Poster Presentations

The poster numbers below correspond with the numbers on each easel.

Electrical and Computer Engineering

1 CIGS Nanoparticles Based Solar Cell Through Layer-by-Layer (LbL) Nanoassembly Process
Presenters: *Azadeh Hemati, Jason Cambridge, & Sudhir Shrestha*

6 Sensor & Ubiquitous Networking – Part 1
Presenter: *Dongsoo (Stephen) Kim*

7 Sensor & Ubiquitous Networking – Part 2
Presenter: *Dongsoo (Stephen) Kim*

8 An Improved Elliptic Curve Scalar Multiplication over GF (2^n)
Presenters: *Brian King & Ishita Verma*

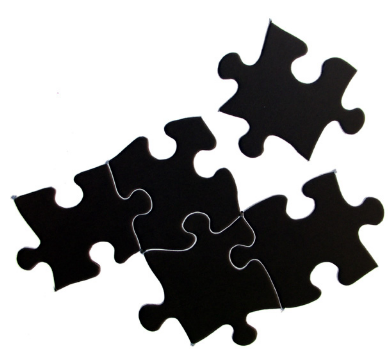
16 Transportation Active Safety Institute
Presenter: *Sarah Koskie*

17 Biometrics for Homeland Security
Presenters: *Mike Beale, Matt Blair, Eliza Du, Jacob Norby, Kai Yang, & Zhi Zhou*

Construction Engineering Management Technology

3 CoIndy Research Program – Bush Stadium Park
Presenter: *Ryan Fitzpatrick*

4 Stormwater Quality Unit Treatment Solutions – The Bush Stadium project case study
Presenter: *Modibo Traore*



Poster Presentations

The poster numbers below correspond with the numbers on each easel.

Mechanical Engineering

2 Advanced Virtual Manufacturing Lab
Presenters: *Daniel Aw & Hazim El-Mounayri*

10 Research at the Richard G. Lugar Center for Renewable Energy
Presenter: *Kyle Cline*

11 Plug-in Hybrid Electric Vehicle
Presenter: *Harpreetsingh Banvait*

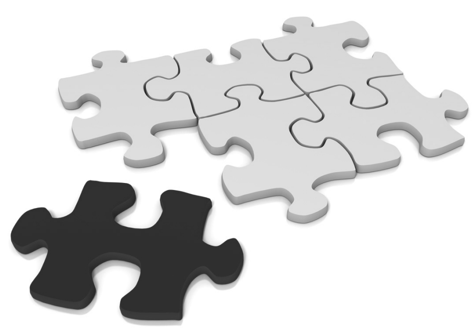
13 Computational Mechanics/Flexible Multibody Dynamics Research
Presenters: *Mohammad Shams, Lee Stark, & Cagkan Yildiz*

14 Re-ignition by Hot Jets for Wave Rotor Combustors
Presenters: *Indika Perera & Sameera Wijeyakulasuriya*

15 Wave-Rotor Constant-Volume Combustor
Presenters: *Tarek Elharis & Sameera Wijeyakulasuriya*

Mechanical Engineering Technology

12 Determine Valve C_V
Presenter: *Bob Durkin*



Motorsports Engineering

9 Don Schumacher Racing
Presenters: *Kirk Barber & Paul Lucas*

Technology

5 The Woodrow Wilson Indiana Teaching Fellowship
Presenter: *Charlie Feldhaus*

INDI INTEGRATED NANOSYSTEMS DEVELOPMENT INSTITUTE
IUPUI
Indiana University – Purdue University Indianapolis

CIGS Nanoparticles Based Solar Cell Through Layer-by-Layer (LbL) Nanoassembly Process

Azadeh Hemati, Jason Cambridge, Joshua Keith, Mangilal Agarwal, Sudhir Shrestha, and Kody Varahramyan

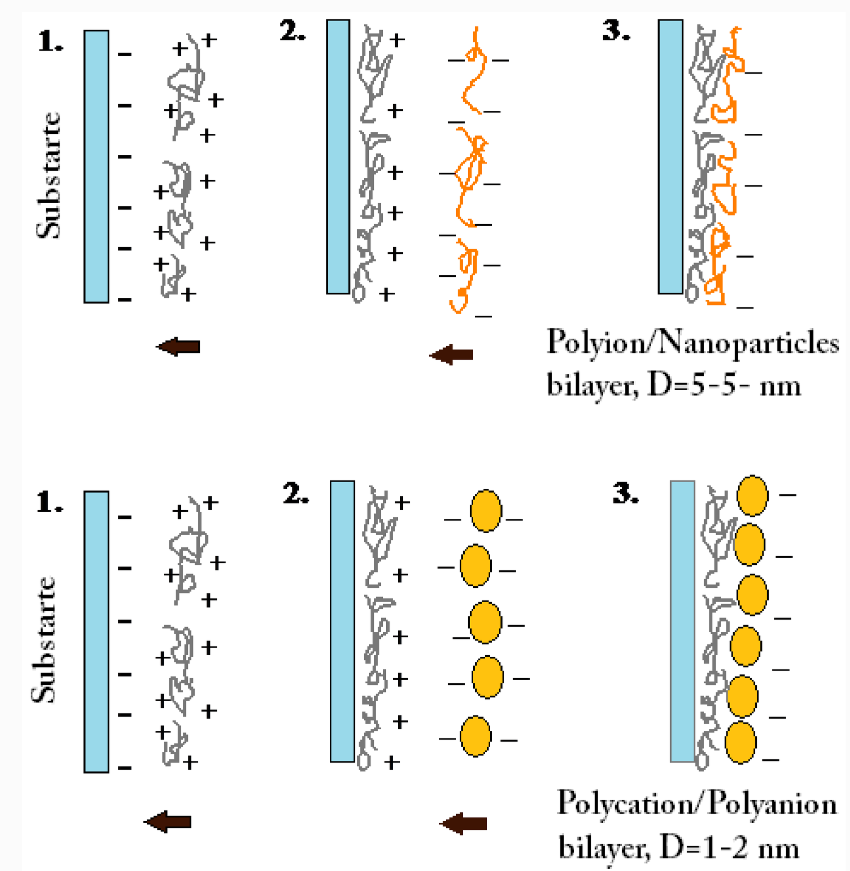
Thin Film Solar Cells

- **165,000 terawatts** of energy fall on earth everyday from the **sun**
- To fulfill our energy needs we need only a fraction of it
- Thin film solar cells using **CIGS and LbL nanoassembly** provides: **Flexibility**, **higher efficiency**, and l**ower cost**

Layer-by-Layer Nanoassembley

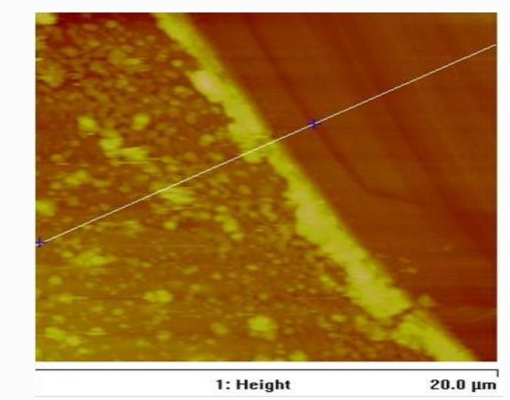
- LbL uses electrostatic attraction of oppositely charged polymers/ particles to form thin multilayer films
- It is an inexpensive, versatile and readily scalable thin film deposition technique

LbL Deposition Process

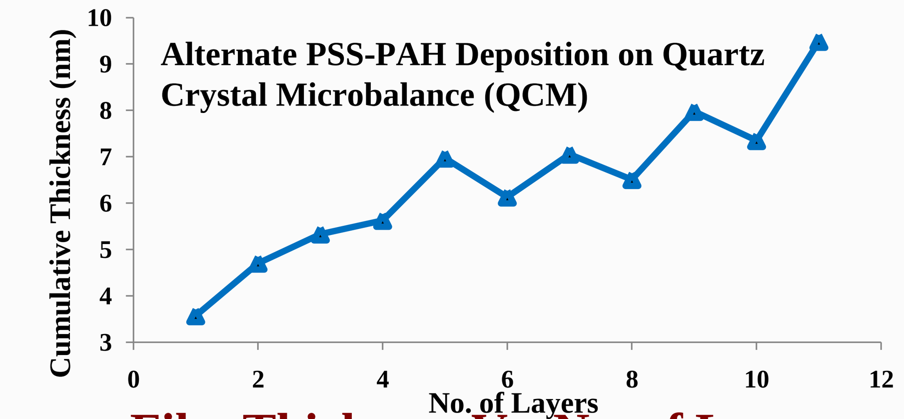


Layer-by-Layer Deposition

LbL on a Quartz Crystal Microbalance (QCM)

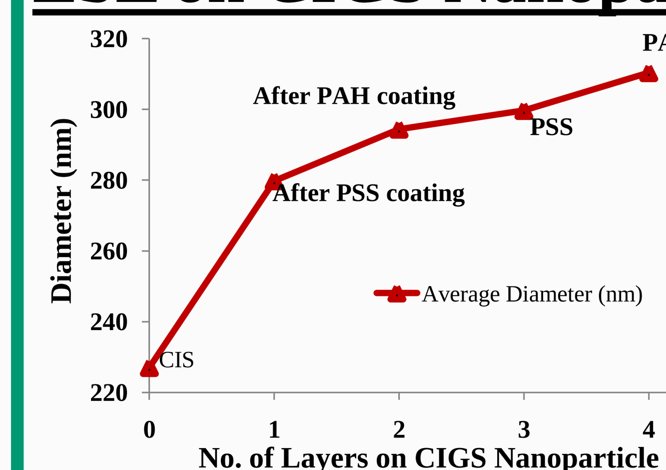


AFM Image of a LbL Film

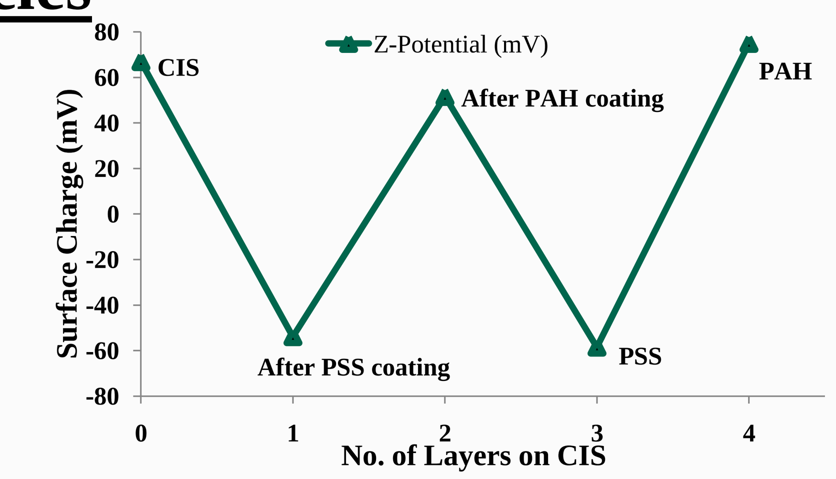


Film Thickness Vs. No. of Layers

LbL on CIGS Nanoparticles



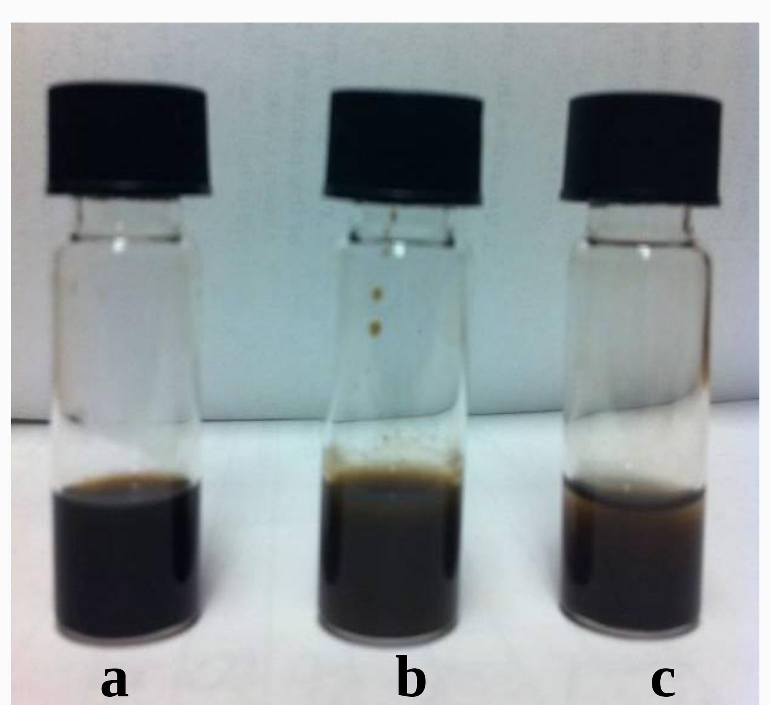
Particle Size Vs. No. of Layers



Surface Charge Change with Coating

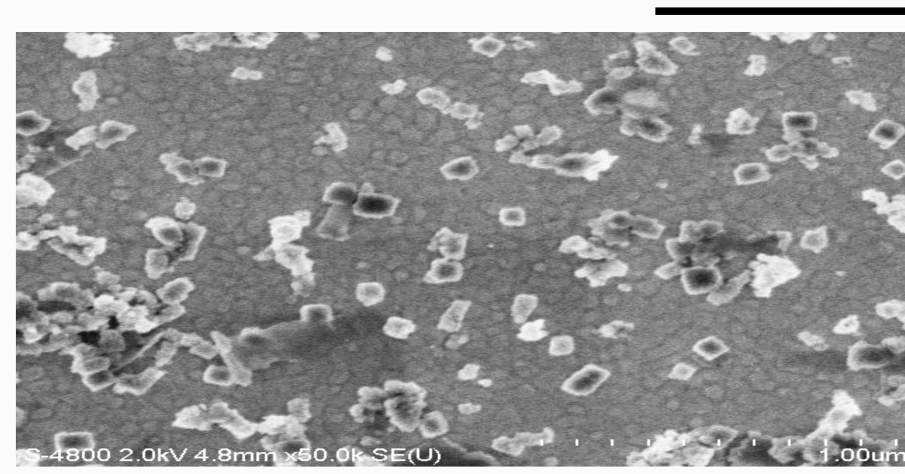
CIGS Nanoparticles

- Copper Indium Gallium Selenium (CIGS) have tunable wide band gap best suited for photovoltaic applications
- CIGS nanoparticles were synthesized from metal-chlorides and purified by centrifugation and precipitation process in INDI labs

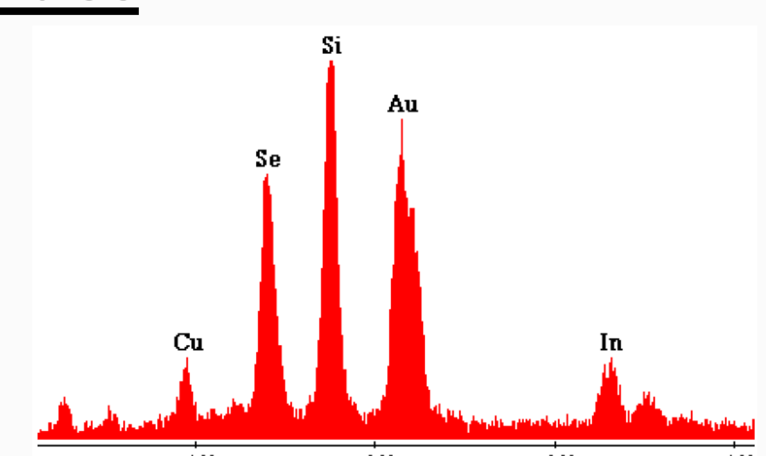


CIGS Nanoparticles Dispersed in (a) Chloroform (b) Water and (d) Acetone

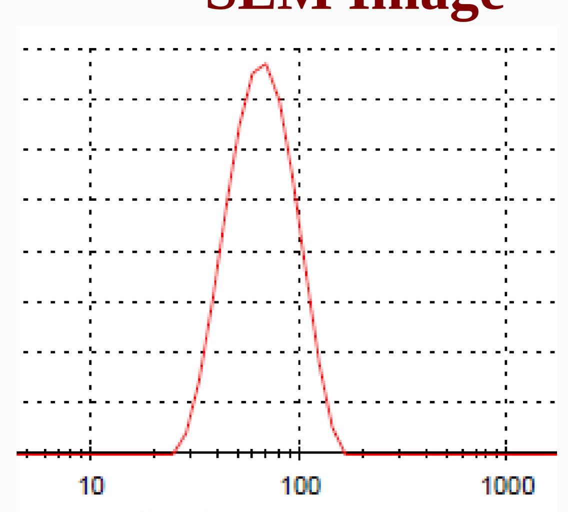
Characterization of CIGS Nanoparticles Synthesized in INDI Labs



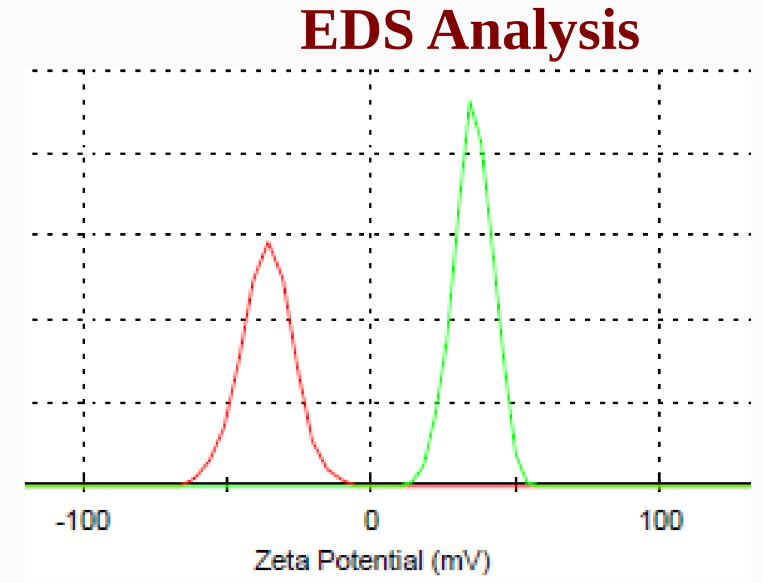
SEM Image



EDS Analysis



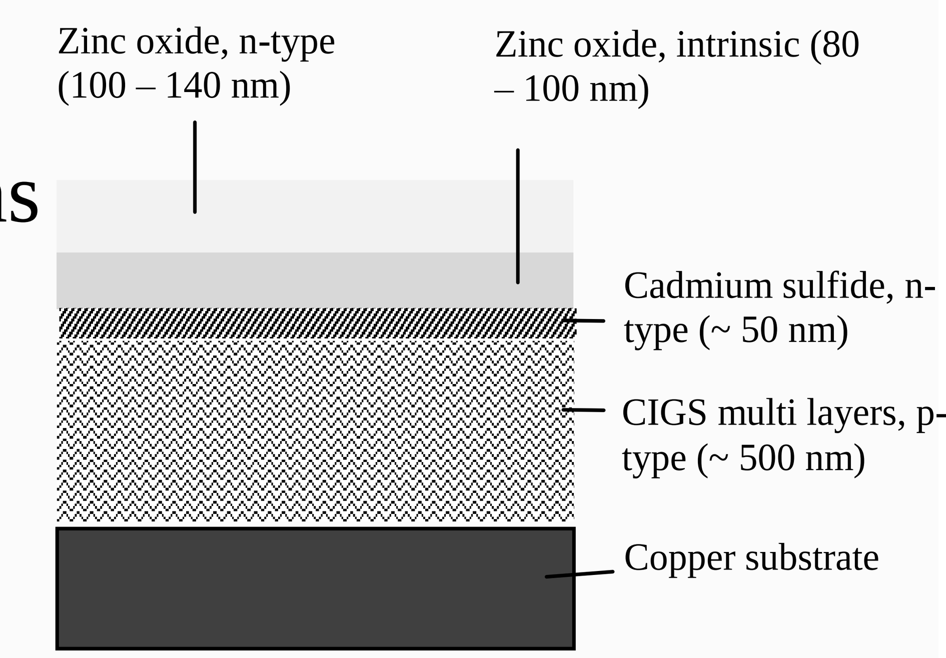
Size Distribution



Surface Charge in NaOH (-ve) and Water (+ve)

CIGS Solar Cell Through LbL Process

- The solar cell device is fabricated through LbL process using CIGS nanoparticles
- The incoming photon creates electron-hole pair in CIGS layer generating photocurrent
- LbL CIGS nanoparticles films have higher light absorption, thus higher efficiency



Schematic of LbL CIGS Solar Cell Device

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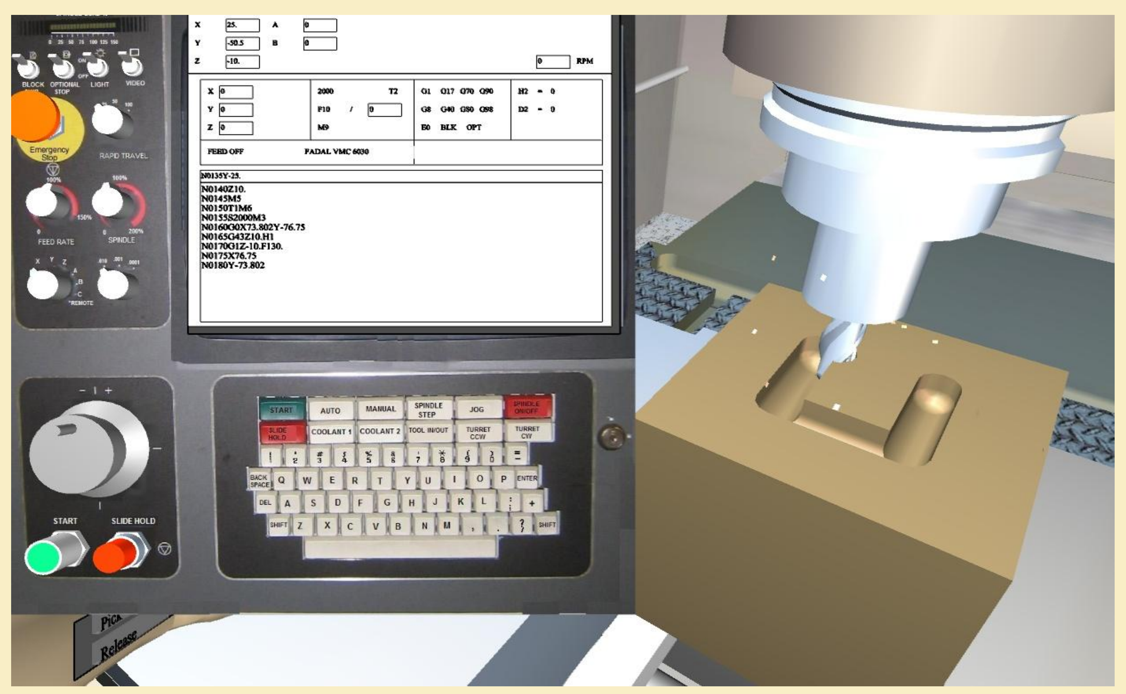
Advanced Virtual Manufacturing Lab

H. El-Mounayri, T. Wasfy, and D. Aw (IUPUI)

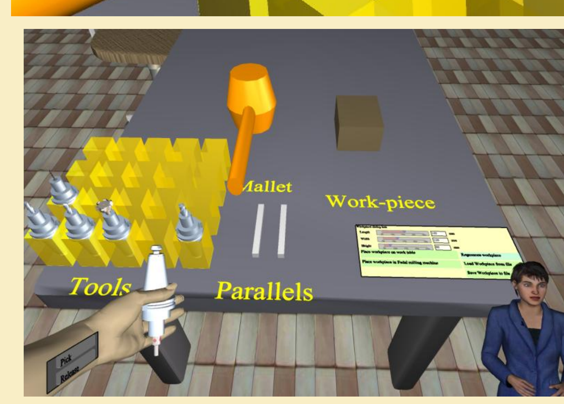
The AVML (Advanced Virtual Manufacturing Lab) is a state-of-the-art web-based technology for learning, training and research in Advanced manufacturing. It is an effective, realistic, and comprehensive tool for training tomorrow's workforce in Advanced manufacturing.

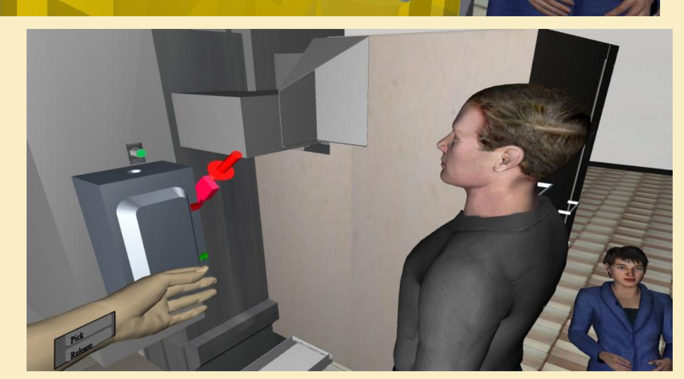
Technology training capabilities:

Hands-on use of fully functional CNC milling and turning machines

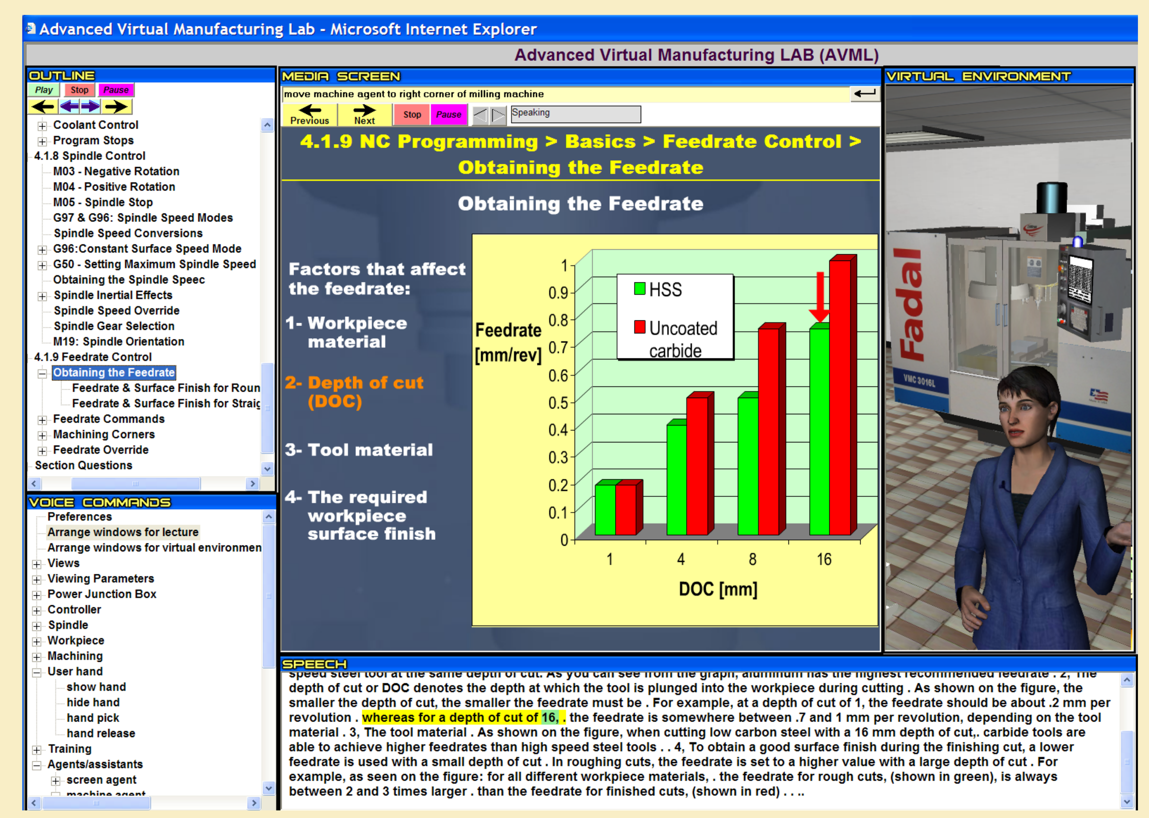


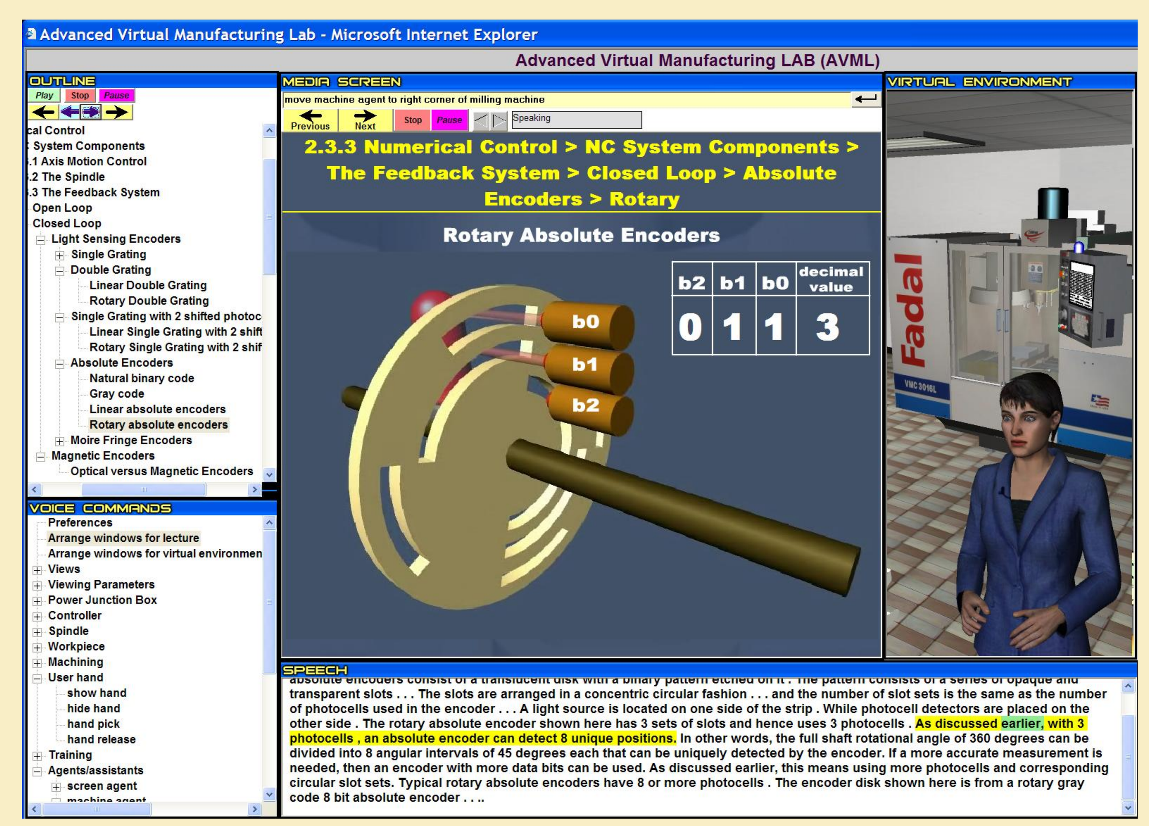
Step-by-step process training with the help of animated instructors.





