Industrial Research Chair Control of Oilsands Processes

# NSERC Senior Industrial Research Chair

# in

# Control of Oil Sands Processes

**Chair Holder: Biao Huang, Ph.D., P.Eng, Professor**

Department of Chemical and Materials Engineering
University of Alberta

Document prepared by

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Special thanks to the CPC group members for sharing the summary of their work:

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# Outline

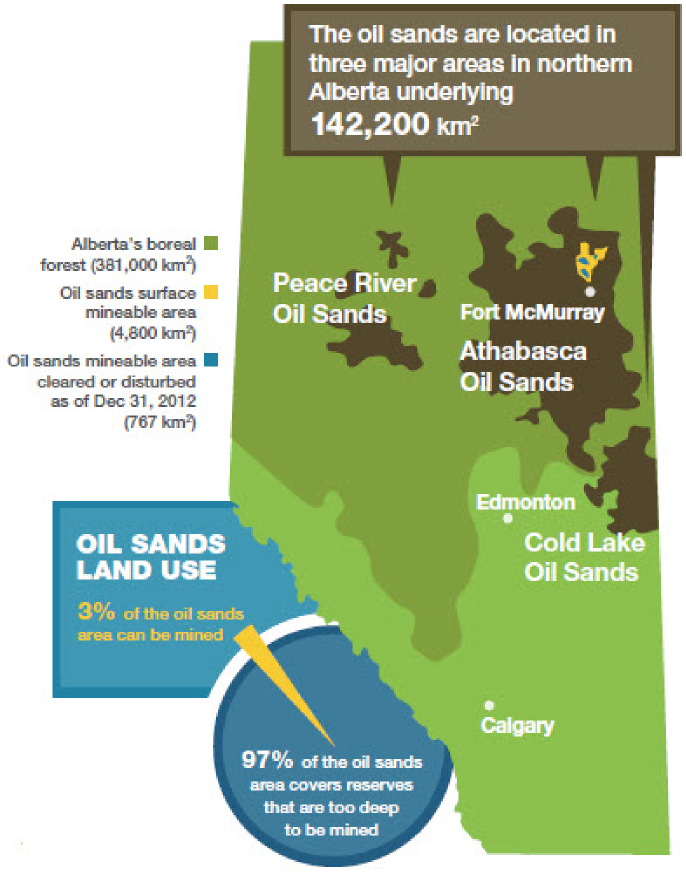
- Introduction
- IRC Term 1
- IRC Term 2
- Software Development
- Lab Resources

Section 1:

# INTRODUCTION

# Canada’s Oil Sands

- Alberta’s oil sand deposits lie under **142,200 square kilometres ($km^2$)** of land in the **Athabasca, Cold Lake** and **Peace River** areas in northern Alberta.
- Canada’s total oil sands reserves is the **third largest in the world** after Venezuela and Saudi Arabia.
- As of 2016, Alberta's oil sands proven reserves were estimated as **165.4 billion Barrels (bbl).**
- **Surface Minable Area (SMA)** only found within Athabasca oil sands area equals to 4800 $km^2$ which represents **3.4% of the total oil sands area**.
- In 2016, crude bitumen production including mined and in situ methods were estimated as **2.5 million barrels per day (bbl/d)**.

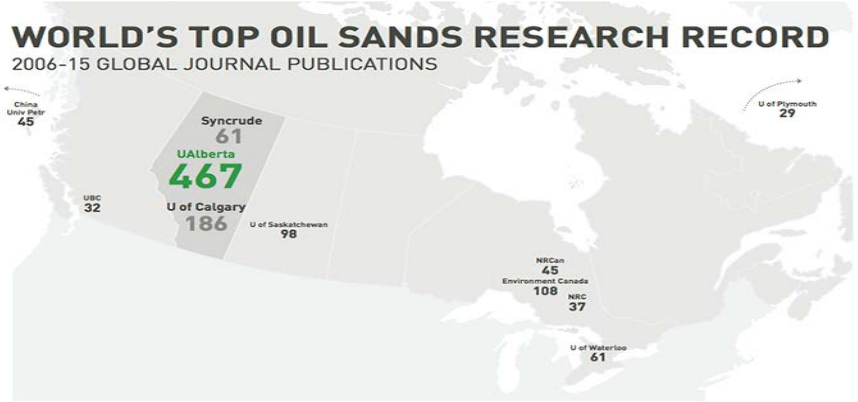



Source: Alberta Energy Website

# Oil Sands Research in University of Alberta

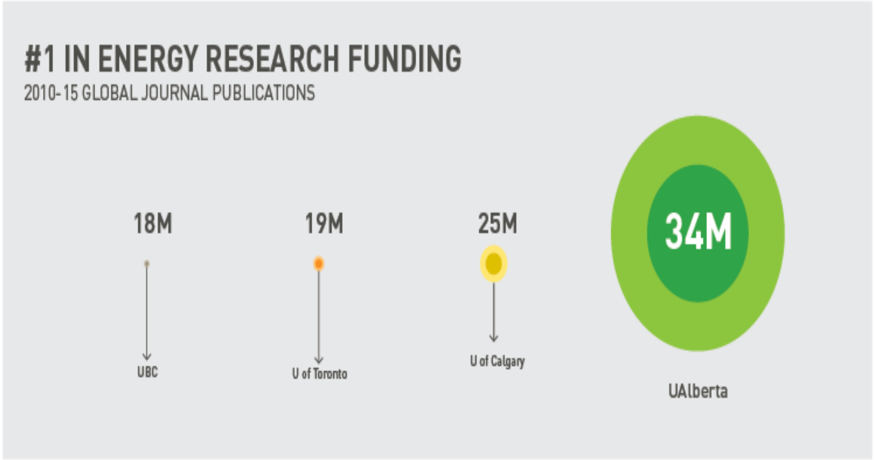
✓ **U of A has the Worlds 'top oil sands research record:**

- Between 2006 and 2015, researchers in U of A published **467 papers** on oil sands.
- The publications are **cited** for more than **3700** times.




✓ **U of A has the Worlds 'top oil sands research funding in Canada:**

- Between 2006 and 2015, U of A was awarded **$33.9 million** in funding for energy research from NSERC.
- The funding is one-third more than any other university in Canada.




Source: University of Alberta, Faculty of Engineering Website

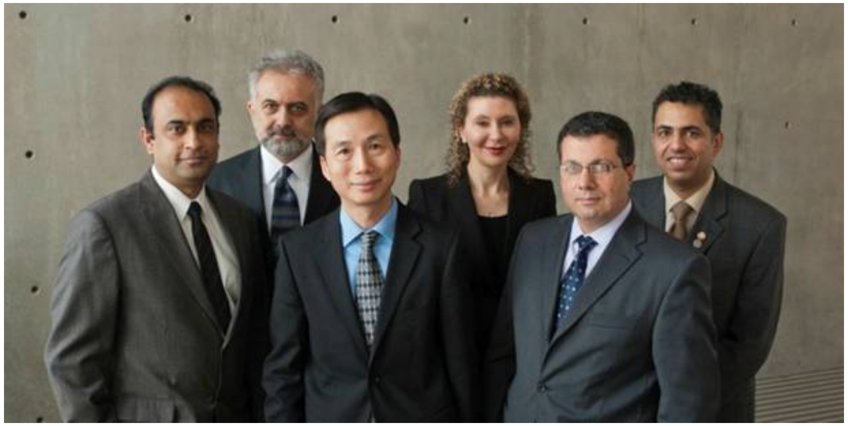
# Industrial Research Chairs (IRC) Program

**Industrial Research Chairs (IRC )** are distinguished appointments which are intended to:

- assist universities in **improving existing strengths** for a great research endeavour in science and engineering **of interest to industry**.
- Assist in **development of research efforts in undeveloped fields** in Canadian universities with a **significant industrial need**.
- Improve the **training environment for graduate students and postdoctoral fellows** ( where appropriate) by providing the opportunity for significant cooperation with the industrial partner(s) and exposing them to unique industrial research challenges.

**NSERC** offers three type of **IRC**:

- **Senior IRC:** for distinguished senior researchers (five-year appointment, renewable)
- **Associate IRC:** for early stage researchers with exceptional promise (five-year appointment, renewable once)
- **Executive IRC:** for outstanding R&D professionals (five-year appointment, non-renewable)



Six U of A NSERC IRC Chairs
Photo taken Nov. 30, 2011 during IRC ceremony.

