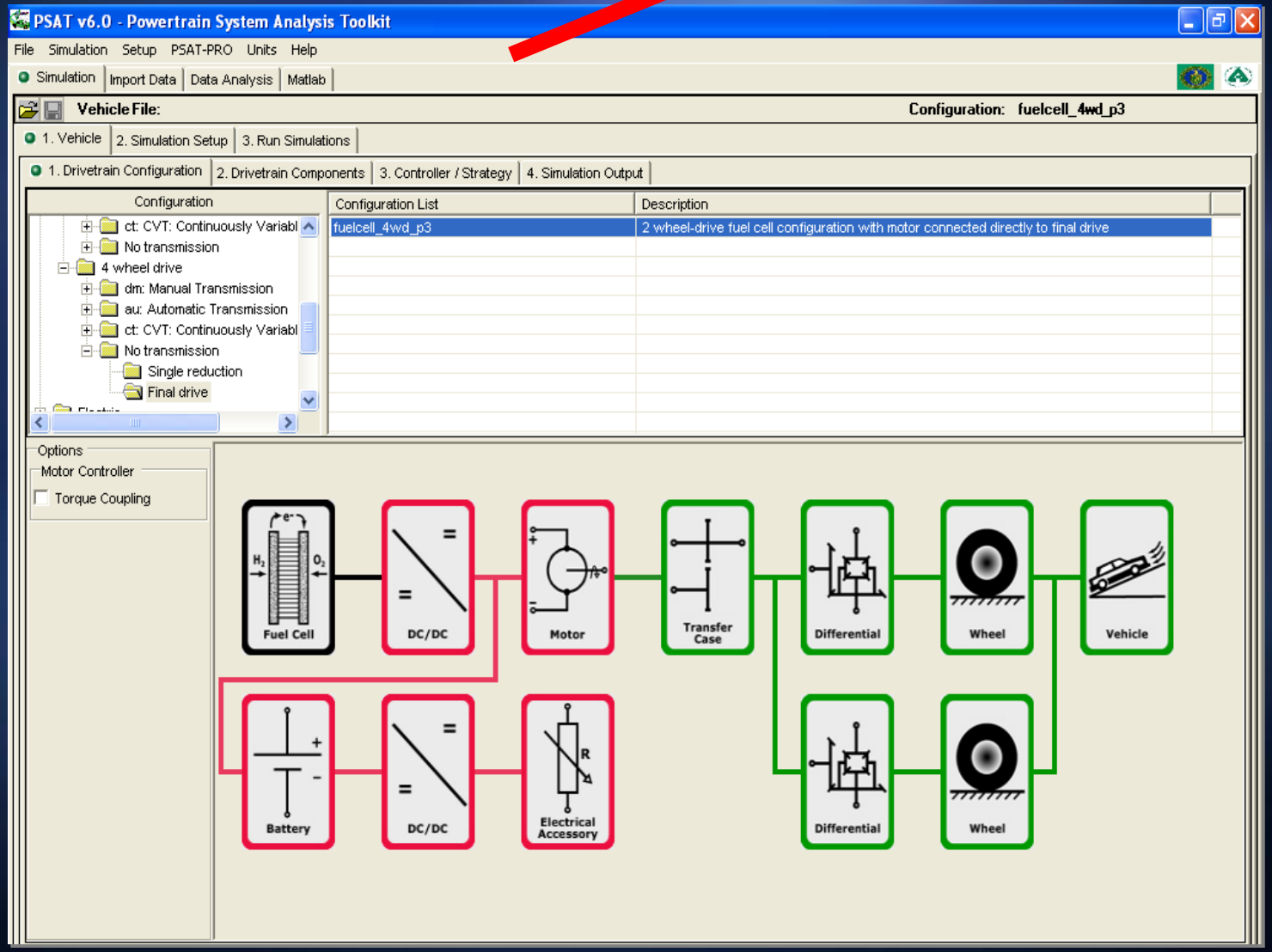
100 % inventor / 0 % university IP Ownership Rule

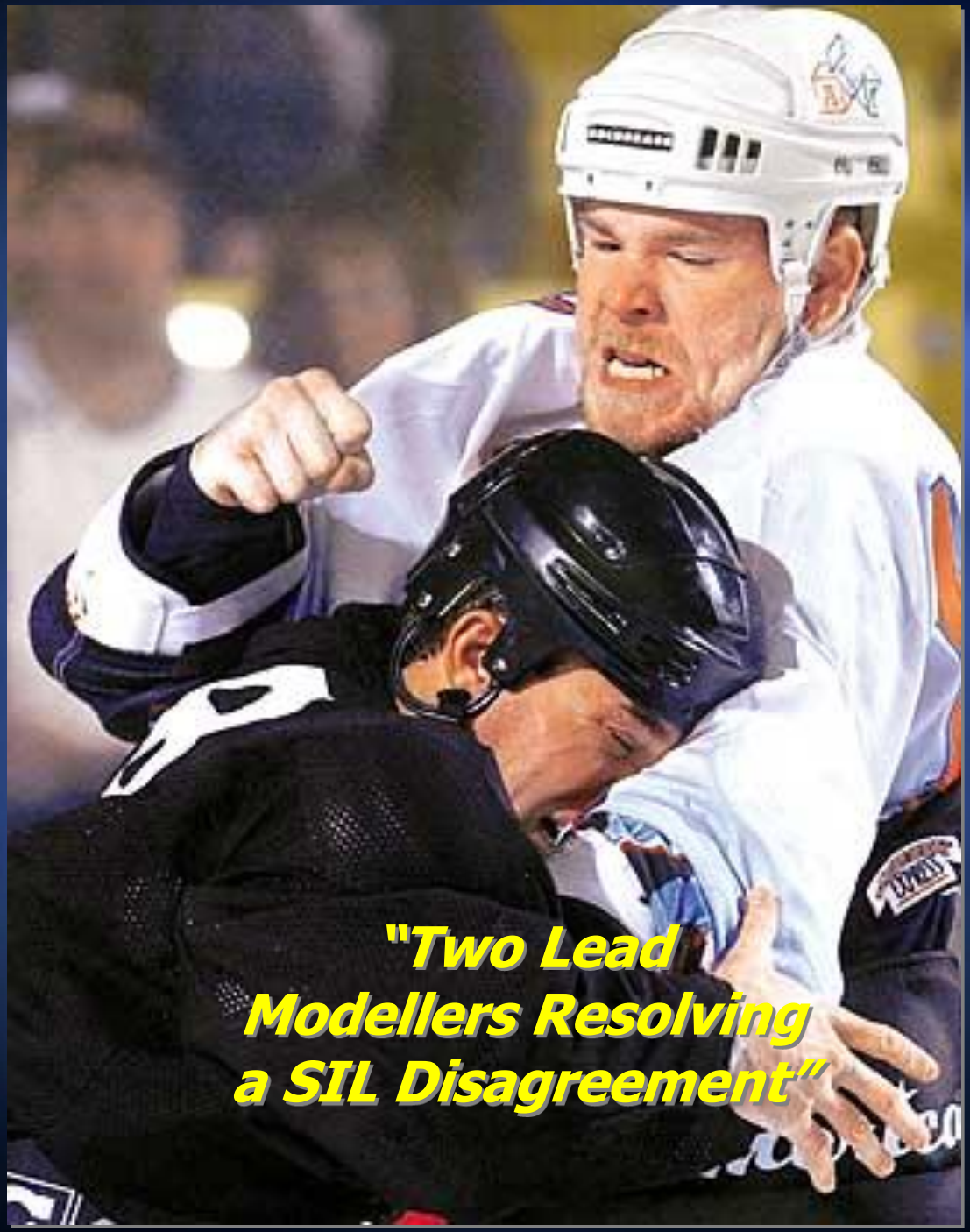
The future…

Graduating to Research…

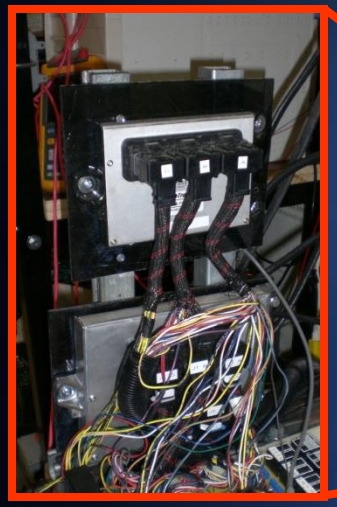
- University of Waterloo Alternative Fuels Team (UWAFT) complements and is complemented by various research efforts

Software-in-the-Loop (SIL)



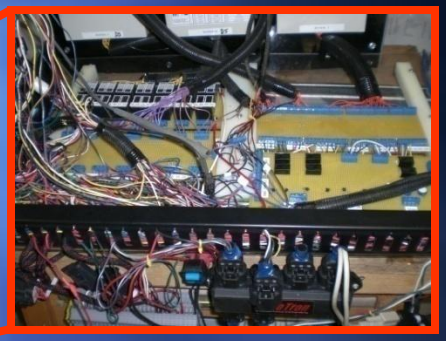

"Two Lead
Modellers Resolving
a SIL Disagreement"

Hardware-in-the-Loop (HIL)



MotoTron Controller

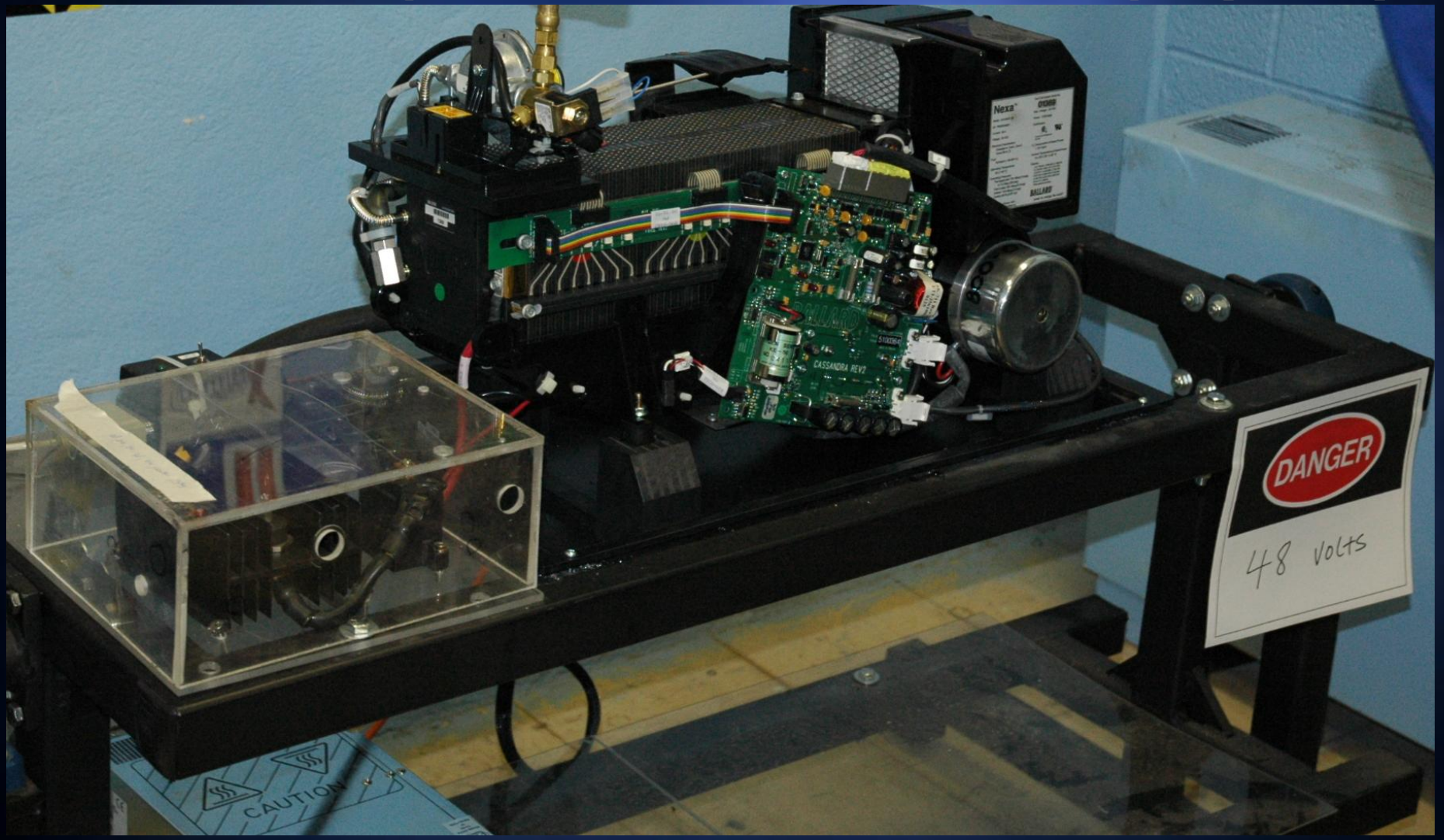
Dr. Fraser, Mech Eng
Dr. Fowler, Chem Eng



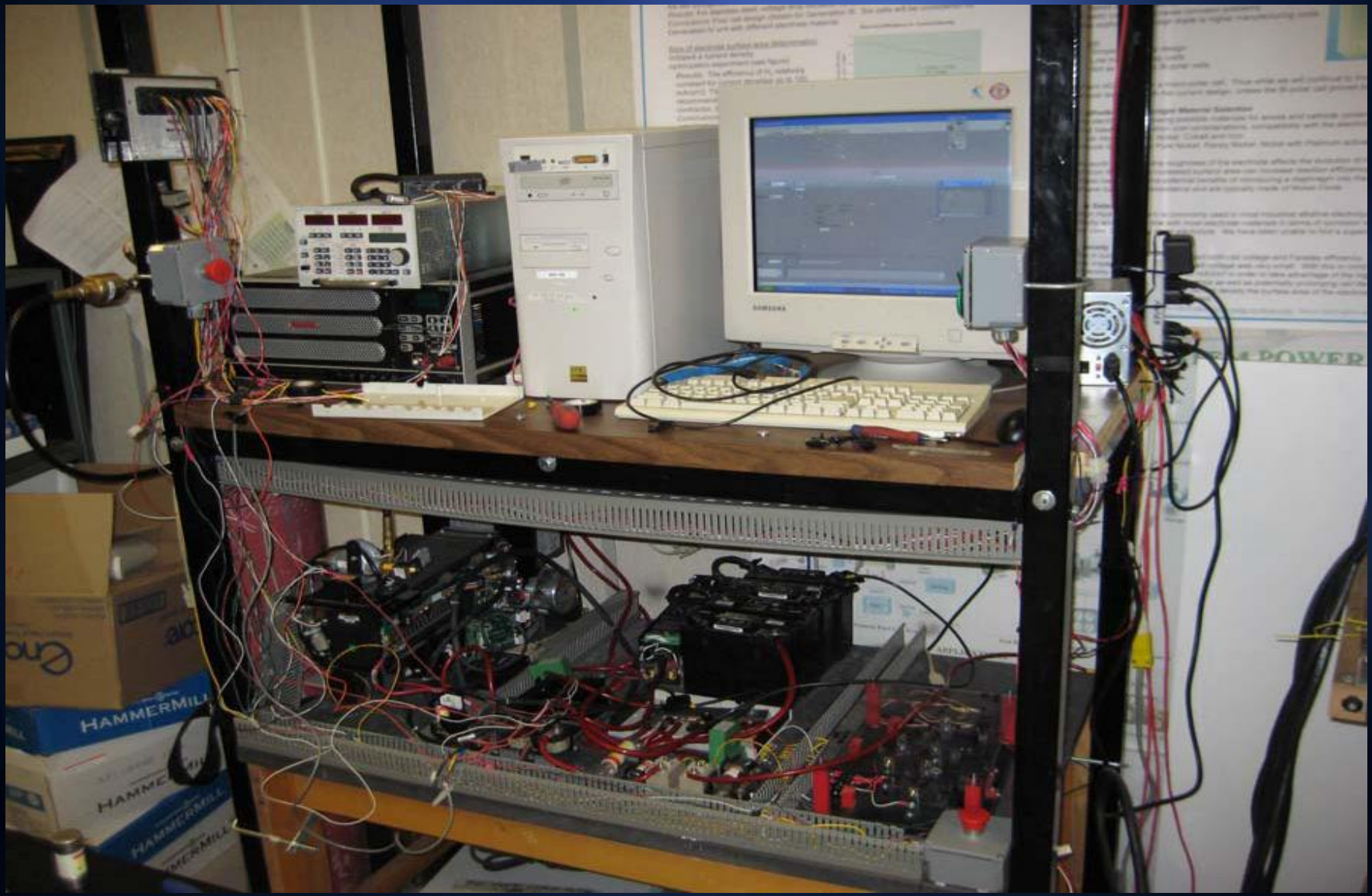
Complete Vehicle Wiring Harness and Connections

National Instruments PXI

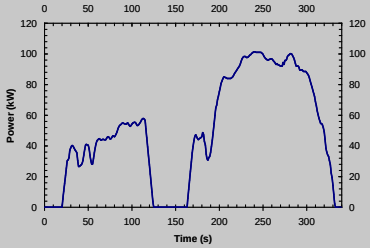
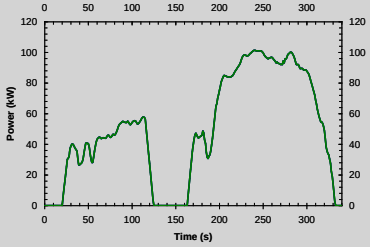
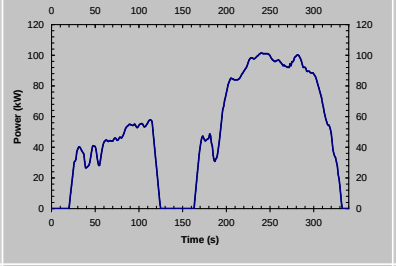
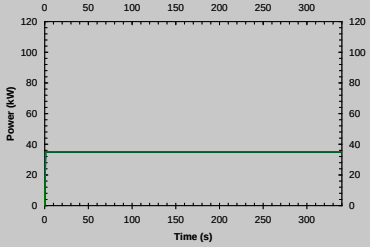
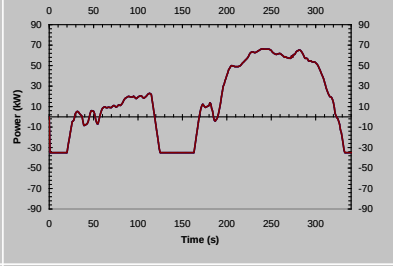
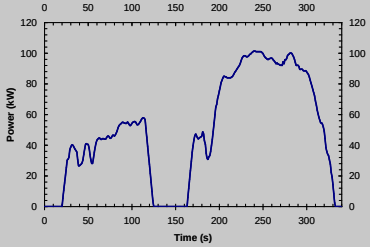
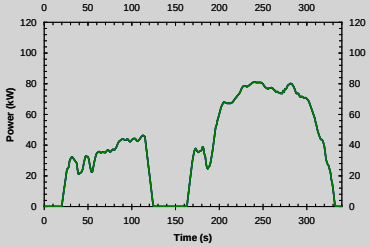
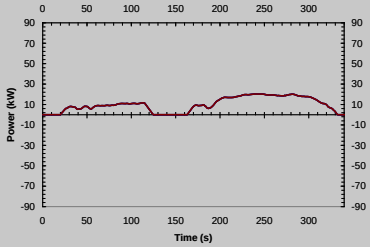
1 kW Component-in-the-Loop (CIL)



Battery CIL Testing



What Contributes to Battery Degradation?