Multimedia lecture delivery with text-to-speech &synchronized animated illustrations.





Technology featured in:

Indiana Business Magazine

Inside Indiana Business TV program

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COINDY RESEARCH PROGRAM
BUSH STADIUM PARK

Ryan Fitzpatrick | Crossroads of Indianapolis, Director
Modibo Traore | Construction Engineering Management Technology

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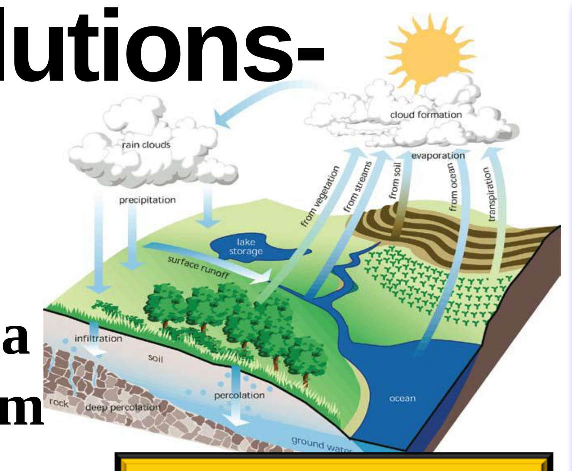
TAKE ACTION!!! GET INVOLVED!!!

NRDC NATURAL RESOURCES DEFENSE COUNCIL THE EARTH'S BEST DEFENSE

"Polluted stormwater is the result of local land-use policies and our everyday personal actions!"

Stormwater Quality Unit Treatment Solutions- The Bush Stadium project case study

Modibo B. Traore
Department of Engineering Technology, IUPUI, Indianapolis, Indiana
Construction Engineering Management Technology (CEMT) Program



The Water Cycle (FISRWG, 1998)

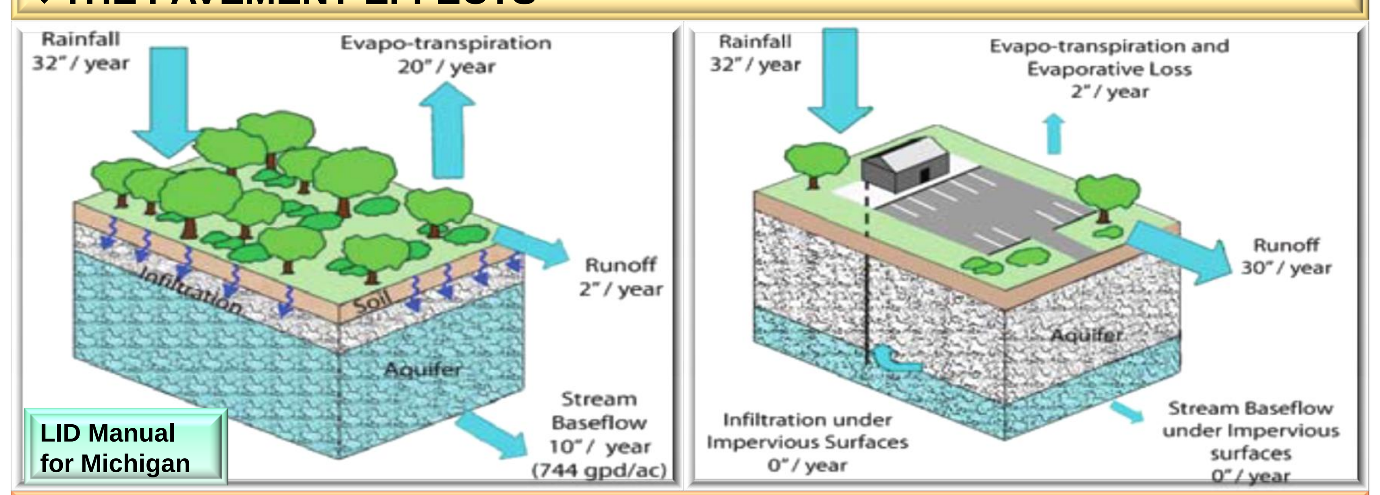
INTRODUCTION

Stormwater runoff pollution, the dirty, untreated water resulting when rain or snow melt picks up pollutants en route to area streams, rivers or lakes, has been cited as the greatest threat to water quality.
According to the US Environmental Protection Agency (EPA), 90 % of the "first flush", the delivery of a disproportionately large load of a pollutant is typically carried by the first 1-1/2 in. of rainfall through traditional horizontal runoff into rivers and streams (EPA, 1999).
The EPA's Municipal Separate Storm Water Sewer System (MS4s) Program policies set a benchmark for municipalities and government agencies, to develop and implement stormwater Best Management Practices (BMPs) for stormwater treatment systems to reduce the discharge of various "first flush", thereby protecting water quality.

WHERE DOES STORMWATER COME FROM AND WHERE DOES IT GO?

"Stormdrains lead the "first flush" of the Pollutants directly to local waters. No filters. No treatment."

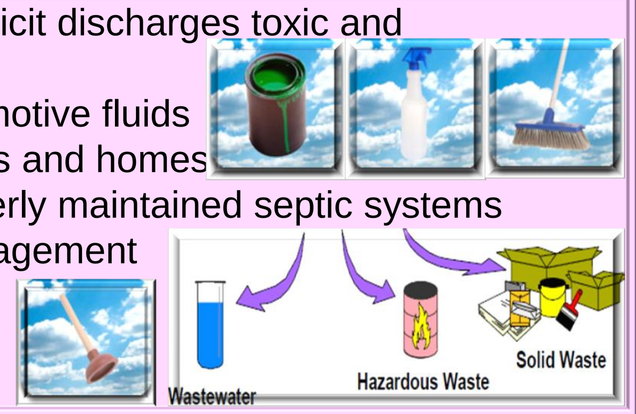
❖THE PAVEMENT EFFECTS



WHY IS STORMWATER A PROBLEM?

❖**"First flush"** picks up and mixes with illicit discharges toxic and hazardous materials including:

- oil, grease, paint, solvent, and automotive fluids
- fertilizer and pesticides from gardens and homes
- bacteria from pet waste and improperly maintained septic systems
- soil from poor construction site management
- sand from wintertime snow removal
- soap from car washing
- debris and litter



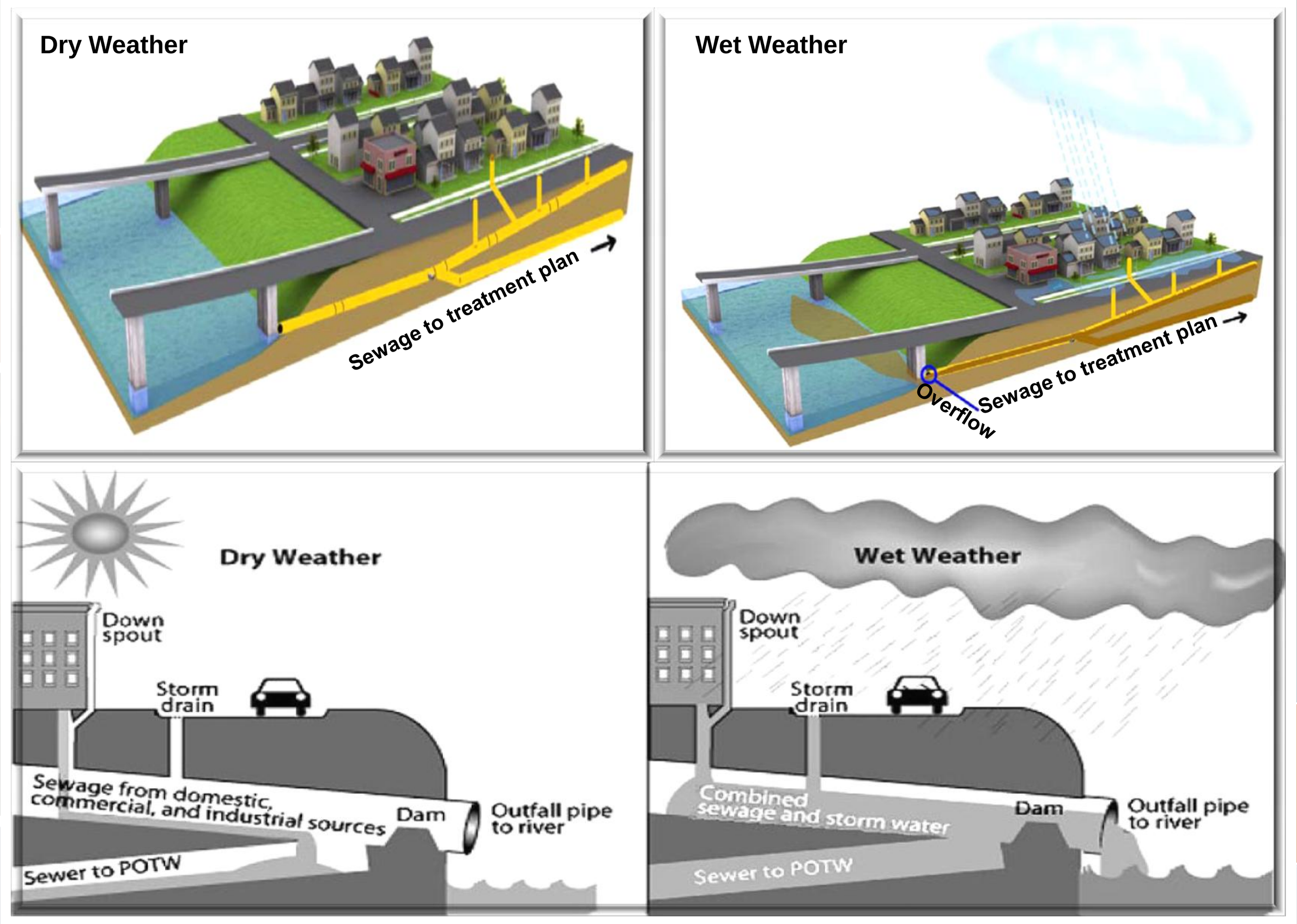
"The polluted runoff closes swimming beaches and fishing grounds, threatens water resources, harms natural areas, and generates flooding."

❖STORMWATER BARRIERS TO OVERCOME:

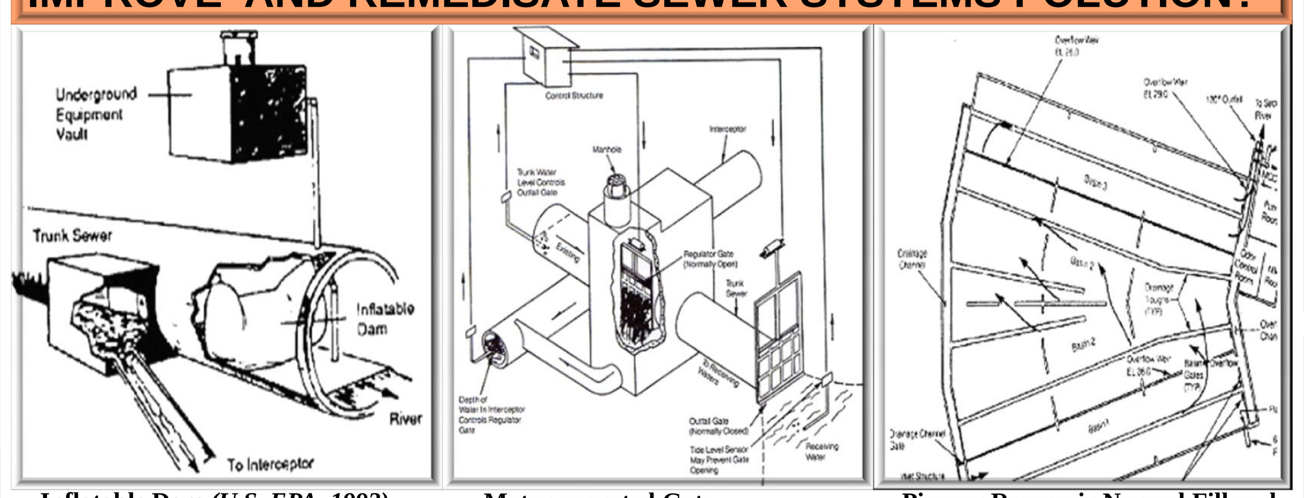
1. Limited land and site-specific challenges
2. Time is money
3. Barriers in codes and resources
4. Lack of government staff capacity and resources
5. Maintenance
6. Resistance to change

THE ISSUE OF COMBINED SEWER OVERFLOWS

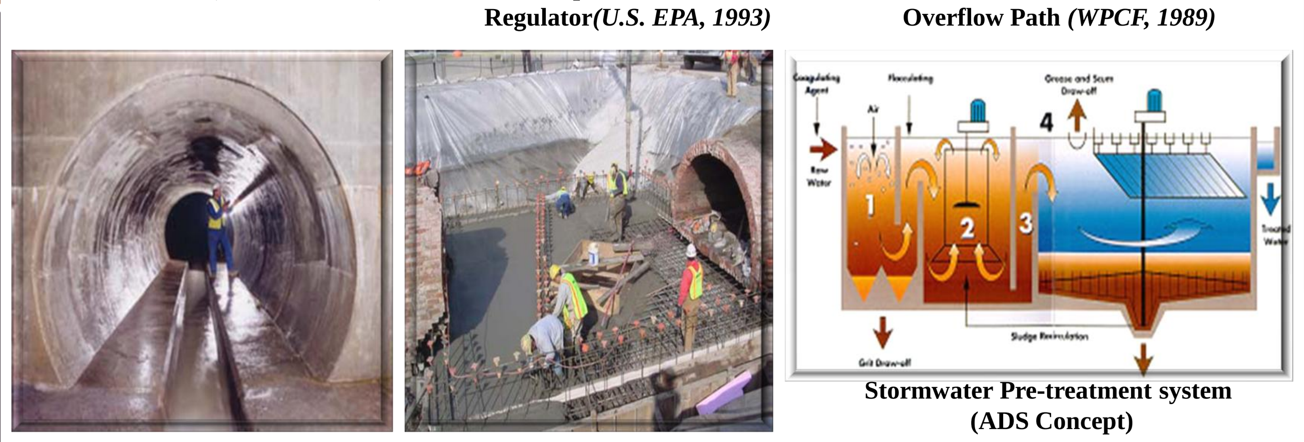
The combined sewers are systems where the storm drain and sanitary sewers have a connection. As the graphic below illustrates, in dry weather, both the stormwater and the sanitary waste go to a treatment facility. With small storms, the system has enough capacity to treat both the wastewater flow and the additional stormwater. But in larger storms, the pipe overflows, resulting in discharge of mixed stormwater and untreated sewage directly into rivers and watersheds.



WHICH CSO CONTROL TECHNOLOGIES ARE USED TO IMPROVE AND REMEDISATE SEWER SYSTEMS POLUTION?



Inflatable Dam (U.S. EPA, 1993) — Motor-operated Gate Regulator (U.S. EPA, 1993) — Pioneer Reservoir Normal Fill and Overflow Path (WPCF, 1989)



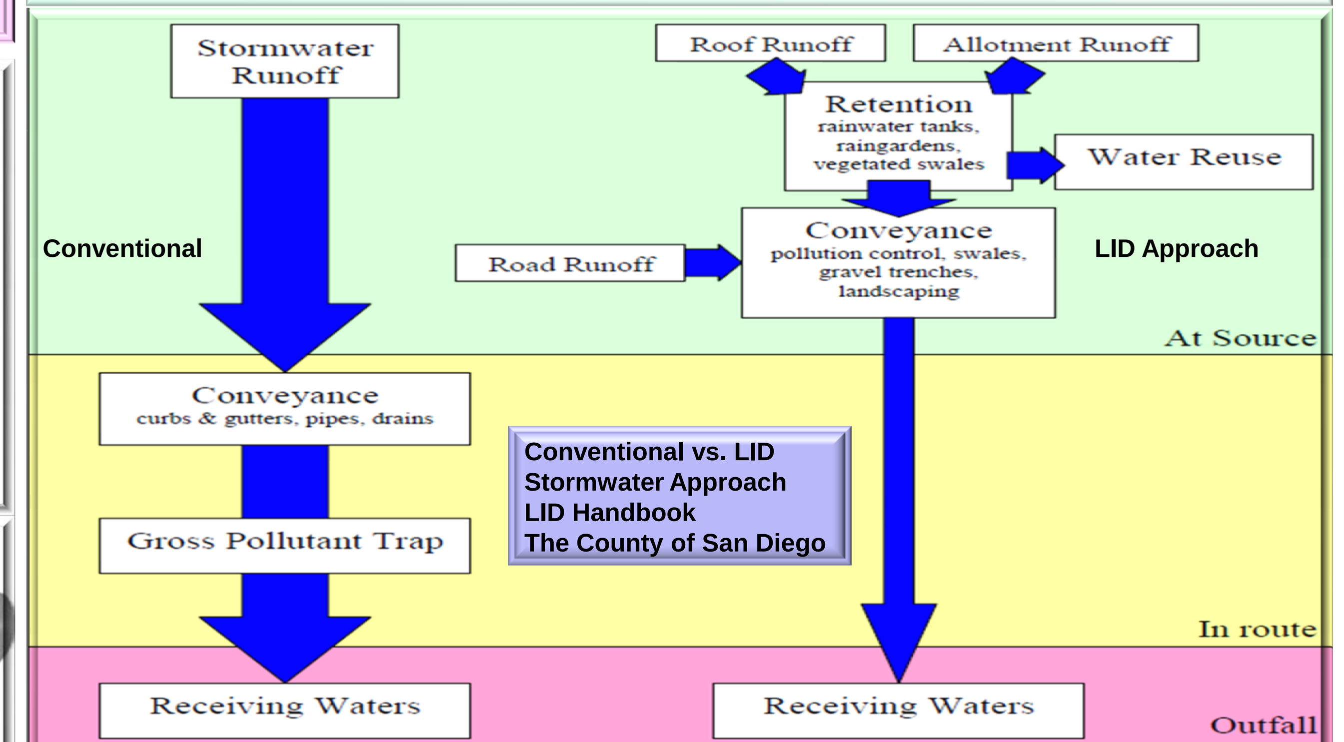
Storage and Remote Treatment- Deep Tunnel Option — Crews working on a sewage overflow reduction project along Michigan Street, near Pogues Run, Indy — Stormwater Pre-treatment system (ADS Concept); Wet-Weather Treatment Technologies Enhanced High Rate Clarification (EHRC) System (IDI, 1999)

THE EPA'S FEDERAL STORMWATER REGULATION

❖**The EPA developed BMP's "PHASE II" Program as stormwater asset management guidelines.** As a result, the EPA fixed the target Total Suspension Solids (TSS) removal rate benchmark to 80% on an average annual basis. Permit holders have to employ BMP's rules to reduce polluted stormwater, and municipalities whose population exceeds 50,000 must use BMPs policy to manage their own stormwater discharges.

THE LOW IMPACT DEVELOPMENT (LID)

A subset of BMP is LID or environment sensitive design (ESD)
The goal is to emulate the stormwater function that had in its natural state, before it was touched by human. LID techniques can include green roofs, cisterns, rain gardens, permeable pavements, and swales. The benefit of using a LID system is that pollutants can be stopped, monitored, controlled and treated before reaching area streams, rivers, lakes or drainage.



WHAT ACTION TO TAKE AROUND BUSINESSES AND HOMES?

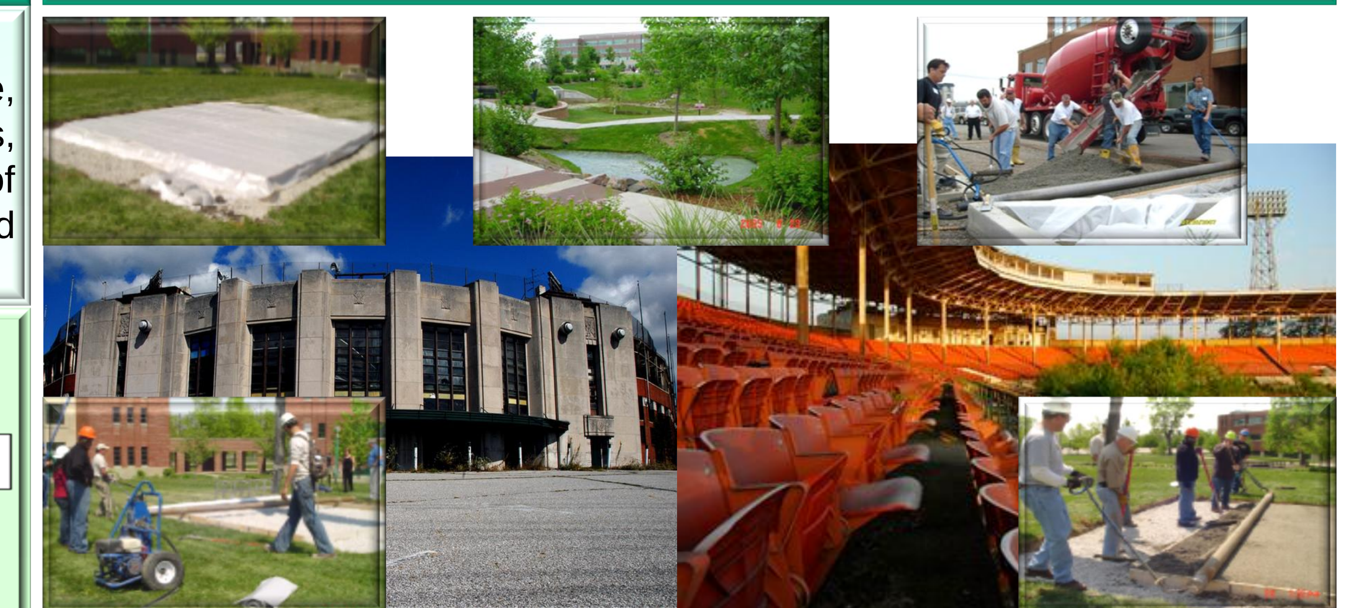
IMPLEMENT LID IMPACT, DEVELOP STORMWATER GREEN SOLUTIONS AWARENESS, AND HELPS CONSERVE WATER!

GET INVOLVED! TAKE ACTION!
REVIVE THE WORLD'S OCEANS; STEM THE TIDE OF TOXIC CHEMICALS & SAVE ENDANGERED WILDLIFE AND WILD PLACES

CITIES, DEVELOPERS, AND OWNERS MUST DEVELOP STRATEGIES TO REDUCE RUNOFF POLLUTION INCLUDING:

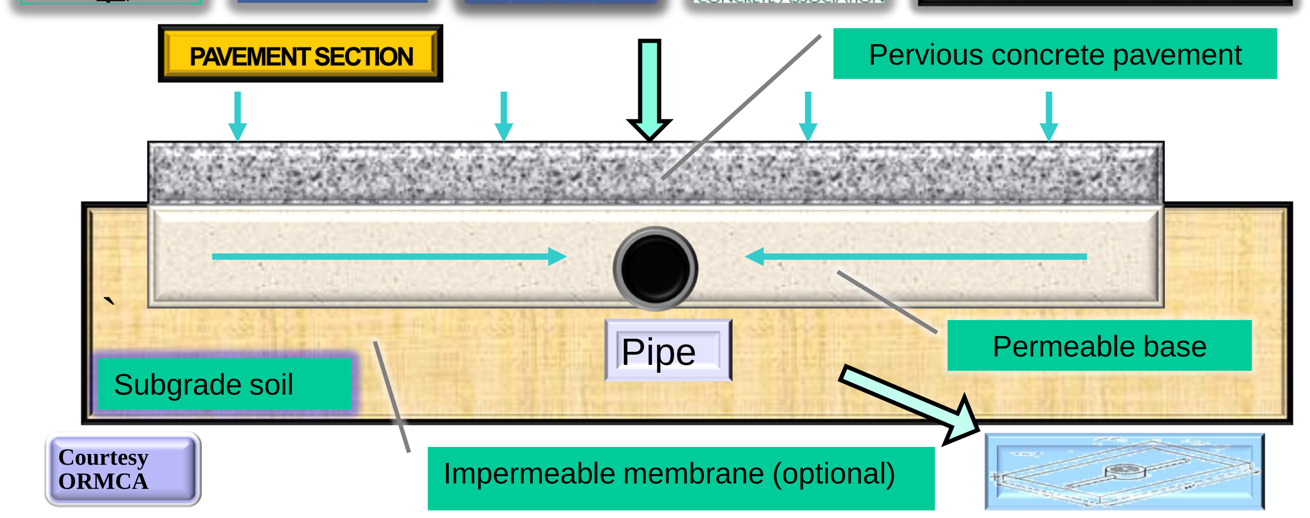
Preserving undeveloped land & wetlands, educating the public to raise awareness on stormwater pollution, initiating outreach methods and goals, controlling construction site runoff, detecting and eliminating improper connections and discharges, establishing special maintenance routines and procedures for municipal parks, roads, and watershed, adopting ordinances, and implementing community responses to Runoff pollution.

COINDY-BUSH STADIUM PROJECT CASE STUDY



❖ **PAVEMENT MUST HAVE FREE DRAINING SUBBASE AND SHOULD BE PLACED LAST IN A PROJECT IN A CLEAN AREA!**

HOW DOES PERVIOUS CONCRETE WORK?



❖The replacement of the existing impervious asphalt pavement by pervious concrete can have a great impact.

❖**Pervious concrete application can:**
✓**Reduce stormwater rain off and first flush to prevent CSO effect**
✓**Boost the project sustainability aspect**

➢Pervious concrete was first used in 1852, it is receiving renewed interest, partly because of federal clean water legislation & U.S.EPA's BMP policy

➢Pervious pavements function like storm water retention basins and allow the stormwater to infiltrate the soil over a large area, thus facilitating recharge of precious groundwater supplies

➢The high flow rate of water through a pervious concrete pavement allows supporting sustainable construction, providing a solution for construction that is sensitive to environmental concerns, and helping owners comply with EPA stormwater regulations

➢This unique ability of pervious concrete offers advantages to the environment, public agencies, and building owners by controlling rainwater on-site and addressing stormwater runoff issues. This can be of particular interest in urban areas, or where land is very expensive

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The Woodrow Wilson Indiana Teaching Fellowship

Dr. Charlie Feldhaus – Associate Professor of Organizational Leadership

The Woodrow Wilson National Fellowship Foundation has selected IUPUI as one of four universities in Indiana to offer the Woodrow Wilson Indiana Teaching Fellowship. This initiative funded by a $10 million grant from the Lilly Endowment and administered by the Woodrow Wilson Foundation is designed to increase the number of STEM (science, technology, engineering, and mathematics) teachers in high-need Indiana schools.

THE WOODROW WILSON
Indiana Teaching Fellowship

For more information contact:

Dr. Kathy Marrs, Project Director
kmarrs@iupui.edu

or

Dr. Charles Feldhaus
cfeldhau@iupui.edu

Stipends

- Support provided to 80 selected fellows (20 at each university) each year with a stipend of $30,000.
- Offered to either recent college graduates or career changers who possess a degree in science, technology, engineering, and/or mathematics.
- Each Fellow who accepts the $30,000 stipend and completes the program must commit to teach mathematics, science and/or engineering technology education for three years in a high-need Indiana secondary school.