Source: http://www.nserc-crsng.gc.ca

# NSERC Senior IRC Chair Holder in Control of Oil Sands Processes

**Dr. Biao Huang** joined U of A in 1997 as an Assistant Professor in the **Department of Chemical and Materials Engineering**, and is currently a Professor, **NSERC Senior Industrial Research Chair in Control of Oil Sands Processes (since 2011) and Alberta Innovates Industry Chair in Process Control**. For IRC Introduction, please watch the video to the right: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To watch video: Click dark frame below or use link: https://www.youtube.com/watch?v=haIB0ALhxlY


**IRC announcement**: Dean of Engineering Faculty (Left 1), NSERC President (Left 2), Dr. Biao Huang (Right 2), University of Alberta President (Right 1)

Section 2:

# IRC TERM 1

# Journey to IRC Term 1

❖ Long term collaboration with industry since 1998 led to IRC term1:

**CRD #1 1998-2001**

**Funding:**
NSERC
Syncrude

**Objectives:**
Integration of Advanced Controller Auditing and Process Reengineering Strategies for Oil Sands Industry.

**CRD #2 2001-2005**

**Funding:**
NSERC
Syncrude

**Objectives:**
Controller Performance Assessment towards Energy Efficiency and Reduction of Gas Emissions for Syncrude Canada Upgrading Unit.

**CRD #3 2005-2009**

**Funding:**
NSERC
Syncrude

**Objectives:**
Development of control system performance diagnosis and optimal troubleshooting technology for oil sands industry.

**CRD #4 2009-2014**

**Funding:**
NSERC
Syncrude

**Objectives:**
Improving oil sands process operation through advanced estimation for process control systems.

**IRC 2011-2015**

**NSERC Industrial Research Chair Term 1**

# Objectives

Develop solutions for performance improvement of control systems within existing oil sands infrastructure that will lead to better

- **Instrumentation**
- **control**
- **unit-wide/plant-wide operations**

Extend the breadth and depth of Canada's oil sands expertise.

Enable collaboration with industry to convert research outcomes into implemented solutions.

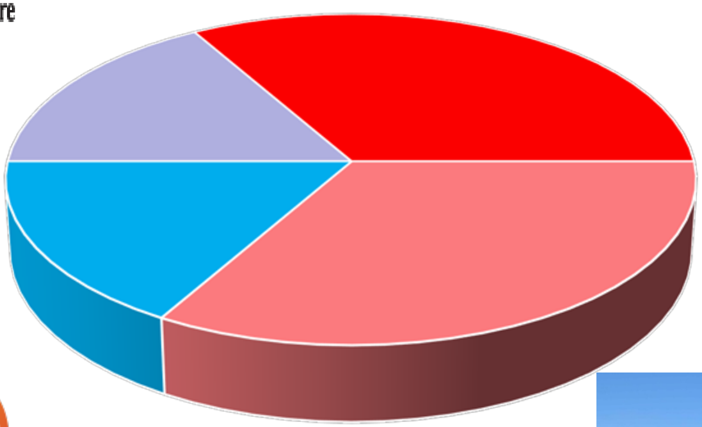
Train highly qualified personnel.