	Total Power Provided	Primary Power Source	Secondary Power Source
Non-Hybrid			**No Secondary Source**
Hybrid Load Leveling			
Hybrid Load Following			

Battery Research

PHEV / BEV Utility Integration

Li-Ion Thermal Control

Li-Ion Degradation Modelling

Second Use / Recycling

Hybrid Energy Systems Research

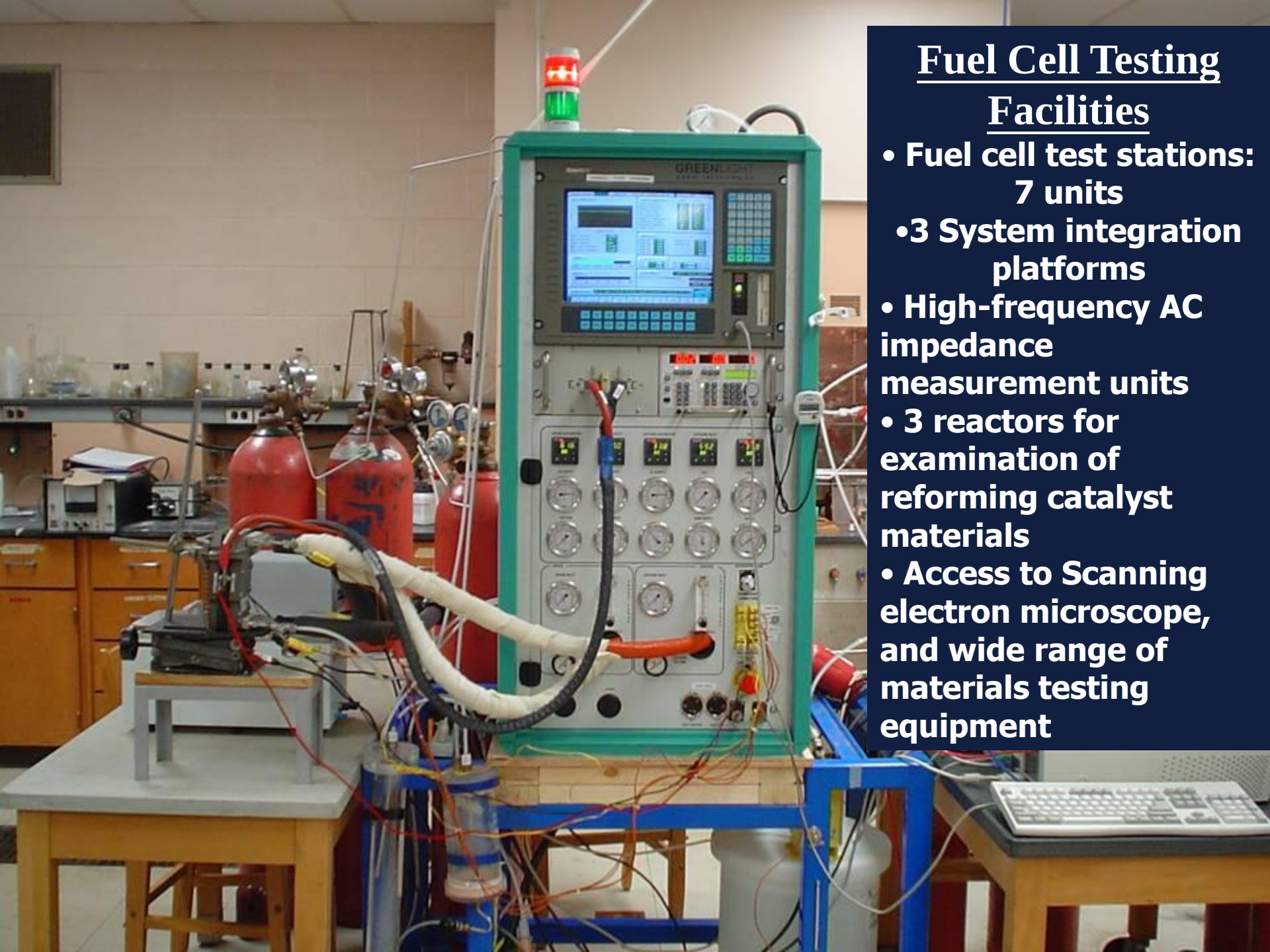
Fuel Cell Hybrid Electric Vehicles (FC-HEVs)

Plug-in Hybrid Electric Vehicles (PHEVs)

PHEV / BEV Utility Integration

Hydrogen Highway

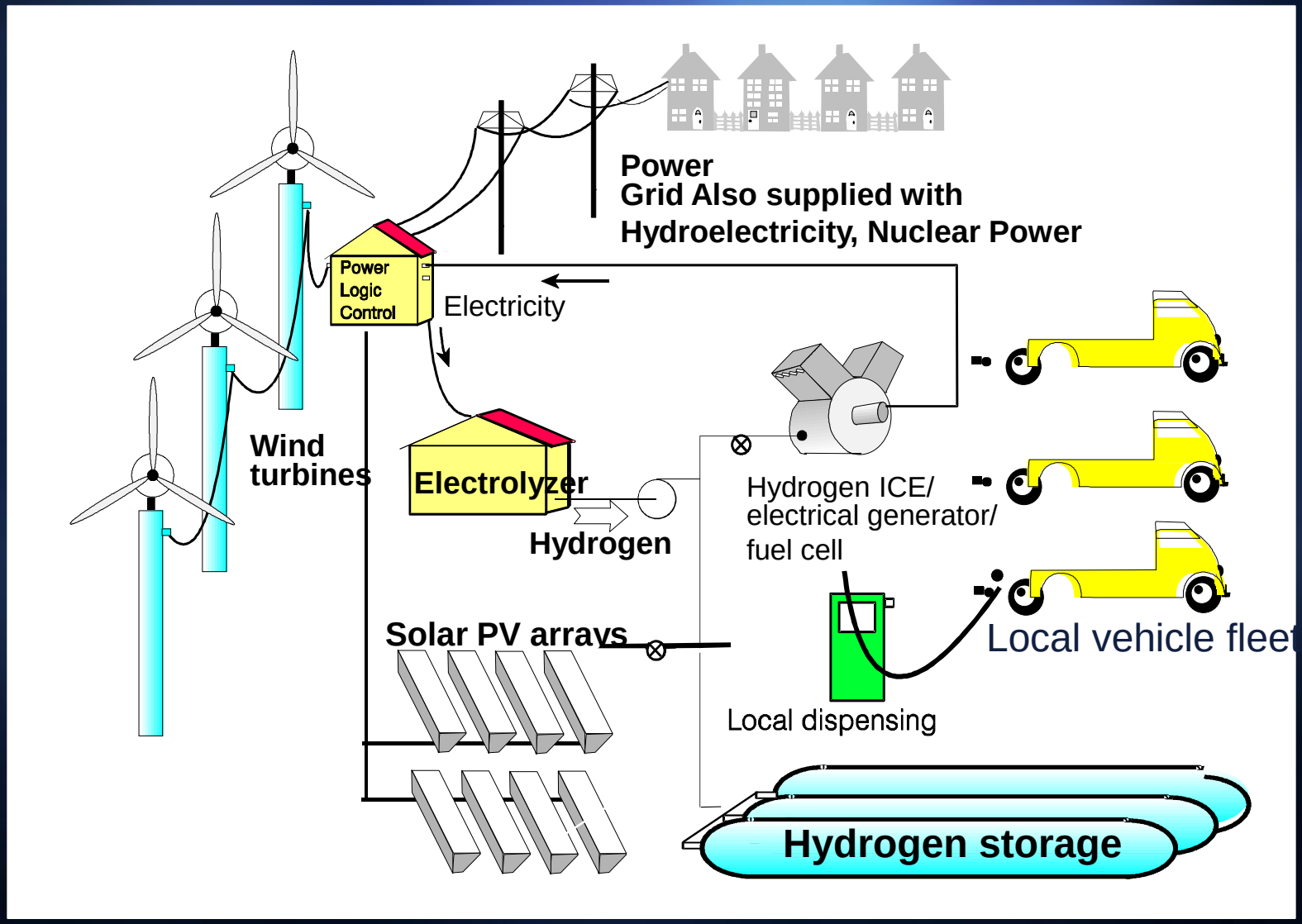
Mission 2050



Fuel Cell Testing Facilities

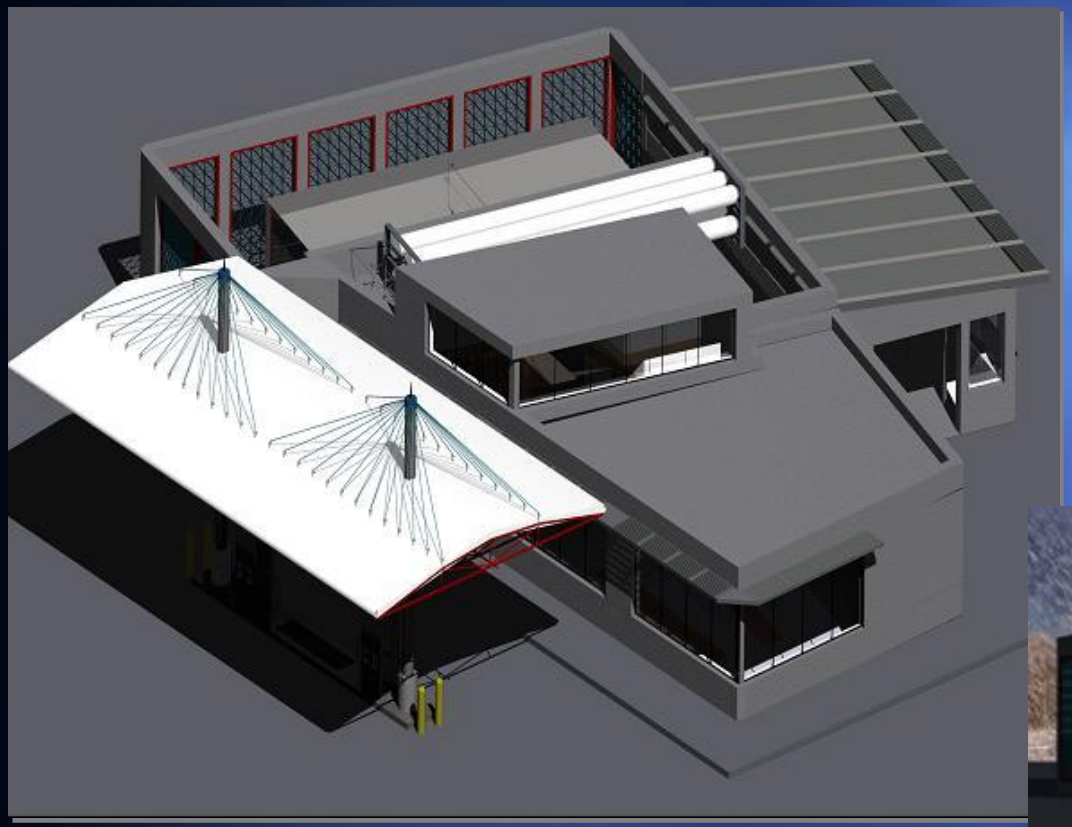
- Fuel cell test stations: 7 units
- 3 System integration platforms
- High-frequency AC impedance measurement units
- 3 reactors for examination of reforming catalyst materials
- Access to Scanning electron microscope, and wide range of materials testing equipment

Integrated renewable system – Hydrogen Highway

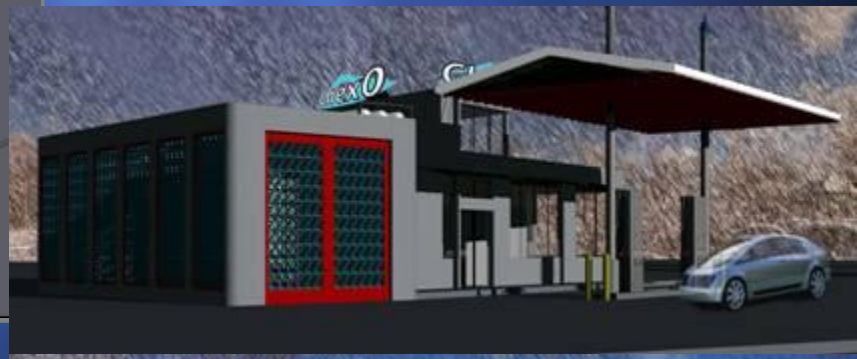


Ref: G Rambach, DRI, Nevada

Design of a Hydrogen Retail Station



Waterloo was the Honourable Mention winner in the National Hydrogen Association 2005 H2U Competition