Application Process

The program at IUPUI is designed around the core components of the Transition to Teaching (T2T) curriculum and includes integrated STEM courses that are designed to prepare the Fellows to teach in urban schools. Indiana Teacher Certification will be available in math, science, engineering technology education and/or computer education

Fellows may select one of the three Master of Science degree options :

Master of Science in Secondary Education-Science Education
Master of Science in Mathematics-Math Education
Master of Science in Technology-STEM Education

The on-line application is currently available at:
http://www.wwteachingfellowship.org/about_the_program/indiana.php

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Sensor & Ubiquitous Networking

Contact to D.Kim (dskim@iupui.edu), B.King (briking@iupui.edu), or P.Salama (psalama@iupui.edu)

Remote Reconnaissance

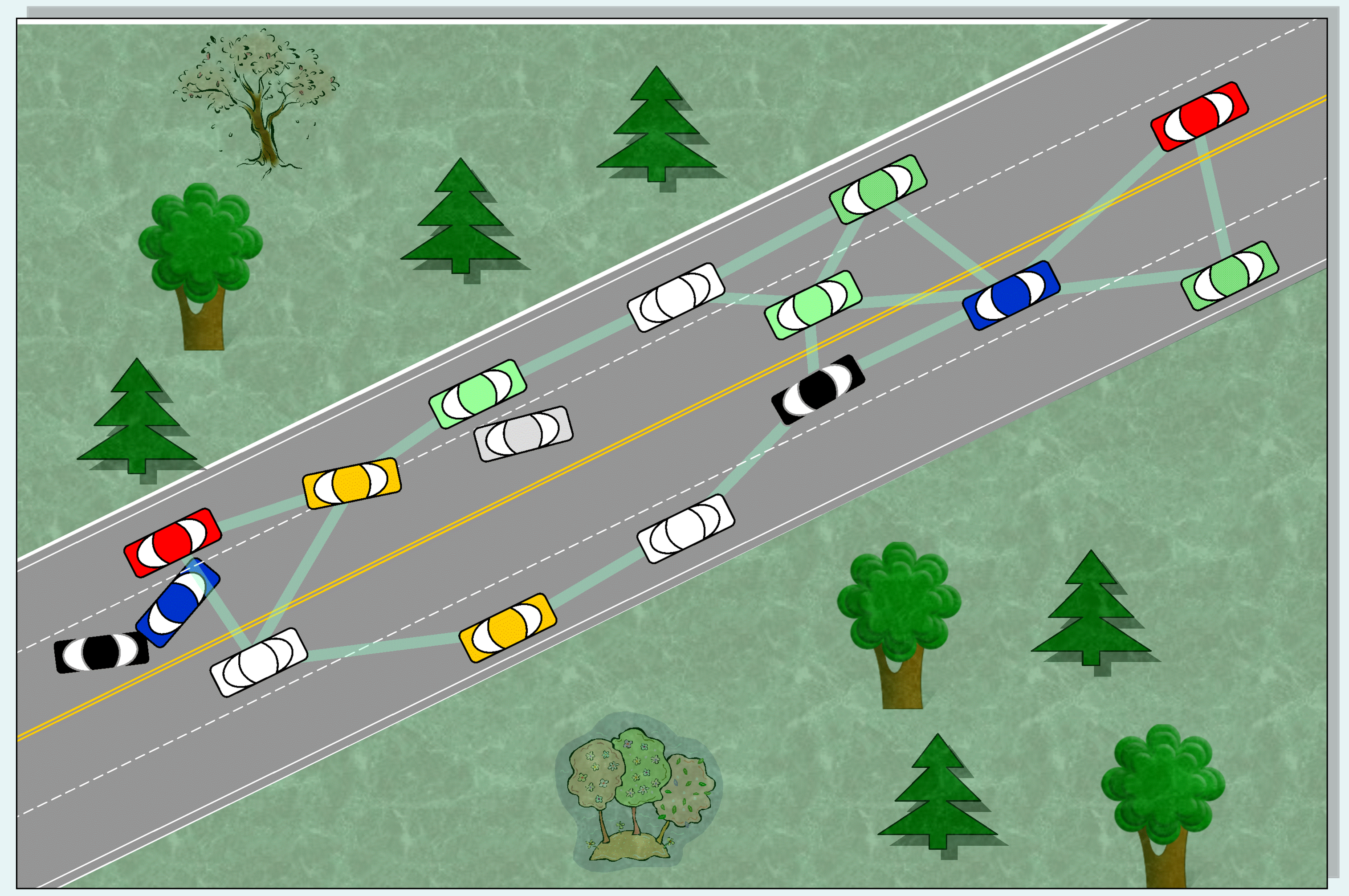
GOALS

- Protect from hazards ahead over obstacles
  - snipers or armored vehicles
  - chemical / bio / nuke contaminations

METHODS

- Sensors form an ad-hoc networks
  - dispersed from airplanes
  - wrapped with plastic rocks, and invisible to enemy
  - RFID-tagged to distinguish friendly army from hostile army

V2V Communication Networks



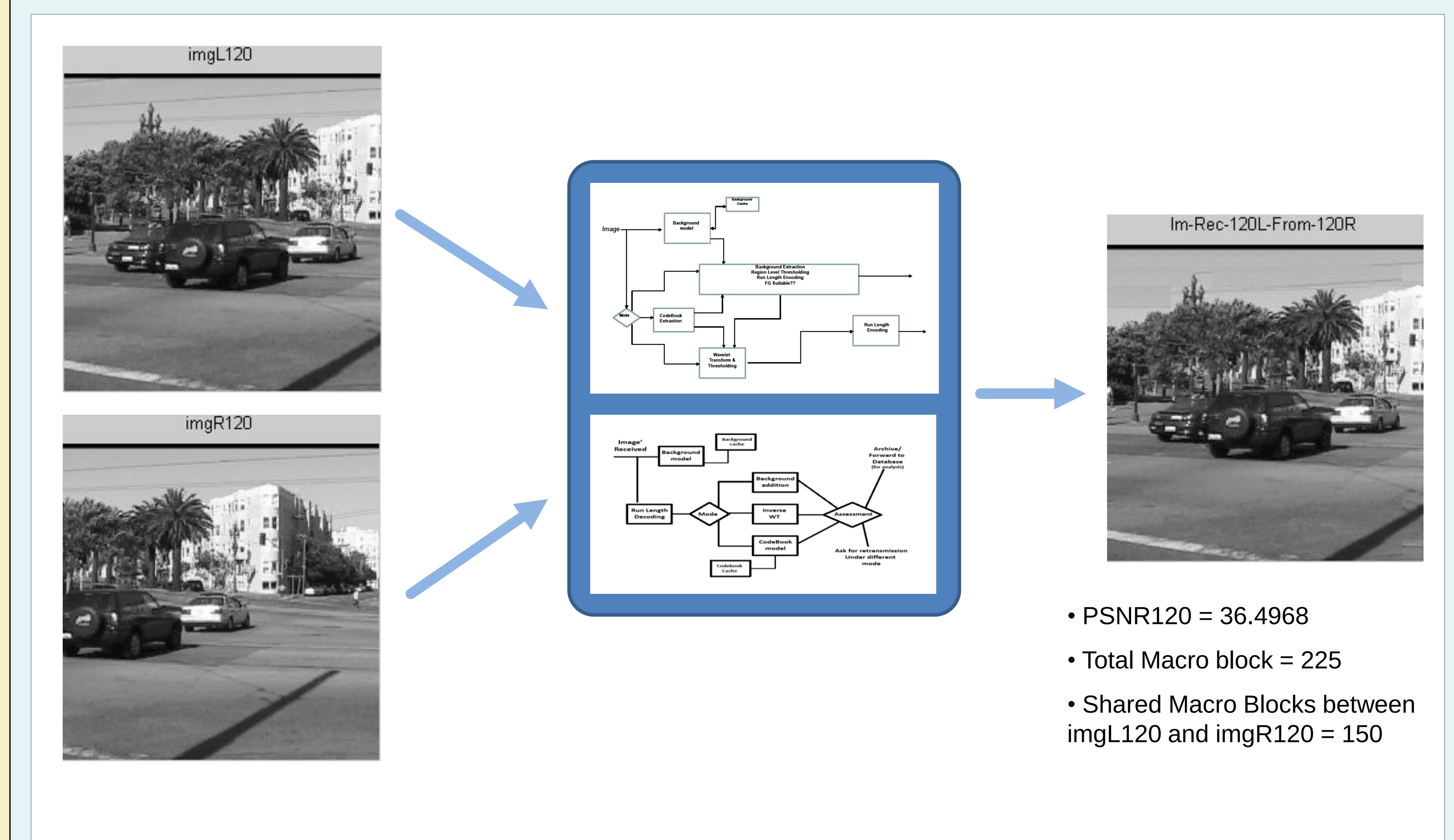
GOALS

- Anticipate a dynamic driving condition ahead to improve safety
  - to recognize blind-spot
  - to collaborate with traffic signals
  - early warnings for a sudden stop on highway
- Optimize traffic flows

MILESTONES

- GM demonstrated for sensing other vehicles a quarter-mile ahead
  - used an existing infra-structure networks (OnStar)
- CarTALK2000
  - cooperative driver assistance systems
  - self-organizing ad-hoc radio network
  - standardized effort from EU, Japan, and DaimlerChrysler,

Image Fusion for Sensor Networks



APPLICATIONS

- Military applications / battle field surveillance
- Habitat / environmental monitoring,
- Industrial process control, etc.

Approach

- Problem:
  - Transmission of data, in particular multimedia content, is the most expensive sensor operation. So in-network processing has to be performed to compress the data; but due to the complexity of predictive encoding, it's infeasible to apply it on resource starved multimedia sensors.
  - To develop a light weight encoding system that shifts the complexity of computing cross correlation between two spatially adjacent nodes to the decoder (base station) in wireless multimedia sensor networks WMSN.
- In Sensor-Processing
  - Sensors perform local in-sensor compression using background subtraction and discrete wavelet transform (DWT) encoding to exploit spatial redundancy
  - History readings of the same sensor node are used to exploit temporal redundancy.

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Sensor & Ubiquitous Networking

Contact to D.Kim (dskim@iupui.edu), B.King (briking@iupui.edu), or P.Salama (psalama@iupui.edu)

PARTICIPATING MEMBERS

- Electrical and Computer Engineering (IUPUI)
- Biomedical Engineering (IUPUI)
- Biochemistry, School of Medicine (IUPUI)
- Pharmacology & Toxicology, School of Medicine (IUPUI)
- Clinical Medicine (IUPUI)
- School of Health & Rehab. Sci. (IUPUI)
- Chemistry, School of Science (IUPUI)
- Earth Science, School of Science (IUPUI)
- Electrical and Computer Engineering (Purdue Univ., WL)
- Electrical and Computer Engineering (Ohio State Univ.)

OBJECTIVES

- to form a multi-disciplinary team from engineering, medicine, and science
- to apply cutting-edge technologies to improve health, the environment, and safety using
  - embedded microsystems
  - sensors
  - wireless communication - Wi-Fi, Bluetooth, Zigbee, WiMax
  - Radio Frequency Idetification (RFID)

CHARACTERISTICS

- Rapid deployable and self-organizing
- Large-scale deployment
- Multi-hop routing
- Low maintenance and low cost
- Low power and low data rate

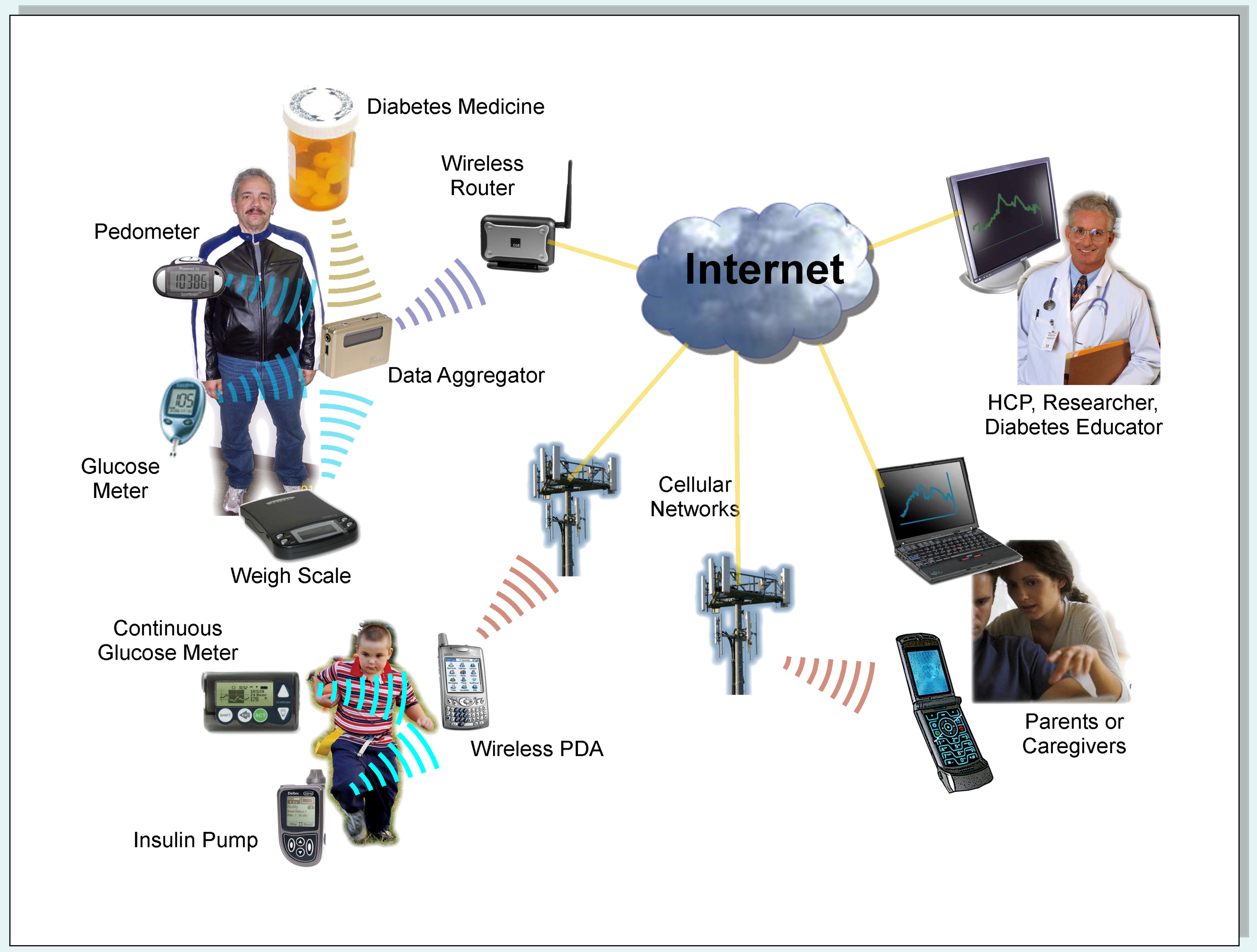
APPLICATIONS

- Medical and health services
- Military
- Precision agriculture
- Habitat monitoring
- Smart building and home automation
- Infrastructural monitoring

INDUSTRIES

- Motorola, Samsung, Crossbow
- Freescale, TI, Intel, Atmel
- IBM, Microsoft, Mitsubishi, Sun Micro
- GM, BMW, Toyota
- Google, Yahoo

Diabetes Maintenance



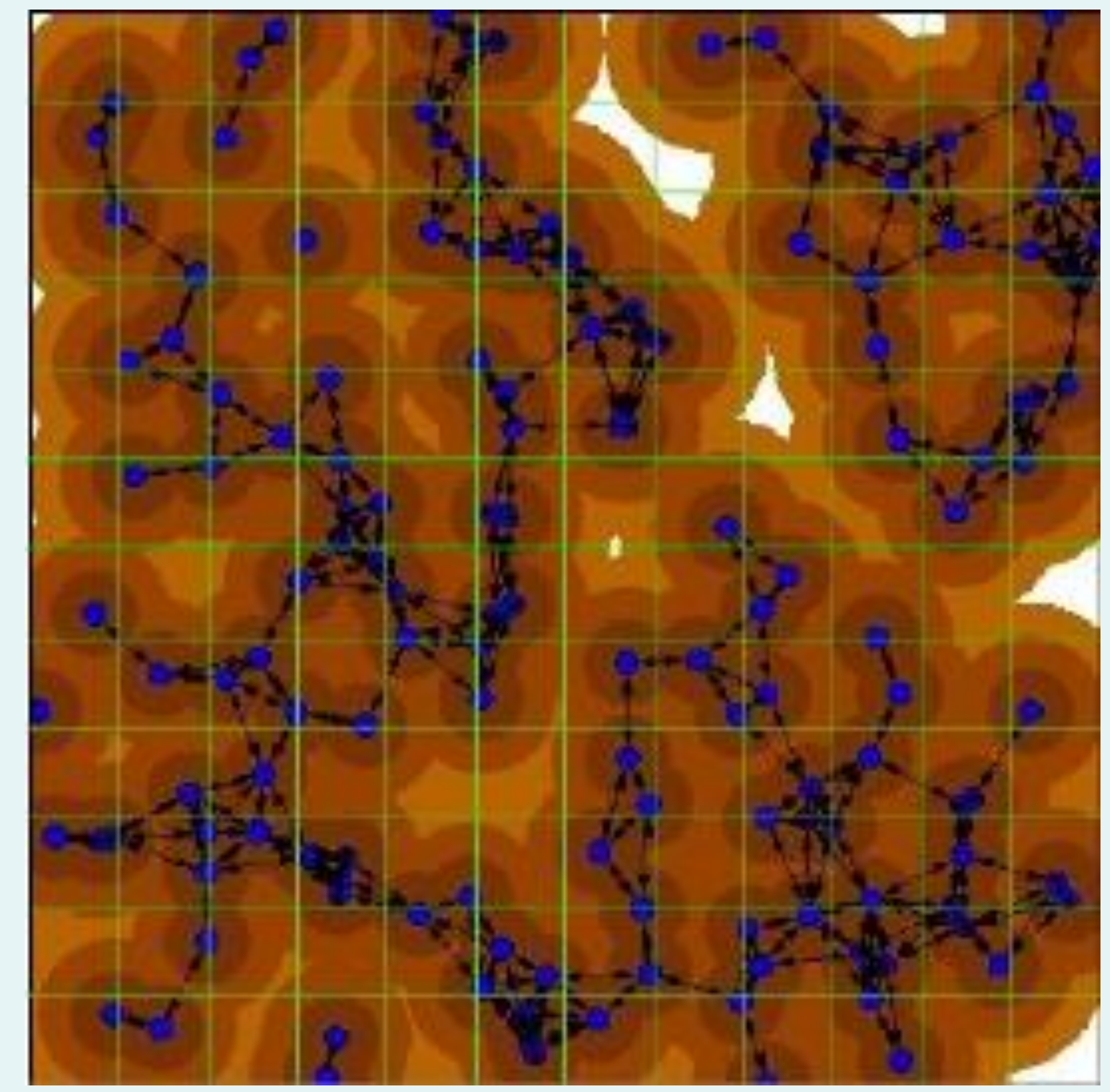
GOALS

- Help maintain diabetes remotely and in real-time
- Improve patients' compliance with medical advice
- Alert emergency state for T1D to caregivers in real-time

METHODS

- Once consented by a patient, information related to diabetes is collected to a health center quietly, wirelessly, and invisibly. This includes
  - blood sugar level
  - insulin or glucagon injected
  - daily exercise and weight
  - medicine intake

Sensor Fusion



GOAL

Integration of information from temporally, spatially, categorically different sensor data into a unified interpretation.

APPROACH

- Sensor consensus
- Image fusion
- Multimodal integration and interpretation
- Sensor data management
- Security
- Encryption and decryption

An Improved Elliptic Curve Scalar Multiplication over GF(2^n)

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Indianapolis

Department of Electrical and Computer Engineering

by Ishita Verma (BS/MSECE) and Brian King (ECE briking@iupui.edu)

- Public Key cryptography is an essential to today's e-commerce applications.
- Elliptic Curve Cryptography (ECC) requires low bandwidth and less computational complexity for signature generation and key generation.
- The most practical application of using the field GF(2^n) in public key cryptosystem is Elliptic Curve Cryptography (ECC).
- Binary fields denoted by GF(2^n) are constructed by selecting an irreducible polynomial *p* of degree *n* in $Z_2[x]$.

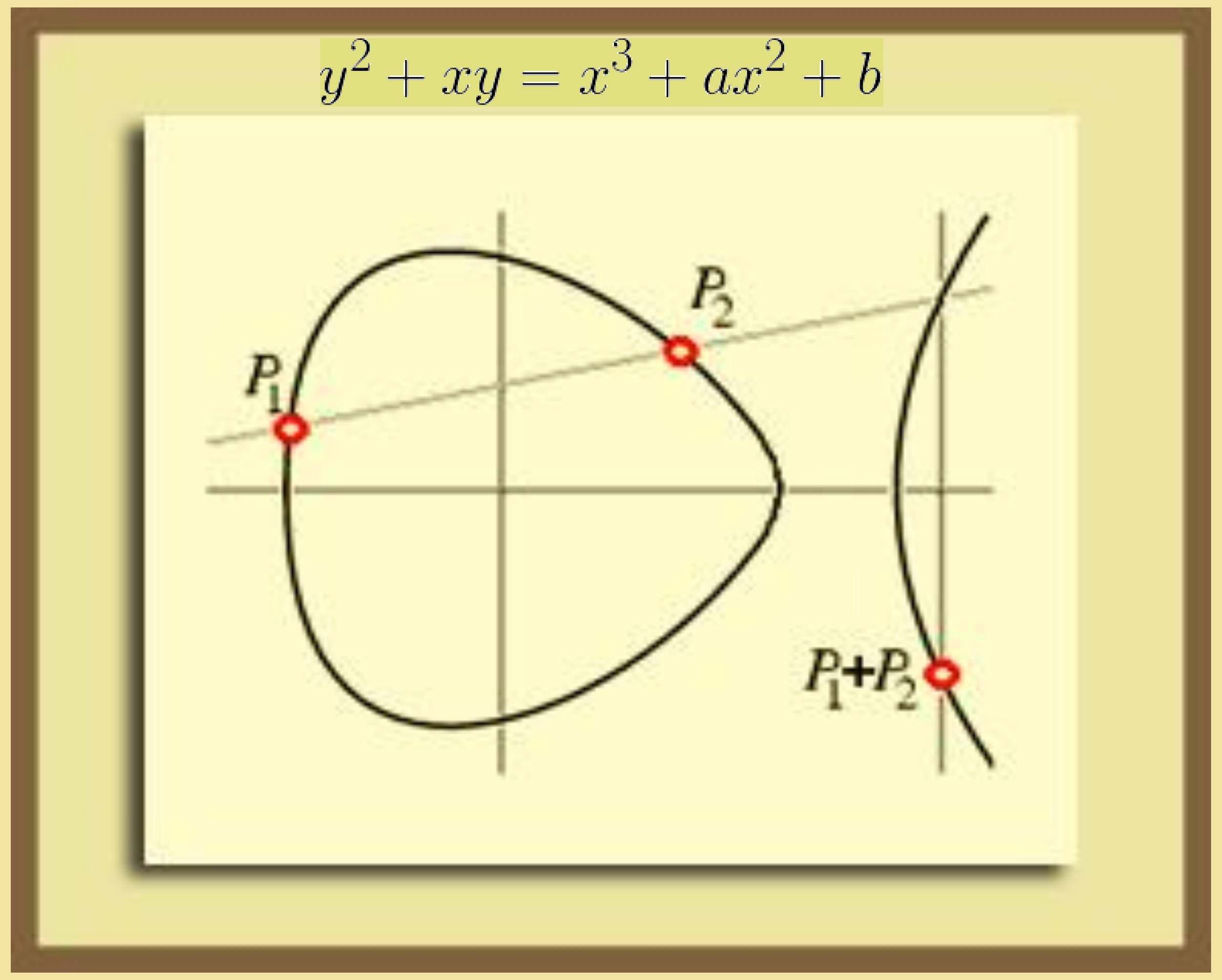
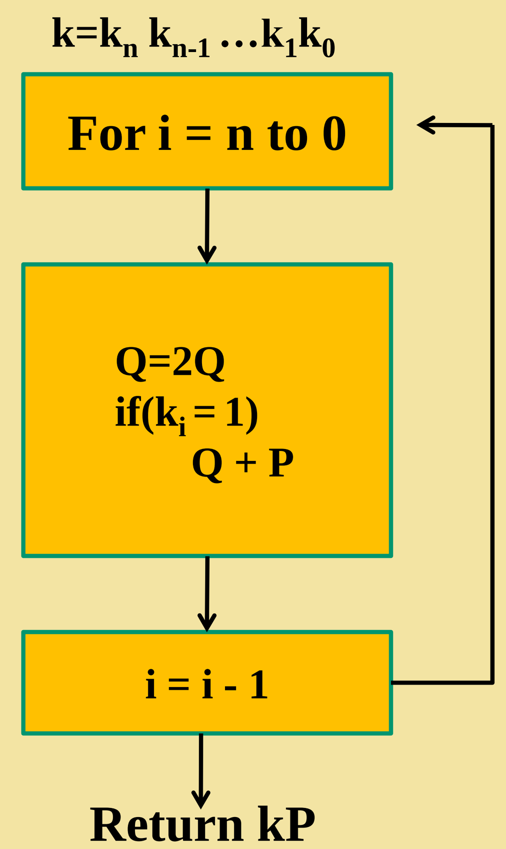


Fig. 1. Addition on an Elliptic Curve. 2P can be found by a tangent line drawn at point P, kP can be found by tangent at point (k-1)P

- The necessary elliptic curve computation is to compute the multiple of a point, *kP*, where $kP = 2(\ldots(2(2P + k_{n-1}P)+k_{n-2P})+\ldots+k_0P$
- This computation is analogous to the "square and multiply" method used in Z_n to compute an element to a power.
- The group operations on an Elliptic Curve ordered according to increased processing costs: field add, field square, field square, and field inverse.
- In this project we developed various schemes of replacing high cost field operations in the scalar multiplication with low cost operations.
- Development of such schemes are especially important for small embedded system devices such as Smart Cards and RFID.

Double and Add method to compute *kP*

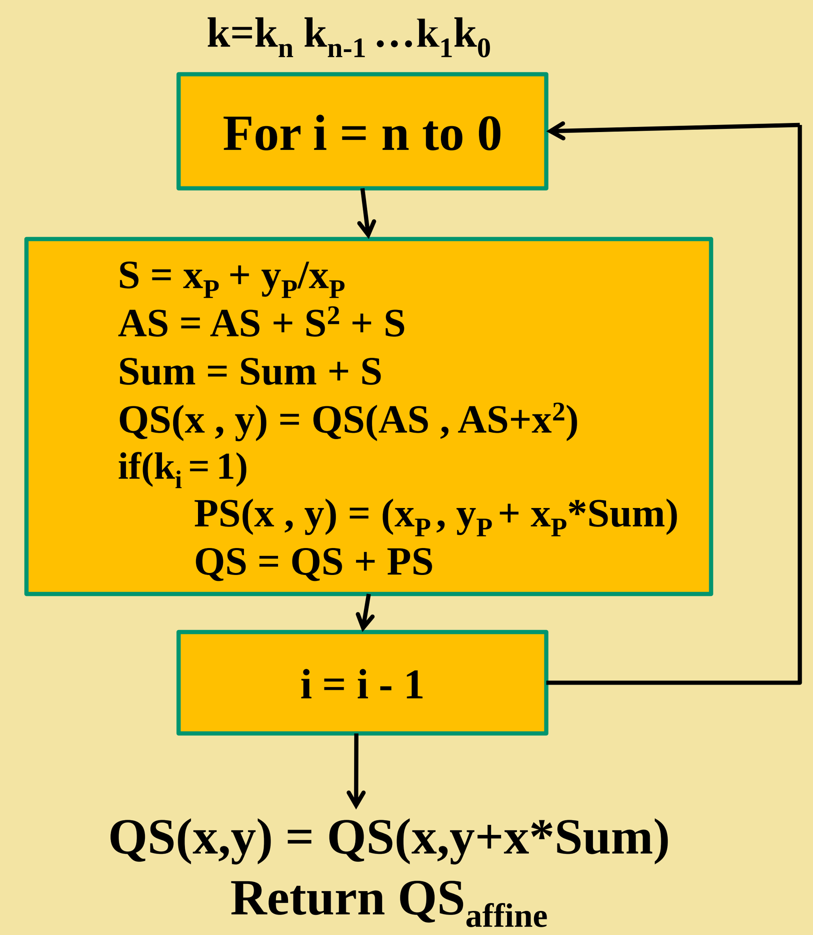


Example
Compute23P
23=10111

Q=0
Q=2*0+P=P
Q=2*P
Q=2*2P+P=5P
Q=2*5P+P=11P
Q=2*11P+P=23P

This is the basic Affine method using many "double" and "add" each requiring a field inverse

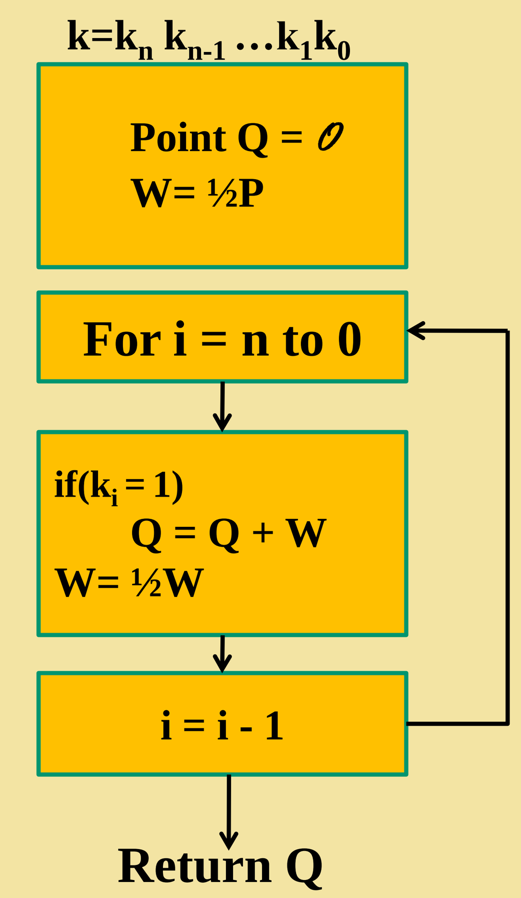
Isomorphic Map and Add method to compute *kP*



For an elliptic curve $E_{a,b}$ an isomorphic curve $E_{a+\gamma,b}$ can be defined where γ is suitably chosen.

In our scheme a point (x,y) would map as (x,y+x*S) where S = x + y/x and is equal to γ

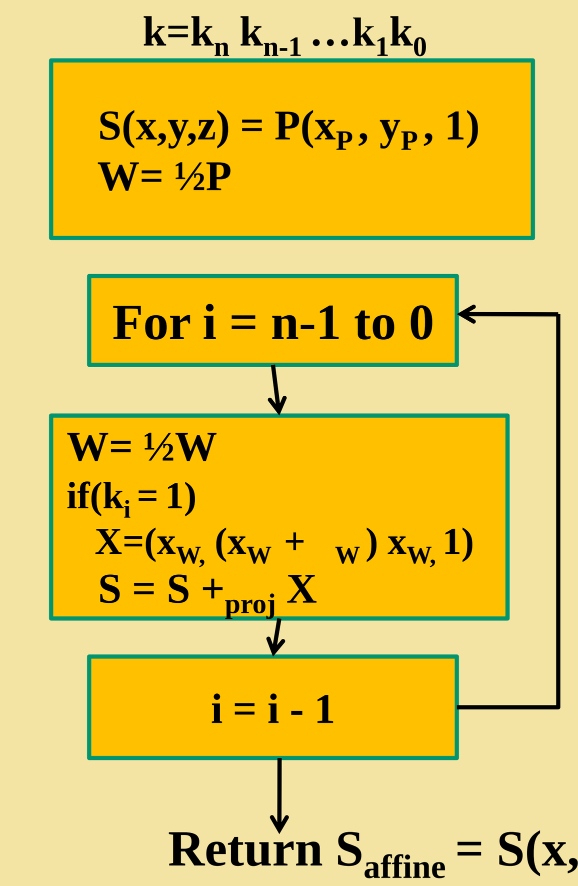
Add and Half method to compute *kP*



For a point to be halved easily, it can be represented in halving coordinates shown as P(x,) = P(x, x+y/x).

Thus for ½P (u ,) = half(P(x , y))
u^2 = s($_{½P}$ + $_P$ + x + 1)
= solution to ^{2} + = a + x

Projective Points Half and Add method to compute *kP*



The use of projective point arithmetic to computer kP is such that one delays the computation of a field inverse until the very end.