Objectives

# Industrial Partners and Yearly Cash Contributions

Syncrude
Securing Canada's Energy Future

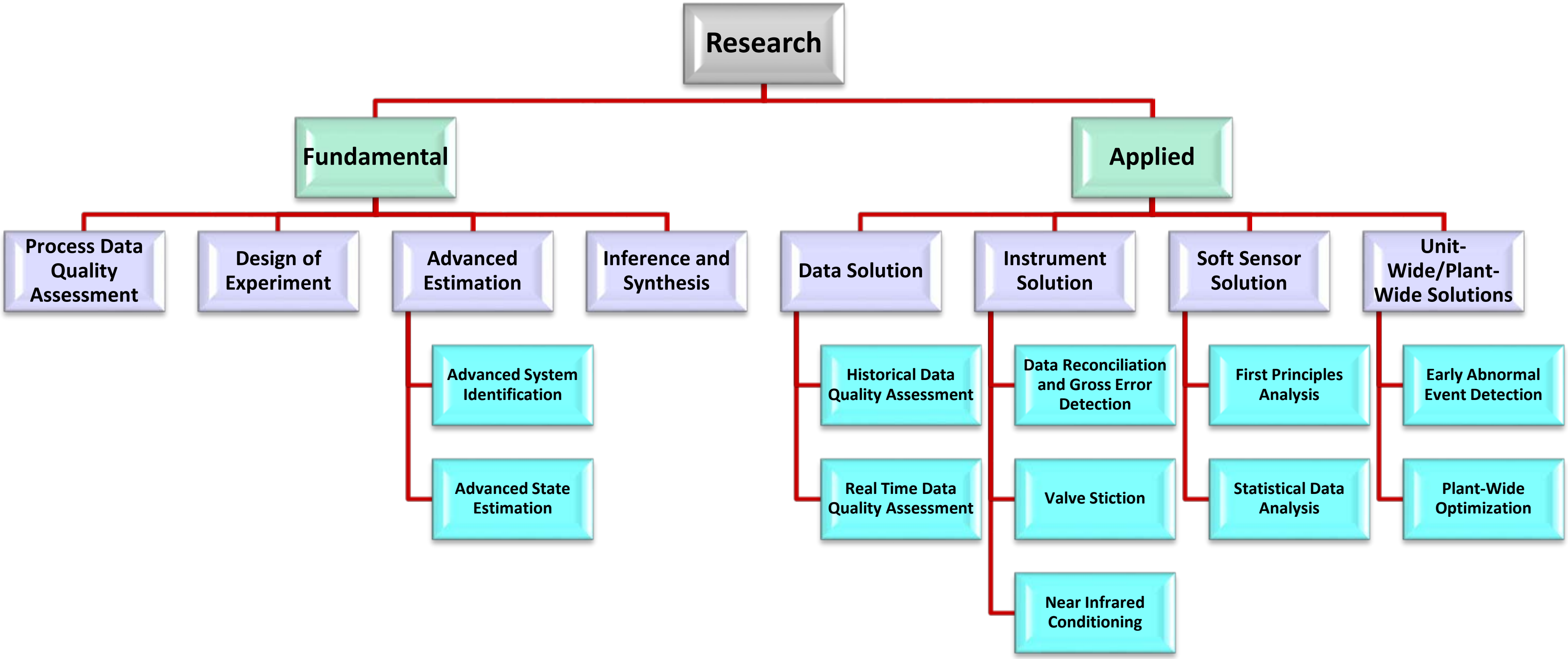
NSERC CRSNG



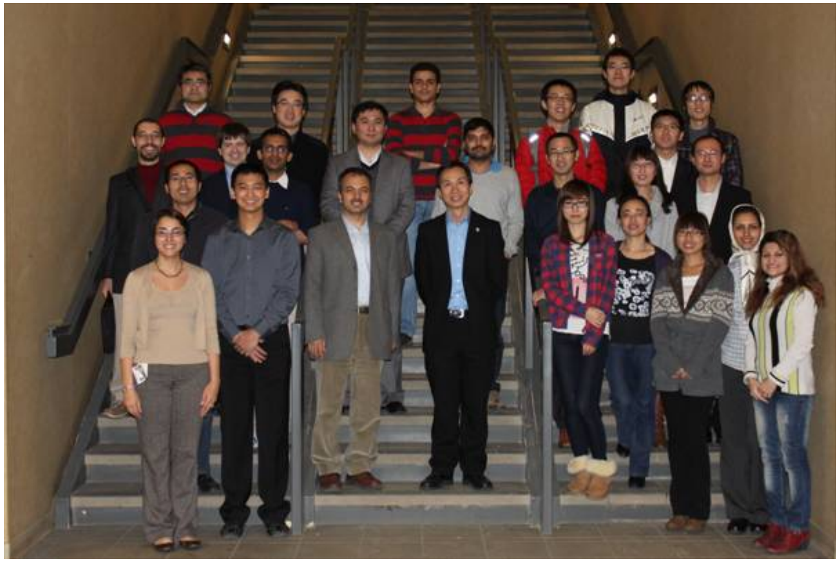
SUNCOR ENERGY

Alberta Innovates Technology Futures

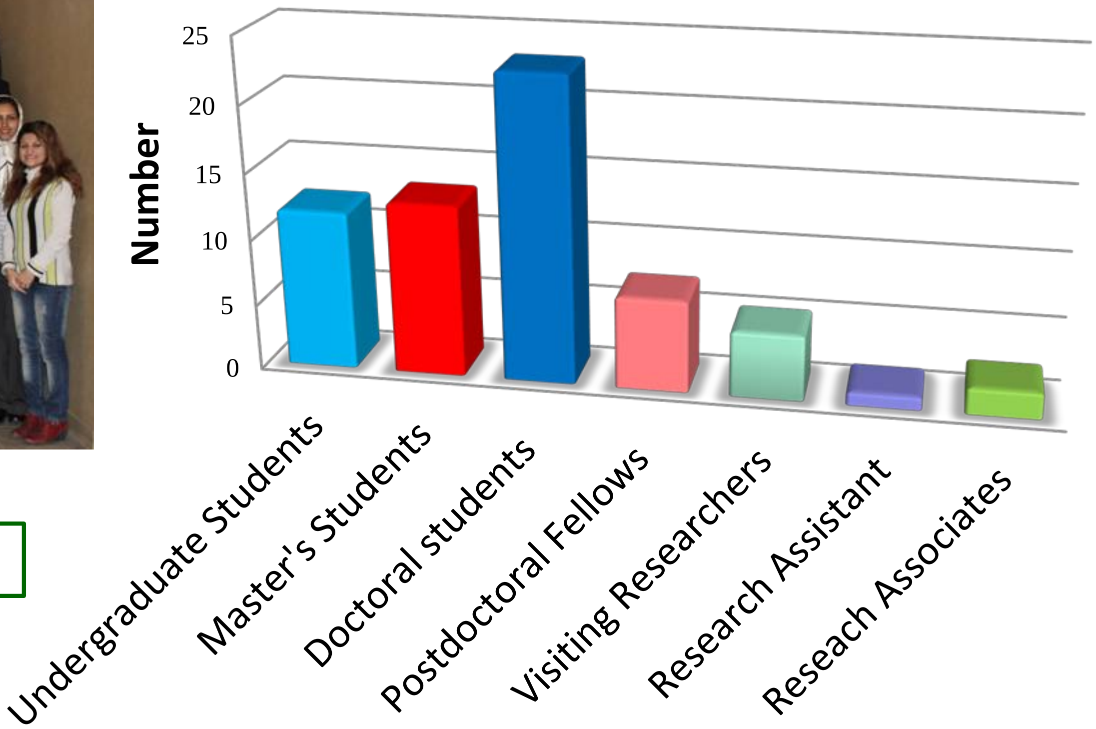
# Projects Overview



# Research Team



Group Photo taken on November 30, 2011



# SAMPLE PROJECTS AND ACHIEVEMENTS

# Laboratory-Scale Image Processing and Signal Fusion Based Detection

## ❖ Problem

In industry, monitoring the **interface level** such as the Primary Separation Vessel (PSV) froth/middling interface is often captured using three methods including Differential Pressure (DP), profiler and camera where

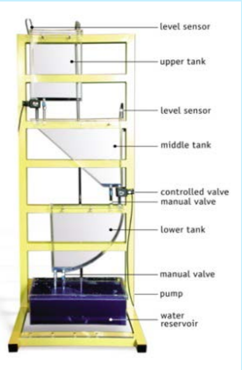
- **DP** is always available but not very accurate and may fail to reflect the variation in the interface level.

-**Profiler** is not always reliable but is reasonably accurate when it is reliable.

- **Camera** is very accurate but not always available.

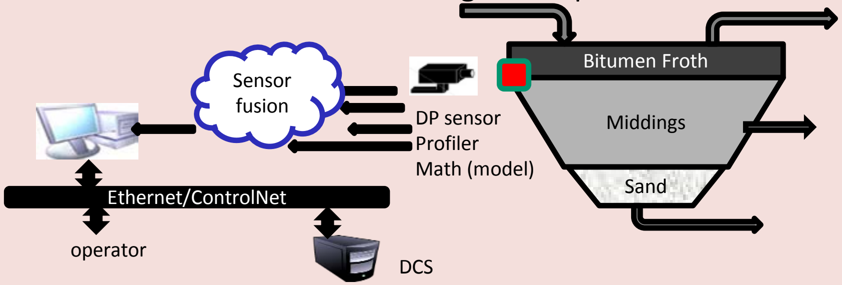
## ❖ Objective

In laboratory, **an image processing and signal fusion** based detection strategy is developed and tested, and the main objective is to **detect the water level** in the upper tank by processing the captured image of the upper tank.



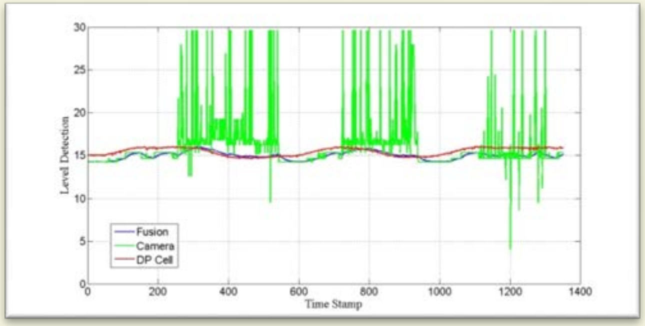

## ❖ Solution

- Level signals from Camera, DP-cell and math(model) sensor are fused based on **Kalman Filtering** technique.




## ❖ Results

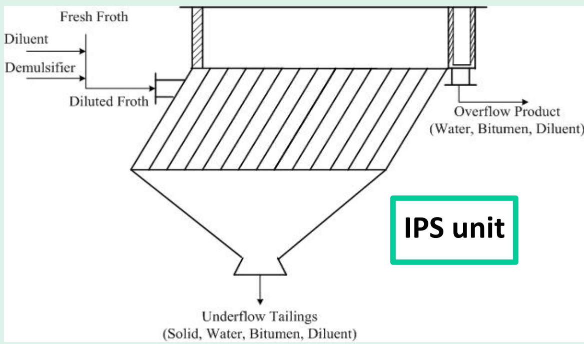
- Closed-loop control using fused signal exhibited **reduced variability** in process output.



# Inclined Plate Settlers (IPS) N:B Soft Sensor

## ❖ Problem

The **Naphtha to Bitumen (N:B)** ratio in the IPS product stream indicates the quality of bitumen froth and, thus, serves as one of the key indicators of the separation process performance. However, the laboratory measurements of N:B is available in a **slow rate manner**.



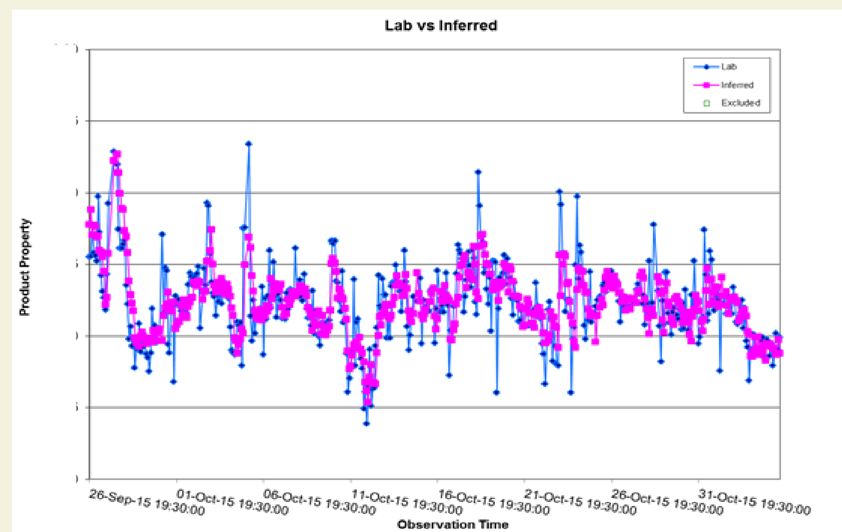

## ❖ Objective

Design a **soft sensor** for **real-time monitoring** of the N:B ratio in the IPS product streams.