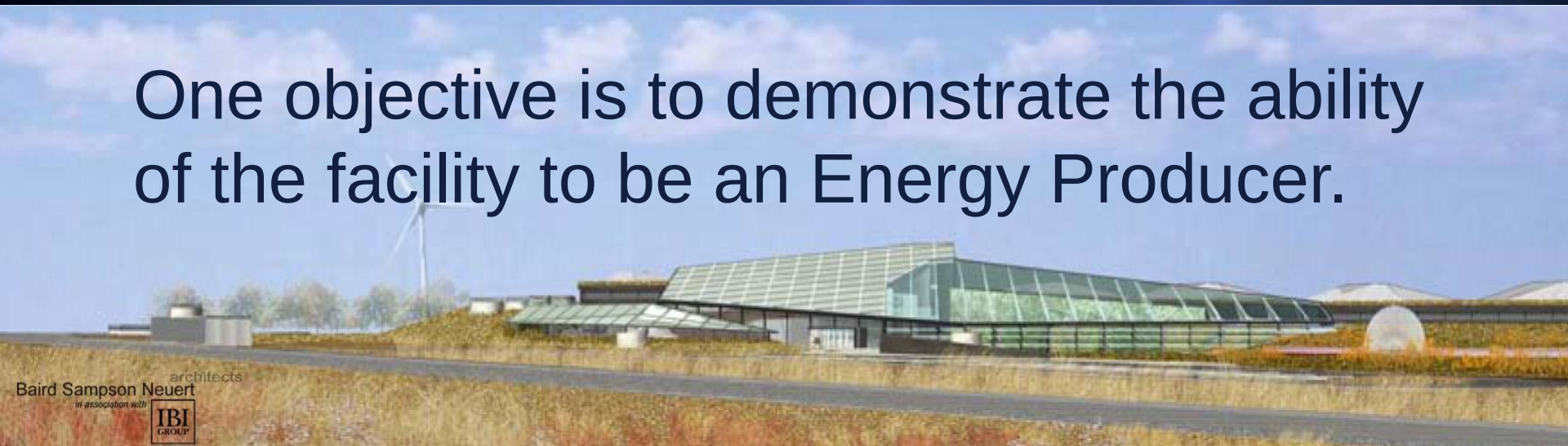


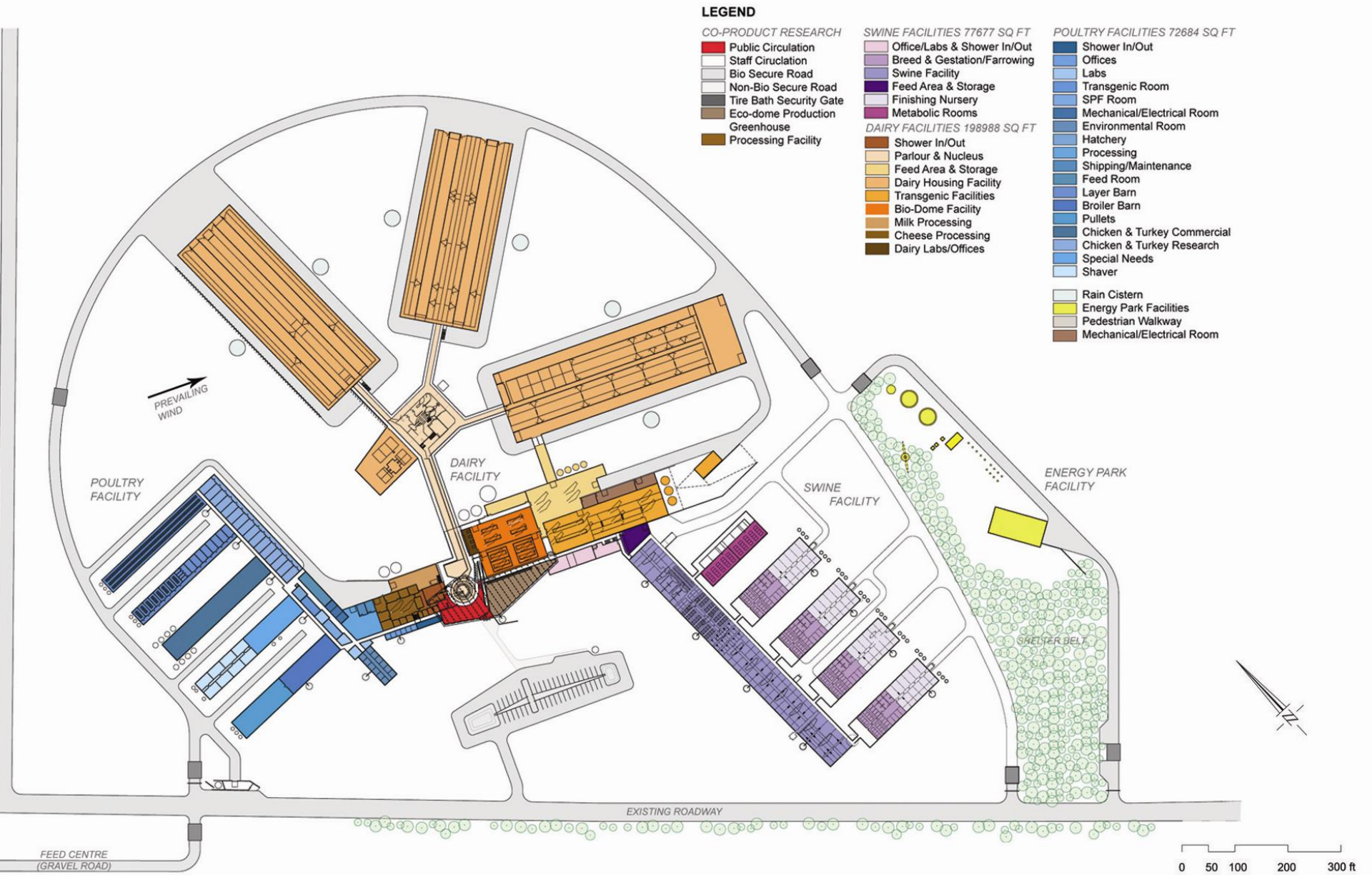
Mission 2050

An Integrated Vision of Agri-Food Research

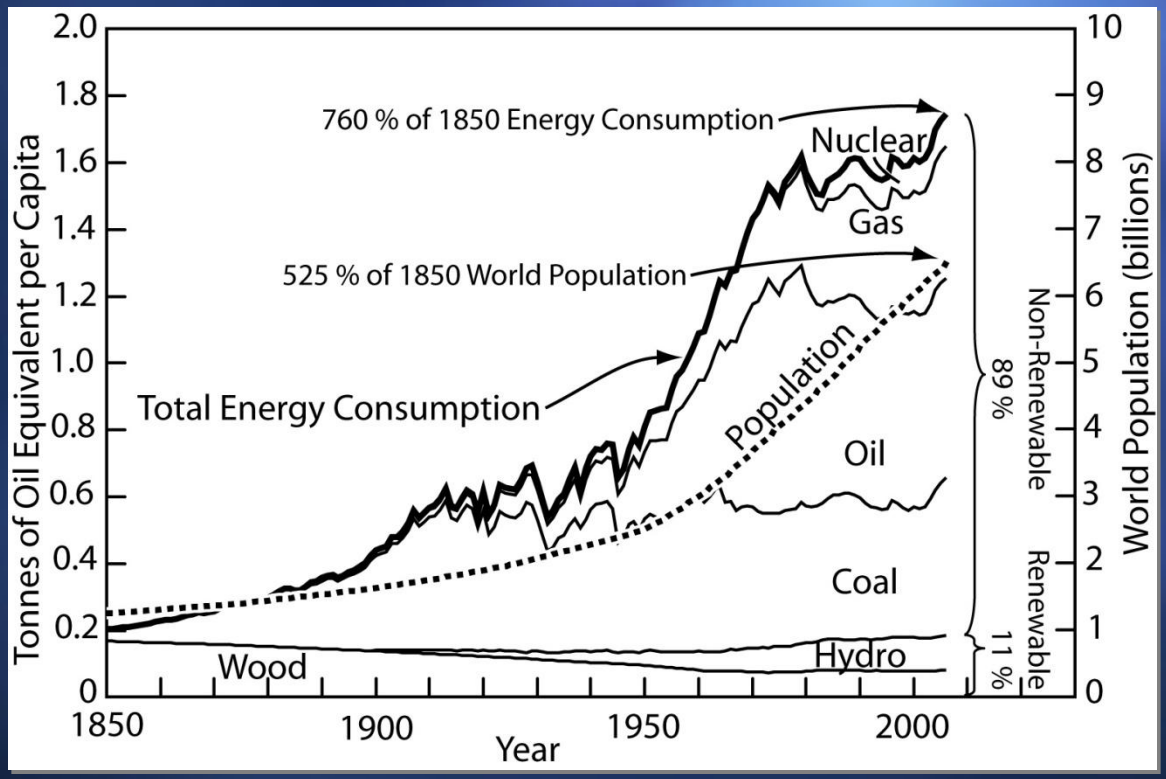
- Univ. of Guelph & Univ. of Waterloo
- Operating Farm (700 dairy cows, 5000 swine, 20,000 poultry)

One objective is to demonstrate the ability of the facility to be an Energy Producer.




LEGEND
CO-PRODUCT RESEARCH
Public Circulation
Staff Ciruclation
Bio Secure Road
Non-Bio Secure Road
Tire Bath Security Gate
Eco-dome Production Greenhouse
Processing Facility
SWINE FACILITIES 77677 SQ FT
Office/Labs & Shower In/Out
Breed & Gestation/Farrowing
Swine Facility
Feed Area & Storage
Finishing Nursery
Metabolic Rooms
DAIRY FACILITIES 198988 SQ FT
Shower In/Out
Parlour & Nucleus
Feed Area & Storage
Dairy Housing Facility
Transgenic Facilities
Bio-Dome Facility
Milk Processing
Cheese Processing
Dairy Labs/Offices
POULTRY FACILITIES 72684 SQ FT
Shower In/Out
Offices
Labs
Transgenic Room
SPF Room
Mechanical/Electrical Room
Environmental Room
Hatchery
Processing
Shipping/Maintenance
Feed Room
Layer Barn
Broiler Barn
Pullets
Chicken & Turkey Commercial
Chicken & Turkey Research
Special Needs
Shaver
Rain Cistern
Energy Park Facilities
Pedestrian Walkway
Mechanical/Electrical Room
PREVAILING WIND
POULTRY FACILITY
DAIRY FACILITY
SWINE FACILITY
ENERGY PARK FACILITY
SHELTER BELT
EXISTING ROADWAY
FEED CENTRE (GRAVEL ROAD)
0 50 100 200 300 ft

We've talked about accessing more energy.



Also need to talk about reducing energy needs..... conservation

THE END

QUESTIONS?

INUKSHH_2UK

THE ~~END~~ BEGINNING

QUESTIONS?

INUKSH$_2$UK

Q & A

-- Joanne

Complex Thermodynamic Systems Optimization & Decision Making

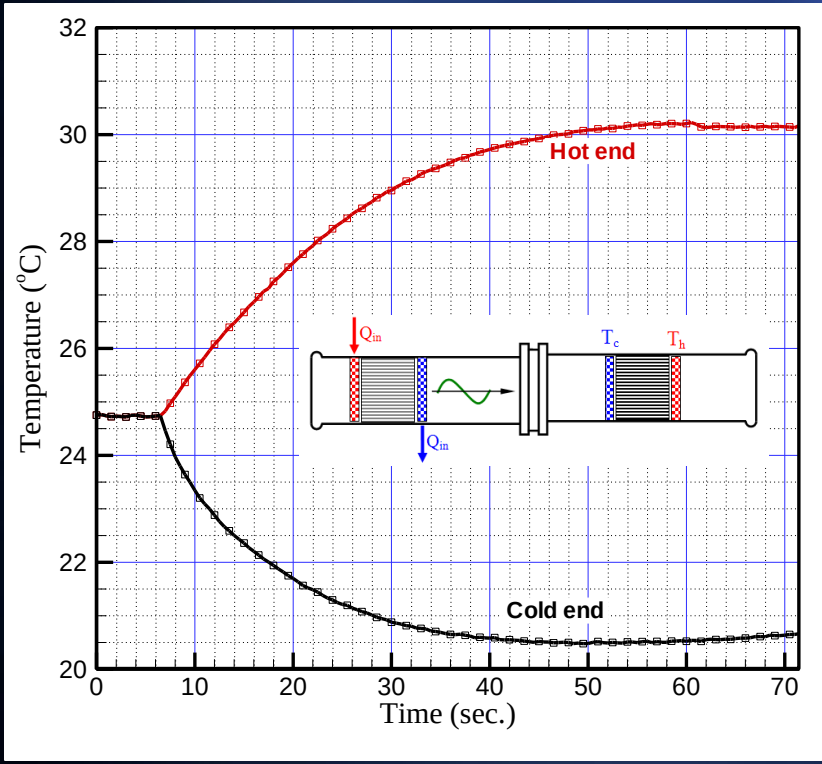
Thermoacoustic Refrigeration

Eco/Urban-system Integrity Monitoring

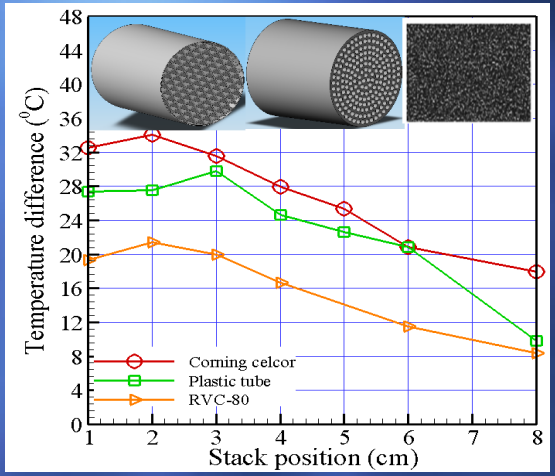
Resourse Sustainability / Waste Impact

Exergy – It's a Decision Making Tool

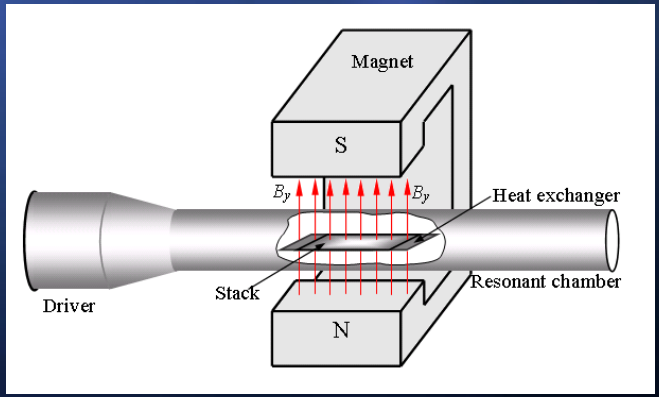
Solar Driven Thermoacoustic Refrigeration