Relationship between P(x',y') and its projective point P(x,y,z) is x' = x/z and y' = y/z². Projective add takes 9M + 0I

Speedup Through Proposed Methods

KEY: M = Multiply I = Inverse
COSTS: Add << Square << Multiply << Inverse

METHOD	DOUBLE	ADD
Montgomery (Standard)	**n(6M)**	-
Affine (Double & Add)	**n(2M + I)**	**n/2(2M + I)**
Map & Add	**n(M + I)**	**n/2(3M + I)**
Add & Half	**n(2.5M)**	**n/2(3M + I)**
Projective Point Half &Add	**n(2.5M)**	**n/2(10M)**
Proj. Point Half & Add with Map	***n(2.5M)***	***n/2(9M)***
Non-Adjacent Form (NAF)	***n(2.5M)***	***n/3(9M)***

Faster Square-Root

Given the following mod trinomial square-root of u^2 can be found by splitting it into two polynomials of it's odd and even bits.

$$t^{233} + t^{74} + 1$$

$$u^2 = O + E$$
$$\sqrt[2]{u^2} = u = Bx^{37} + A$$

These O and E polynomials are then shifted and concatenated back

$$B = O + (x^{74}O) + (x^{148}O) + (x^{222}O)$$

$$A = E + x^{74}(\tfrac{B}{x^{195}}) + (\tfrac{B}{x^{195}})$$

Greedy Approach: Given , solve for

$\Lambda^2 + \Lambda = \beta$ mod trinomial: $t^m + t^n + 1$

special case: *m = 233* *n = 74* *0*
≤ x< 233

$$\Lambda x = \beta x + \Lambda(\frac{m+x+1}{2})$$

x is odd & x < n

$$\Lambda x = \beta x + \Lambda(\frac{m+x+1}{2}) + \Lambda(\frac{m+x-n+1}{2})$$

x is odd & x > n

$$\Lambda x = \beta x + \Lambda(\frac{x}{2}) + \Lambda(\frac{m+x-n+1}{2})$$

x is even & x < n

$$\Lambda x = \beta x + \Lambda(\frac{x}{2}) + \Lambda(\frac{m+x-2n+1}{2})$$

x is even & x ≥ n & x ≤ 2(n-1)

$$\Lambda x = \beta x + \Lambda(\frac{x}{2})$$

x is even & x > 2(n-1)

References

1.S. Liu, B. King,W. Wang, "Hardware Organization to achieve High-Speed Elliptic Curve Cryptography for Mobile Devices"
2.B. King, "Application of Isomorphism of Binary Curves".
3.B. King, B. Rubin, "Improvement to the point halving algorithm".
4.I.Verma, B.King"An Improved Elliptic Curve Scalar Multiplication over GF(2^n)" (draft)

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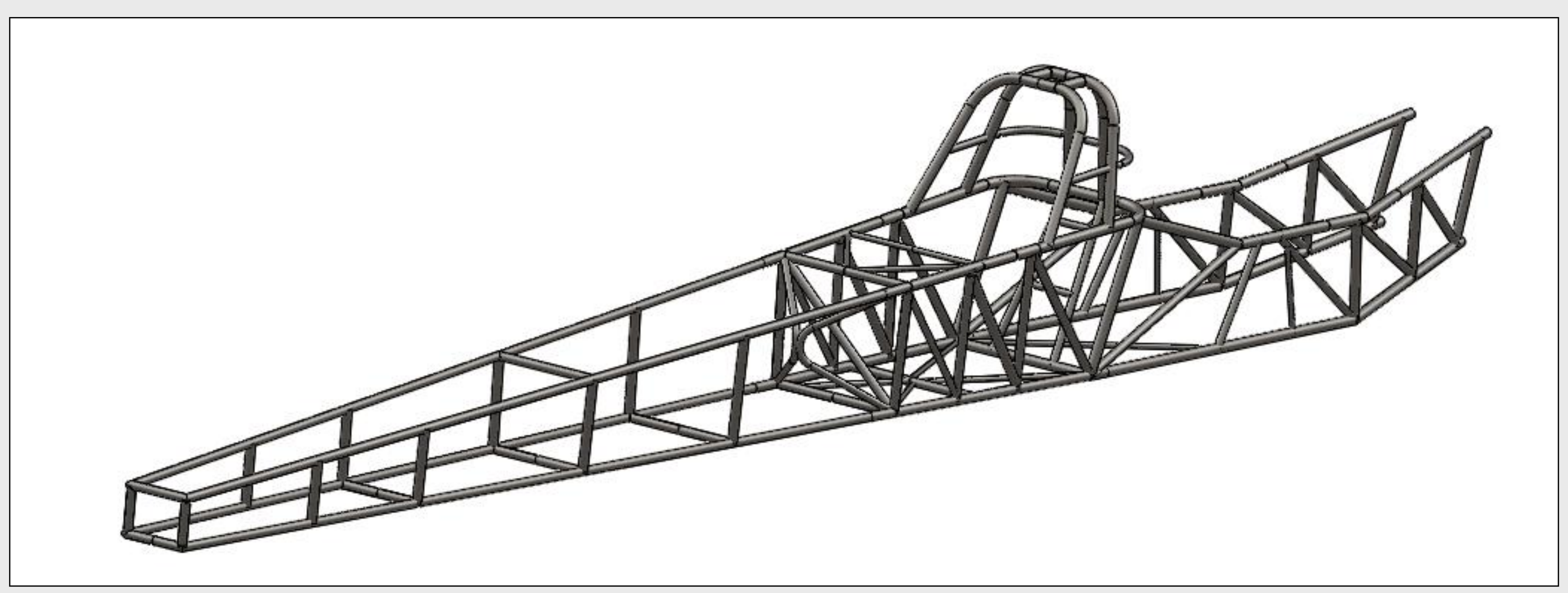
Don Schumacher Racing

Kirk Barber & Paul Lucas

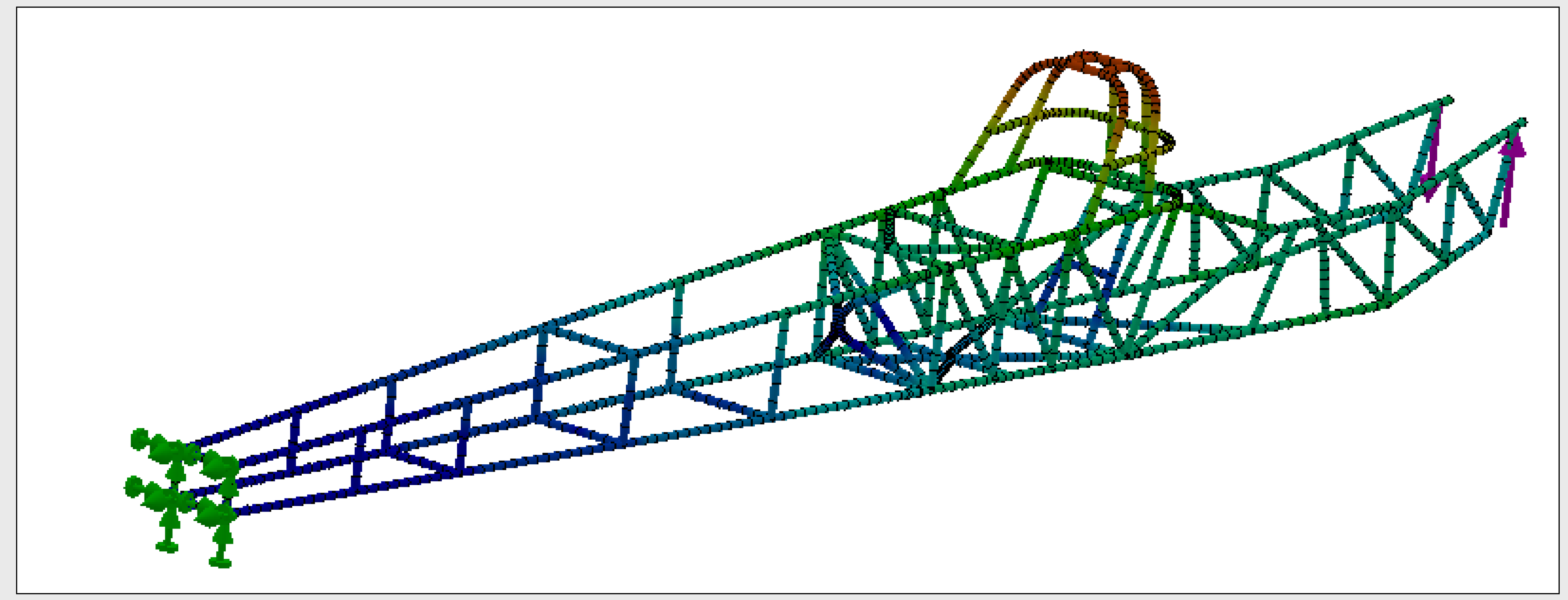
Cory McClenathan Top Fuel Dragster

The team set the fastest 1000 foot time in NHRA history at 3.752 seconds and a top speed of 324.75 miles per hour.

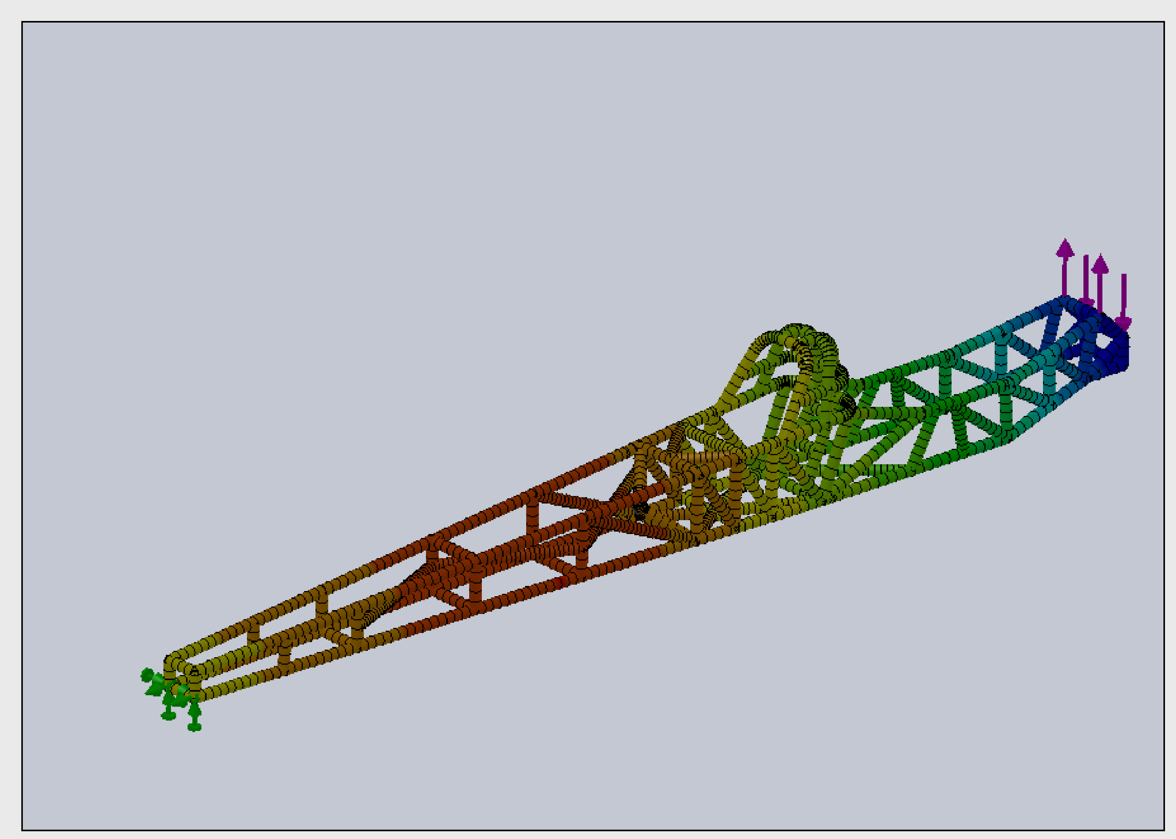
Finite Element Model of a Top Fuel dragster chassis.

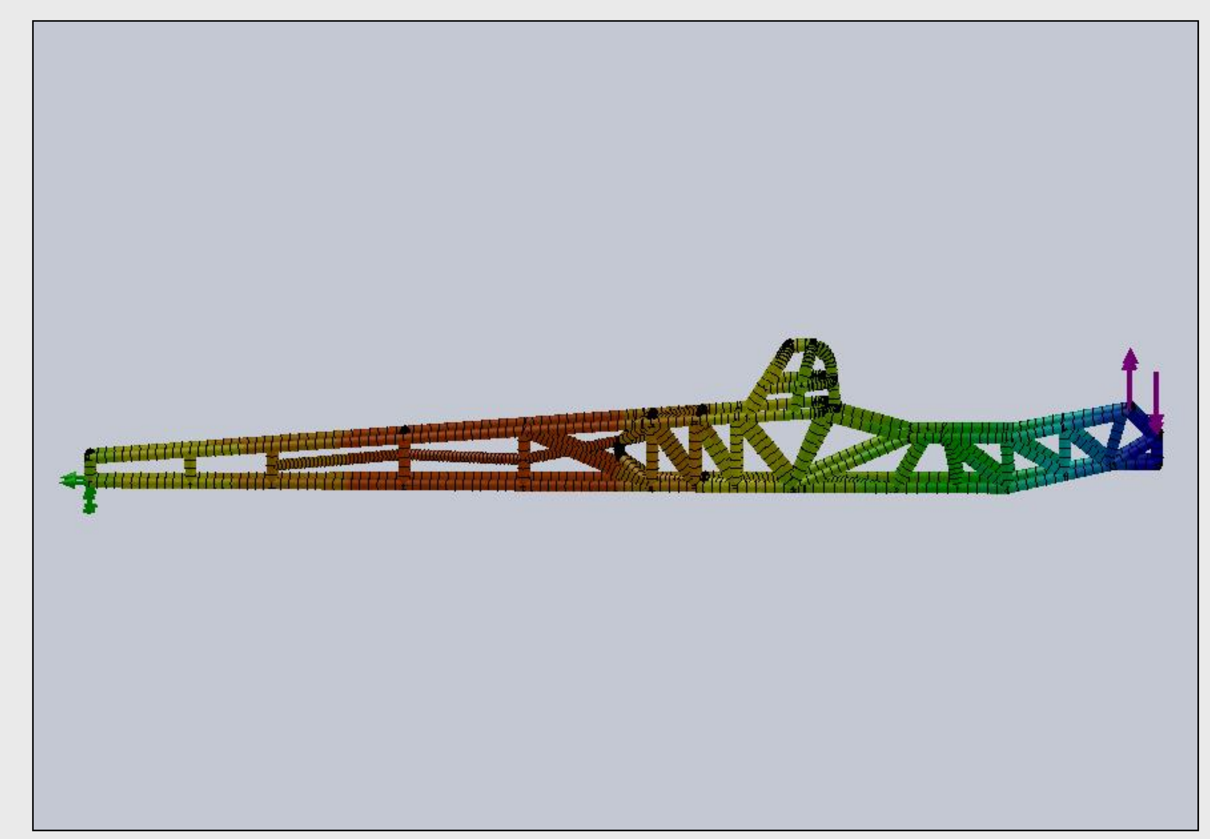


Performing a Finite Element Model of a Top Fuel dragster chassis to find deflections, angle of twist, and deflections on the chassis



Over a hundred different configurations were examined that indicated several trends pointing towards the selected goals.





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Research at the Richard G. Lugar Center for Renewable Energy

Dr. Alan S. Jones, Director

Fuel Cell Research

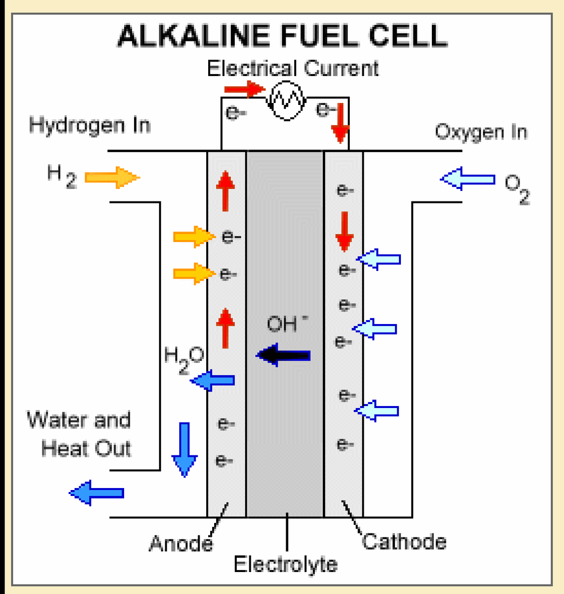
Faculty Researcher: Dr. Rongrong Chen
Research Associate Professor of Mechanical Engineering
Purdue School of Engineering and Technology, IUPUI

Research Highlights: Perfecting Fuel Cell Technologies

OBJECTIVES

- To reduce cost and improve the activity and stability of catalyst materials
- To study high efficiency catalyst materials for ethanol oxidation
- To investigate and improve reformer techniques to produce hydrogen fuel from ethanol
- To develop and evaluate new membranes for direct alcohol fuel cells (DAFC)
- Reduce cost and improve ionic-conductivity and thermal/chemical stability of membranes for DAFC

Types of Fuel Cells



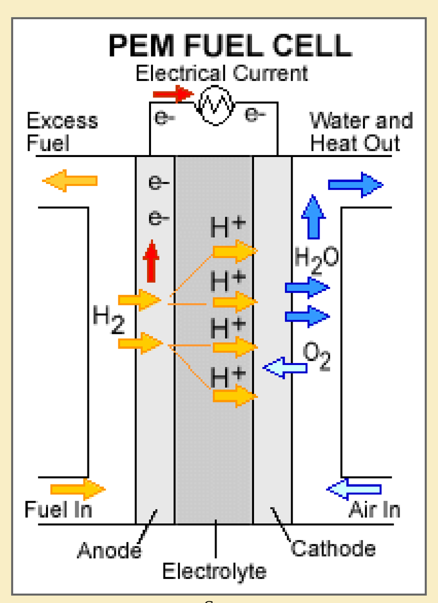
Source: http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html

Alkaline Fuel Cell

This type of fuel cell has advantages in that non-precious metals, such as silver, can be used as a catalyst material to replace platinum. This allows for a cost-reduction for the cell. It also can be operated at relatively low temperatures. However, long term durability of the materials used in this cell is the major obstacle of commercializing this type of cell and a focus of research at the Lugar Center.

Proton Exchange Membrane Fuel Cell

This type of fuel cell, also known as a Polymer Electrolyte Membrane, has advantages in being lightweight and having a high power density. However, it must have pure hydrogen as a fuel and its acidic environment is harsh for catalyst materials that are not platinum. Hydrogen storage is a main issue with this type and an area of interest at the Lugar Center.



Source: http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html

Direct Methanol Fuel Cell

Direct methanol or ethanol fuel cells are a relatively new area of research. These cells run on the same principles as the PEM, but do not require the pure hydrogen energy source. Rather, they can be run on any form of alcohol or hydrocarbon fuels. The fuel is mixed with steam and fed directly into the anode of the cell. There could be many advantages if this type of cell is commercialized, since the fuel source for it would be easy to transport. There is a research focus at the Lugar Center in this new technology.

For more information contact:
Kyle Cline, General Manager
kpcline@iupui.edu
(317) 278-4723

Mission of the Lugar Center

To address the urgent societal needs for clean, affordable and renewable energy sources, improve the nation's energy security, and reduce the negative impacts of climate change. It's primary mission is to promote research and educational excellence in the area of renewable energy through collaborative efforts among faculty in the disciplines of engineering, biology, chemistry, geology, physics, environmental affairs and public policy. The LCRE promotes renewable energy applications through teaching, learning, civic engagement, and synergistic partnerships with industry, government labs and local communities.

Goals of the Center

- Develop an international reputation for excellence in renewable energy research, with an emphasis on renewable hydrogen generation and its applications
- Develop and sustain a core expertise in fuel cell technology and in bio-fuel production and applications
- Develop and sustain research activities through collaborations and partnerships with federal agencies, state government, and industry
- Pursue commercialization of new technologies through industry collaborations

Bio-Fuels Research

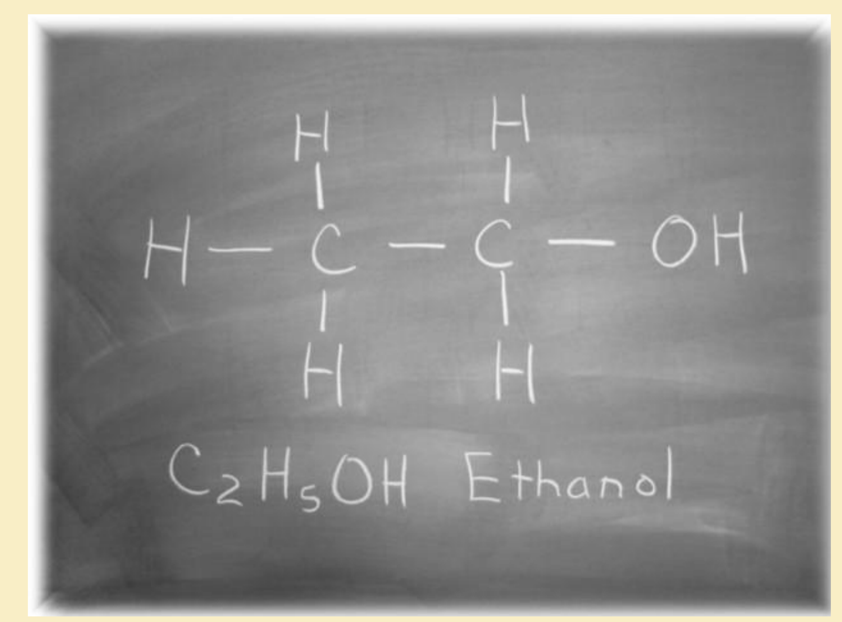
Faculty Researcher: Dr. Mark Goebl
Professor of Biochemistry and Molecular Biology
Indiana University School of Medicine

Research Highlights: Improving Ethanol Production

Ethanol is a biofuel that has gained great interest, especially in the corn fields of Indiana, over the past decade. The principles of making ethanol have been known for thousands of years. Ethanol is made through the anaerobic consumption of sugars by yeast, a process otherwise known as fermentation. One of the main problems encountered with ethanol research today is that the yeasts used to produce the ethanol are picky eaters. Conventional yeast will pass over xylose, a type of sugar, for glucose. Unfortunately, nearly 1/3 of plant material is xylose. What Dr. Goebl and his team have done is genetically alter this trait out of a strain of yeast, so that it will consume both glucose AND xylose without bias. This means that this new form of yeast will also improve corn ethanol and clear some hurdles in the production of cellulosic ethanol, which uses other types of plant material such as grasses, wood waste and straw.

So how much more corn ethanol could be produced from using this new strain? According to Dr. Goebl, approximately 0.5% more than what is being produced today. This may not seem like much, but the math shows the true impact of what that means. In 2008, the United States produced approximately nine billion gallons of ethanol. Dr. Goebl's new yeast strain could increase this production by 45 million gallons. For a vehicle getting 20 mpg, this means that over two million more miles of driving capabilities. Plus, this calculation only takes into account the yeast's ability to consume more, not the fact that it also is able to produce ethanol more quickly. This means that the true potential to improve the production of corn ethanol through the use of this new strain of yeast could increase production by as much as 10%.

From the Academic Laboratory to Commercialization



Source: http://www.in.gov/oed/2344.htm

Dr. Goebl's discovery in the lab has lead to the development of a small company that will help commercialize this new technology. Xylogenics, Inc is the company founded by Dr. Goebl and three of his students, Ross Cocklin, Josh Heyen and Cary Woods, along with several local businessmen, Butch Mercer and Mike Neibler. It has its offices in downtown Indianapolis. The future of this new yeast will move out of the labs at IUPUI and to this new company, which will work with other Hoosier companies that are already producing ethanol in the state. Along with the scientific breakthrough, the potential for creating jobs is enormous.

Collaborating Partners

- Purdue Energy Center
- Delphi Corporation
- Army Research Lab
- Argonne National Lab
- Crane Naval Surface Warfare Center
- Energy Systems Network

Current Funding Sources

Sponsored Research of LCRE Faculty:
- Crane Naval Surface Warfare Center
- Army Research Lab
- U.S. Department of Energy
- Pew Charitable Trusts
- Rolls Royce
- General Motors

General LCRE Funding:
- IUPUI Signature Center Initiative
- Purdue School of Engineering and Technology, IUPUI

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Plug-in Hybrid Electric Vehicle

Harpreetsingh Banvait, Xiao Lin, Yaobin Chen, Sohel Anwar

Background

➢Plug in Hybrid Electric Vehicles are the new generation Hybrid Electric Vehicles. They eliminate the drawbacks of both Conventional Vehicle and Electric Vehicles by combining both in one Vehicle. These vehicles can be charged overnight through the domestic power supply.

➢Plug in Hybrid Electric Vehicles can be used for daily drive of about 40 Miles using the Electricity only. But If the vehicle travels further beyond 40 miles then it would work as an Hybrid Electric Vehicle.

Objective

➢Improve current plug-in Hybrid Electric Vehicle concept by designing and implementing efficient Energy management Strategy.

➢Reach an efficiency of 100 miles per gallon of a gasoline for 30 to 40 miles of drive.

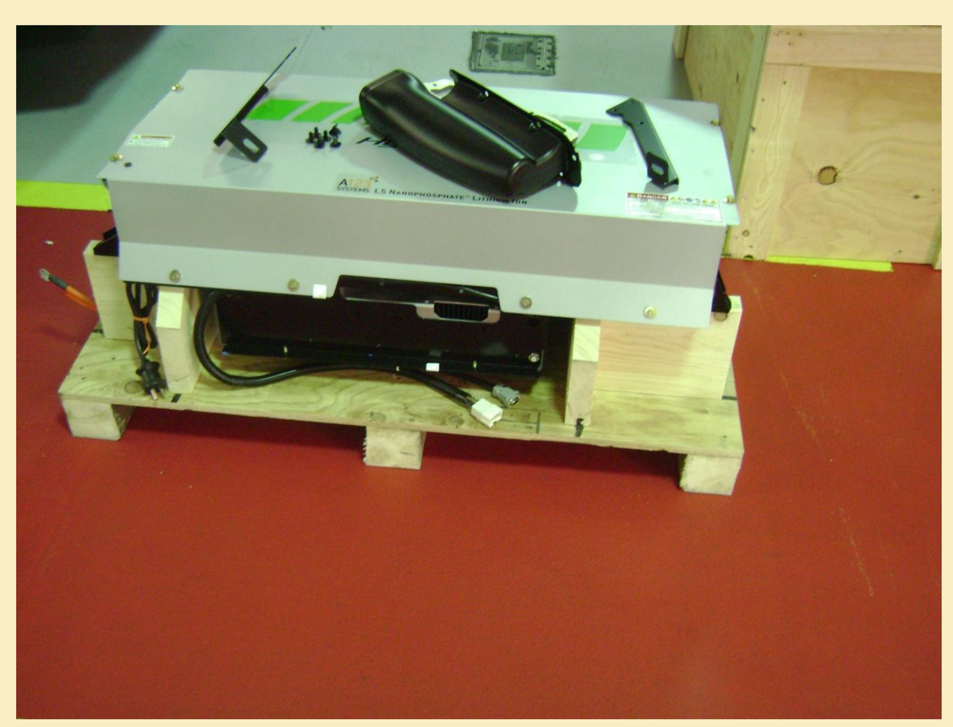
➢Modify a Toyota Prius 2008 to an Plug-in Hybrid Electric Vehicle.

Plug-in Hybrid Electric Vehicle:

➢Two Toyota Prius 2008 are converted to Plug-in Hybrid Electric vehicles.

➢The 5 Kwh Li-Ion Battery is added to the Prius to store energy from domestic Power supply.

➢This Extra battery works along with the Original Prius battery to store the Energy from the Regenerative Braking, Engine Charging and External Charging using the household Power supply.



Simulation and Modeling Results:

➢The Modeling and simulation of the Prius Hybrid Electric Vehicle is implemented using PSAT software. The Existing model for the Prius Hybrid Electric Vehicle is modified for the Plug-in Hybrid Electric Vehicle.

➢A rule based energy management control strategy is proposed and it is optimized using Particle Swarm Optimization technique.

➢Furthermore, this optimization is enhanced by reformulating the optimization control problem.

➢The Objective function of the optimal Energy Management system is as follows:

$$\min J = \int_{t=n}^{t=n+1} \begin{pmatrix} \sigma_e(t)\,\dot{m}_e\big(\omega_e(t), \tau_e(t)\big) + \\ f\big(soc(t)\big)\dot{m}_b(t) \end{pmatrix} dt + p_1 + p_2$$

$$\dot{m}_b(t) = \frac{\big(\omega_m(t).\tau_m(t) + \omega_g(t).\tau_g(t)\big)}{\theta} N$$

$$p_1 = \begin{cases} \mu_1 & soc_{n+1} < soc_l \text{ and } soc_{n+1} < soc_n \\ 0 & \text{else} \end{cases}$$

$$p_2 = \begin{cases} {\mu_2}^{\alpha+1} & \sigma_e(t) \neq \sigma_e(t-1) \\ 0 & \sigma_e(t) = \sigma_e(t-1) \end{cases}$$

➢This system is subjected to different constraints as follows:

$$0 \le \omega_e(t) \le \omega_{e,max}$$

$$0 \le \tau_e(t) \le \tau_{e,max}\big(\omega_e(t)\big)$$

$$\omega_{m,min} \le \omega_m(t) \le \omega_{m,max}$$

$$\tau_{m,min}\big(\omega_m(t), soc(t)\big) \le \tau_m(t) \le \tau_{m,max}\big(\omega_m(t), soc(t)\big)$$

$$\omega_{g,min} \le \omega_g(t) \le \omega_{g,max}$$

$$\tau_{g,min}\big(\omega_g(t), soc(t)\big) \le \tau_g(t) \le \tau_{g,max}\big(\omega_g(t), soc(t)\big)$$

$$soc_{min} \le soc(t) \le soc_{max}$$

➢The result obtained from this simulation are used to train the Neural Network to have online and suboptimal approximation of the results.