## ❖ Solution

- **Multiple Models** are built for different operating modes.
- **First Principle Modeling** is used to determine model structure.
- **Adaptive Soft Sensor** is designed to cope with time-varying behavior.

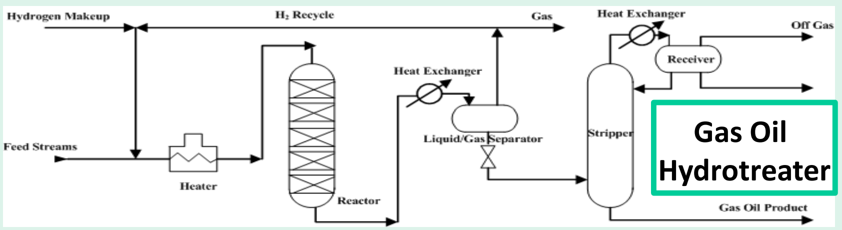
## ❖ Results



# Sulfur Inferential in the Final Gas Oil Product

## ❖ Problem

**Sulfur content** in final gas oil product is a critical parameter. For the consideration of safety and economic optimization, it is crucial to control the sulfur content accurately. The old soft sensor is a static model with a bias updating strategy. However, the temperature profile changes with time as the catalyst ages, so the model parameters corresponding to **temperature variables are time-varying**. Therefore, **the old soft sensor fails to capture the dynamic changes in model parameters**.




## ❖ Solution

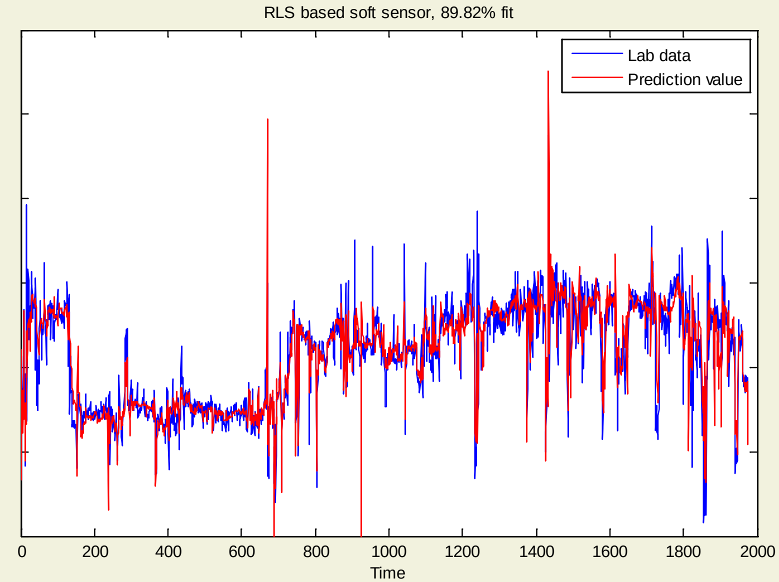
- An adaptive inferential model is developed based on the **Recursive Least Square (RLS)** algorithm.

- Both the **coefficients and the bias term** of the inferential model are **updated** once a reliable lab data is available.

## ❖ Objective

Develop a **soft sensor** in order to predict the **sulfur content** in the final gas oil product when the lab data is not available or reliable.

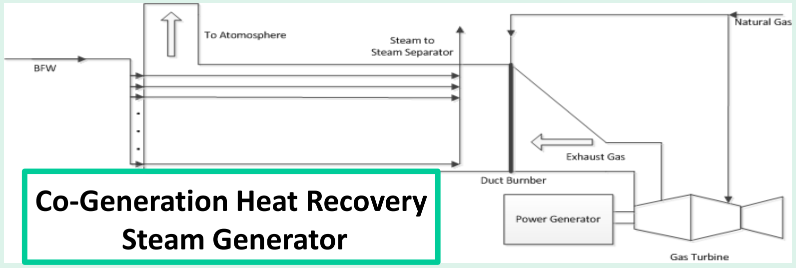
## ❖ Results



# Cogeneration Steam Quality Soft Sensor

## ❖ Problem

Reliable fast rate average **steam quality** and individual pass steam quality is required to implement steam quality control for safety and economics purpose. The **fast rate measurement** of the steam quality is available but has **low accuracy**, and the **reliable measurement** is determined by sampling in a **slow rate manner**.




## ❖ Solution

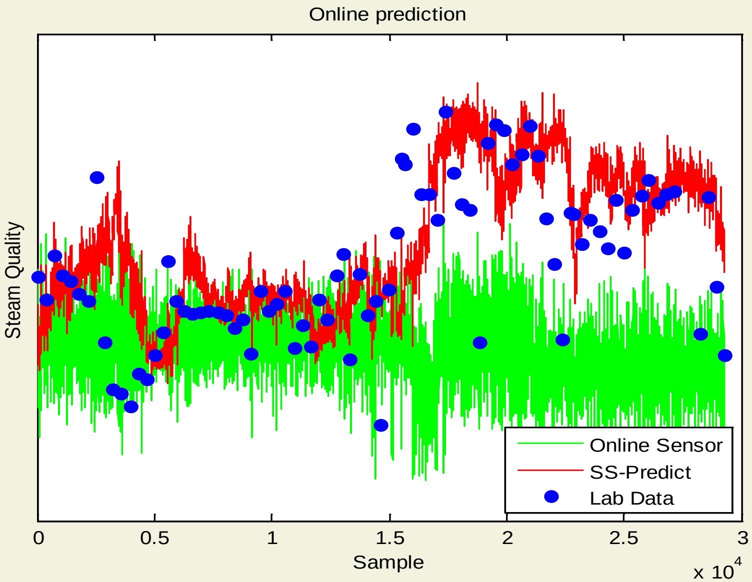
- The **average steam quality** is estimated by developing a model based on the **fast rate** and **slow rate** measurement of the average steam quality.

- The **steam quality of each pass** is predicted by developing a **gray box model** using the **Energy Balance Equations**.

## ❖ Objective

Provide **a more accurate and reliable** approach to perform **online steam quality** estimation for individual passes as well as the overall stream.

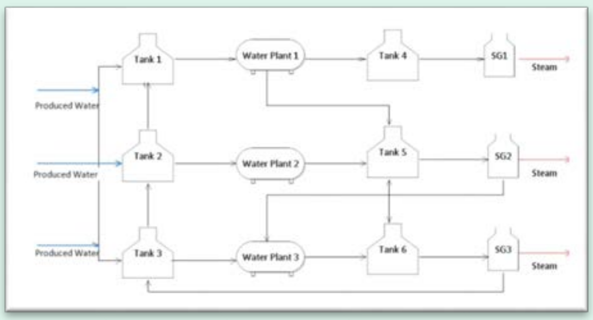
## ❖ Results



# Plant Wide Water Balance Optimization

## ❖ Problem

SAGD process consists of several **water processing and steam generation plants**. Steam production rates across different plants may not be well coordinated due to **plant outage or slowdown**. **Operating costs** for different steam generators may also vary.




## ❖ Objective

Find **an economically optimal distribution of water** across the site in the **presence of changes in operating constraints** by utilizing tanks as buffers.

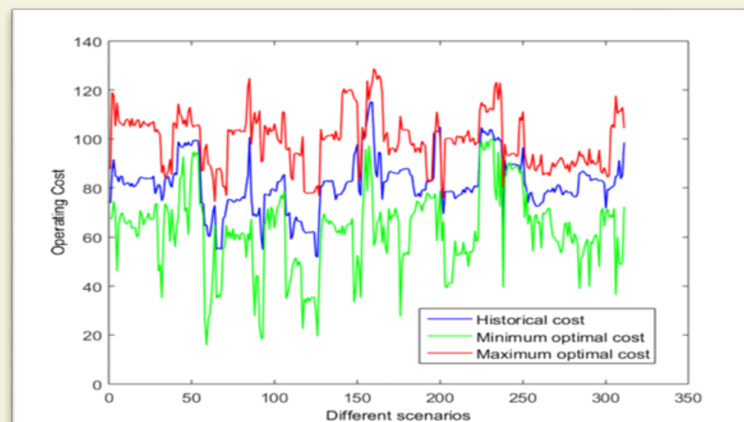
## ❖ Solution

- **Data reconciliation** and **optimization** are performed by constructing mass balance models for all process units.