Heat Driven Refrigerator

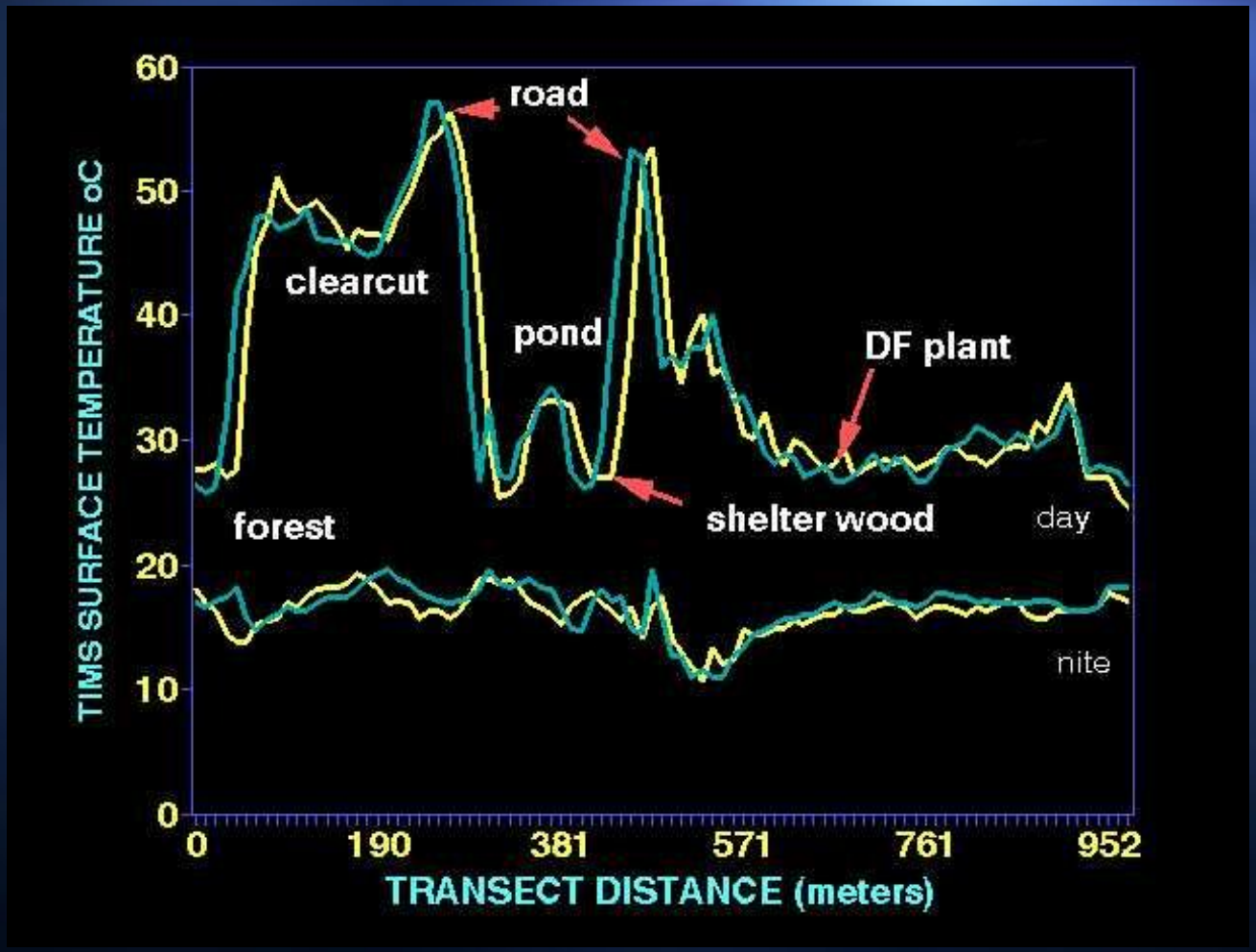


Therporaoustics

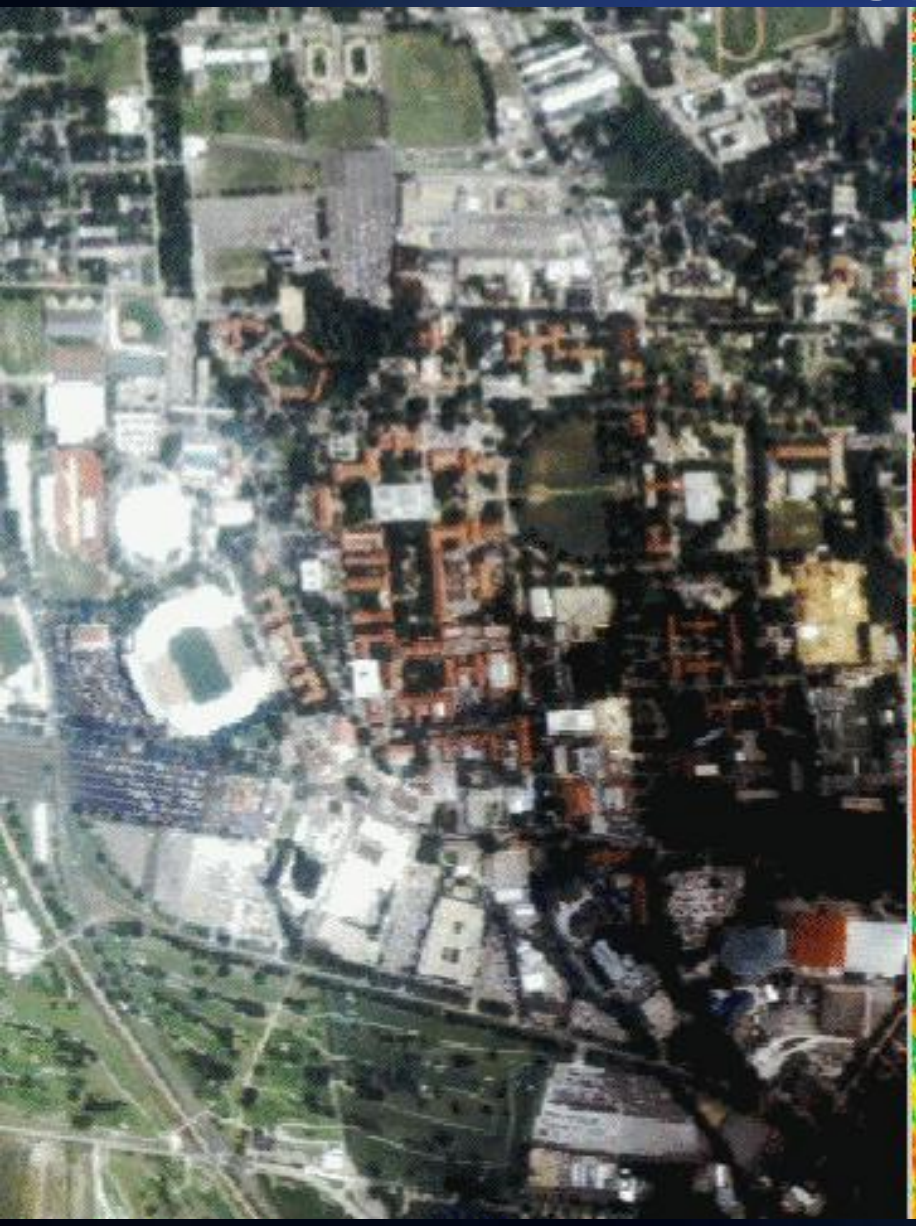


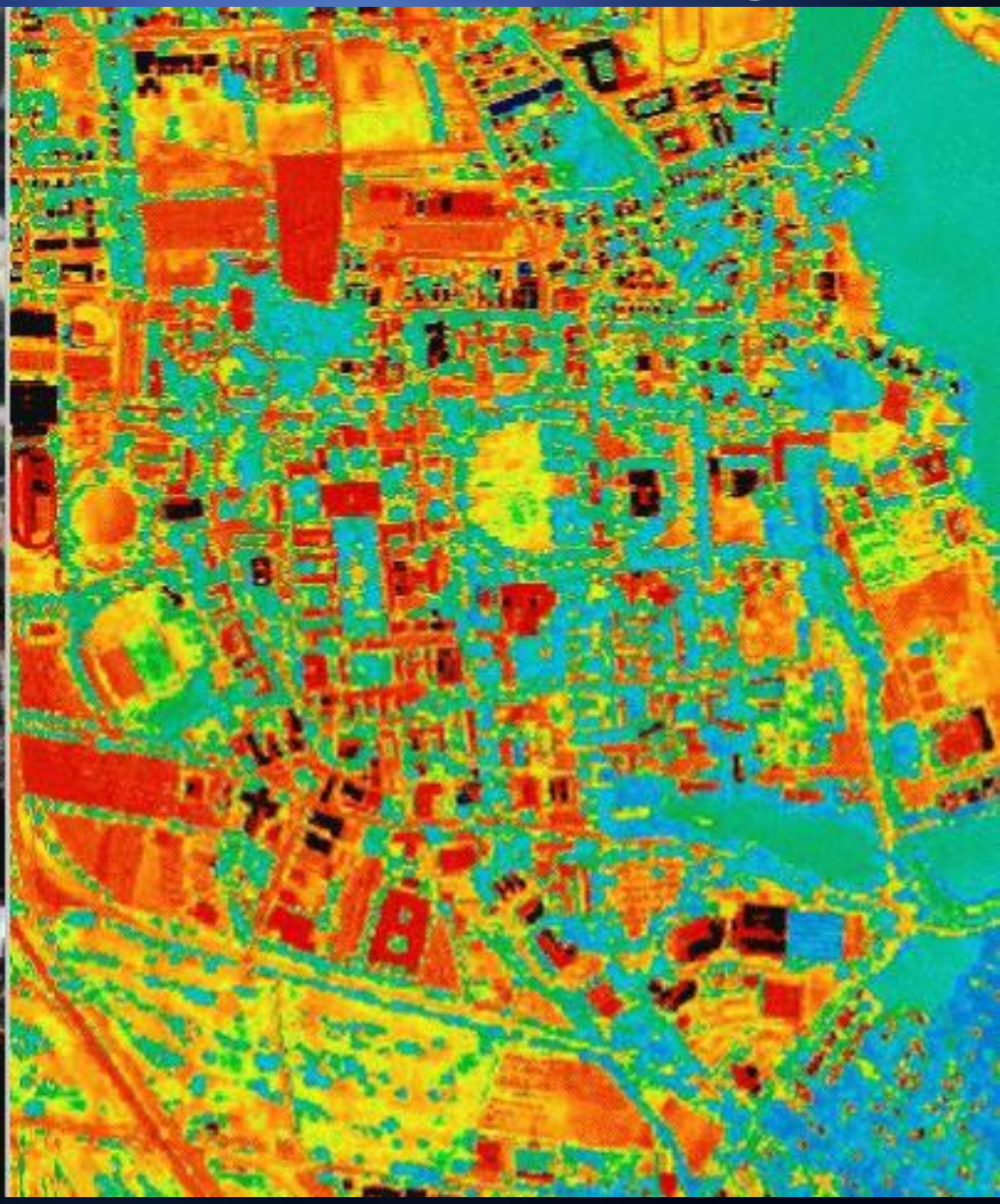
Thermagoustics

Ecosystem Remote Monitoring for Development/Health/Integrity

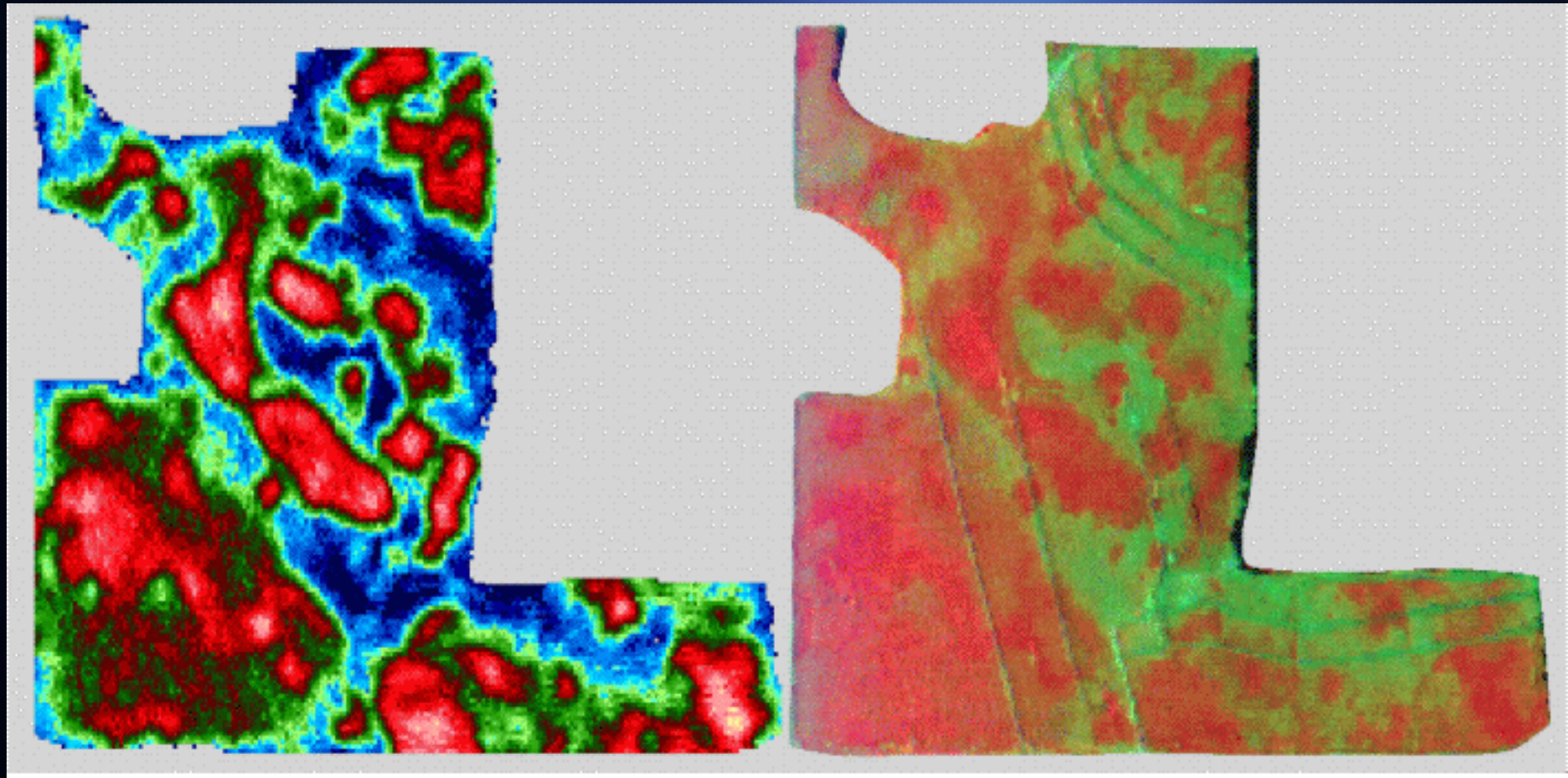


Urban System Remote Monitoring for Heat Island/Energy Consumption/Integrity





Agriculture Prediction and Fertilizer Optimization



Harvested September, 1998 June 26, 1998

Thermal Band correlation > 0.86

D. Rickman, et al., 1999

Temperature Remote Monitoring
for Development/Health/Integrity

"Campus as a Living Laboratory"

"How measure greenness of campus?"

The time is now to monitor.

It is Easier to Boil Ice Than Water?

Q: Ideally, does it take less natural gas to bring 1 kg of ice at -20 ^{o}C, or 1 kg of water at 60 ^{o}C, to a 100 ^{o}C boil?

A: It takes a factor of 3.0 less natural gas to bring the -20 ^{o}C ice to a boil!

Theoretically, the -20 ^{o}C ice can be heated to 88 ^{o}C with no natural gas.

Remember

- Intuition is a poor substitute for the physics of thermodynamics.
- Intuition can seriously limit one's ability to conceive of alternative system improvements/modifications.

Thermodynamics is a Black Box Science

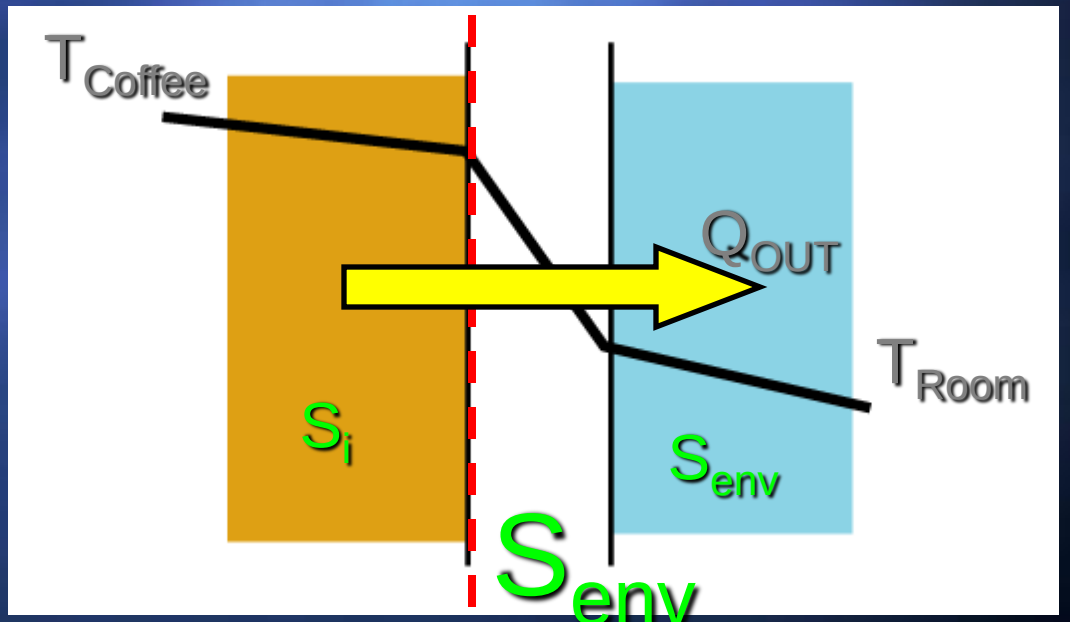
Thermodynamics is a Black Box Science

But Thermodynamic Innovation Requires Thinking Outside the Box

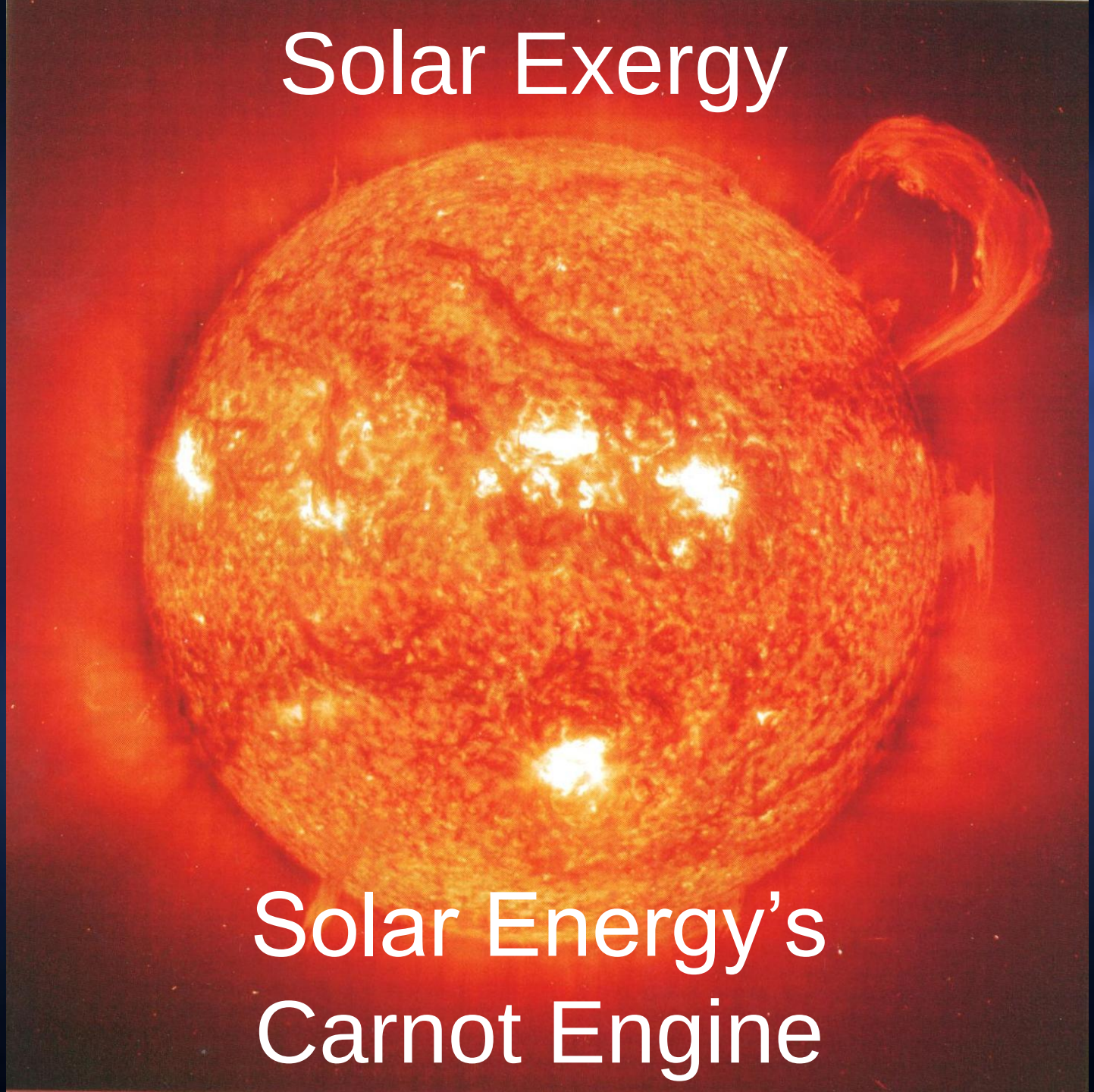
BLACK BOX

(as that is where the action and decision making constraints exist)