➢The results are shown below in table:

	PSO	NN
Results interval	0-4109	0-4109
Drive cycle	UDDS	UDDS
Drive cycle distance	22.34	22.33
Fuel mass	0.08	0.02
Equivalent fuel economy (mile/gallon)	74.40	73.83

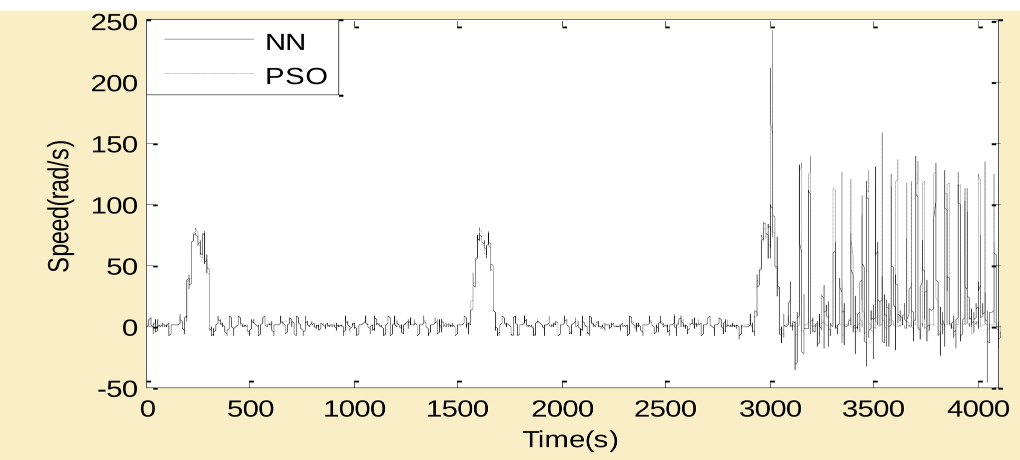


Fig : Engine speed comparison between PSO and neural network

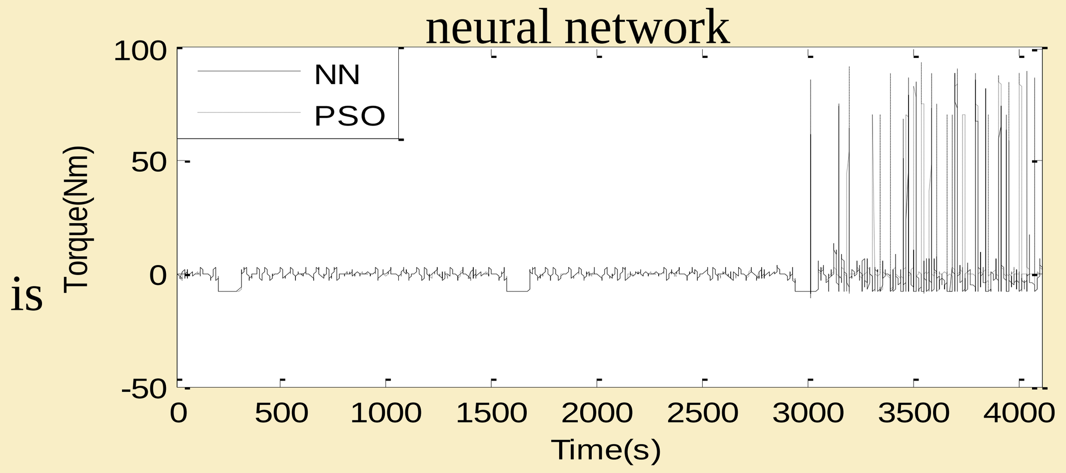


Fig : Engine Torque comparison between PSO and neural network

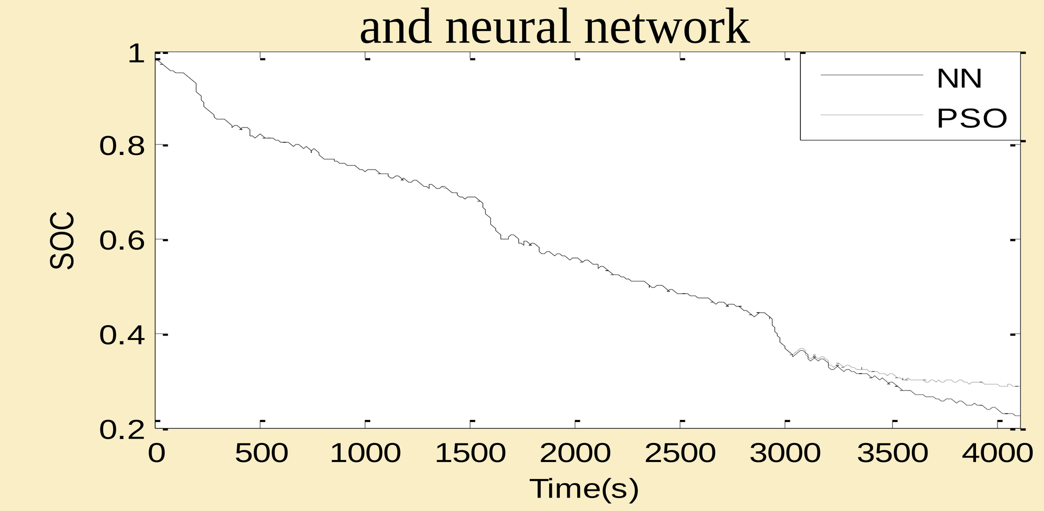


Fig : SOC comparisons between PSO and neural network

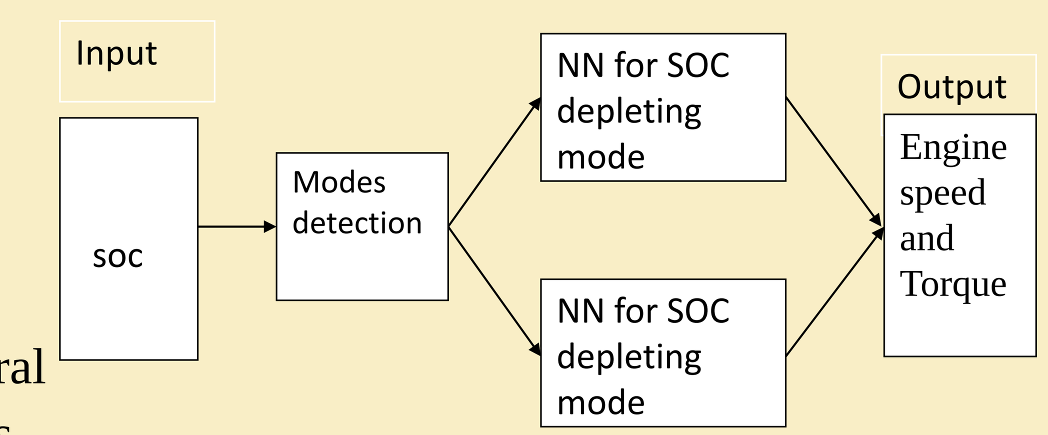


Fig : Neural Network controller setup

[1] H. Banvait, X. Lin, S. Anwar and Y.B. Chen, “Plug-in hybrid electric vehicle energy management system using particle swarm optimization,” in EVS24,May 11-16,2009,Stavanger,Norway.

[2] H. Banvait, S. Anwar, Y. Chen, *A Rule-Based Energy Management Strategy for Plug-in Hybrid Electric Vehicle*, American Control Conference, June 10-12, 2009, St Louis, Missouri.

[3] X.Lin, H. Banvait, S. Anwar, Y.Chen, “*Optimal Energy Management for a Plug-in Hybrid Electric Vehicle: Real-time controller*” ,American Control Conference, June 30- July 02, 2010 ,Baltimore, Maryland.

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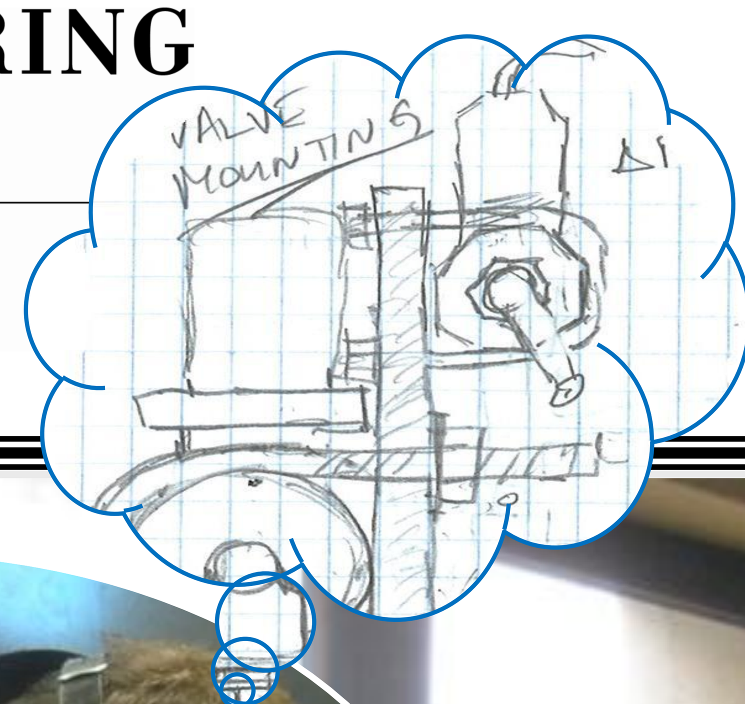


Determining Valve C_v

Bob Durkin, Nick Meyer, Bryan Miller, Demetrius Jermany

Flow Coefficient Testing, Pilot-Operated Solenoid Valves

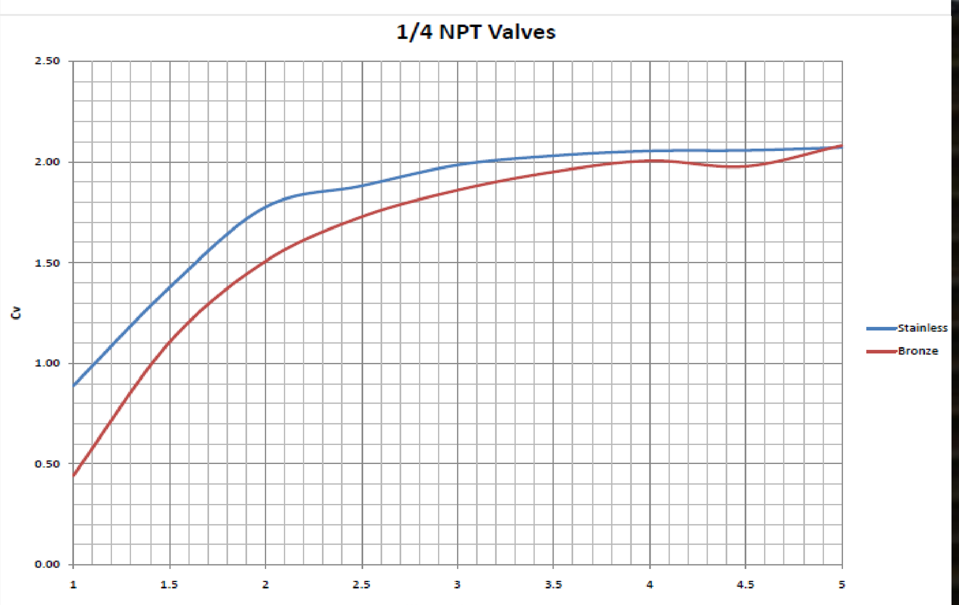
IUPUI Engineering Technology
Indianapolis, Indiana

Instructor:
Robert Durkin

Student Assistants:
Nick Meyer
Bryan Miller

Abstract

Published flow coefficient (C_v) test standards do not directly apply to pilot-operated solenoid valves. These test standards are written for valves with fixed orifice geometry. Pilot-operated solenoid valves have internal geometry that is not fixed until the main port of the valve completely opens. The operating principal of this valve design requires differential pressure to fully open the main valve port. The design is such that closure of the main port is wholly dependent on spring force, while opening the main port is wholly dependent on differential pressure. Existing valve flow coefficient test standards specify one psi of differential pressure when calculating C_v, but fail to consider that this may not be enough pressure to fully open the main port. This research shows that the C_v of a pilot-operated solenoid valve is not constant at low differential pressures, but changes until the main port of the valve is fully open. It also recommends that the determination of the maximum C_v for this type of valve be calculated once the main port is fully open.



Proposed ANSI/FCI 68-2-1998 (R2003)

PROPOSED AMERICAN NATIONAL STANDARD

RECOMMENDED PROCEDURE IN RATING FLOW AND PRESSURE CHARACTERISTICS OF SOLENOID VALVES FOR LIQUID SERVICE (INCLUDING DETERMINATION OF THE VALVE FLOW COEFFICIENT - CV/KV)

Proposed ANSI/FCI 68-2-1998 (R2003)

Fluid Controls Institute, Inc.

Sponsor:

FCI

Fluid Controls Institute, Inc.
1300 Sumner Ave
Cleveland, Ohio 44115-2851

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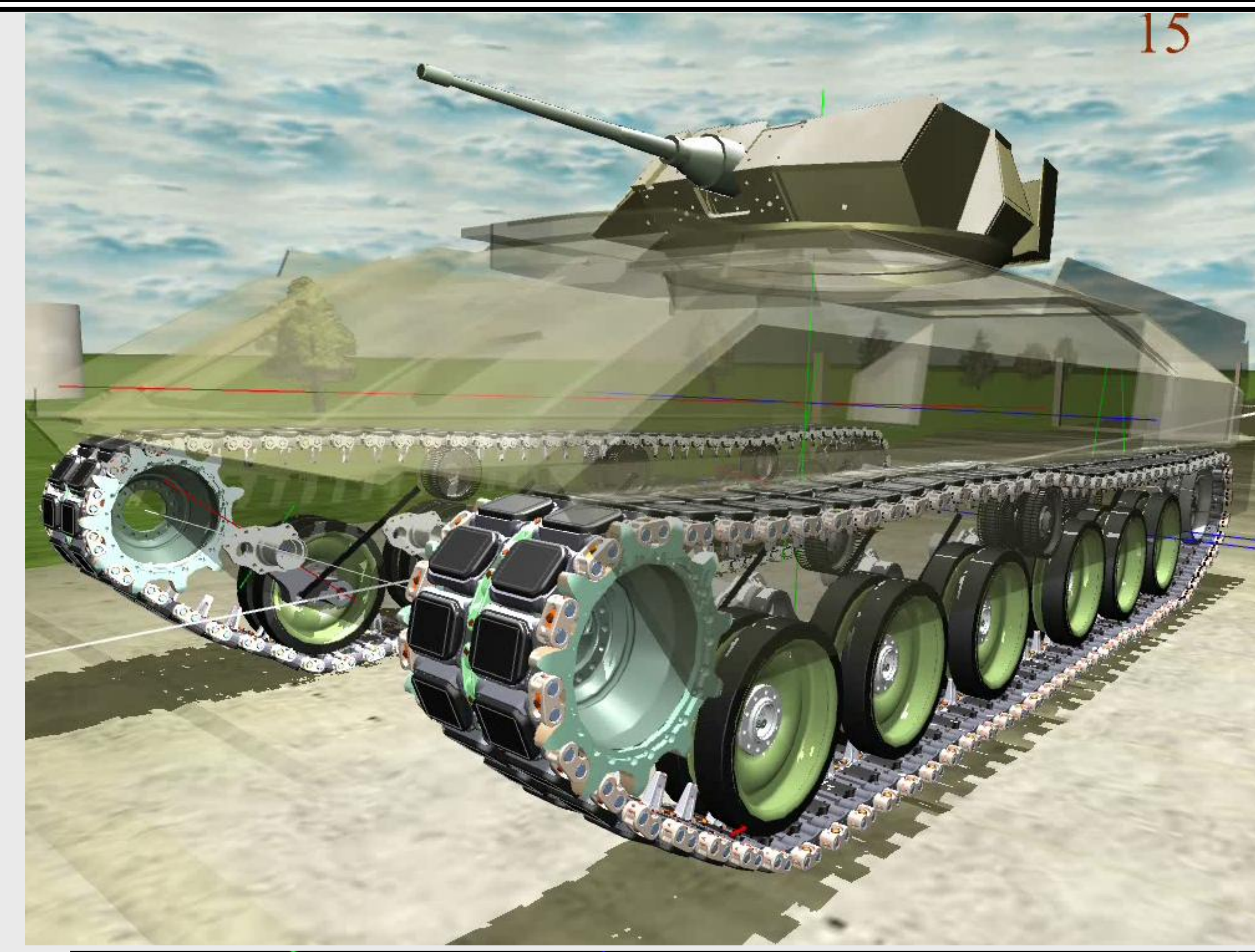
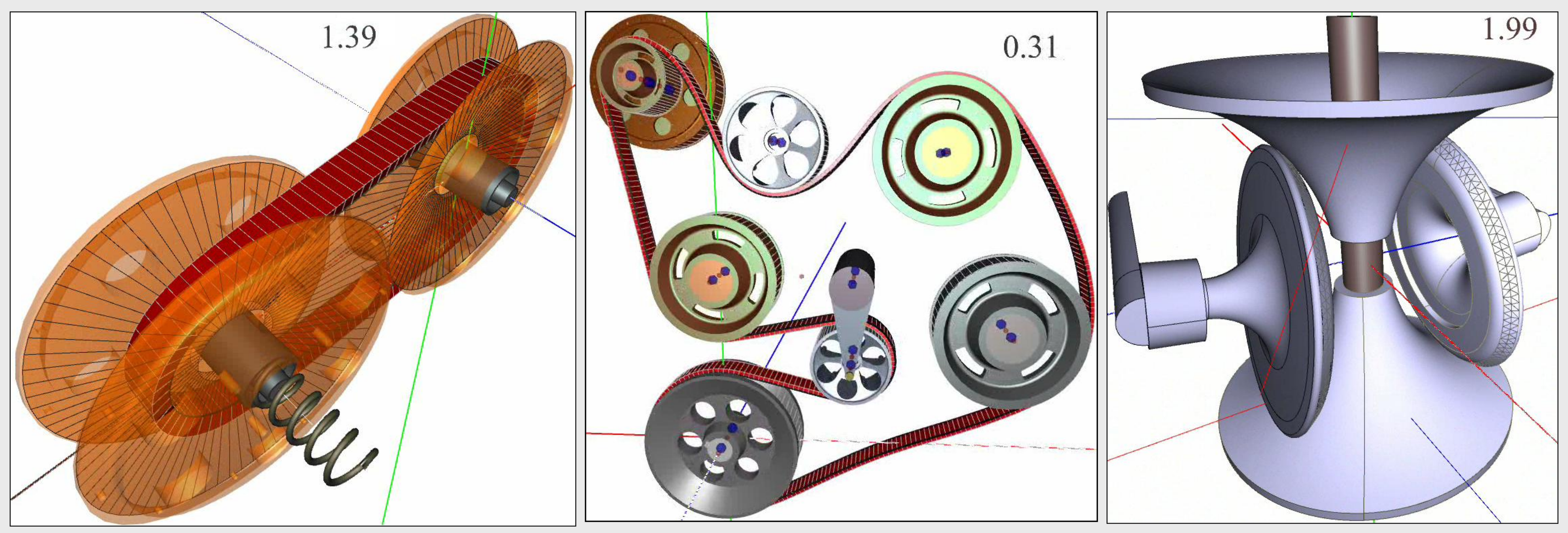
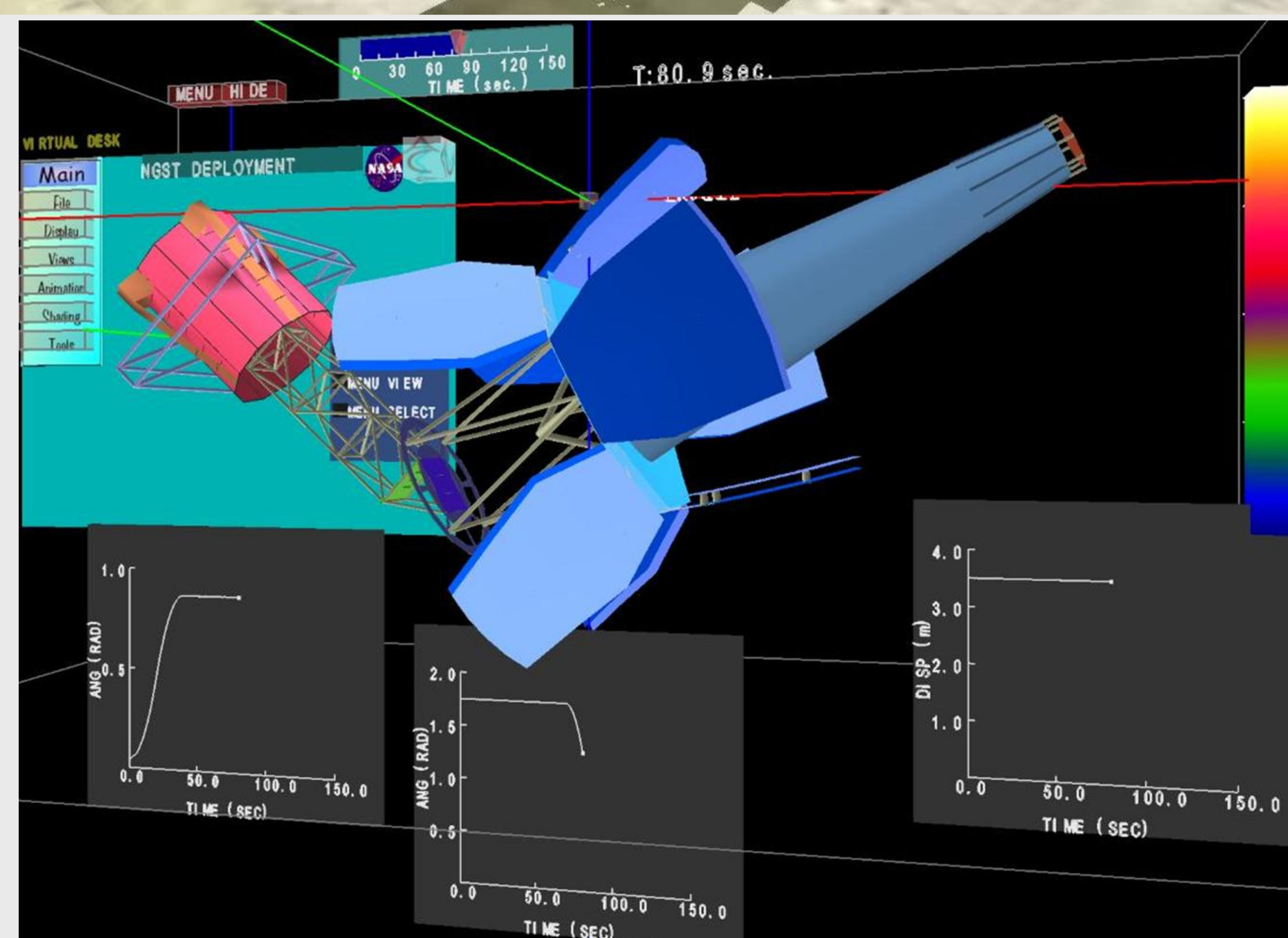
Computational Mechanics/
Flexible Multibody Dynamics Research
Dr. Tamer M. Wasfy

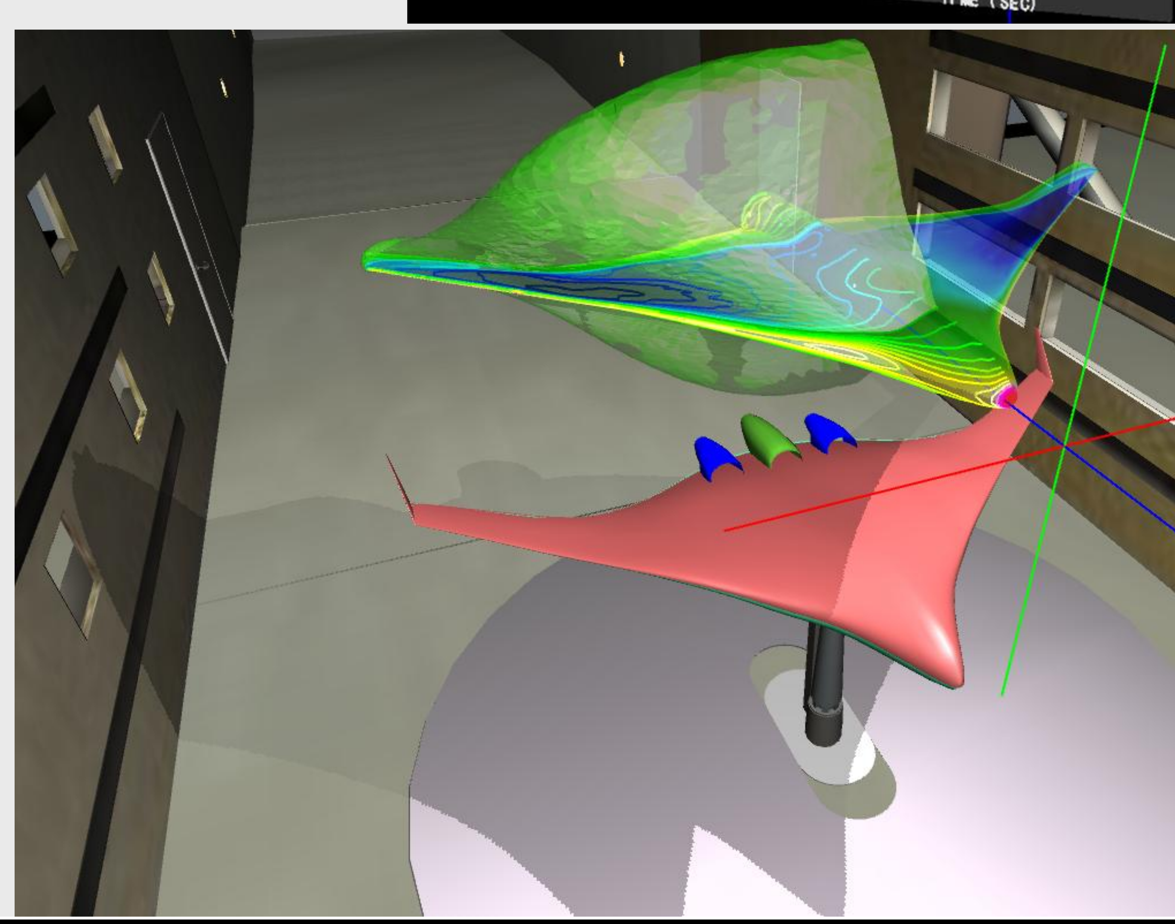
- **Flexible multibody systems.**
  - ➢ Full-ground vehicles:
    Cars, trucks and tracked-vehicles.
  - ➢ Transmission systems
    - ➢ Automotive and industrial belt/chain drives.
    - ➢ Gear boxes.
    - ➢ Continuous variable transmission.
  - ➢ Space-structures.

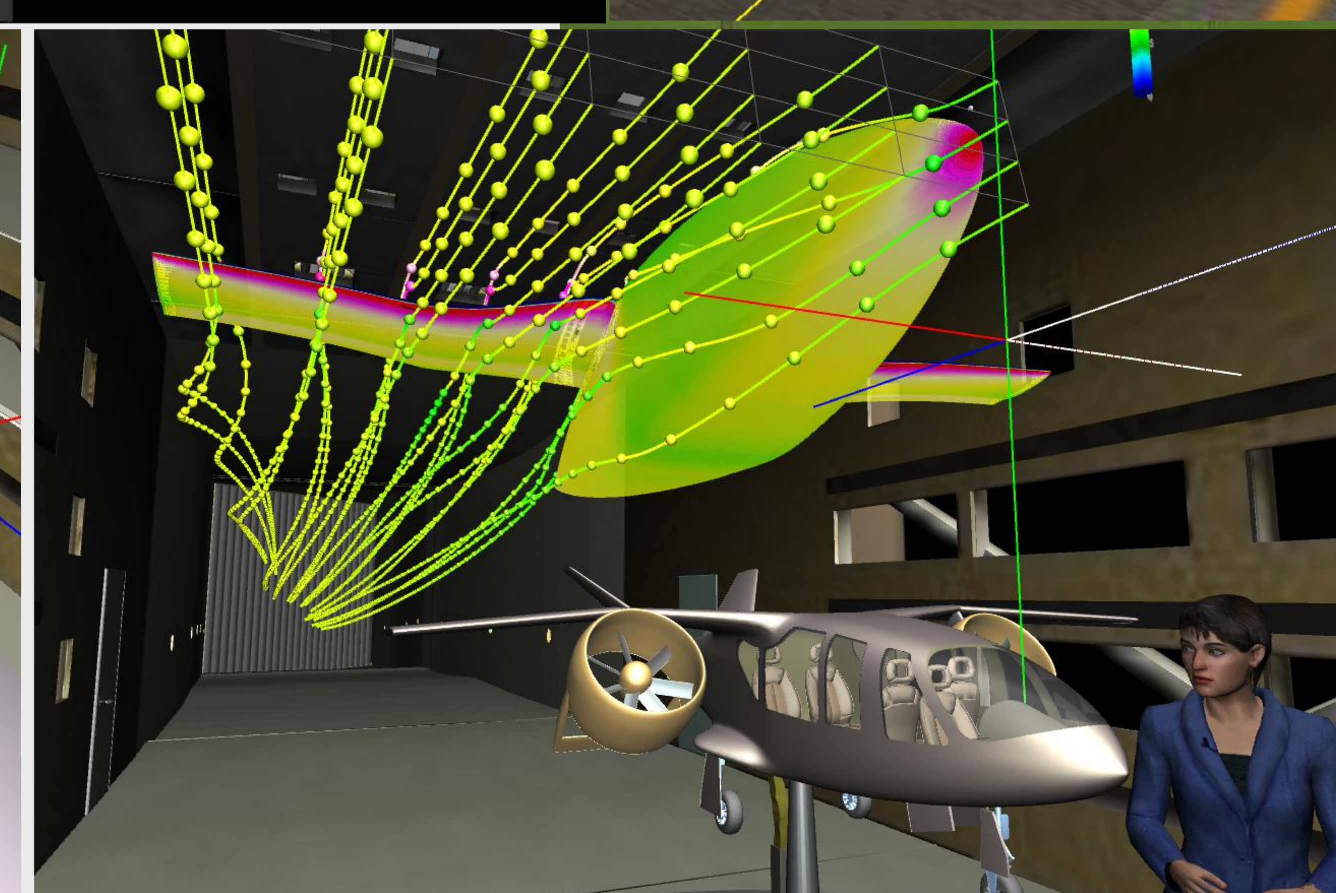






- **Compressible/incompressible fluid flow,** including**:** Shock-waves, Turbulence, and Liquid free-surfaces.
  - ➢ External flow around airplanes and ground vehicles.
  - ➢ Internal flow.
- **Coupled fluid-multibody dynamics.**
  - ➢ Liquid sloshing for tanker trucks.
  - ➢ Airplane wing flutter.