- The solution has been developed in the form of a **GUI based Excel** application that interfaces with **GAMS** optimization software which can be used for **decision-making** on a daily basis by operators or **estimating the missing flow measurement** using the mass balance across the site.

## ❖ Results

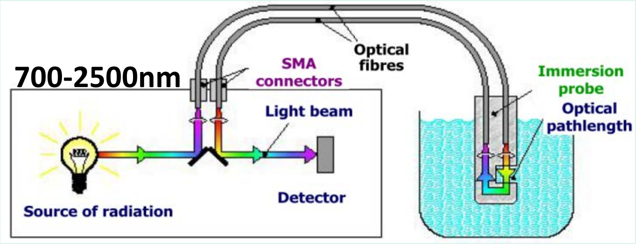
Historical cost of steam production is compared against minimum and maximum cost of production obtained from steady state optimization:



# NIR Based Soft Sensors for Refinery

## ❖ Problem

In **refinery plants**, Near Infrared **(NIR)** spectroscopy is used to check the quality of the considered variable because of its ability to **record properties** in real time through hidden information in spectra.




**Pipeline**

## ❖ Solution

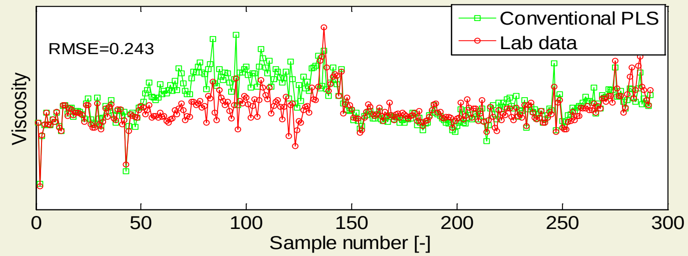
- **Partial Least Squares (PLS)** model is trained based on the spectra information and the quality variable.

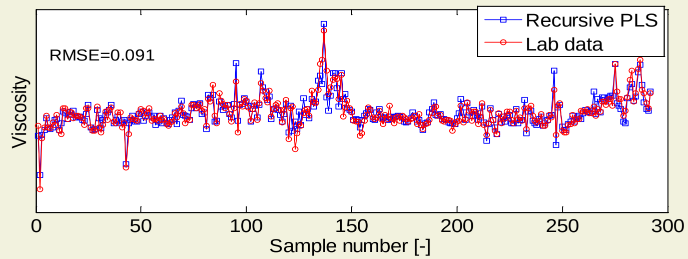
- The model is **updated recursively** using the reliable reference measurement.

## ❖ Objective

Develop a **soft sensor** in order to predict the **Properties** of the **quality variable** in real time using the hidden information in spectra.

## ❖ Results



# HP Steam Generator Steam Quality Soft Sensor

## ❖ Problem

**High pressure (HP) steam generators** function as water tube boilers, where boiler feed water flowing through tubes is heated as it passes through the boiler. The boiler feed water stream is split into several passes that flow through the steam generator in parallel which are rejoined after exiting the steam generator. It is required to maintain the steam quality in a defined range in order to **satisfy safety and economics aspects**. However, the **reliable fast rate** measurement is **not available for each pass and overall steam quality**. The available steam quality measurements are:

- **Fast rate average steam quality (inaccurate)**
- **Slow rate individual steam quality (accurate)**

## ❖ Solution

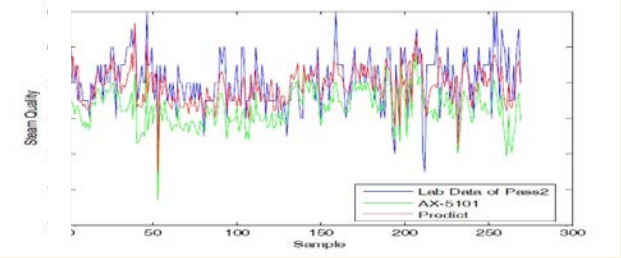
- The fast rate **overall steam quality** which is not reliable enough is rectified using the lab analyses.

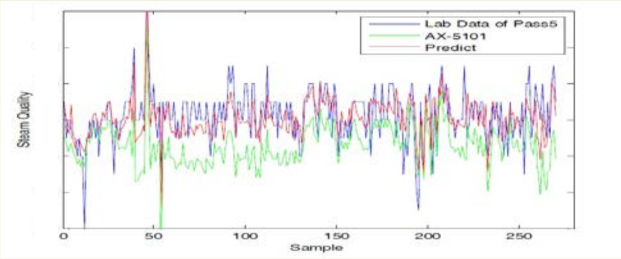
- The steam quality model structure for **each individual pass** is derived using the **Energy Balance Equations**, and the parameters are trained using **reference lab measurements**.

## ❖ Objective

Develop a **soft sensor** to perform **real time steam quality** estimation for individual passes and the overall streams.

## ❖ Results



# PVS Interface Detection Using Camera and Profiler Measurements

## ❖ Problem

It is required to measure and control the Froth/middling interface level in **the Primary Separating Vessel (PSV)** in order to avoid unwanted consequences such as:

- the possibility of **sanding**
- increasing the processing **load on downstream**
- Increasing **environmental impact** due to increased bitumen content in tailings

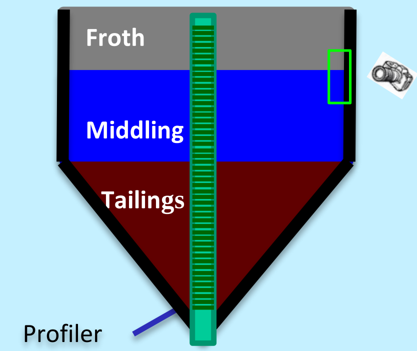
A **camera** can measure the interface correctly; however, it is **not always available**. Therefore, a **profiler** is installed to help in measuring the interface.

## ❖ Solution

- **PLS** model is trained based on the **profiler**, **temperature** and the **camera measurement**.
- The PLS model is **updated recursively** using the **reliable camera readings**.

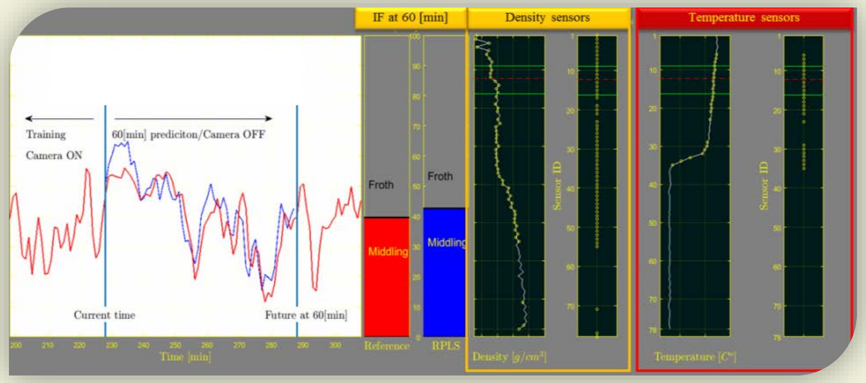
## ❖ Objective

Develop a **soft-sensor** that provides correct and continuous inference of the interface level when the **camera readings** are not reliable using the **profiler measurement**.




## ❖ Results

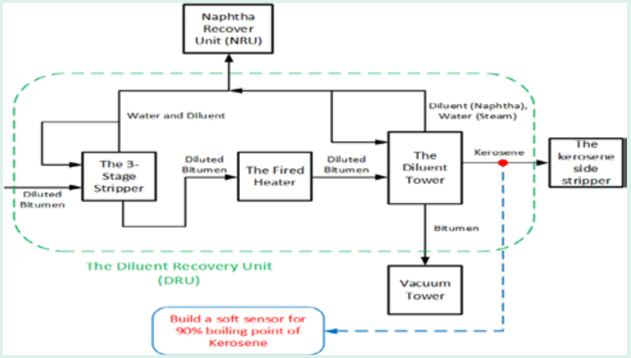
**Soft-Sensor prediction (blue) , reference measurement (red)**



# Soft Sensor for 90% Boiling Point of Kerosene

## ❖ Problem

In **Diluent Recovery Units (DRU),** continuous and fast rate measurement of the refined streams are necessary for plant optimization and control. Here, **90% boiling point of Kerosene** which represents the temperature at which 90% volume of the hydrocarbon (HC) mixture is vaporized in a batch distillation Is **not available on demand**.