Cup of Coffee



Solar Exergy



Solar Energy's Carnot Engine

The Solar Exergy Controversy
(Open System)

$$X_{Petela} = \Phi_{T,Solar}\left(1-\frac{4}{3}\frac{T_0}{T_{Solar}}+\frac{1}{3}\frac{T_0^4}{T_{Solar}^4}\right)$$

$$X_{Castans} = \Phi_{T,Solar}\left(1-\frac{T_{Optimum}^4}{T_{Solar}^4}\right)\left(1-\frac{T_0}{T_{Optimum}}\right) = \Phi_{T,NET}\left(1-\frac{T_0}{T_{Optimum}}\right)$$

$$0 = 4T_{Surface}^5 - 3T_0 T_{Surface}^4 - T_{Solar}^4 T_0$$

$$X_{Kabelac} = \Phi_{T,Solar}\left(1-\frac{T_0^4}{T_{Solar}^4}\right)\left(1-\frac{T_0}{T_{Solar}}\right) = \Phi_{T,NET}\left(1-\frac{T_0}{T_{Solar}}\right)$$

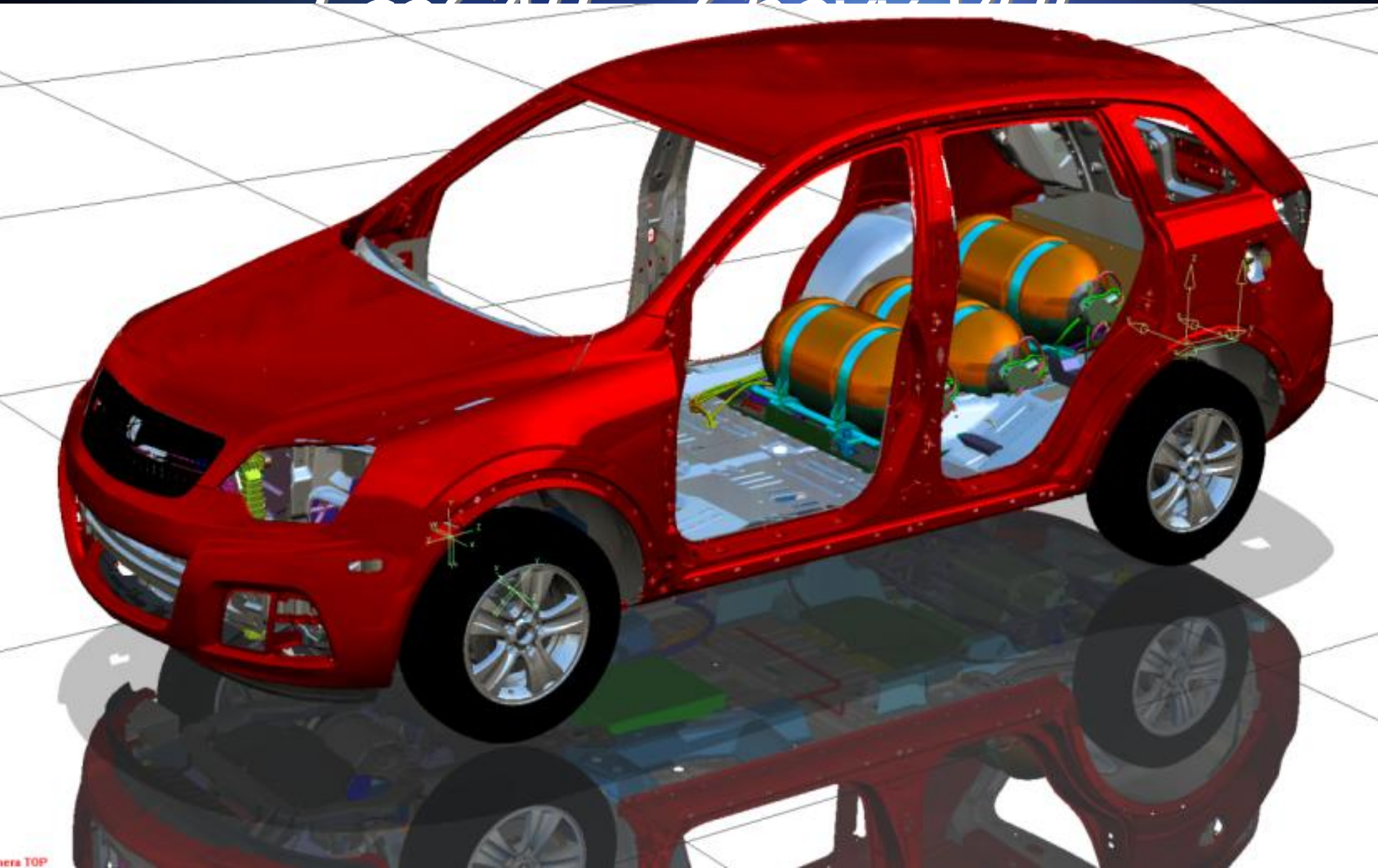
Sustainable Energy Research & Teaching

Stories of Innovation and Entrepreneurship at Waterloo

IIT Rajasthan Workshop

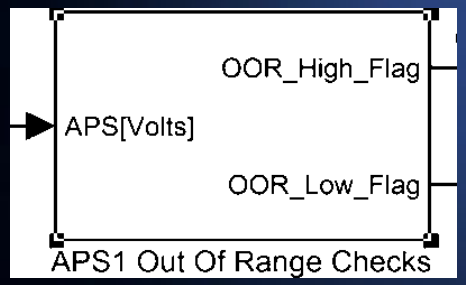
Roydon A. Fraser
Mechanical & Mechatronics Engineering
Nov. 25 2010

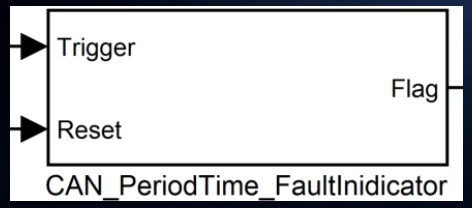
FeaCAR – Chevy VUE

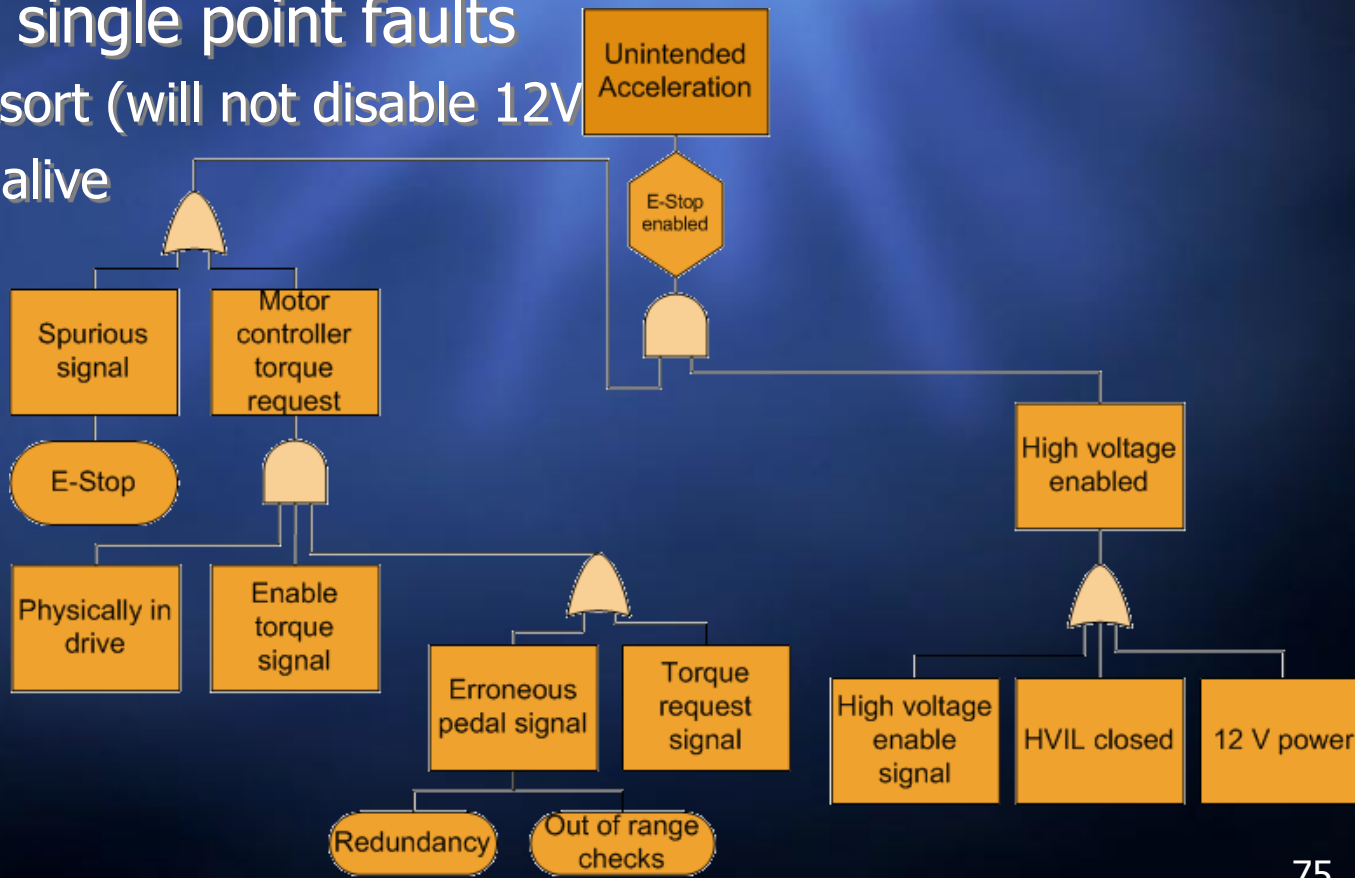


Fault detection

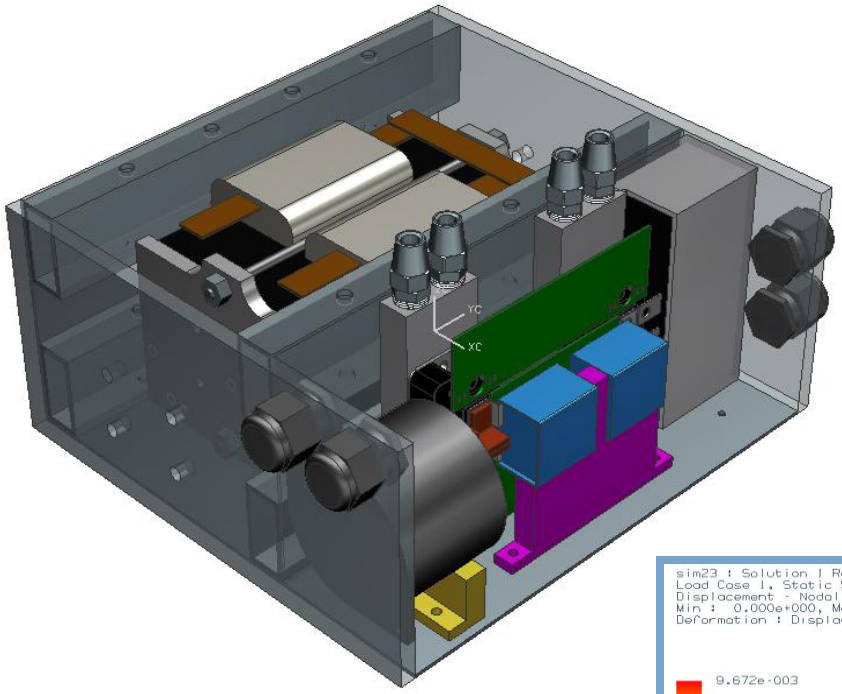
- Detect Faults that may lead to FM
- Remove all single point faults
  - Add redundancy
- If testing with single point faults
  - E-stop last resort (will not disable 12V
  - EPS/ABS still alive