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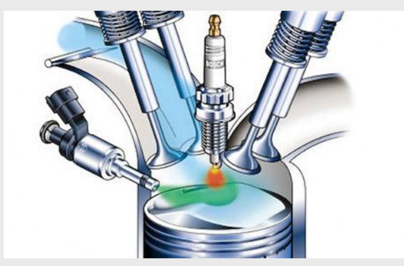
Re-ignition by Hot Jets for Wave Rotor Combustors

Sameera Wijeyakulasuriya, Indika Perera, and Razi Nalim

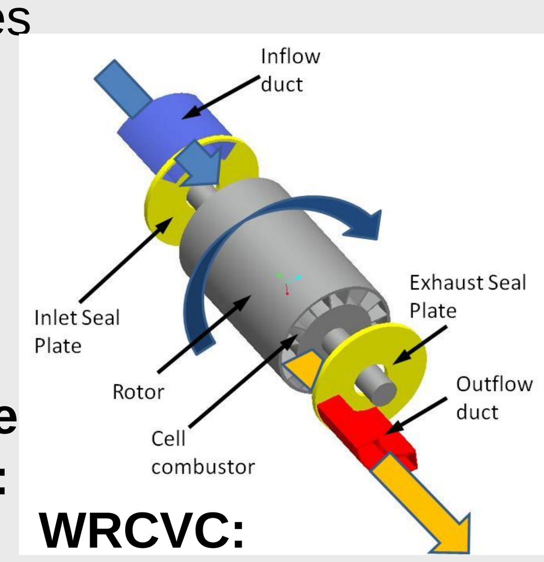
Pressure-Gain Combustion

- More efficient energy conversion for powerplants and aircraft engines
- Deflagrative or detonative modes



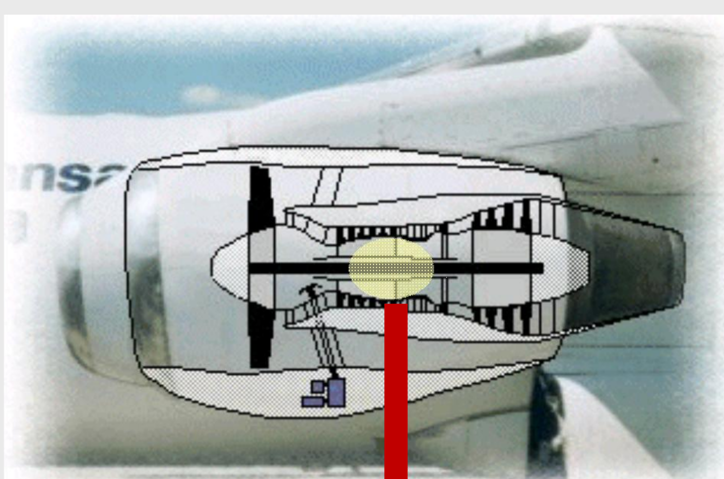
IC Engines: efficient, but heavy

Pulse-jet and pulse detonation engine: integration difficulties

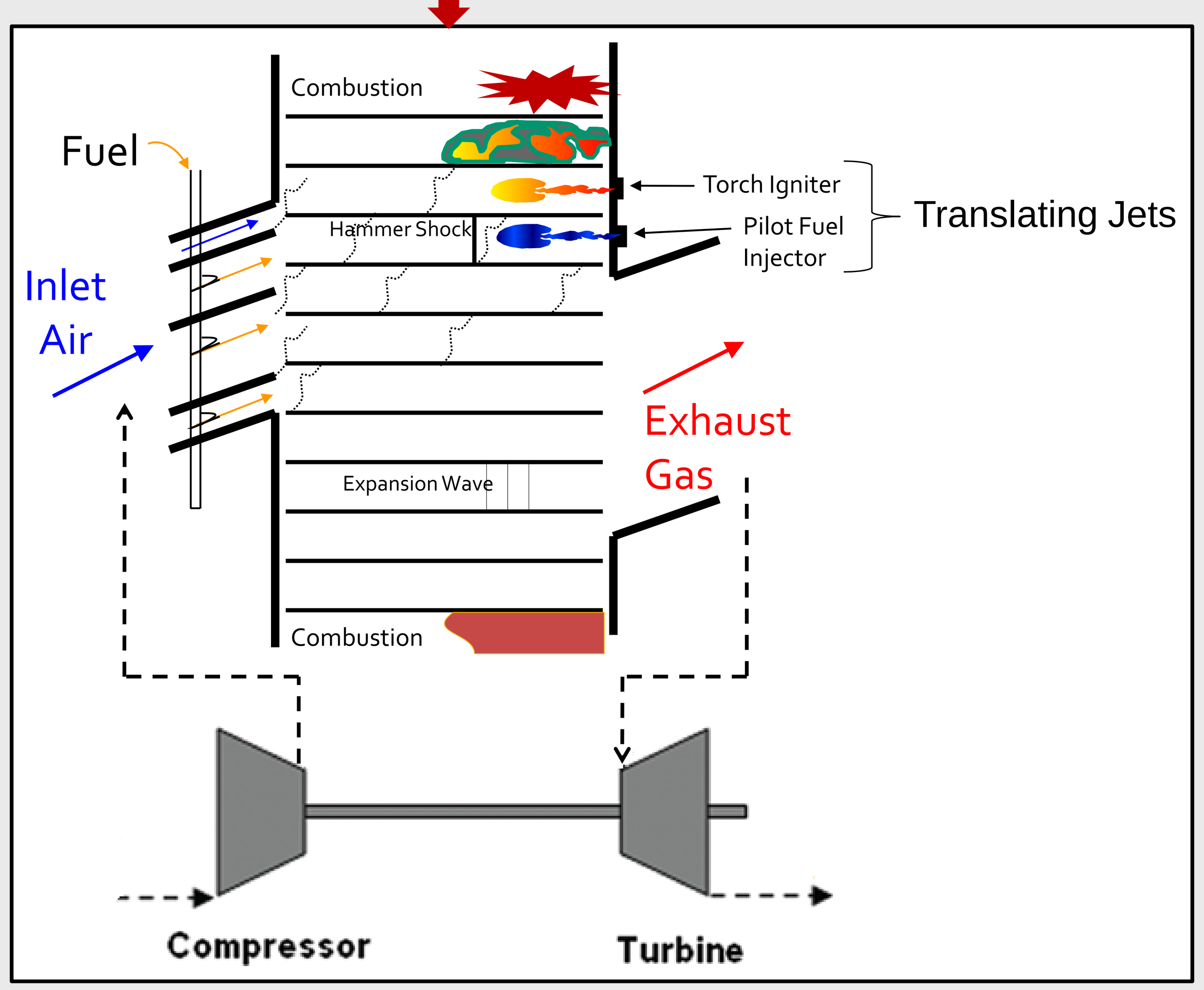


WRCVC: Better Solution

Wave Rotor Combustors



More efficient solution, uses rapid reignition

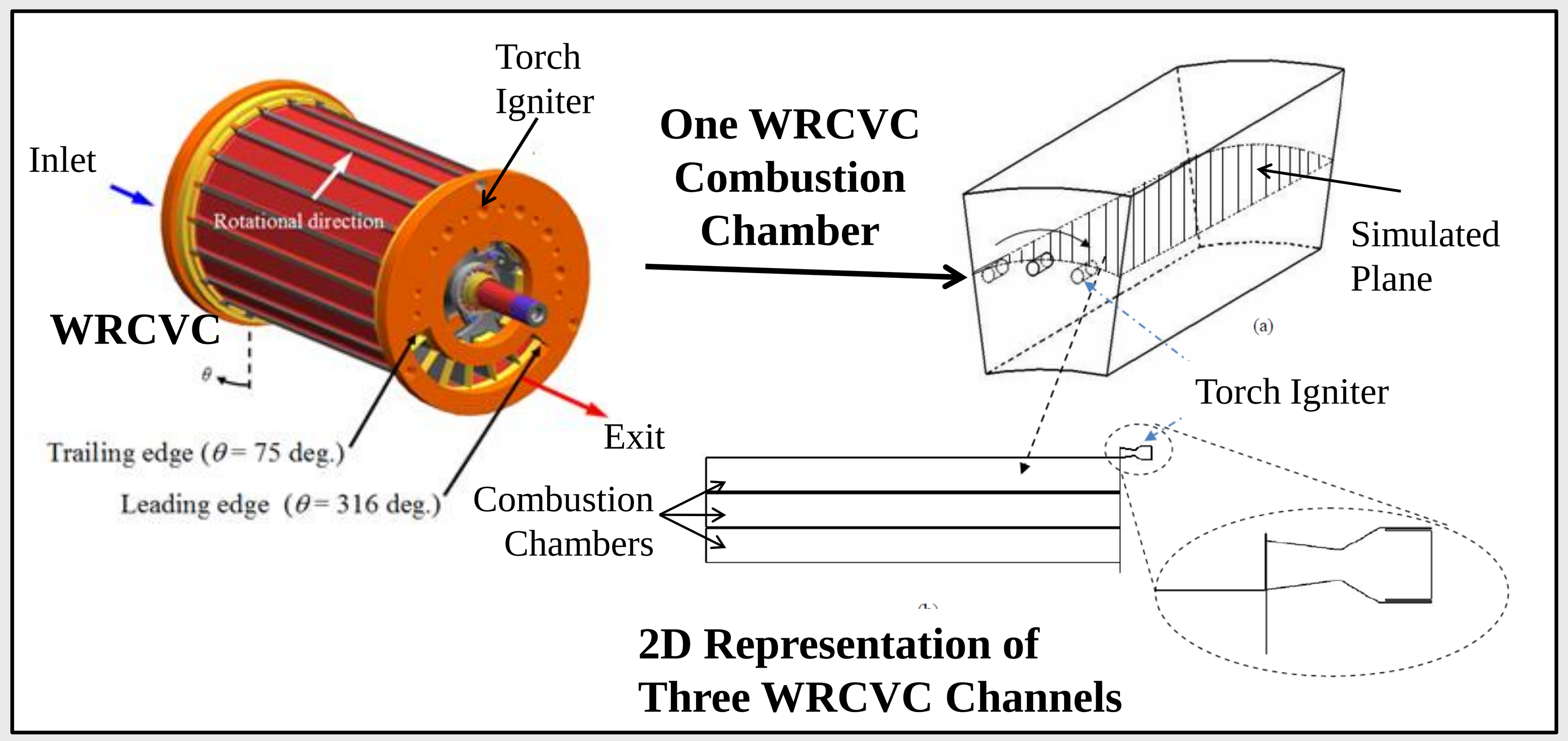


Ignition by Hot Gas Jets

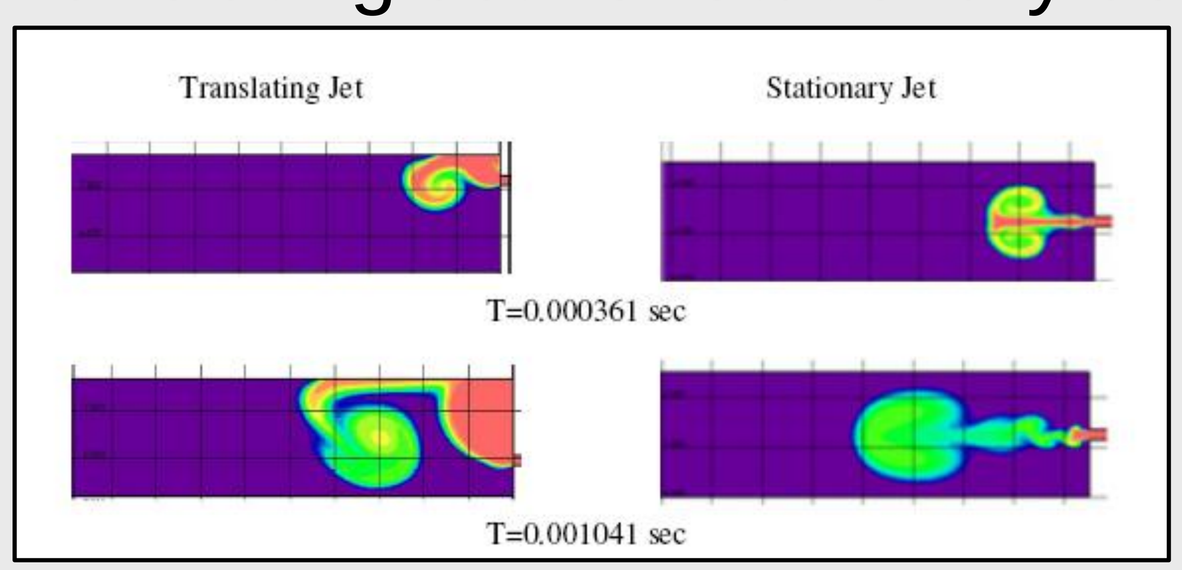
- Applications: Fire and explosion safety in mines, IC engines with pre-combustion chambers, WRCVCs
- Governed primarily by the mixing process
- Depends on the dimensions, composition and velocity of the hot gas jet

Problem Setup: Hot Gas Injection in WRCVC

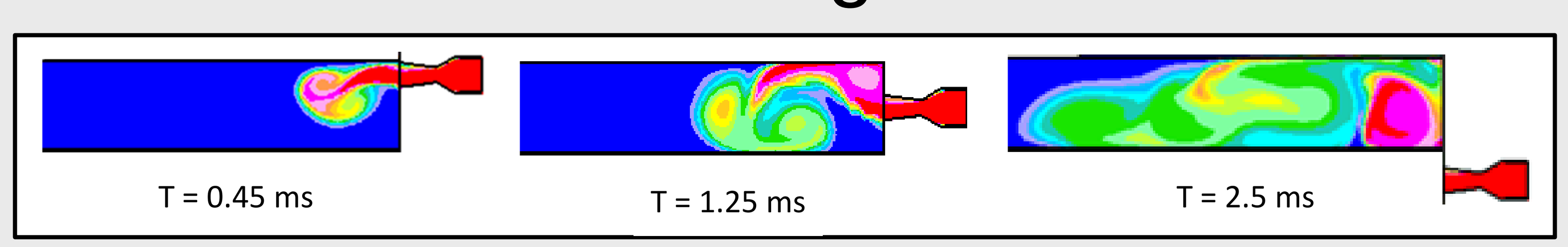
- 2-D analysis of the hot gas injection in to WRCVC channels
- Solved for gas mixing simulations, without chemical modeling
- Used empirical correlations to model ignition delay time



Translating Jet vs. Stationary Jet

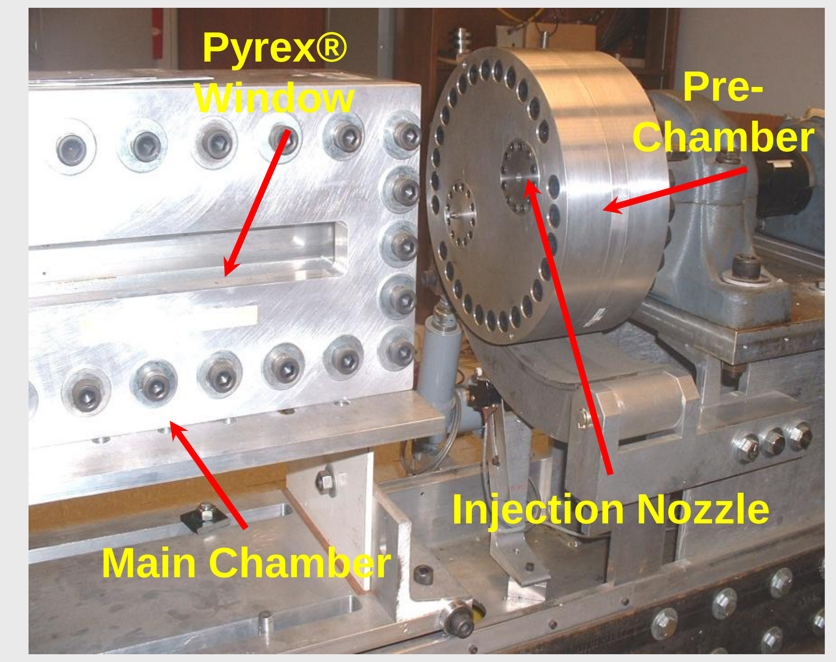


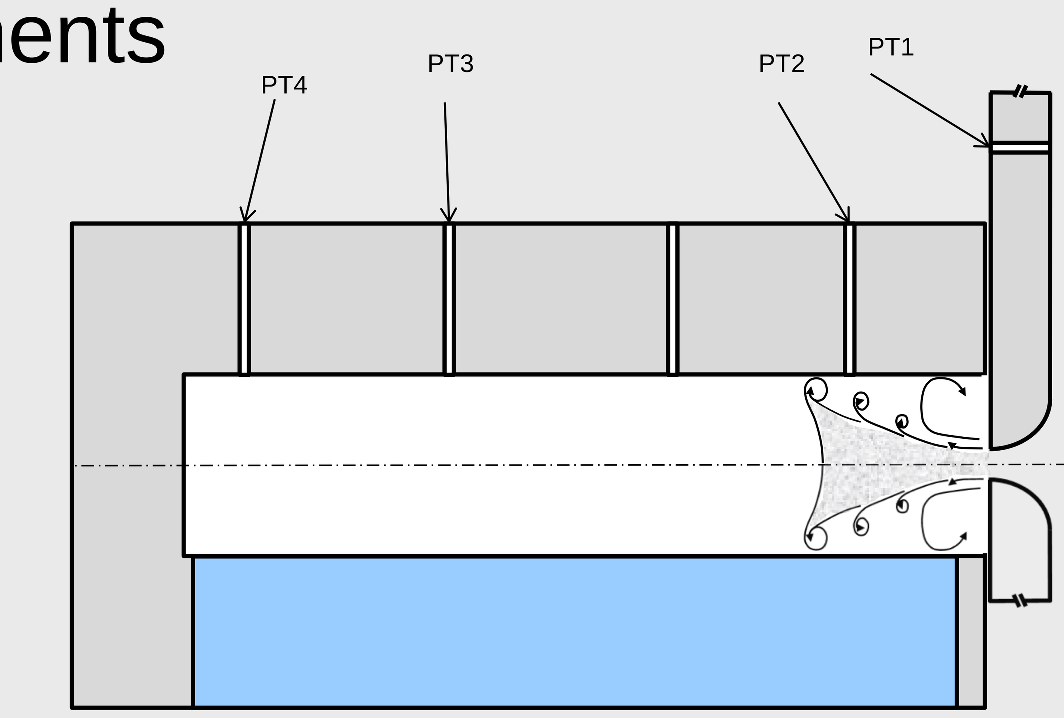
Hot Gas Jet Modeling



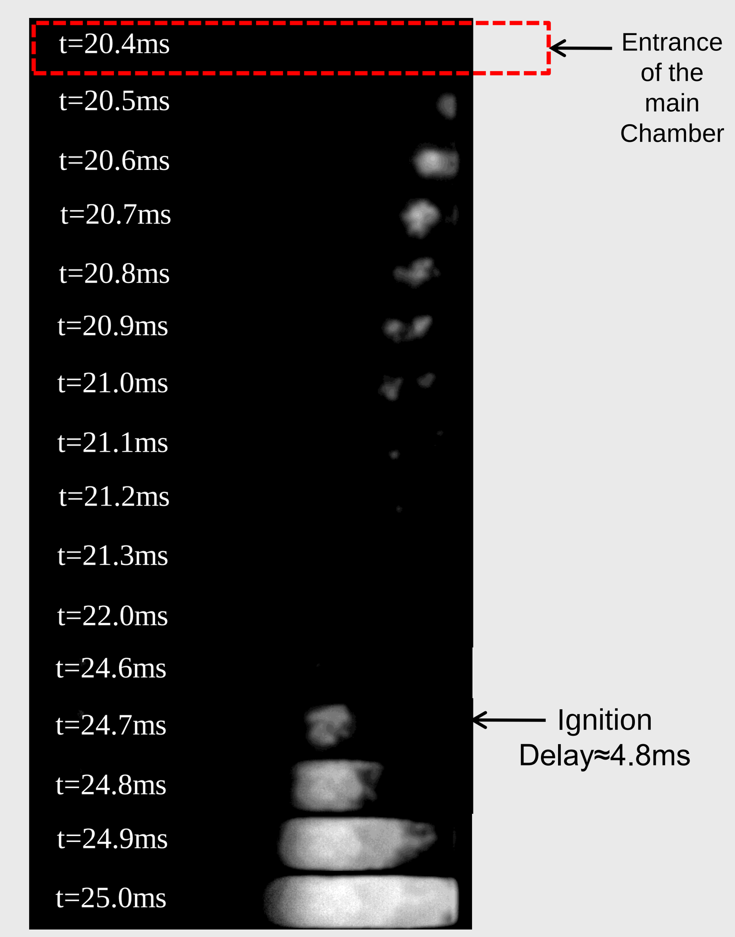
- Increasing jet momentum increases jet penetration
- Higher jet penetration resulted in higher ignition delay times due to higher cold combustible entrainment
- Ignition delay time depends on fuel type and equivalence ratio

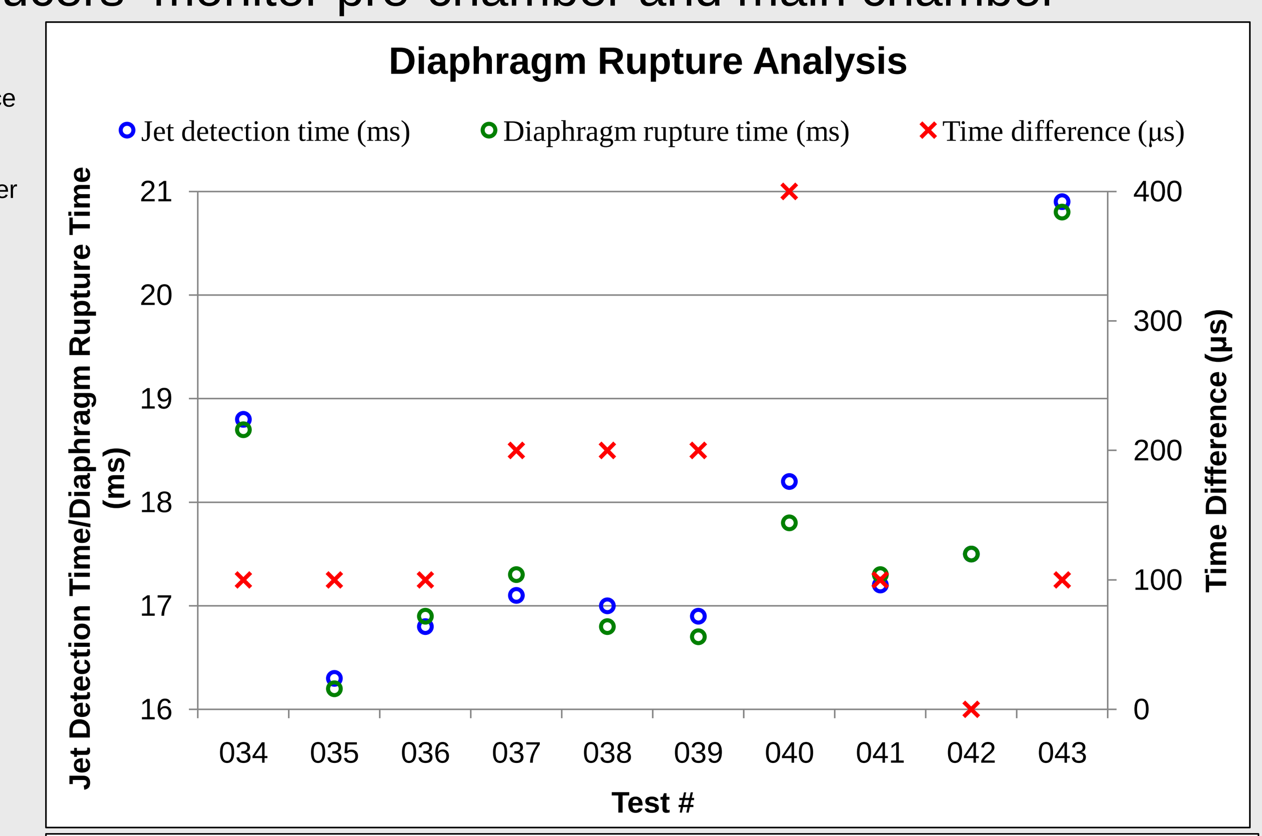
Hot Jet Ignition Experiments

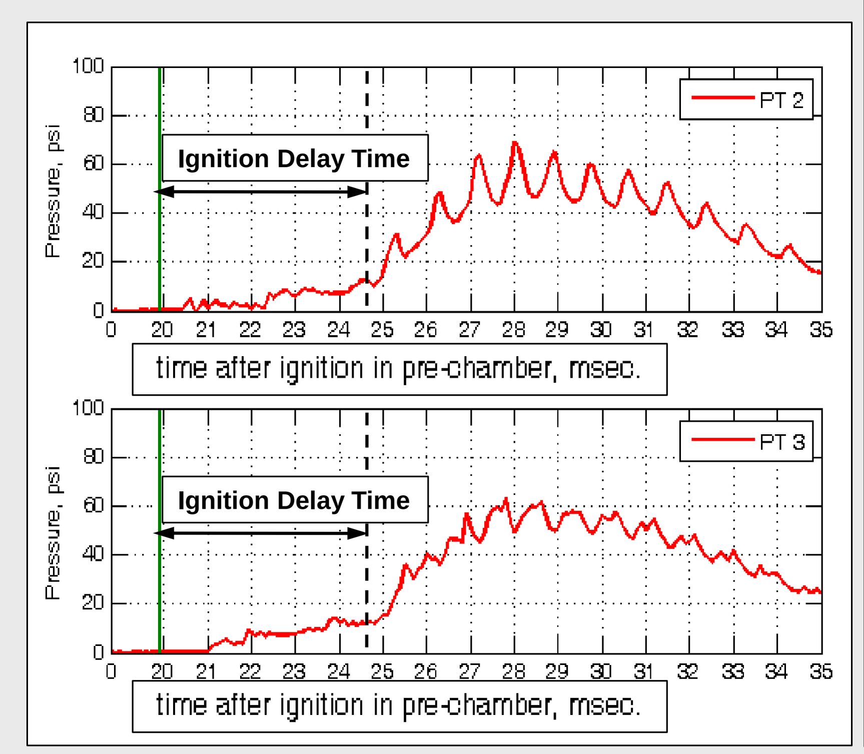


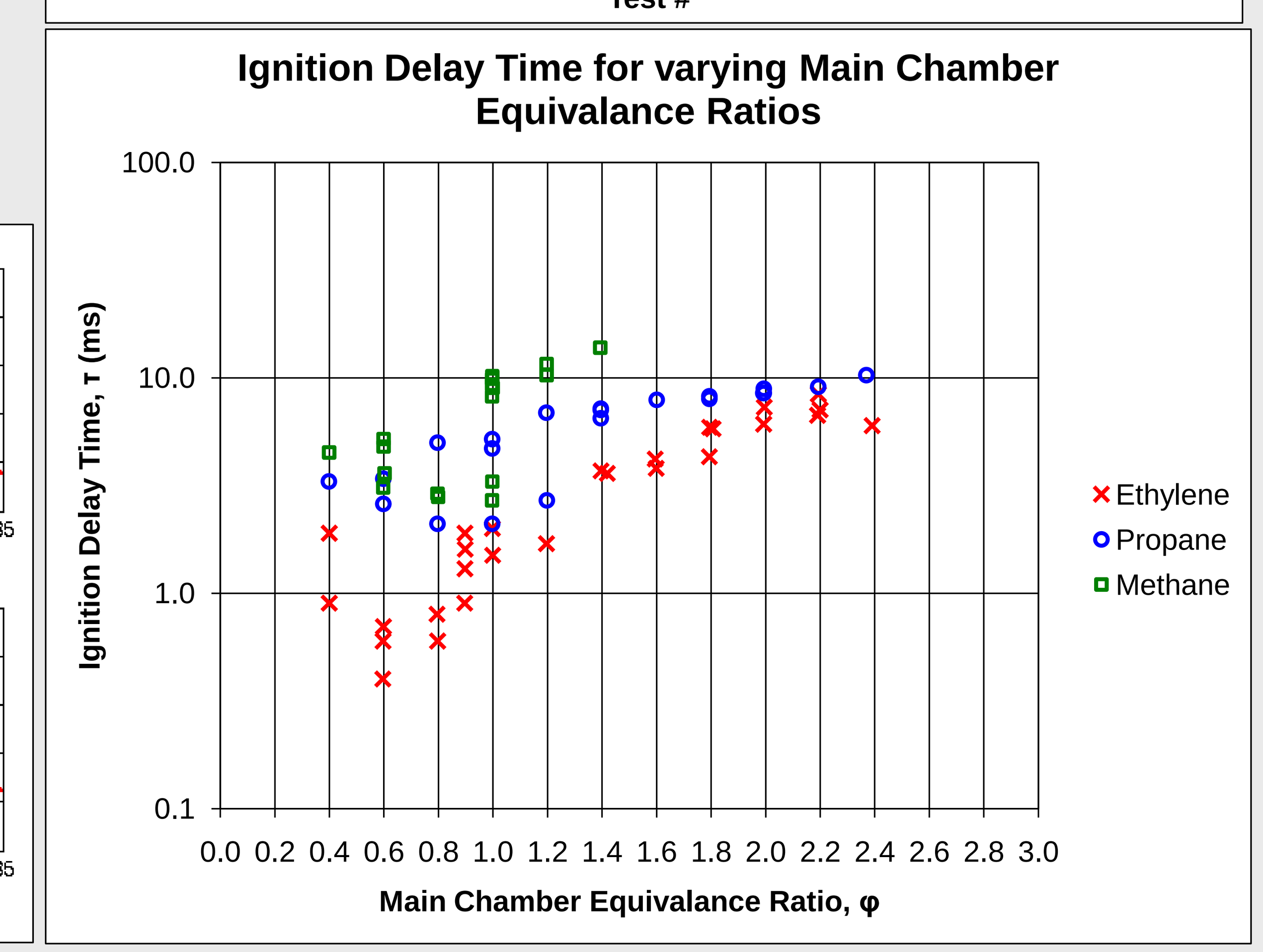


- Pre-chamber burns ethylene with air, φ=1.1
- Main chamber fuel mixtures varied, φ from 0.2 to 3.0
- High-speed camera images ignition and combustion
- Dynamic pressure transducers monitor pre-chamber and main chamber









Acknowledgements

- Rolls-Royce North American Technologies Inc. (LibertyWorks®)
- Computer Networking Center (CNC), IUPUI.