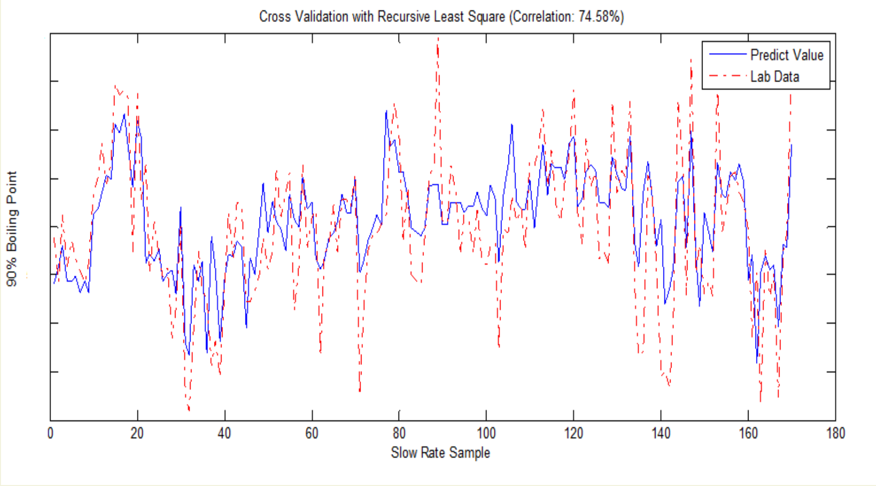

## ❖ Solution

- **Data based predictive model** is developed using fast rate process variables and the reference lab measurements.
- The **model** is **updated** whenever the reference measurement is available.

## ❖ Objective

Design a **soft sensor** for **real time estimation of 90% boiling point of Kerosene** entering the side stripper.

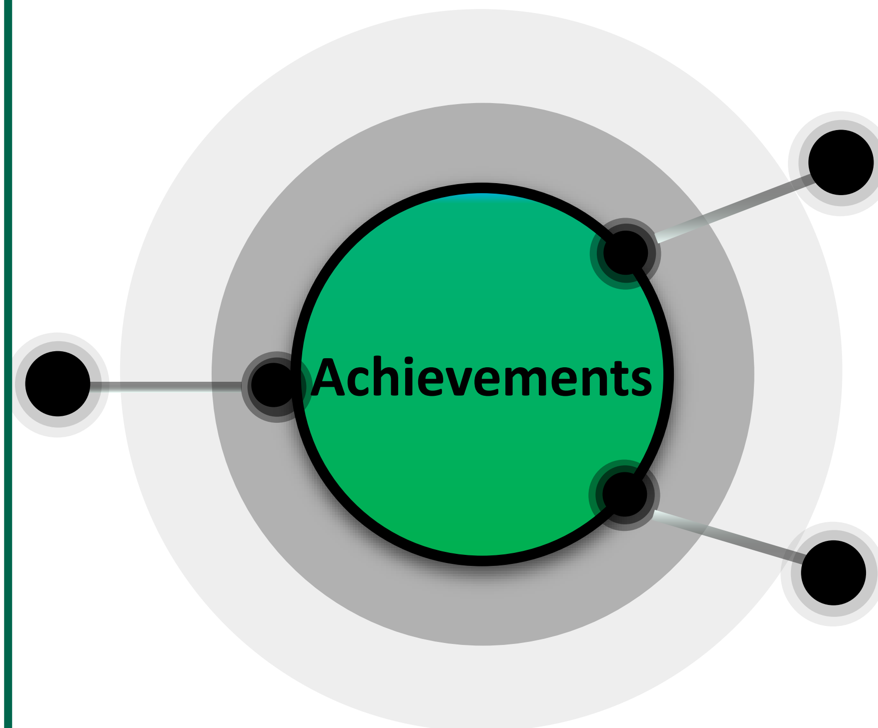
## ❖ Results



# Achievements

**Trained 51 high qualified personnel:**

- 83 % of PhD graduate received industrial/ faculty position offers, and 17 % of them have PDF offers.
- 87 % of MSc graduates received industrial positions offer, and 13 % of them continue as research assistant positions.
- 100% of PDFs received job offers.
- 100% of the researchers received job offers.




**Deliverable Solutions:**
Completed **more than 20 successful applications** and software solutions for the industrial partners with estimated **multi-million dollars in yearly benefits**.

**Publications:**
Published **56 refereed journal papers** in first-tier research journals, **27 refereed conference papers** and **14 abstract refereed conference presentations**. **one book** is published by John Wiley & Sons.

Section 3:

# IRC TERM 2

# IRC Term 2: Objectives

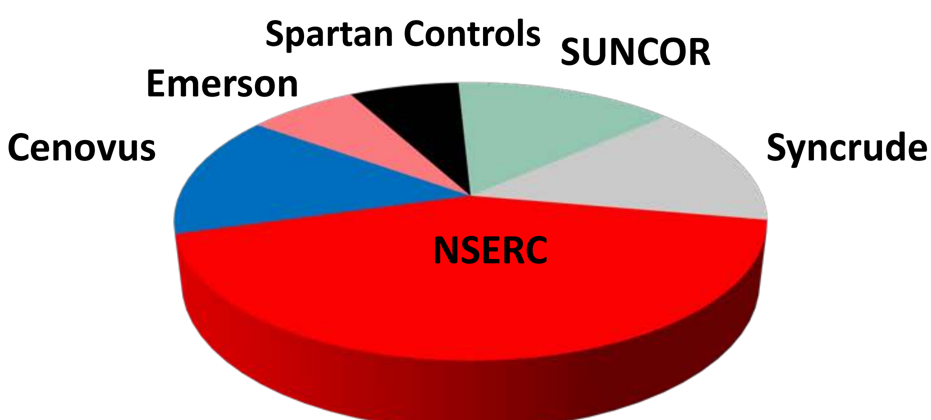
# IRC Term 2: Industrial Partners and Yearly Cash Commitments


EMERSON


SPARTAN Controls

SUNCOR ENERGY

cenovus ENERGY




NSERC CRSNG

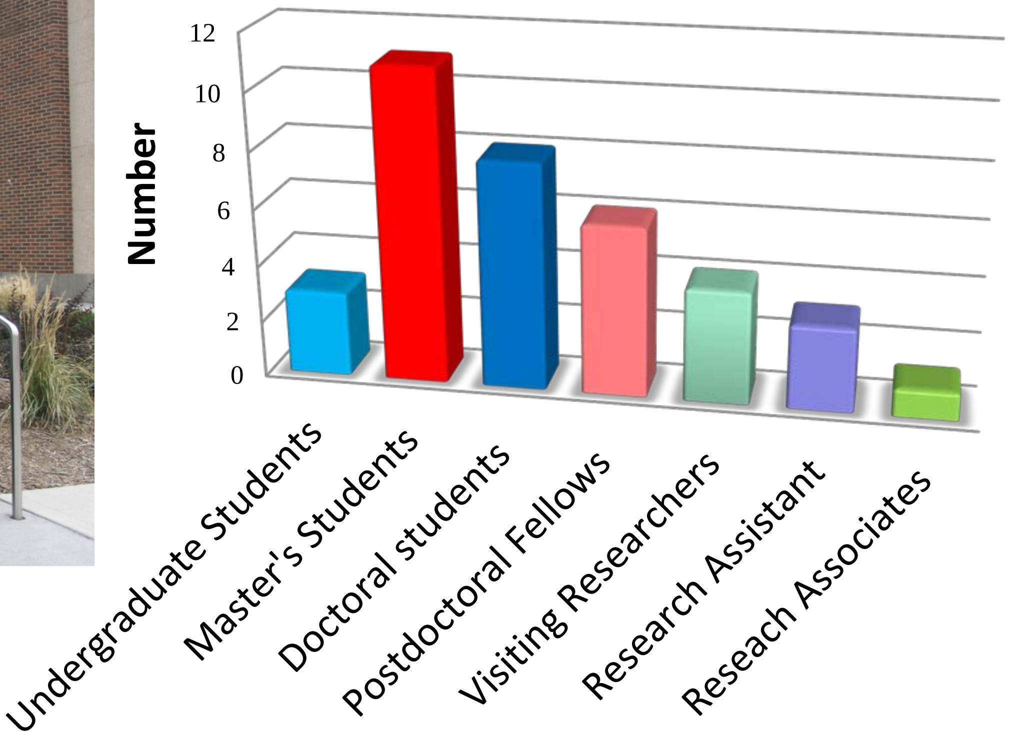
Syncrude Securing Canada's Energy Future