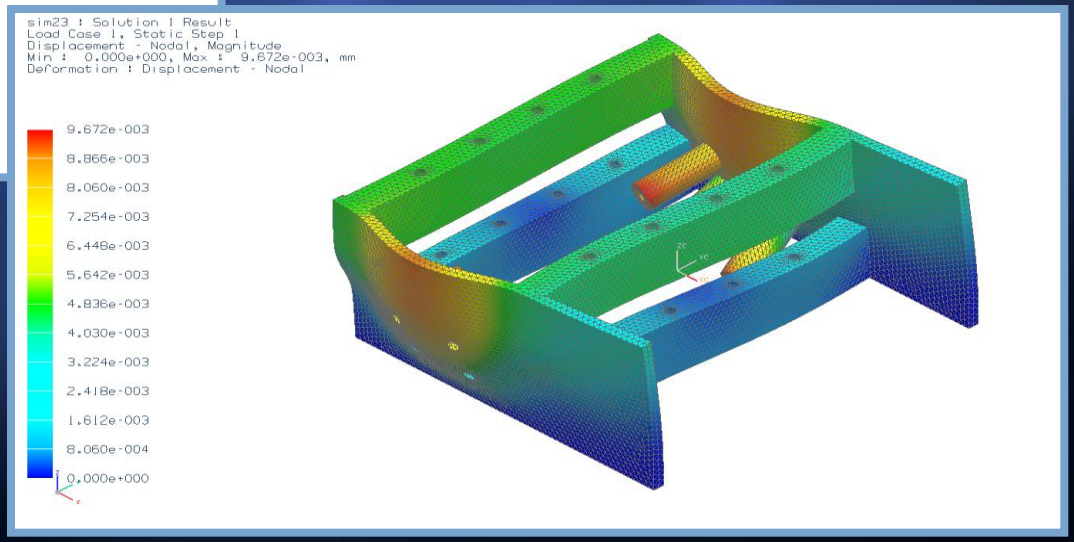




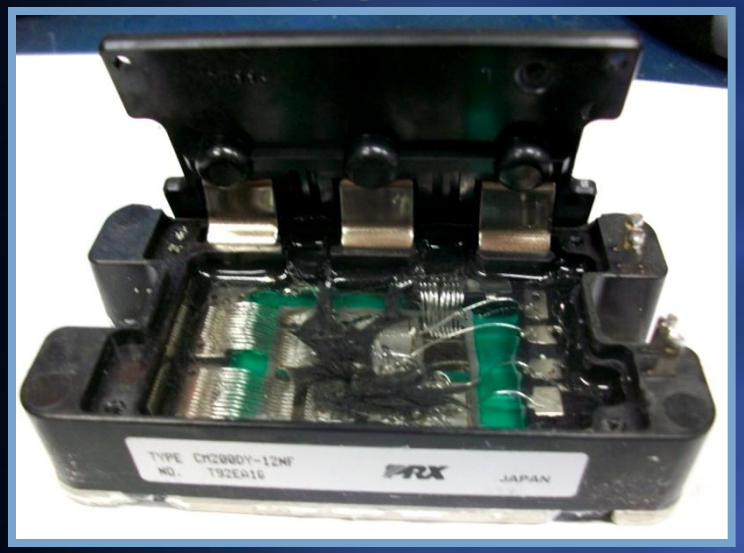


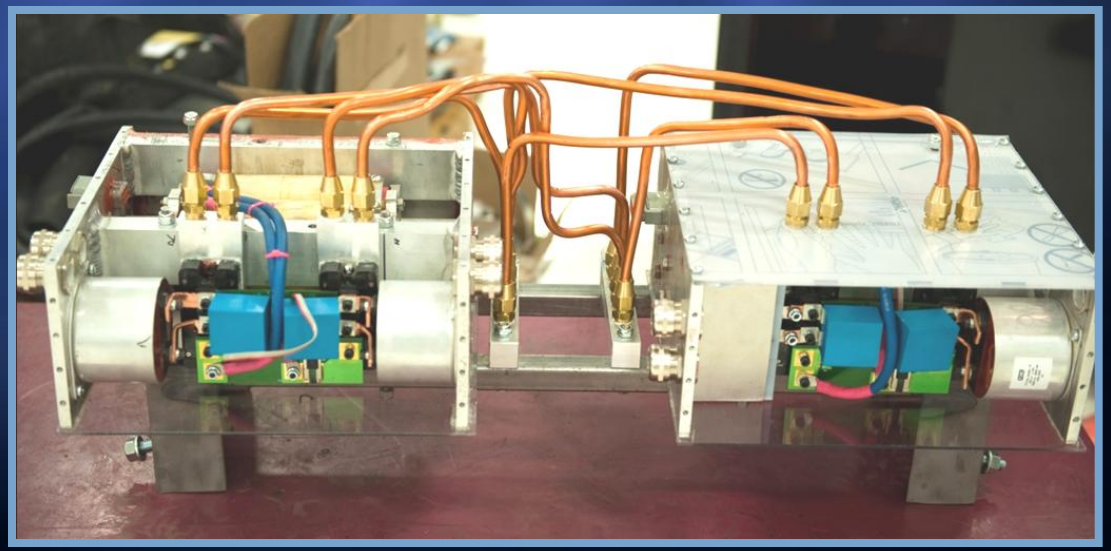
Year 1 design - DC-DC





Year 2 integration - DC-DC





Vehicle Overview

Motohawk
ECU565-128

Motohawk
ECU555-80

High and Low Power DC/DC Converters & Front Motor

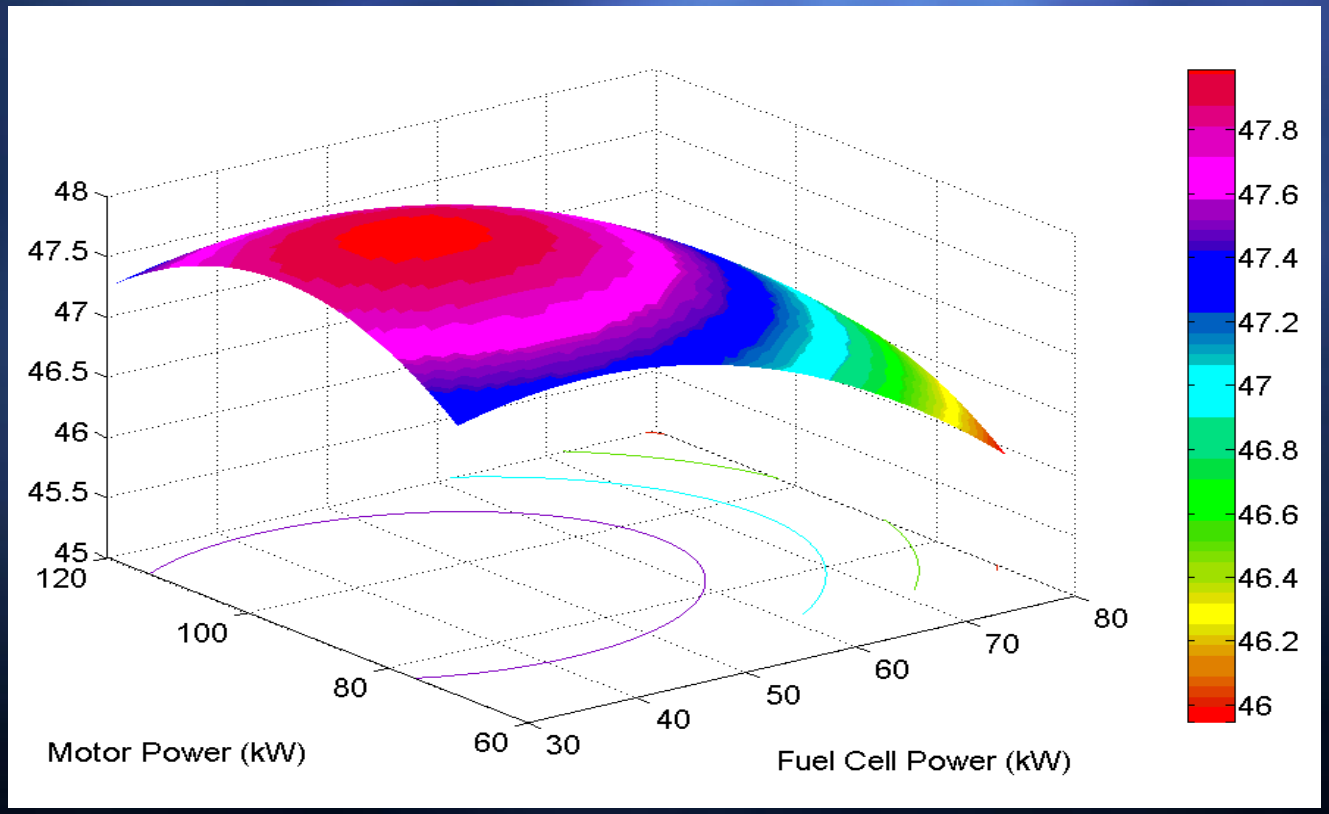
Fuel cell Modules

Rear Motor

H_2 Tank

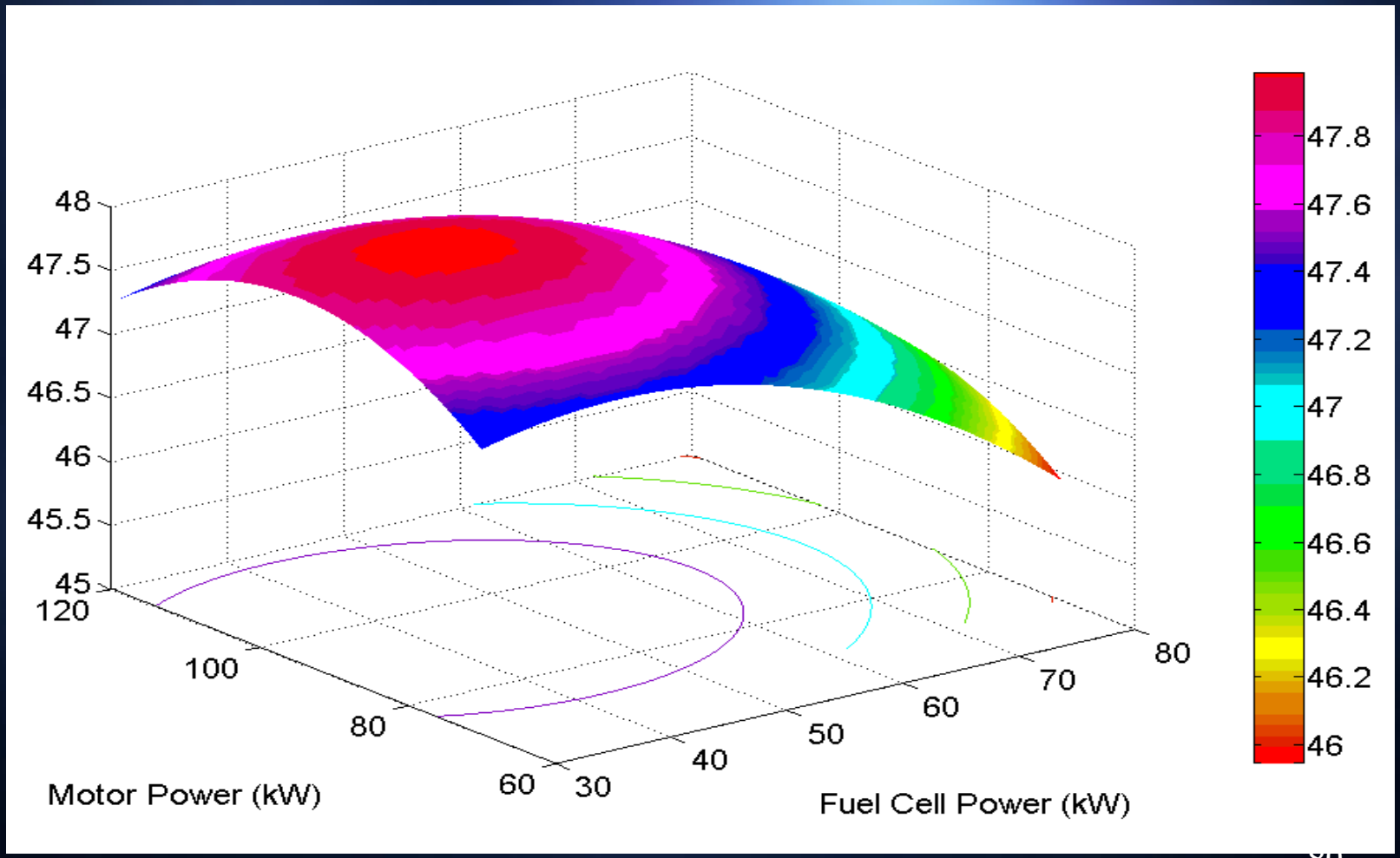
How did modelling help UWAFT?

- Software (PSAT) can answer all of those questions quickly (2 days of simulation):



Vehicle Simulation

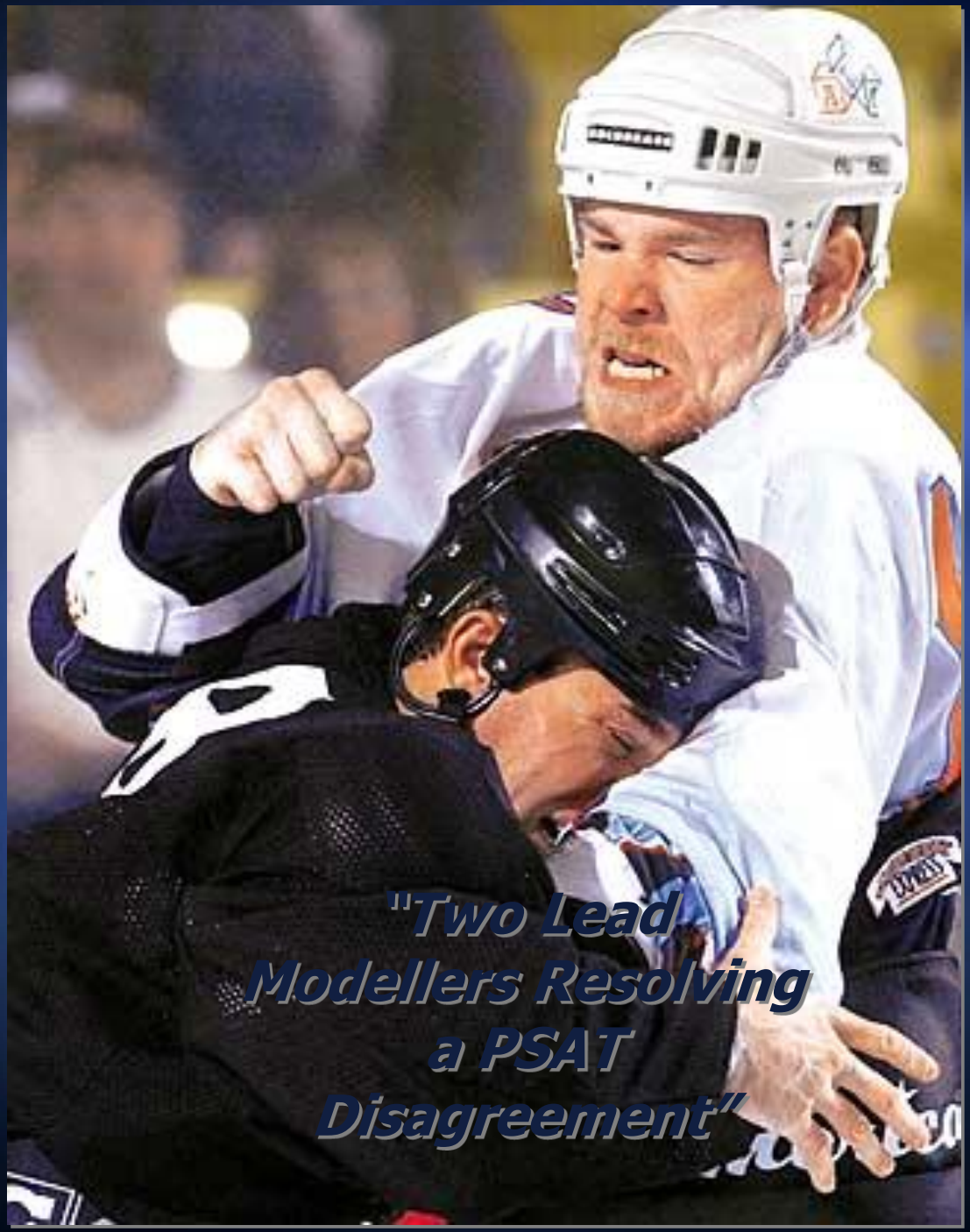
Vehicle Mileage as a Function of Fuel Cell and Motor Power



University of Waterloo Technical Presentation

INUKSH$_2$UK

- Key messages
- 1. IP
- 2. Design involves iteration
- 3. competition critical for achievement and #’s involved
- 4. Be flexible in definition of design


"Two Lead
Modellers Resolving
a PSAT
Disagreement"

Hard at Work


QUESTIONS?
POWERED BY E85
Waterloo
Challenge
1
Growing Green
Millennium
Firestone

Click to edit Master title style

Outreach

The results…

Erik Wilhelm

team captain/hydrogen lead

PhD Student @ ETH Zurich

I watched as it **shaped the lives** and careers of more than 200 young Waterloo engineering students….

…carried a lot of **significance** for me and those involved.

Master's
Chemical Engineering

Dan Sellan

mechanical integration

PhD Student @ University of Toronto

...Challenge X **opened my eyes** to many novel and ground breaking technologies that I would not have been otherwise exposed.

...the **soft skills developed** during my tenure with UWAFT have been proven to be invaluable...

Bachelor's
Chemical Engineering

Dave Shilling

controls lead

Lead Engineer @ Turnkey Solutions

...the opportunity to meet and learn from

industry leaders

...not have been possible without the tremendous

support of the sponsors

...could **not** have been taught in the classroom...

Bachelor's
Mechanical Engineering

Charles Hua

team captain & hydrogen lead

Offered Hybrid Vehicle Engineer @ GM

… was definitely an opportunity of a lifetime.

What I was able to take away from being involved in this competition were skills that I normally wouldn't have had the chance to develop in any other situation.

Master's
Chemical Engineering

Taylor Mali

business director

Systems Design Engineering @ AECL

...Challenge X confirmed by desire to pursue a career in the advancement of energy technology.

The real success of Challenge X is of course the development of engineers to pursue the future of sustainable technology in the automotive industry and beyond. I certainly have benefited from the Challenge X experience and will carry these skills with me throughout my entire career.

Master's
Chemical Engineering

Alex Koch

team captain

New Team Captain

….?

Master's
Mechanical Engineering

An Integrated Vision of Agri-Food Research

Economic , Social & Environmental Sustainability Rural Economic Incubator

Total Resource Recovery/Waste to Energy

Environmental & Resource Conservation Organics Applications

Emission Monitoring & Sequesterization Biogas/Biomass Reactor

Integrated Renewable Energy Systems

High Performance Facility Design

'Plug & Play' Research Infrastructure Innovative Animal Management Systems

Biological Sensorics Measurements, Verification & Validation

Energy & Operational Efficiency Optimized Environment for Achievement

Technology Development & Transfer

Biomass to Bio-Products Multi-Industry Partnerships

Beta Testing Site Scalable Systems

Education and Outreach

Integrated Experiential Learning Graduate & Undergraduate Teaching

K-12 Curriculum Links Applied Producer Learning Centre Training HQP's

Rural Development

Economic Diversification from Novel Co-Products Farm as Energy-Exporter

Multi-Dimensional Rural Partnerships Skill Intensive Rural Employment

MISSION 2050

Sphere of Focus:

Multidisciplinary Research

DAIRY

SWINE

POULTRY

CO-PRODUCTS

ENERGY

CROPS

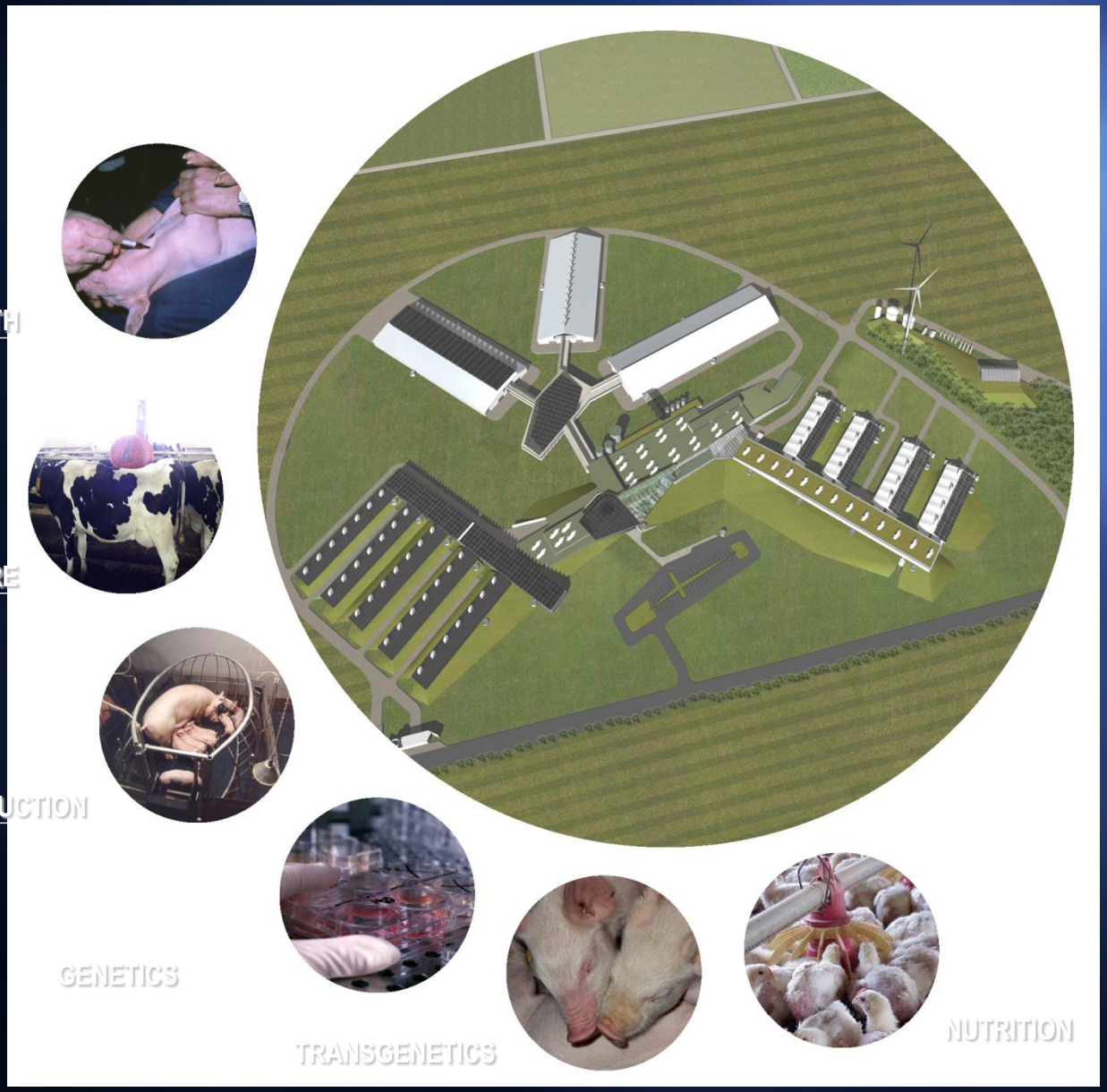
EDUCATION

ENVIRONMENT

MISSION 2050

Sphere of Focus:

Animal Research



MISSION 2050

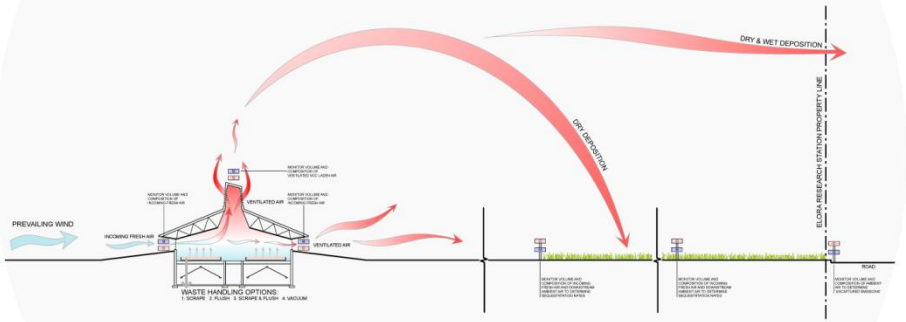
Sphere of Focus:

Co-Products from Organics

MISSION 2050

Sphere of Focus:

Emission Research, Monitoring & Mitigation



EMISSION MONITORING

EMISSION MICRO TURBINE

ANIMAL EMISSION

FIELD EMISSION

WASTE EMISSION

ENVIRONMENTAL EMISSIONS

SEQUESTERING EMISSIONS

MISSION 2050

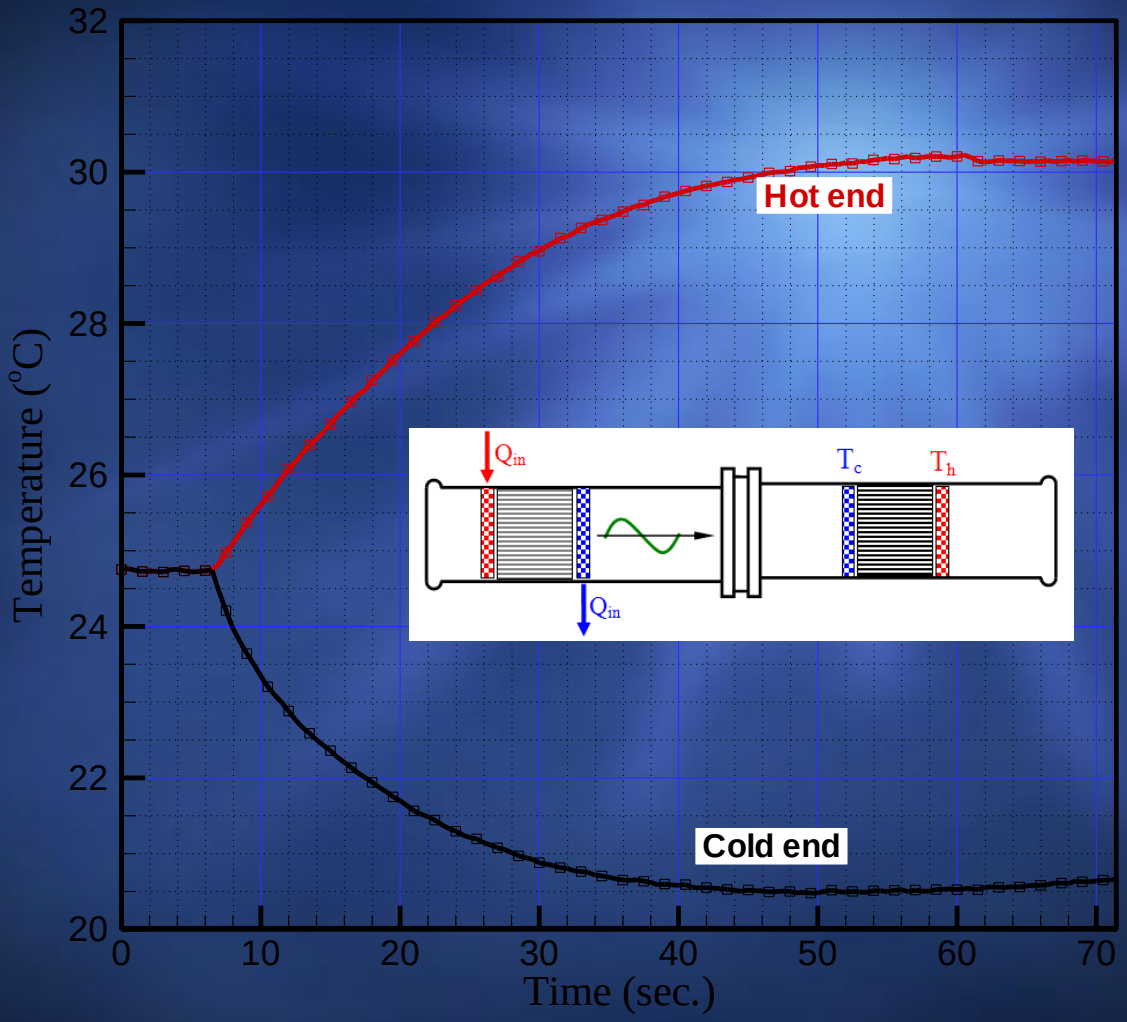
Advantages

- Simple in construction
- More reliable
- Use inert gases or air as working fluids
- Less noise and vibration
- Low grade energy input

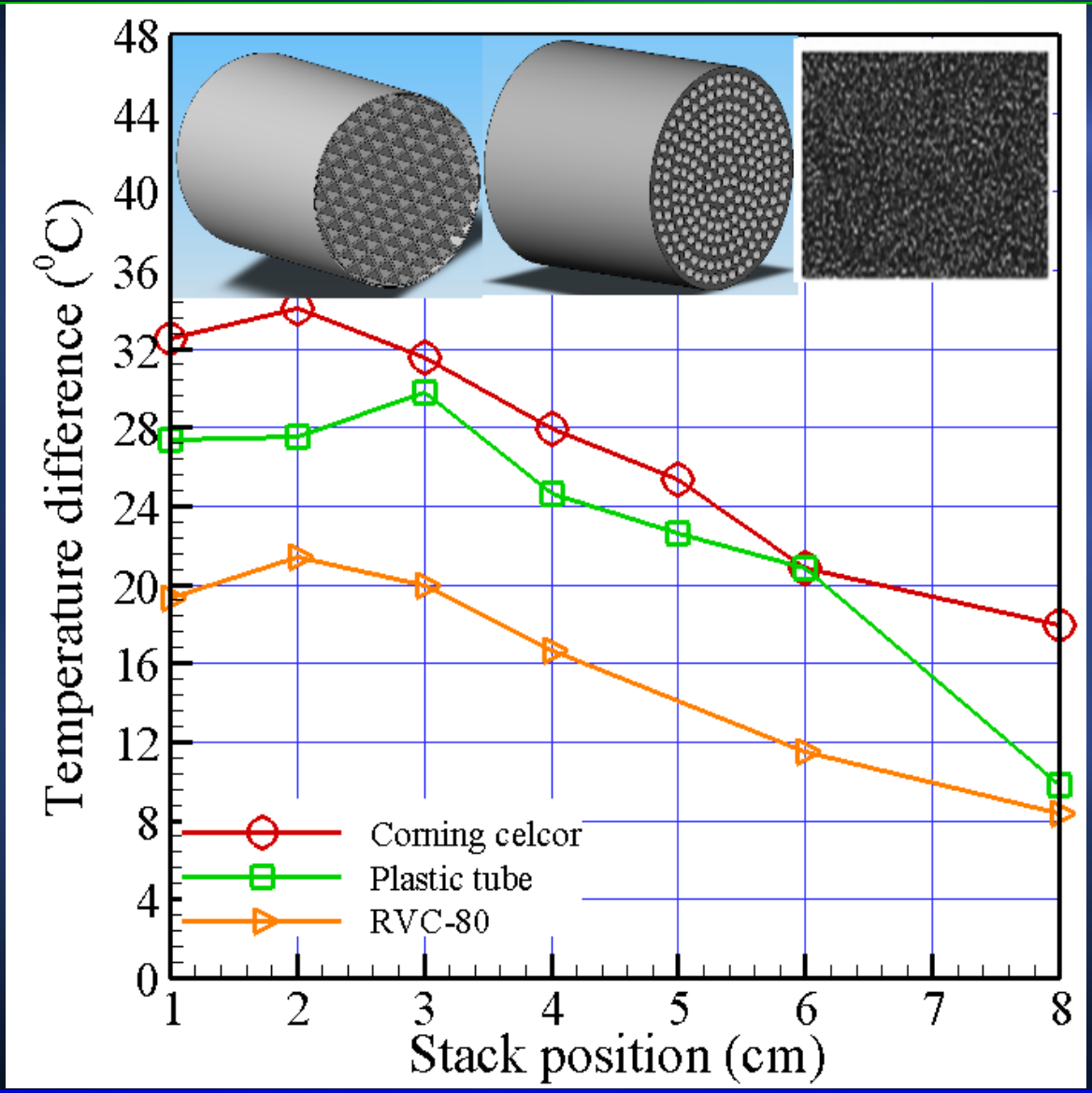
Disadvantage

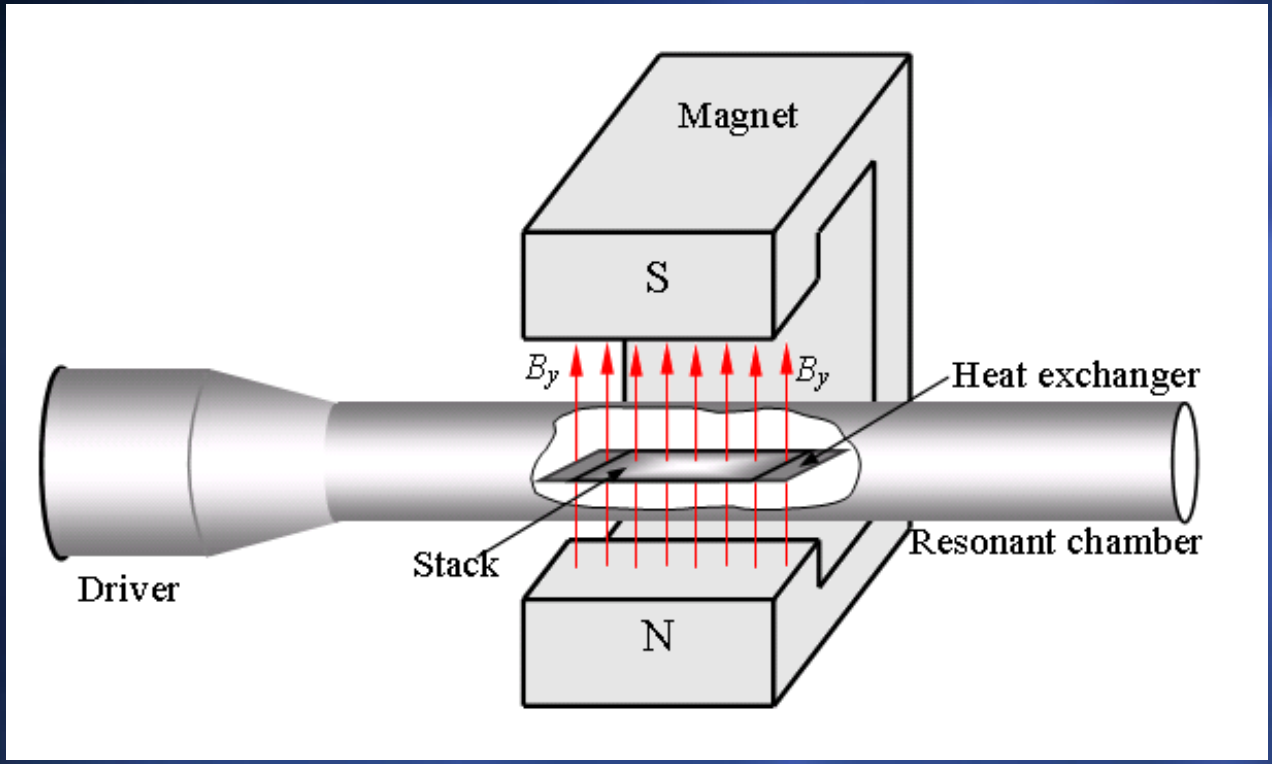
- Low relative efficiency

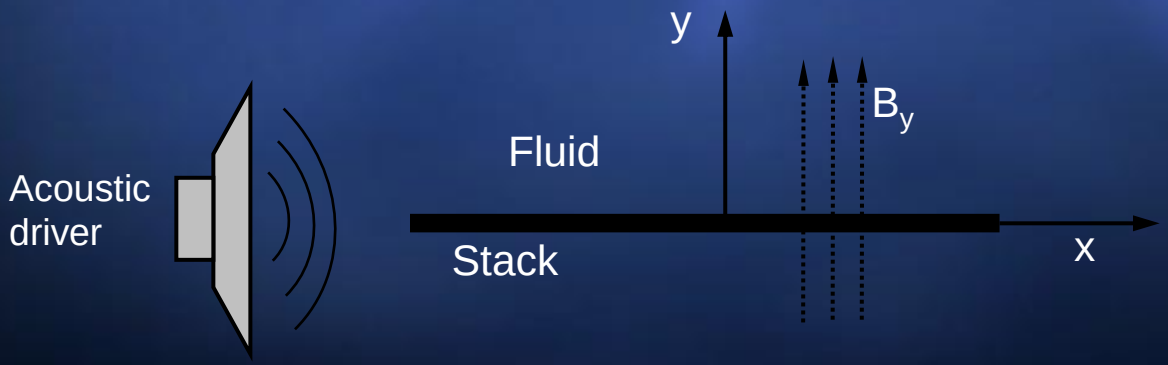
Thermal Performance of a Heat Driven Thermoacoustic Refrigerator