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TRANSPORTATION ACTIVE SAFETY INSTITUTE

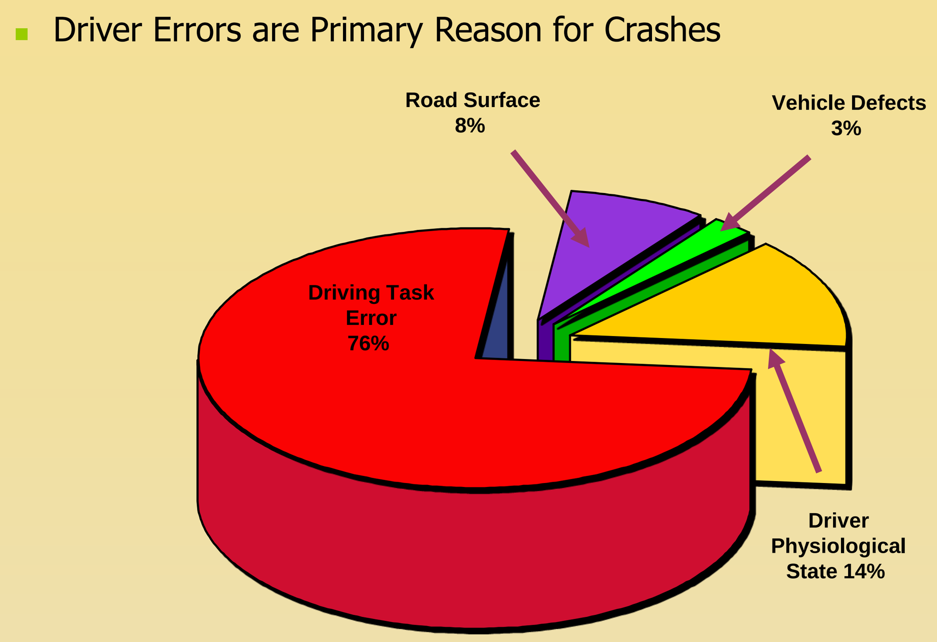
Director: Yaobin Chen, Associate Director: Sarah Koskie

TASi
Transportation Active Safety Institute

Mission

Our mission is to advance the use of active safety systems to reduce vehicle crashes and save lives.

Need For Active Safety



Driver Error accounts for about 76% of all automobile crashes.

Research Focus

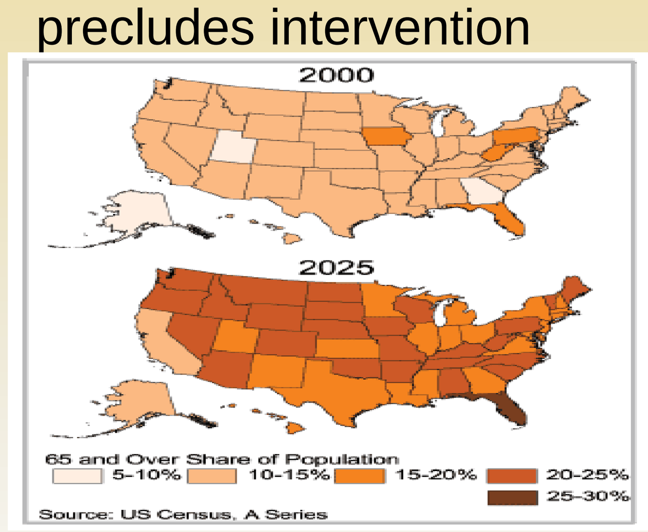
- Accident Data-Mining
  - Benefit/cost analysis
  - Accident/field data analysis
- New Senors and Algorthms
- Human Factor/Biomechanics
- Testing Protocols/Standards
- Evaluation/Validation
  - Human machine interface
  - Field operation tests
- Testing Methodology
  - Lab/bench tests
  - Closed-course test track
  - On-road tests

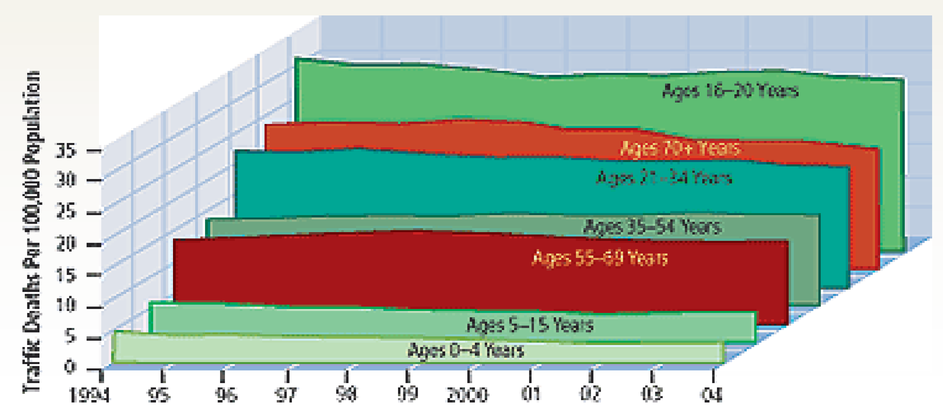
Research Projects

- SHRP2 Strategic Highway Research Program – naturalistic driving study – 150 vehicles (Transportation Research Board)
- Fatigue and Sleep-Deprived Driving (Industry)
- Data Analysis And Mining Of Crash Data (Industry)
- Accident Benefit Analysis for Active Safety Systems (Internal)
- Human Factors For Semi-Autonomous Driving (USDOT)
- Assessment of Older/Teen Driver Safety (Internal)
- Alcohol Sensing and Sensor Testing/Evaluation (Internal)
- Comparative Fuel Economy Study with Adaptive Cruise Control (Internal)
- Fault Tolerance Control for Automatic Parking Systems (Internal)
- Relationship of Brake Reaction Time and Driving Safety (Industry)

Insuring Older Driver Safety

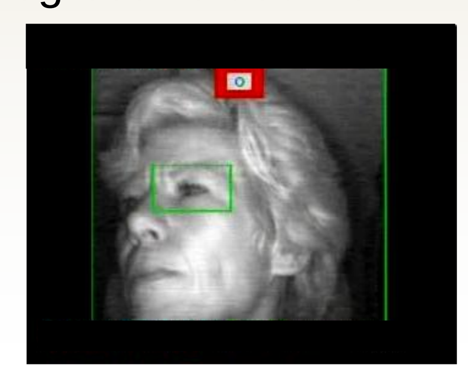
Problems
- Aging US population
- Aging process negatively impacts visual, cognitive and physical skills needed for driving
- Lack of standardized driver assessment precludes intervention





Goals
- Maintaining older drivers' independence without compromising overall road safety
- Identifying at-risk drivers

Research Objectives
- Develop and validate objective driver assessment measures
- Investigate adapting safety systems to support older drivers
- Develop technologies to monitor driving performance and its progressive decline

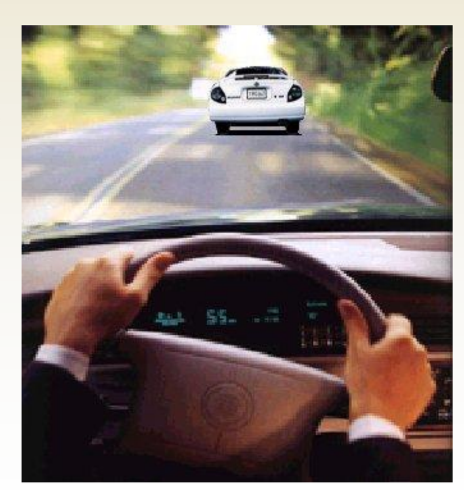


Human Factors For Semi-Autonomous Driving Systems

Goal
- Address a critical technology and knowledge gap that prevents the near-term availability of vehicles with limited-ability autonomous driving capability

Objectives
- Identify effective mechanisms for interaction between driver and automation
- Identify potential misconceptions and misappropriations
- Develop countermeasures to avoid them

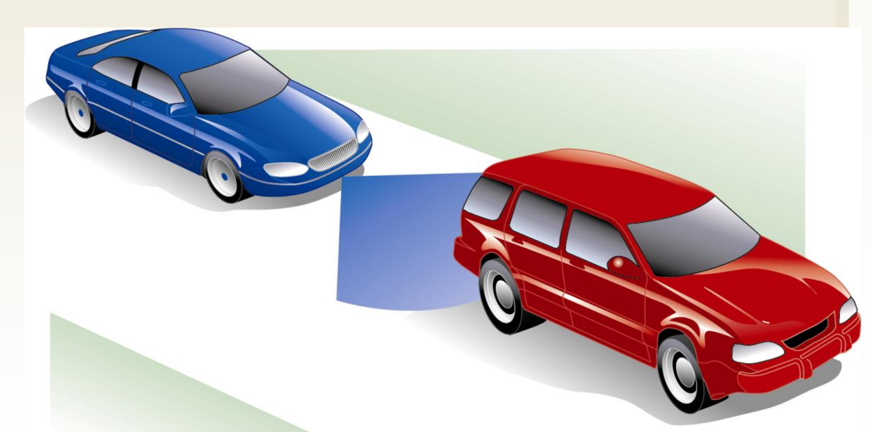
Approach
- Driving simulator experiments
- Test track experiments
- Road test experiments



Human Factors

Lane Keeping

Adaptive Cruise Control



Reseach Facilities and Labs

Driving Simulator Laboratory

- DS-600c Driving Simulator

- Compumedics Siesta Wireless Diagnostics System
  - EEG, ECG, EMG, EOG, leg and respiratory sensors

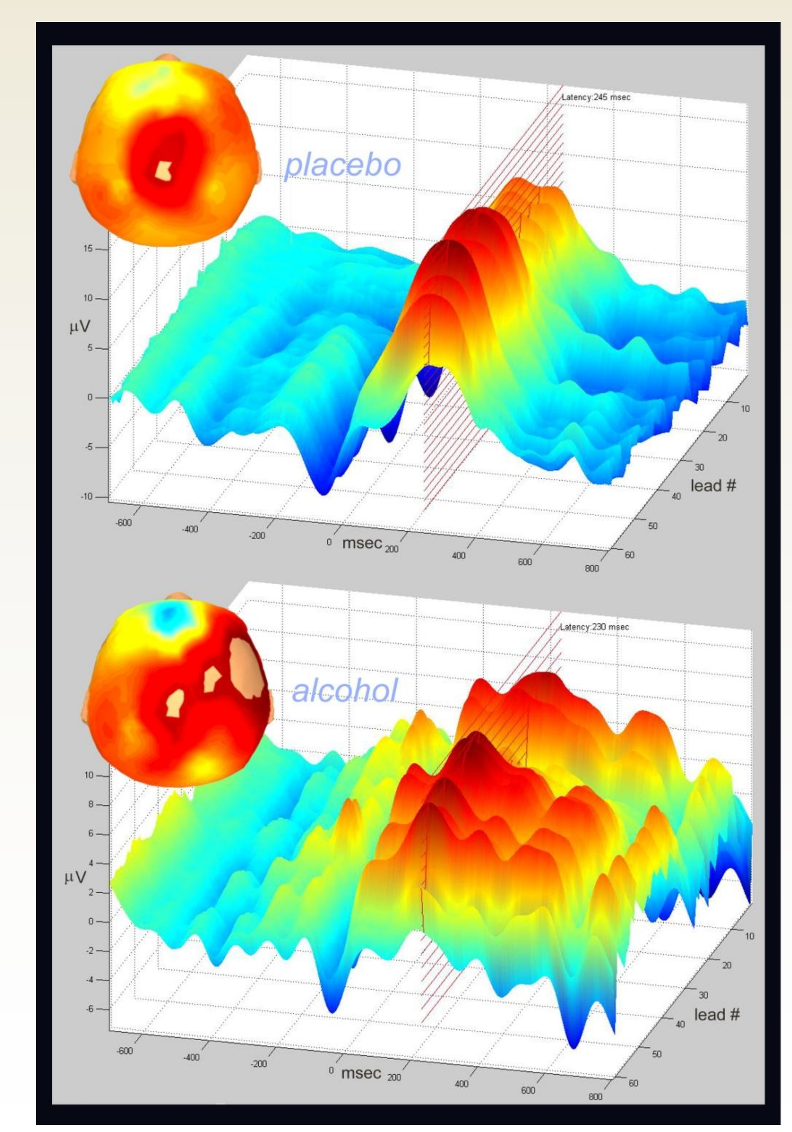
- **Driving Safety and Rehabilitation Research Laboratory (DSRRL)**

- Visual, cognitive, behavioral and sensory assessment technologies

- **Alcohol Sensor Testing Laboratory**

NSL Stop-Signal ERP before and after alcohol

- Event-related potentials are the brain's electroencephalographic signature of responses to repeated stimuli that are important and novel.
- This rendering shows the ERP of the brain's effort to withhold a reflexive response from an individual before and after his brain was exposed to a constant alcohol concentration of 60 mg%, three-quarters of the legal limit for driving in Indiana.



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Wave-Rotor Constant-Volume Combustor

Tarek Elharis, Sameera Wijeyakulasuriya & M. Razi Nalim

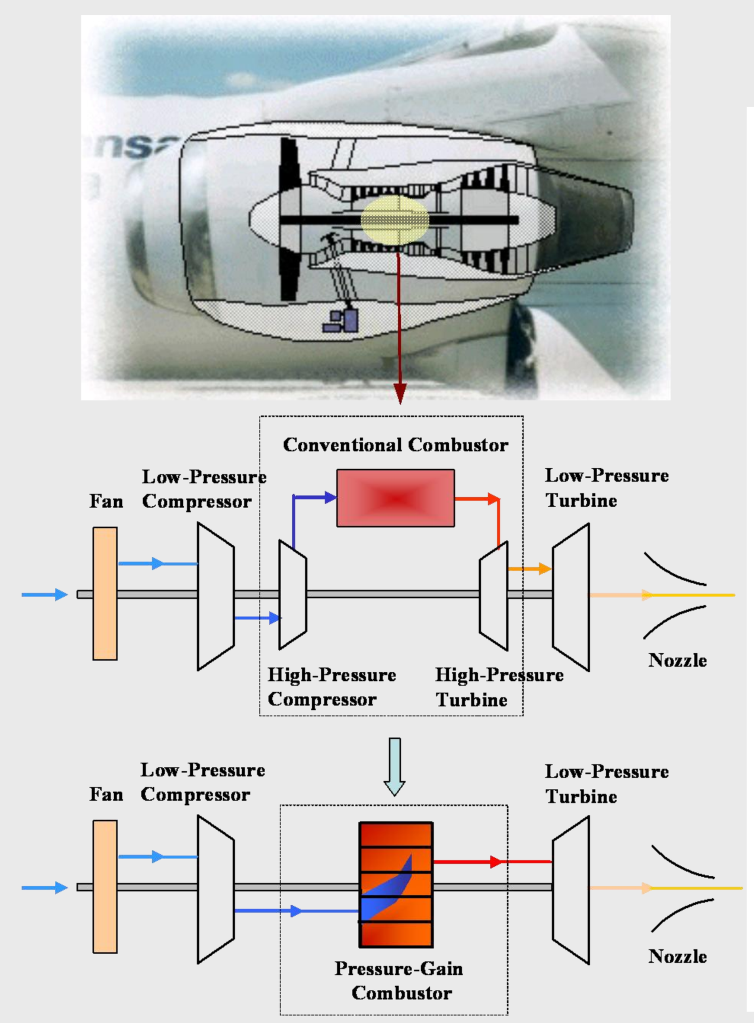
Introduction to the WRCVC

The Wave-Rotor Constant-Volume Combustor (WRCVC) is a new concept for efficient combustion engines for power plants and transportation. By rotation, its chambers:

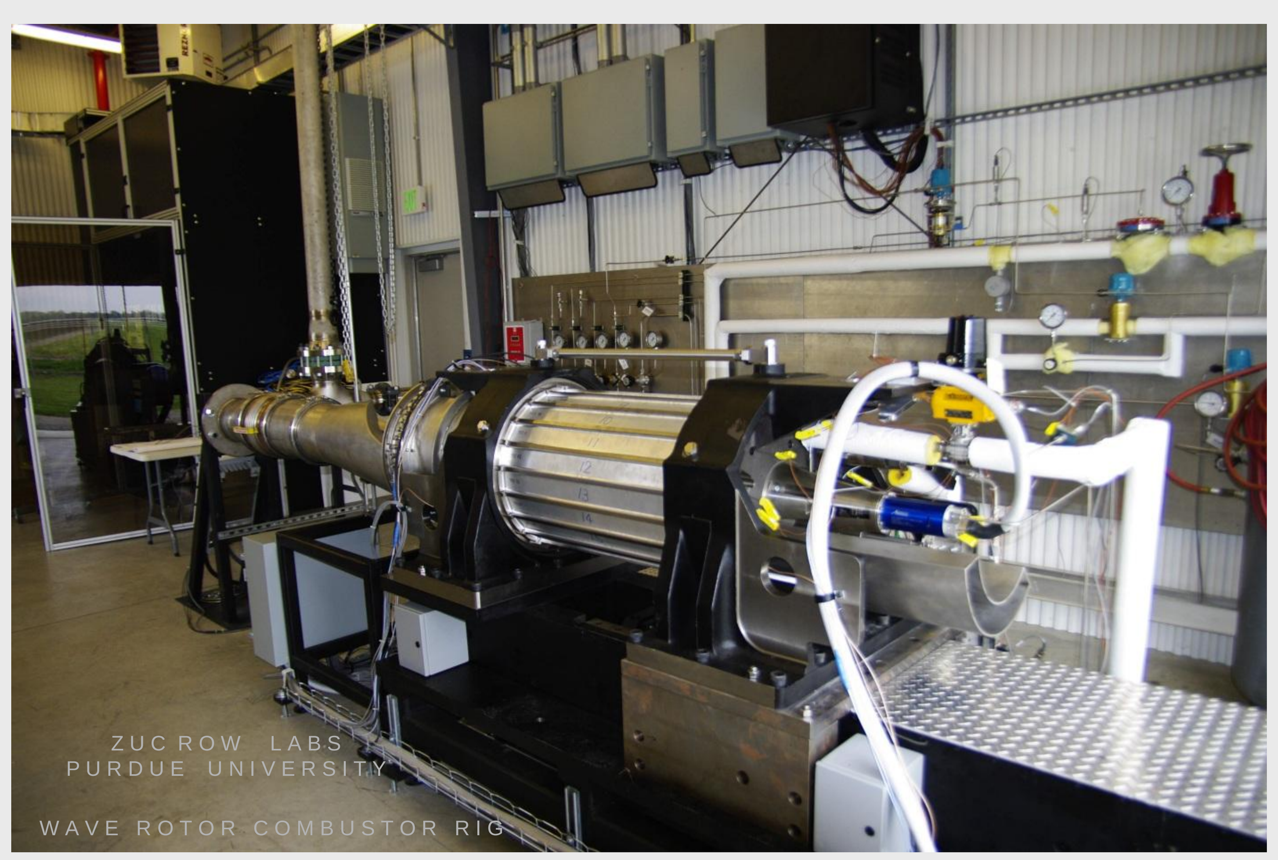
- Generate high pressure by burning a confined gas mixture
- Deliver working gas with higher pressure than conventional gas turbine and jet engines
- Receive fresh combustible mixture in stratified layers

Application Benefits

- Gas turbine engines with lower weight, higher output power, lower fuel consumption, lower CO_2 emissions and other pollutants.
- Novel engines with gas compression, combustion, expansion, power shaft, all in one moving part.
- Small-scale engines for UAV, soldier, and portable device applications
- New propulsion systems



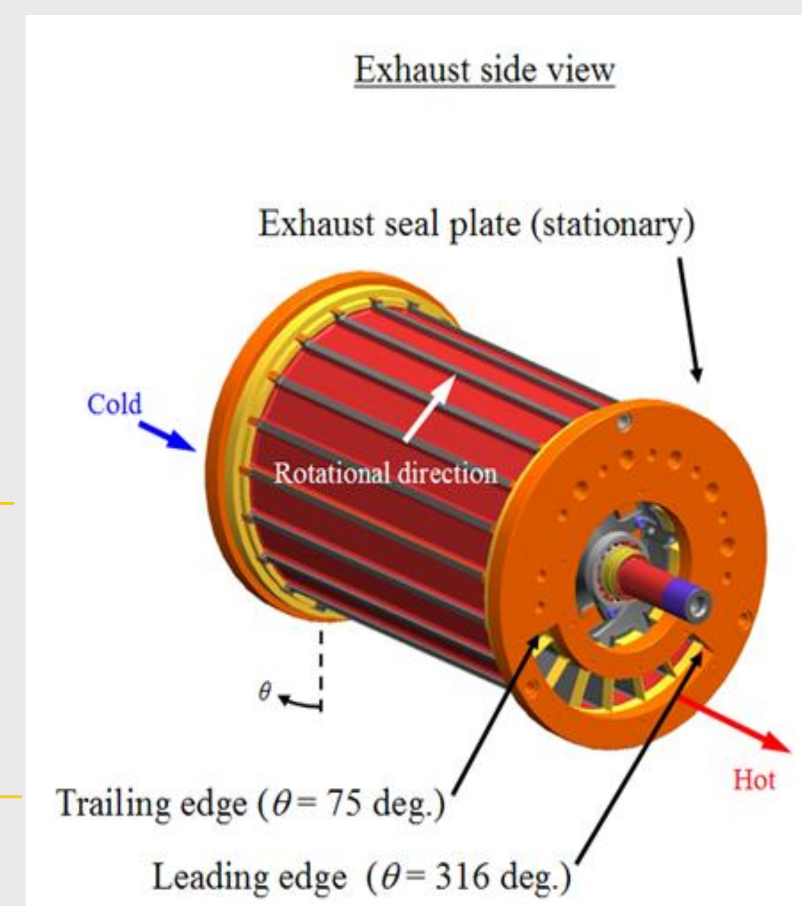
WRCVC for gas turbine and aircraft engines

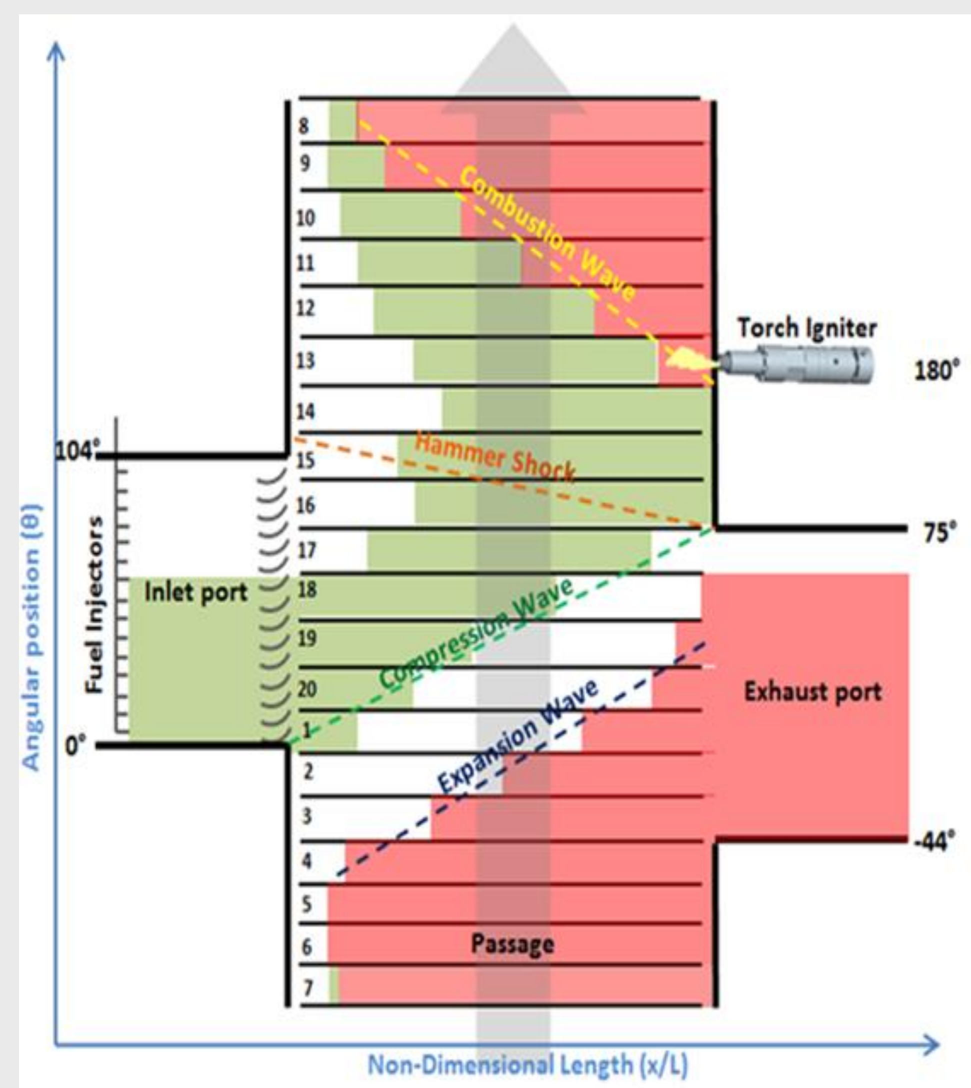


Wave-rotor constant-volume combustor rig at Purdue Zucrow Labs

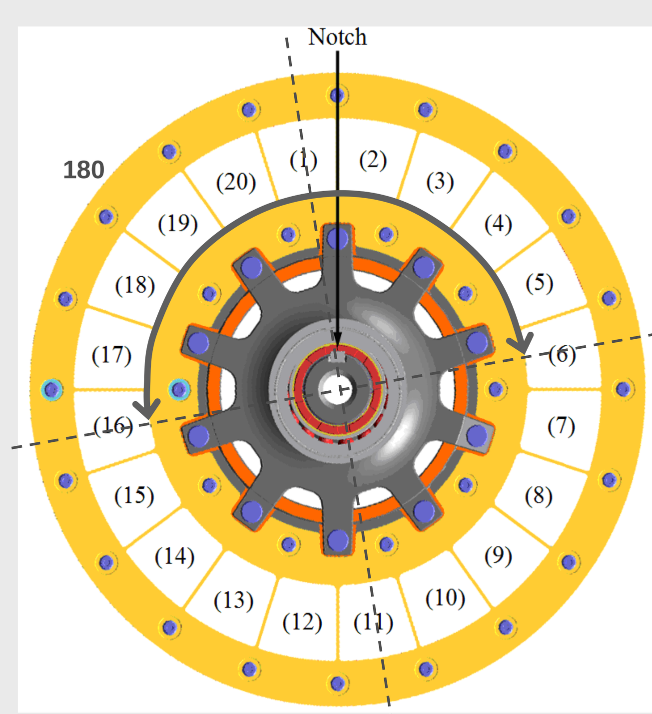
Wave Dynamics

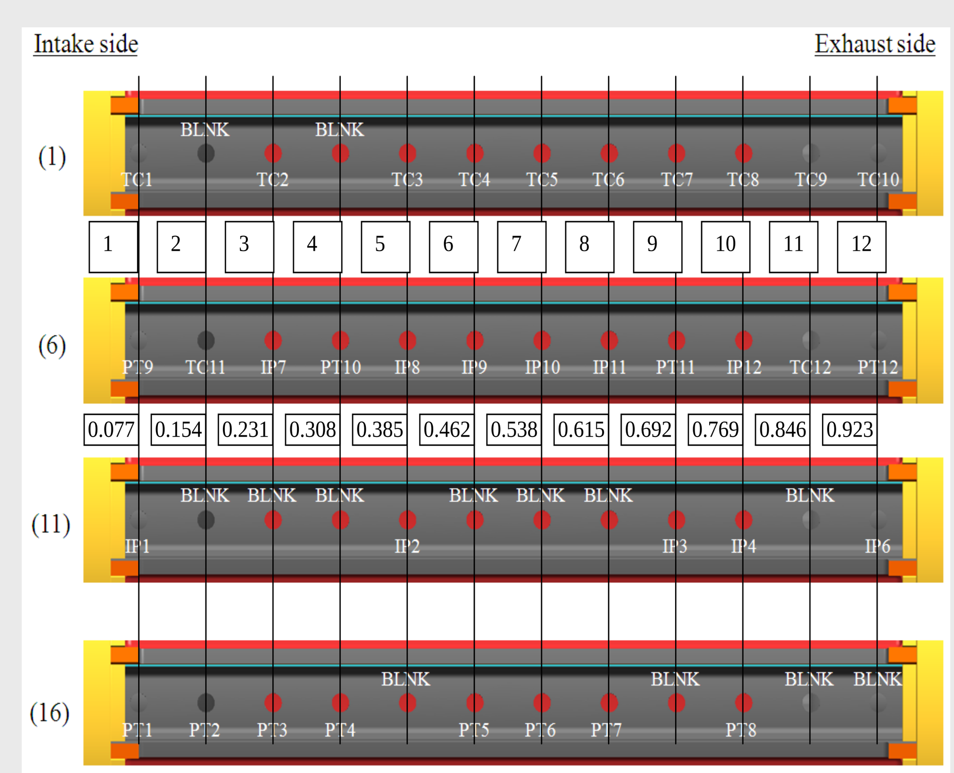
- Continuous high pressure hot exhaust gas delivered from combustor passages to turbine or nozzle.
- Air-fuel mixture flows in at high speed and comes to a sudden stop in the channel, generating compression.
- Mixture is trapped in closed volume, and burning generates pressure, unlike an open or continuous flame.
- Combustion is initiated by hot gas from another channel or a torch igniter





Rotor assembly with stationary seal plates [L] Developed view [R]