# IRC Term 2: Projects Overview

- Research
  - Fundamental
    - Estimation Technology
    - Monitoring Technology
    - Data-Mining Technology
  - Applied
    - Sensor Solution
      - Similarity Measurement
      - Dealing with outliers and uneven sampling rates
      - Employing recent advances in machine learning methods
    - Safety Solution
      - Modeling of Process Systems with Non-Gaussian Distributions
      - Distributed Monitoring for Large-scale Processes
    - Optimization Solution
      - Global Trajectory Design
      - Adaptive Trajectory Design (ATD)
      - Pattern Matching Trajectory Design

# IRC Term 2: Research Team


Group Photo taken on November 8, 2016



# SAMPLE PROJECTS AND ACHIEVEMENTS – YEAR 1

# High Steam Quality Soft Sensors

## ❖ Problem

In order to achieve **safe production and efficient energy consumption** in steam generators, steam quality, the mass proportion of vapor in saturated steam, is expected to be measured and controlled within a tight operating region. Currently, **existing online calculation** of steam quality is based on flow rate measurements from inlet and outlet passes, which provides **inaccurate estimations** in certain operation conditions.

## ❖ Solution

- The models are developed considering **thermodynamic condition**, **conservation laws** and **process data analytics**.
- A **package** is developed for the **soft sensor implementation and maintenance**.

## ❖ Objective

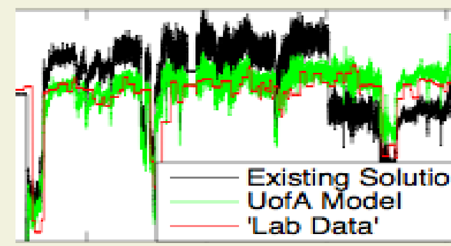
Develop a model to **predict the steam quality** ($X_{SQ}$) in real-time more precisely in different operating conditions (including very high steam quality operation condition) to **increase the set-point** and **reduce unnecessary fluctuations** in steam generation process.

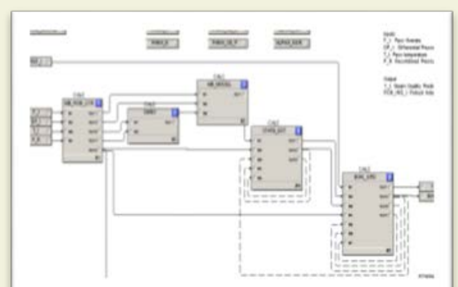
## ❖ Results

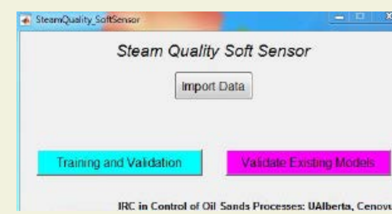
Ex.1:

| Online Test | Exis. | UofA |
|---|---|---|
| Avg. MAE | 1.51 | 0.85 |
| Avg. $3\sigma$ | 2.17 | 1.06 |

Ex.2:





# Once Through Steam Generator (OTSG) Scaling Prediction

## ❖ Problem

**Fouling/scaling in heat transfer equipment (HTE)** has been a long time issue in the process industry. The buildup of undesired substances inside the equipment reduces the available area for heat transfer, consequently reducing the thermal efficiency. Therefore it would be highly beneficial to develop a model that **predicts the scale buildup** so that fouling/scaling removal is planned in advance.

## ❖ Solution

The predictive model is developed based on:

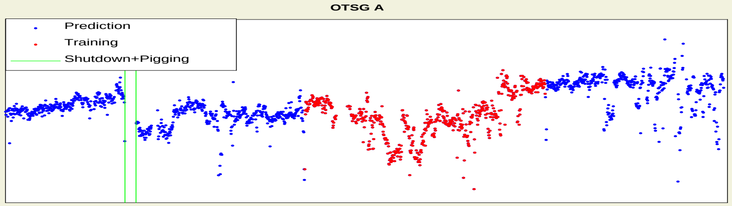
- **engineering principle**: dynamic properties of scaling procedure

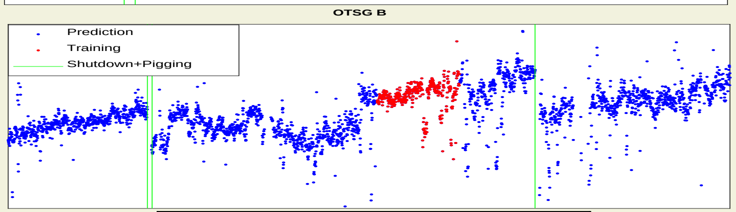
- **data analysis**: extract latent features to represent non-stationary trends

## ❖ Objective

**Predict fouling/scaling buildup** in OTSG tubes in real-time.

## ❖ Results




| | Prelim. % Error* |
|---|---|
| OTSG A | 2 to 7% |
| OTSG B | 5 to 10% |

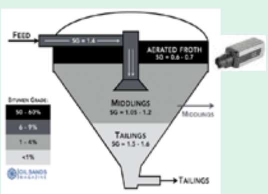
∗ *Assuming no scale is left in the OTSG after pigging*

# Camera image processing for PSV interface

## ❖ Problem

The level of the **froth middling interface** in primary separation vessel (PSV) plays an important role in overall bitumen recovery in conventional oil sands bitumen extraction process. To maintain the interface within a certain range of level, the accurate measurement is always desired. **Online camera detector** usually has the best performance.

**PSV**




**Sight Glass Camera**

## ❖ Solution

- **Markov random based image processing** techniques are investigated for detecting PSV interface.
- As an independent approach, space based **Kalman Smoothing and Edge Detection** techniques are also developed which has been applied in an industrial project.

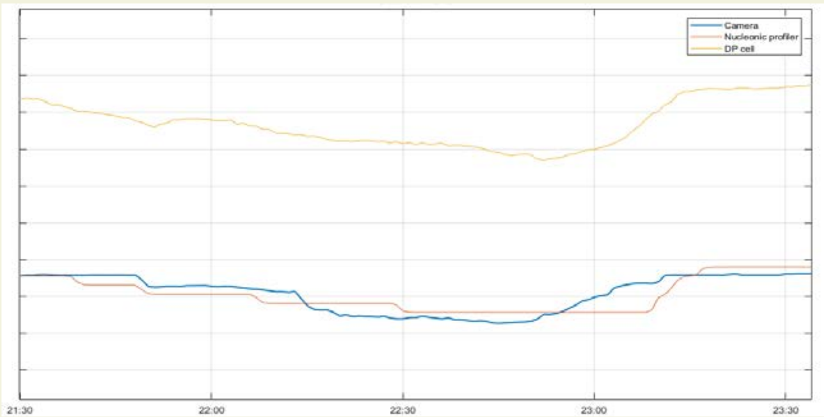
## ❖ Objective

**Detect PSV interface by image processing** techniques on video frames obtained from a camera and develop:

- **More reliable and accurate interface estimation** than other instruments (Nucleonic profilers, DP cells or Capacitance probes).
- **Non-intrusive advance data analytic technique**.

## ❖ Results

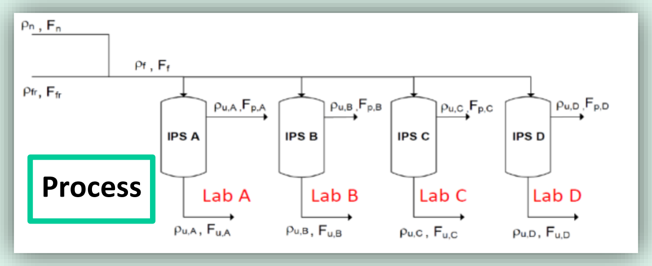
Real-Time Trends



# New N:B Ratio Soft Sensor

## ❖ Problem

The **Naphtha to Bitumen (N:B) ratio** in the IPS product stream indicates the quality of bitumen froth and serves as one of the key indicators of the separation process performance. However, product N:B measurements are **not available "on demand"** and cannot be used for closed loop control.