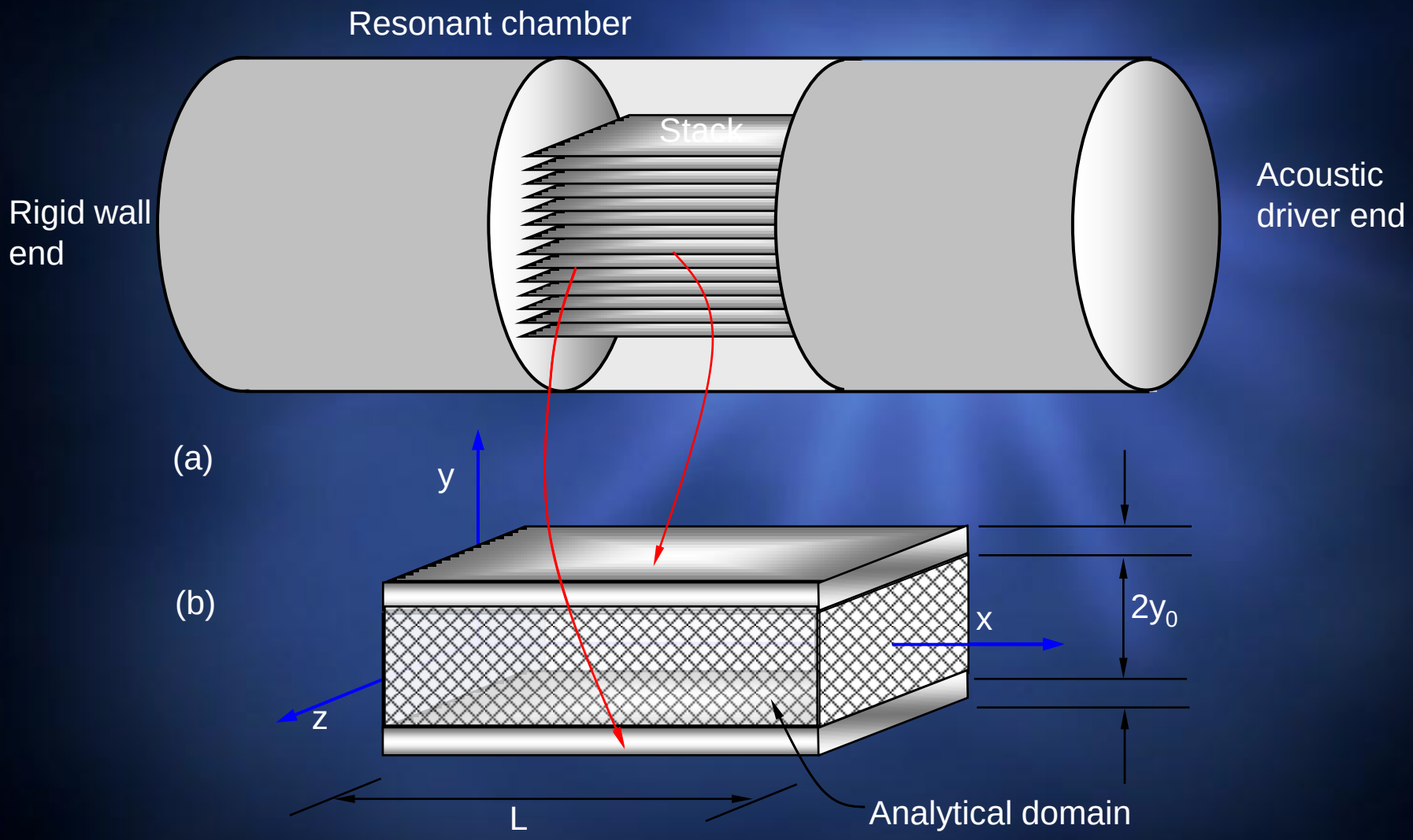
Thermal Performance of an Acoustically Driven TAR Using Different Stack Materials





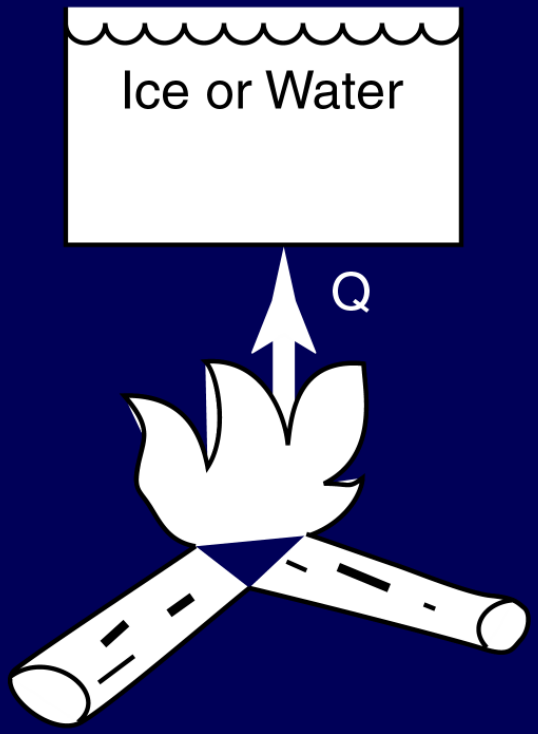


S. Mahmud, R.A. Fraser, Influence of a magnetic field on a single-plate thermoacoustic system, Int. J. Thermal Sci., 45 (2006) 29–40.
S. Mahmud, R.A. Fraser, The thermagoustic irreversibility for a single-plate thermoacoustic system, Int. J. Heat Mass Transfer., 49 (2006) 3448–61.



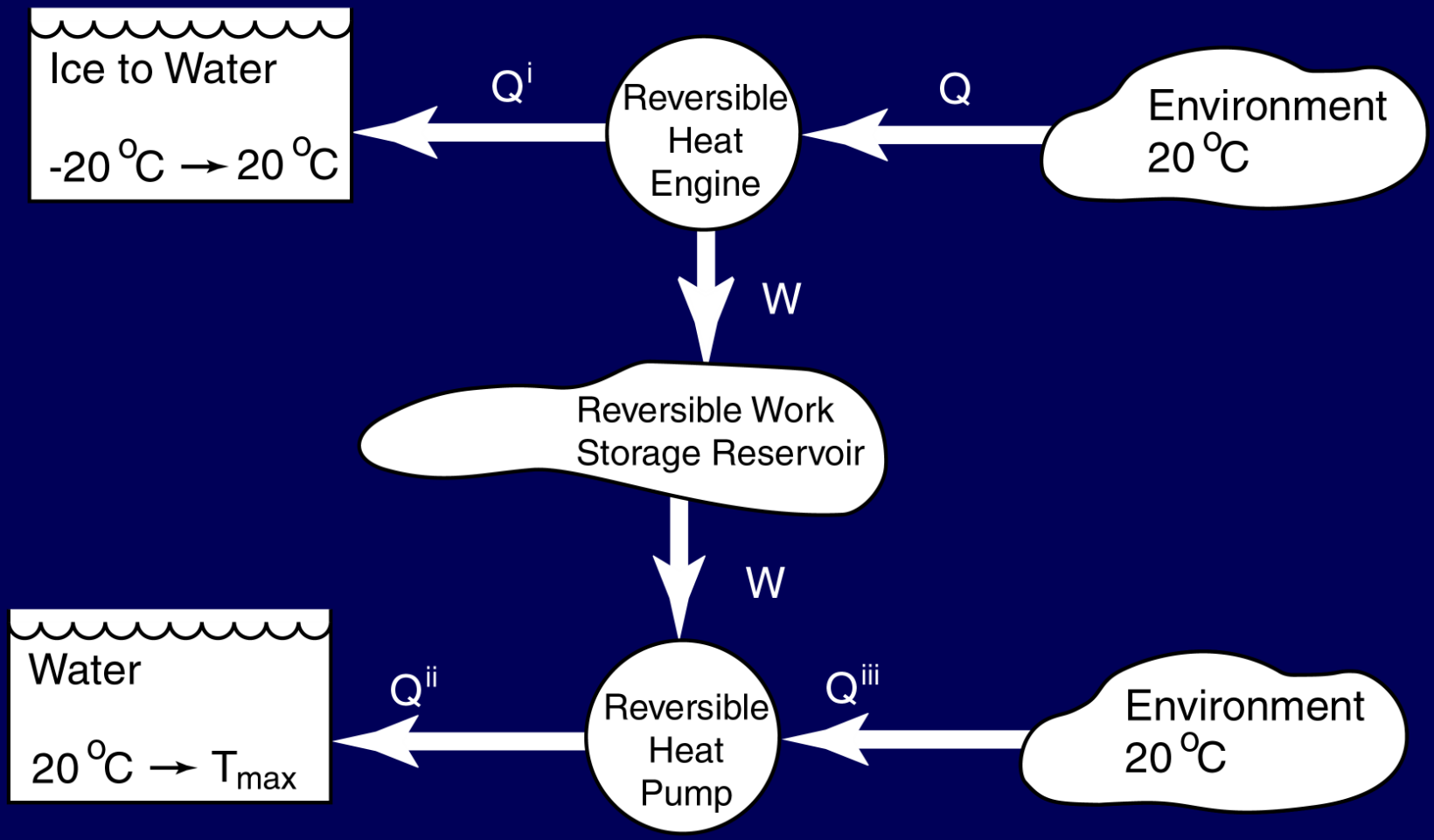
S. Mahmud, R.A. Fraser, Therporoustic convection: modeling and analysis of flow, thermal, and energy fields, ASME J. Heat Transfer, Article in Press, 2009.

Energy, not Exergy, Approach

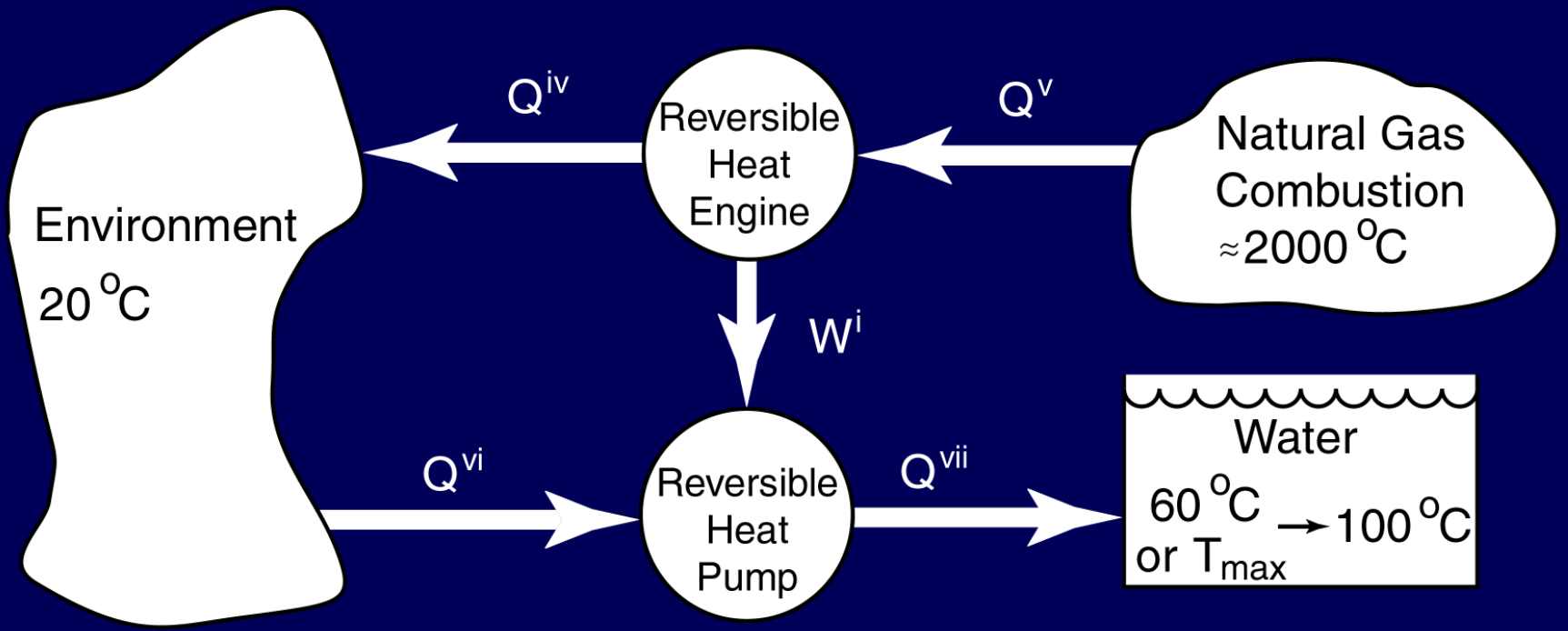


Energy approach requires less Natural Gas to heat 60 ^{o}C water to 100 ^{o}C.

Exergy Approach



Exergy Approach (Continued)



Remember

- It is not about entropy!
- Do not ignore the environment.
- Exergy destruction necessitates that one deals with the environment.

Learning From Each Other

- Story of an Engineer and Ecologist (and Economist?) discovering new science and understanding.

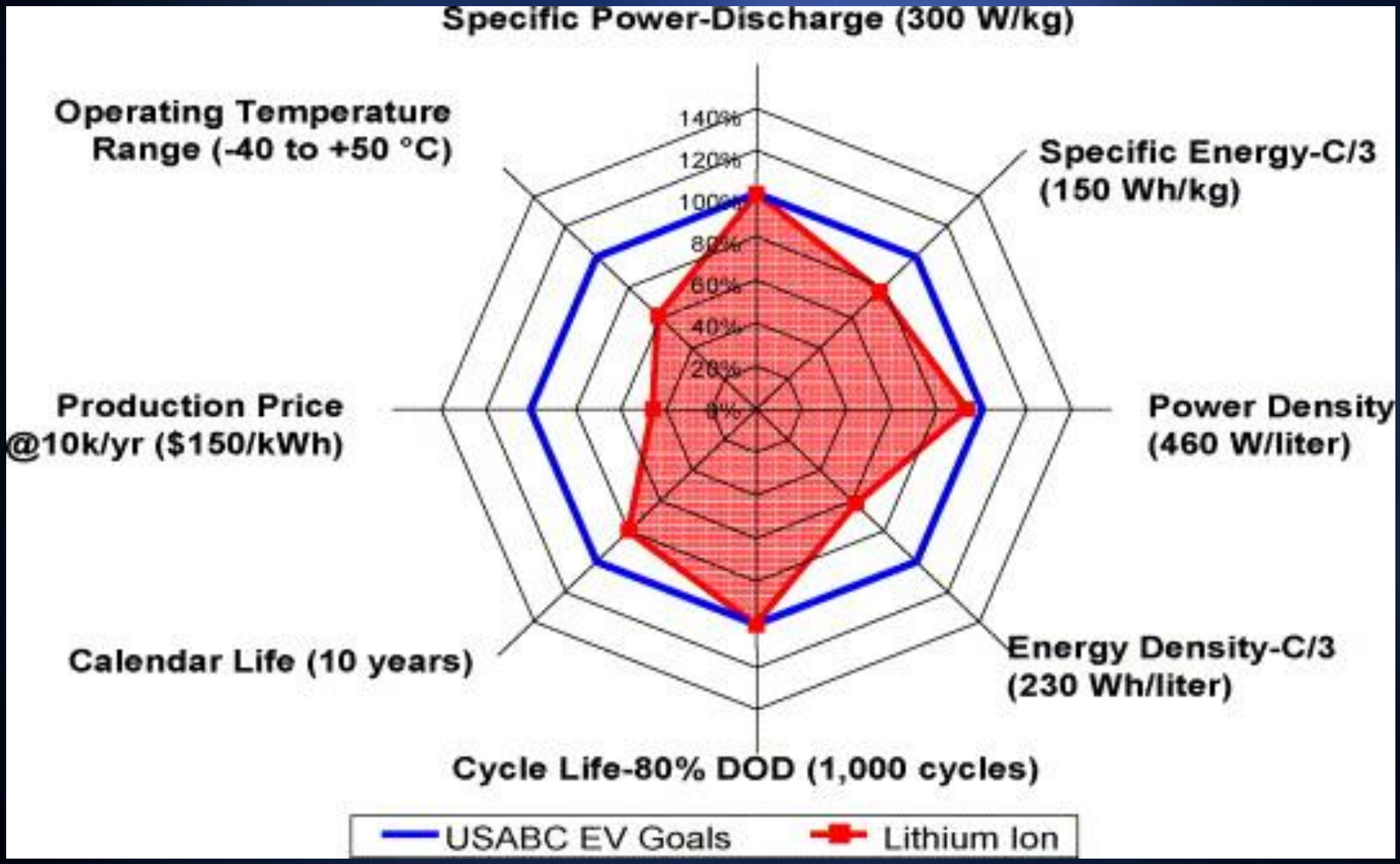
  - The Engineer discovering ecological concepts with new and exciting engineering applications.
  - The Ecologist discovering engineering clarity to 2nd Law concepts applied to living systems.

Conclusions

- Until Ecology and Economics includes the Second Law of thermodynamics, complex system models are just wishful thinking.

A BLACK BOX Principle

Progress – Battery Technology



Barriers – Recharge Time, Cost, Durability, Range

	Mechanical	Electrical	Controls
	Life Cycle 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
	Finalized Component Selection and Acquisition		
Y1 Competition	Vehicle Modification	Vehicle Harness / System Design	HIL finalization setup
	Component Integration	Vehicle Harness setup	HIL– Safety and Fault mitigation Implementation
	Controls Integration and vehicle trouble shooting		
Y2 Competition	Aero, Light weighting, Ride and Handling and NVH	Refinement and Optimization	Refinement and Optimization
	99% Buyoff – Vehicle Ready for Production		
Y3 Competition			

June 2008 — June 2009 — June 2010 — June 2011

*Jehlik, 2008

ChallengeX

2004 Year 1 : rapid protyping of green technology using advanced software simulations

2005 Year 2 : implementation of design into 2005 Equinox

2006 Year 3 : optimization of design meeting original stock performance

2007 Year 4: Competition Finale


CLEARANCE 15'0"