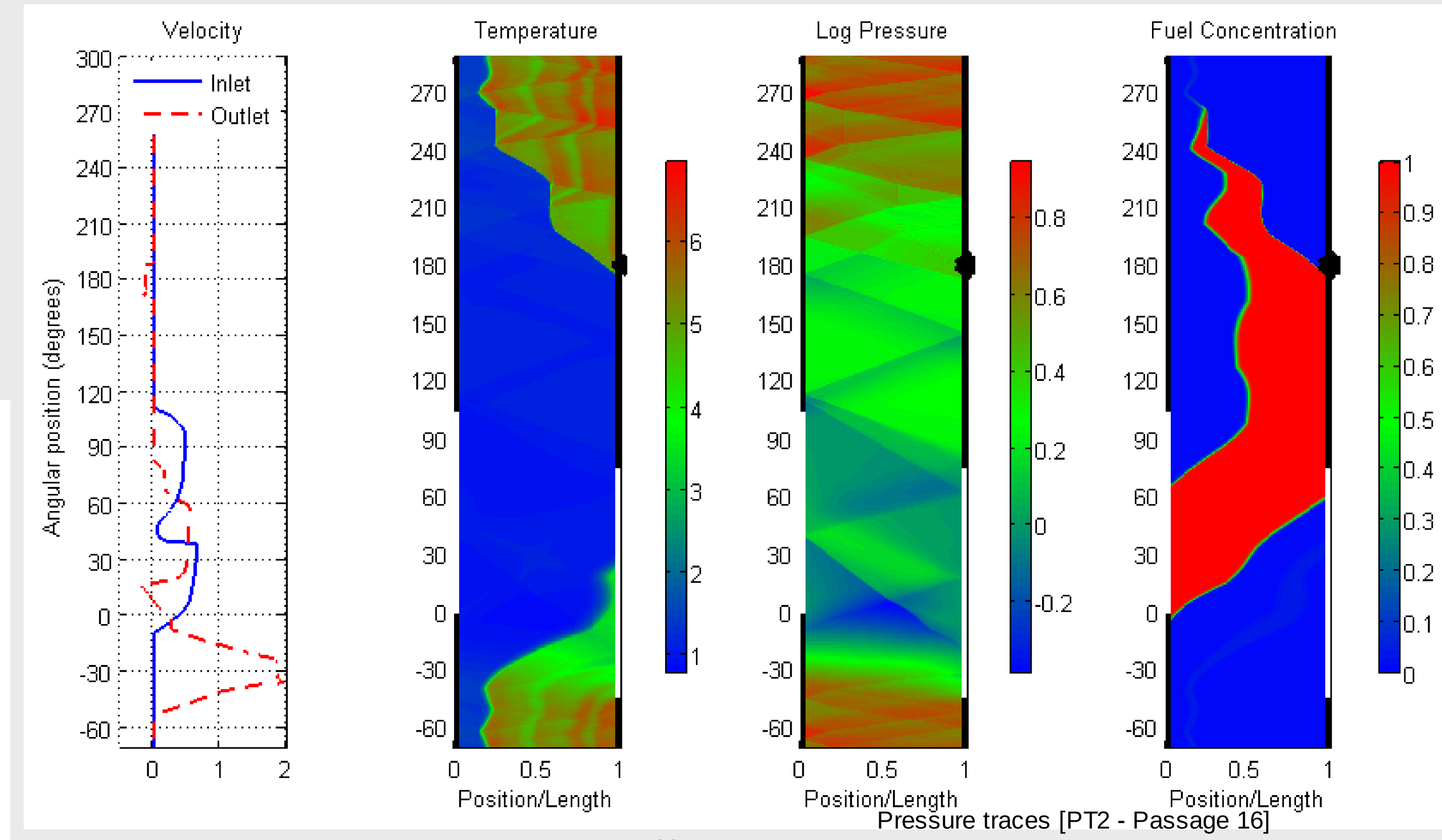


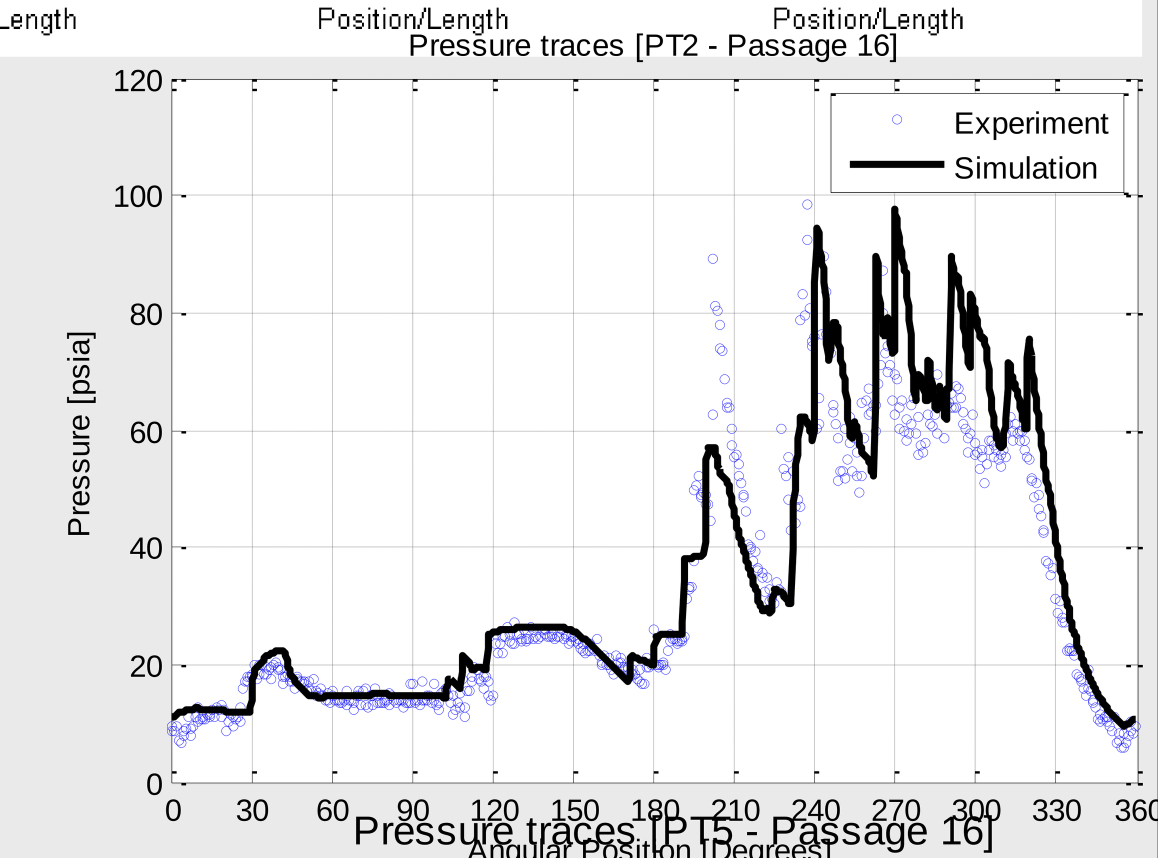


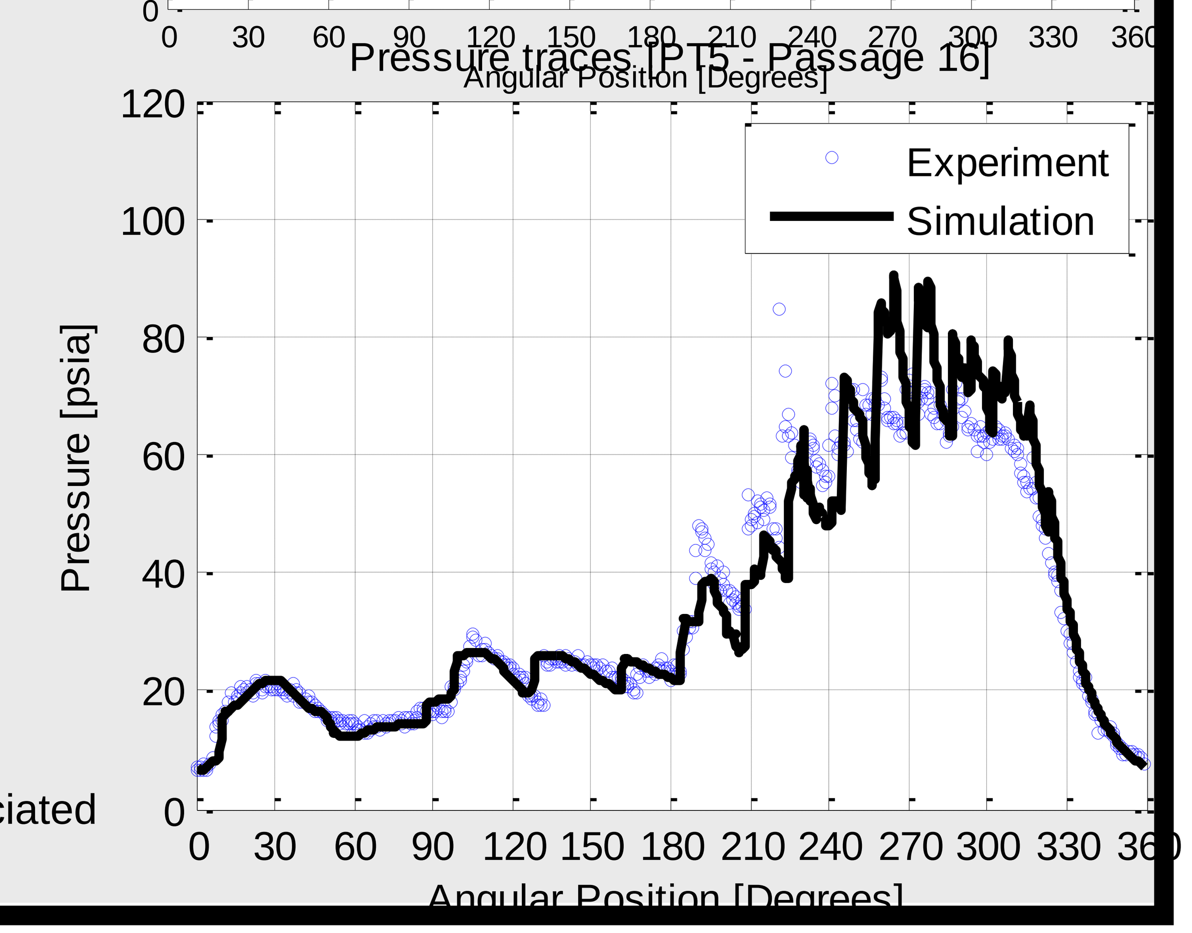
Instrumentations set-up on rotor (Pressure, Temperature, Flame sensing)

Simulation & Experiment

Measurements by fast pressure transducer match predictions







- Successful combustion achieved on rotor
- Combustion mode tested indicated rapid deflagration
- Predictions from simulations match the experimental data
- Flame and ignition are simulated with a phenomenological model
- Passage to passage leakage effect are evident, and may be reduced with tighten clearances

Acknowledgments

Support from Rolls-Royce North American Technologies Inc., LibertyWorks® is appreciated

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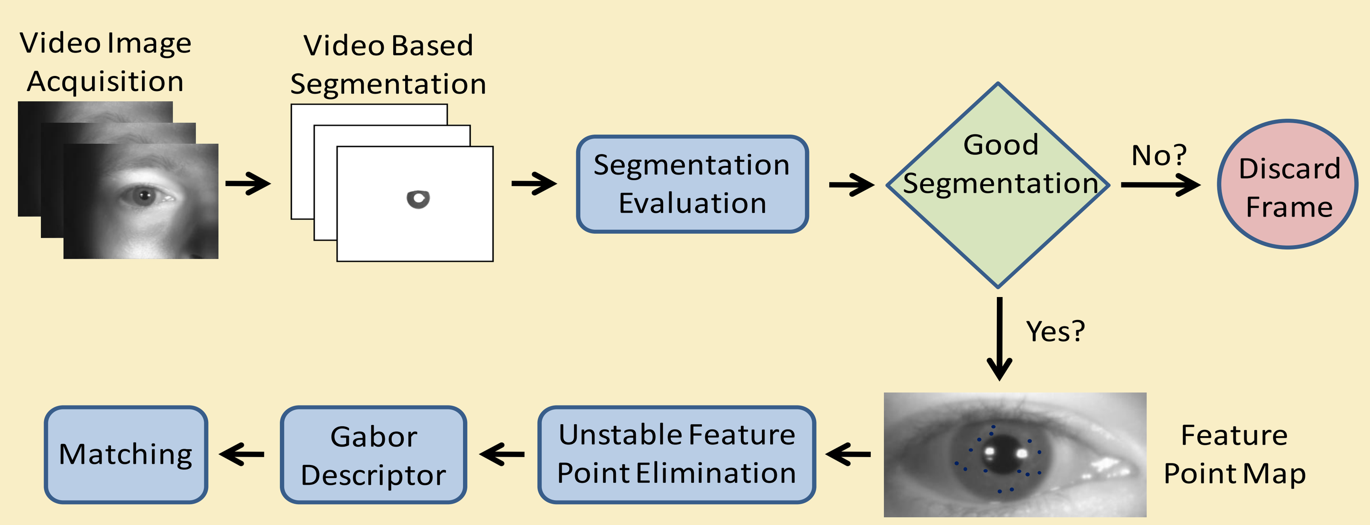
Biometrics for Homeland Security

Dr. Eliza Du, Zhi Zhou, Kai Yang, Luke Thomas, Craig Belcher, and Emrah Arslanturk
Pattern Recognition and Biometrics Laboratory
Department of Electrical and Computer Engineering
Indiana University-Purdue University Indianapolis

Non-cooperative Iris Recognition System

- The state-of-the art systems cannot perform off-angle iris recognition
- It is even more challenging to perform non-cooperative iris recognition
- We proposed & designed the world first non-cooperative iris recognition system

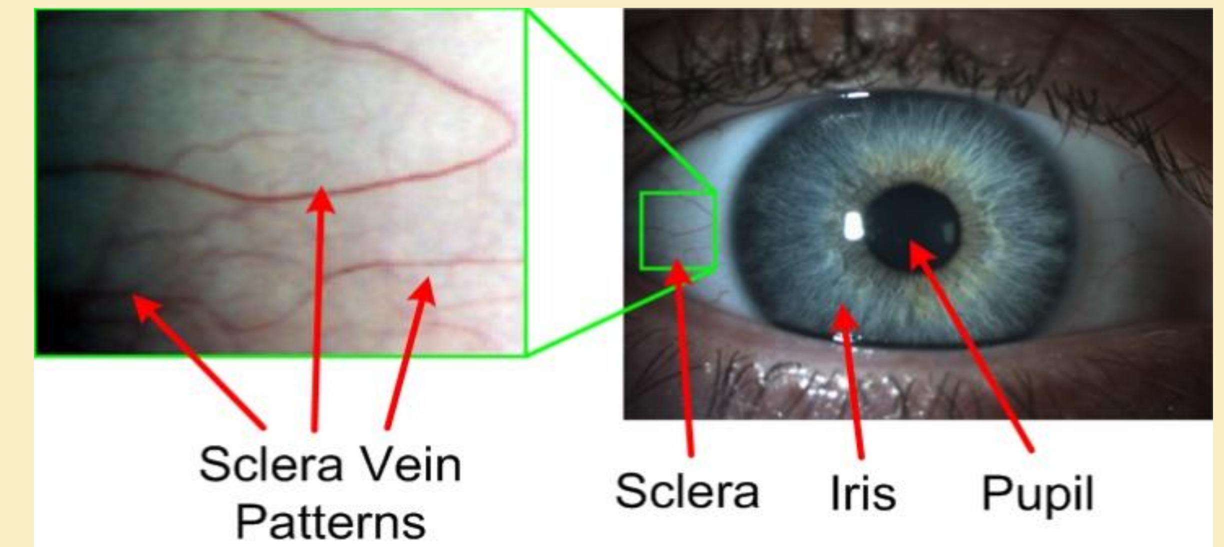


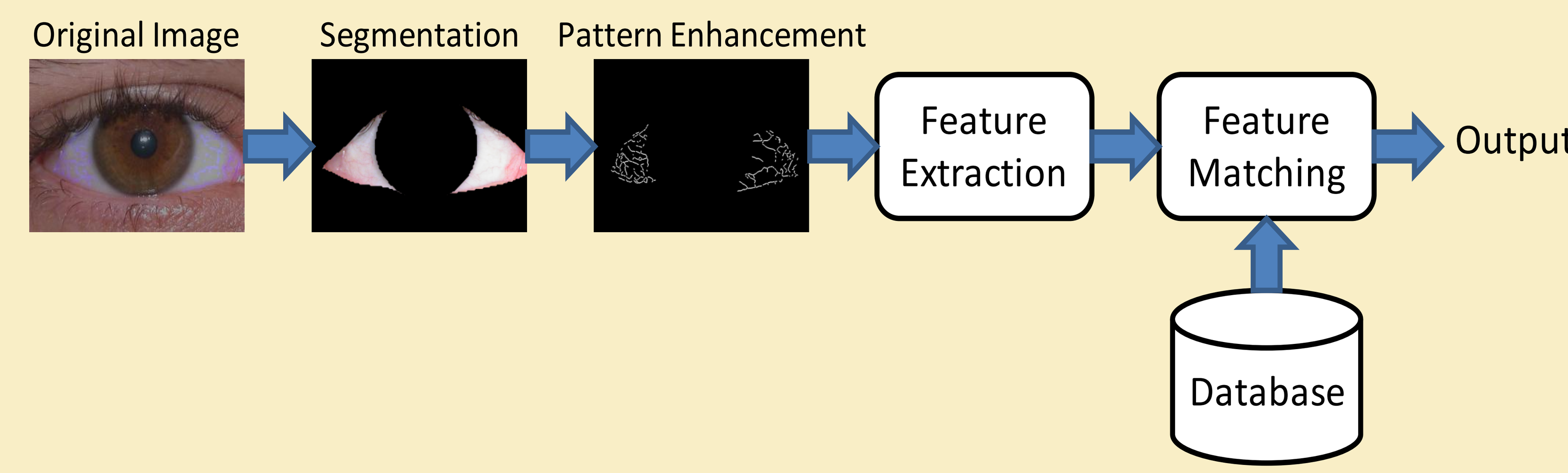
Our related publications:

1. Y. Du, C. Belcher, Z. Zhou, "Scale Invariant Gabor Descriptor-based Noncooperative Iris Recognition", EURASIP Journal on Advances in Signal Processing, 2010.
2. C. Belcher and Y. Du, “Region-based SIFT approach to iris recognition,” Optics and Lasers in Engineering, vol. 47, no. 1, 2009, pp. 139-147.
3. Y. Du, E. Arslanturk, Z. Zhou, and C. Belcher, “Video-based Non-cooperative Iris Image Segmentation,” IEEE Trans. On Systems, Man, and Cybernetics, Part B, 2010 (in press)

Sclera Recognition System

- Iris recognition system would not work very well under visible wavelengths since iris patterns in dark and brown eyes are hard to be extracted in visible lights.
- We proposed a new concept for human identification: sclera recognition. The sclera patterns i can be obtained non-intrusively in the visible wavelengths.
- Our proposed sclera recognition system is a line-descriptor based feature extraction, registration, and matching method that is illumination-, scale-, orientation-, and deformation-invariant, and can mitigate the multi-layered deformation effects and tolerate segmentation error.





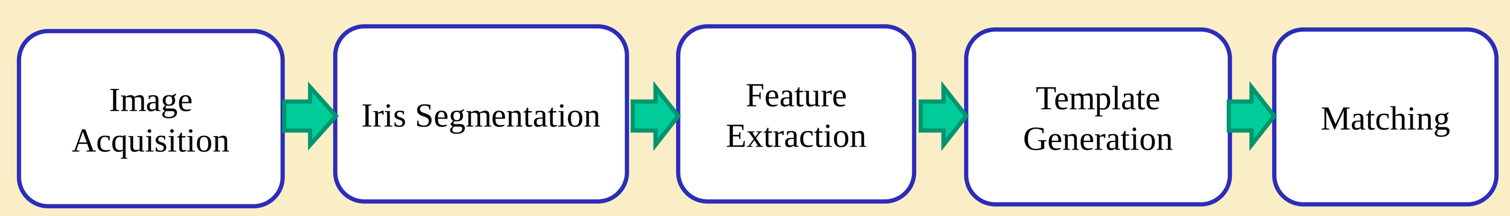
Our related publications:

1. N. Thomas, Y. Du and Z. Zhou, “A new approach for sclera vein recognition,” SPIE Symposium on Defense, Security + Sensing, vol. 7780 pp. 770805-1-770805-10, 2010.
2. Z. Zhou, Y. Du, N. Thomas and E. Delp, “Multimodal eye recognition,” SPIE Symposium on Defense, Security + Sensing, vol. 7780 pp. 770806-1-770806-10, 2010.
3. Z. Zhou, Y. Du, N. Thomas and E. Delp, “A New Human Identification Method: Sclera Recognition ,” IEEE Trans. On Systems, Man, and Cybernetics, Part B, 2010 (submitted)

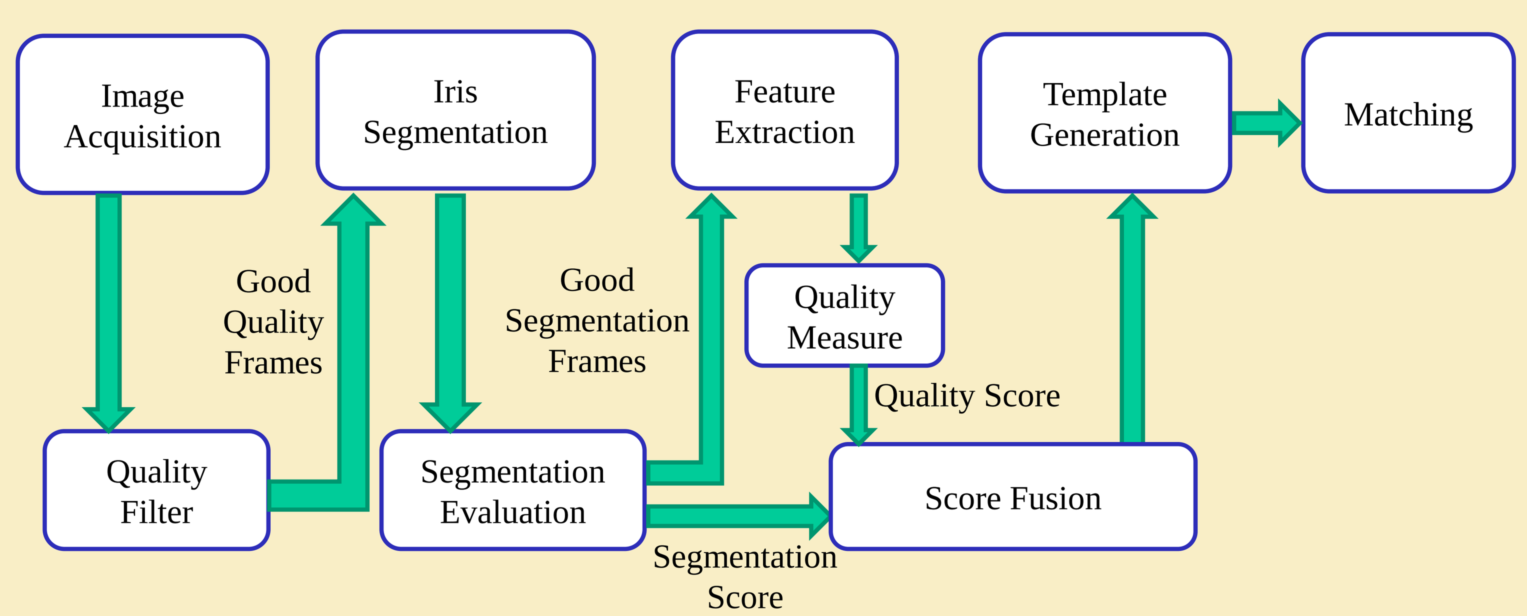
Transforming Traditional Iris Recognition Systems to Work on Non-idea Situations

- The traditional iris recognition systems would not work well under a non-ideal situation,
- It will be desirable to transform the traditional systems to perform in non-ideal situations without a costly update.
- We propose a method that upgrades the traditional iris recognition system to work on non-ideal situations. It employs video-based image processing techniques to quickly identify and eliminate the bad quality images from iris videos for further processing.

Traditional Iris Recognition System



Our Proposed Iris Recognition System



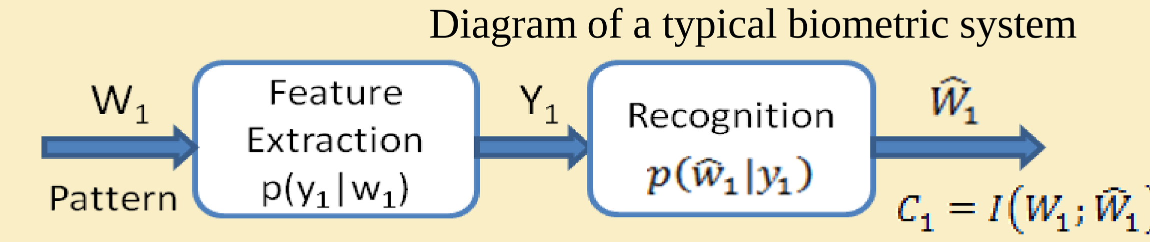
Our related publications:

1. Y. Du, C. Belcher, Z. Zhou, and R.W. Ives, “Feature Correlation Evaluation Approach for Iris Image Quality Measure,” Signal Processing, 90(4), 1176-1187, 2010.
2. Z. Zhou, Y. Du and C. Belcher, “Transforming traditional iris recognition systems to work in nonideal situations,” IEEE Trans. Ind. Electron, vol. 56, no. 8, 2009, pp. 3203-3213.
3. C. Belcher, and Y. Du, “A Selective Feature Information Approach for Iris Image Quality Measure,” IEEE Transactions on Information Forensics and Security, 3(3), 572-577, 2008.

Key Incorporation Scheme for Cancelable Biometrics

- Once a biometric pattern is stolen, the user will quickly run out of alternatives and all the applications where the associated biometric pattern is used become insecure.
- Traditional cancelable biometric would reduce the recognition accuracy since this kind of approach treat the transformation process and feature extraction process independently.
- We first theoretically analyzed the limitations of traditional cancelable biometric methods, and proposed the Key Incorporation Scheme for Cancelable Biometrics that could increase the recognition accuracy while achieving “cancelability”.

Diagram of a typical biometric system



Diagrams of two kinds of set of current cancelable biometrics scheme

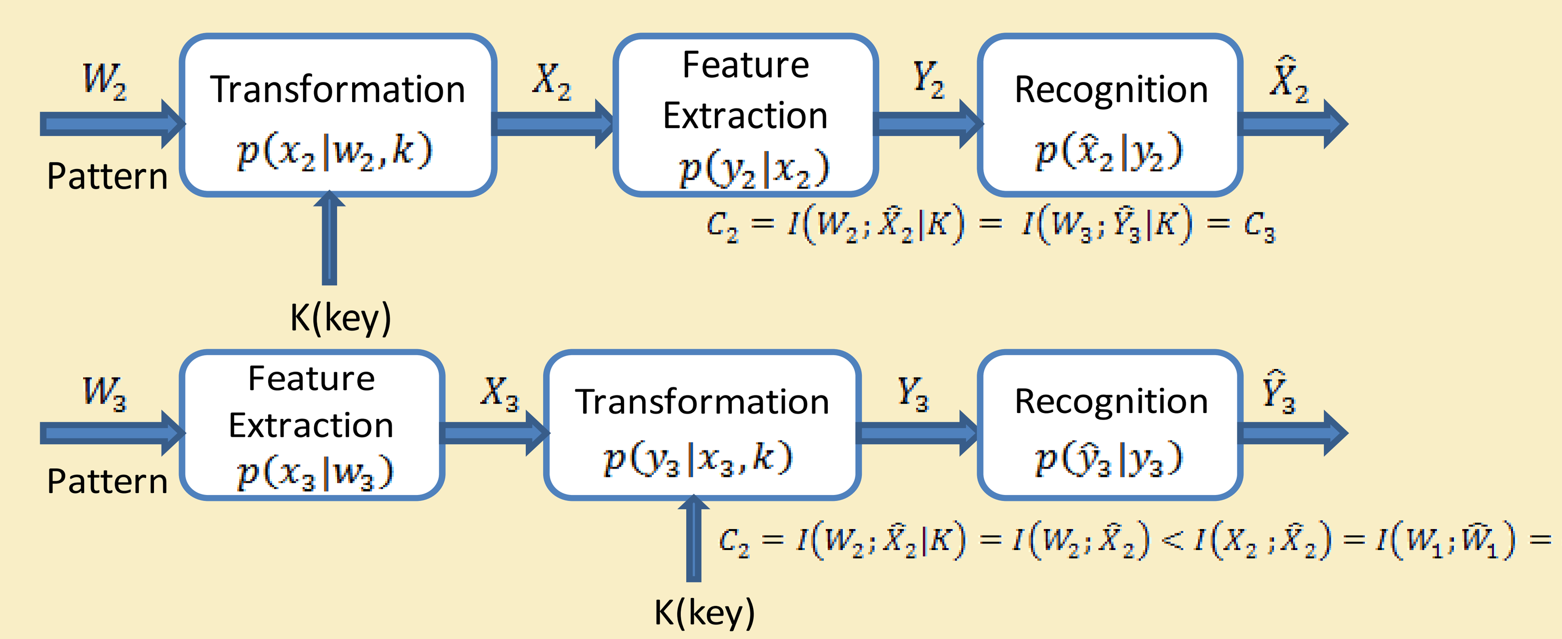
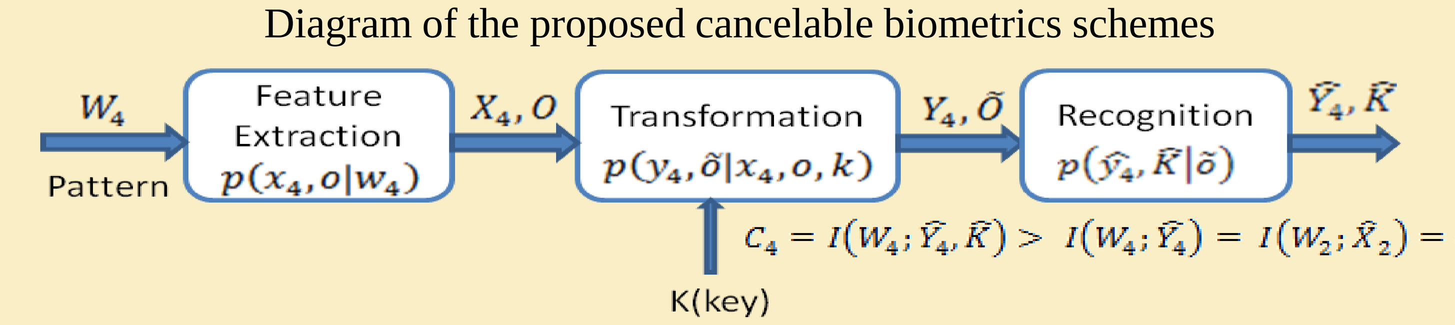


Diagram of the proposed cancelable biometrics schemes



Our related publications:

1. Kai. Y, Y Du, Z. Zhou, and C. Belcher, “Gabor Descriptor Based Cancelable Iris Recognition Method,” Proceedings of IEEE International Conference on Image Processing, 2010 (accepted)
2. K. Yang, Y. Sui, Z. Zhou, Y. Du and X. Zou, “A new approach for cancelable iris recognition,” SPIE Symposium on Defense, Security + Sensing, vol. 7780 pp. 77080A1-77080A8, 2010.
3. Kai. Y, Y Du, Z. Zhou, C. Belcher, and J. Liang, “ Key Incorporation Scheme for Cancelable Biometrics,” IEEE Trans. On Systems, Man, and Cybernetics, Part B, 2010 (submitted)