## ❖ Objective

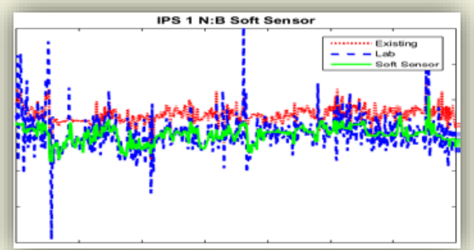
Design a **soft sensor for real-time monitoring of the N:B ratio** in the IPS product streams in order to maintain N:B in feed at desired level so as to **achieve effective separation at an affordable cost**.

## ❖ Solution

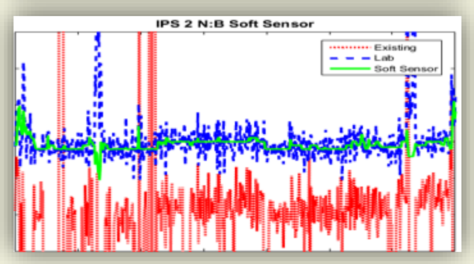
- The model structure is obtained by employing the **first principles knowledge** of the process.

- The **bias term** of the inferential model is **updated** once a reliable lab data is available.

## ❖ Results




**54%**
**Improvement**




**86%**
**Improvement**

# Early Prediction of Flare Events

## ❖ Problem

- **Undesirable flare events** cause: Emissions such as NOx, SOx, CO, CO2, etc.

- Heat Noise **Flare Gas Recovery System (FGRS)** is implemented to help in **reducing the flaring events** by recovering the waste gases.

- When **flare-gas flow rate is greater than the capacity** of the FGRS, the excess waste gas is combusted and **flared out**.

Photo is taken from The John Zink Hamworthy Combustion Handbook

## ❖ Solution

**Data analytics methods** are used in Time-domain and Frequency-domain analysis to develop an early detection index of flare events. The methods used are :

- **Moving-Window Wavelet Transform** on unit wise
- **Principle Component Analysis** combined with a decision making layer that synthesizes the unit-wise detection result (Hierarchical-PCA)

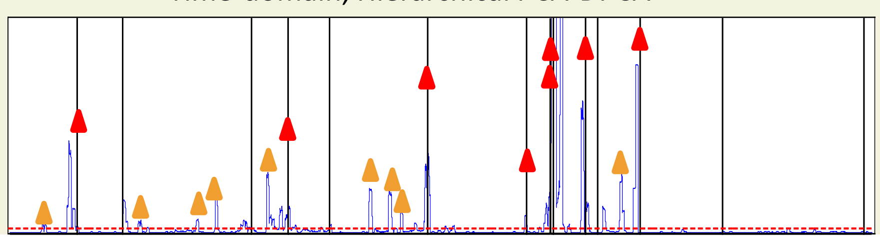
## ❖ Objective

Provide **early indication of potential flaring conditions** that may occur to give operator time to adjust operations.

## ❖ Results

Frequency domain, Moving-Window Wavelet Transform applied unit-wise


Time-domain, Hierarchical PCA-DPCA

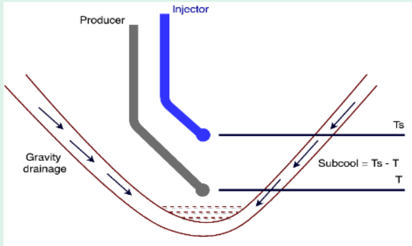


# Steam Breakthrough Monitoring in SAGD

## ❖ Problem

In SAGD, the expanded steam chamber has a tendency to enter the producer directly, known as **steam breakthrough** event, if a barrier does not block its path. This event results in **production liner damage** and **pump cavitation**.

**Steam breakthrough condition**

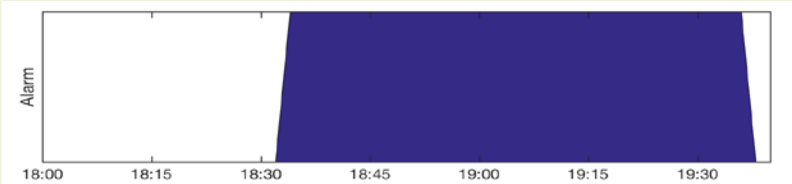


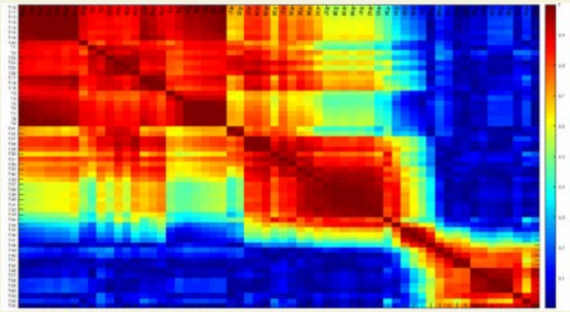

## ❖ Objective

**Predict the steam breakthrough** event and find its **root causes** using data analytics methods.

## ❖ Results

Plot below shows alarm could have gone on at 18:32 should the monitor be available. The operators made shutdown at 19:40.



## ❖ Solution

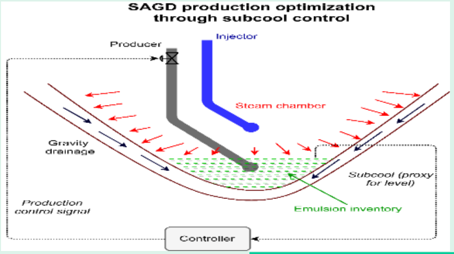
- **Downhole temperature** monitoring could provide an early detection.

- **Correlation study** performed on the well distributed temperature measurements indicates different characteristics in different parts of the well.

# Control Performance Assessment for Subcool Control Automation

## ❖ Problem

SAGD production is commonly **optimized** through **subcool**. The **MPC controllers** are recently deployed on the SAGD operations instead of the traditional control strategies.




Industrial Practice:

- ➢ Manual
- ➢ PID loops
- ➢ MPC

Existing practice (Manual, PID loops)

Recent transition (PID loops, MPC)

## ❖ Solution

The **trends** for variabilities, constraint handling abilities of the controllers, performance metrics, etc., are studied and the different **automation setups are compared**.

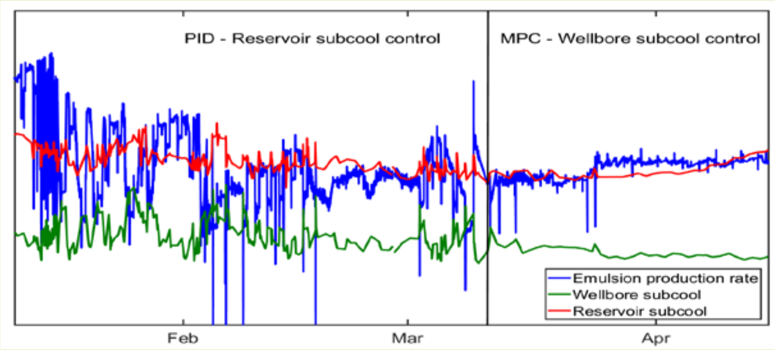
## ❖ Objective

Study the automation setups for their abilities to **handle**:

- Injection and production header **disturbances**
- Operation **mode changes**
- **Process constraints**
- **Stochastic disturbances**

## ❖ Results

**Trends of key process variables under PID loops and MPC control**



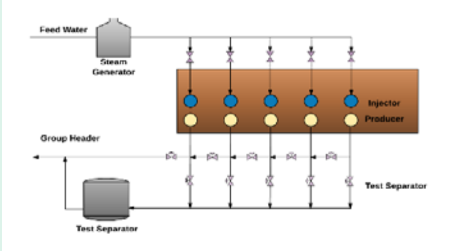
# Emulsion Flow Rate Soft Sensor in SAGD

## ❖ Problem

- **Unavailable** produced **wellhead flow rate** measurement.

- **Necessity** of continuous produced flow rate measurement in **achieving production targets**.

- **Unavailable test separator measurement "on demand"** due to the test separator rotation.




## ❖ Solution

- A predictive model for emulsion flow rate of each well pair based on **pump and pressure measurement** is developed.

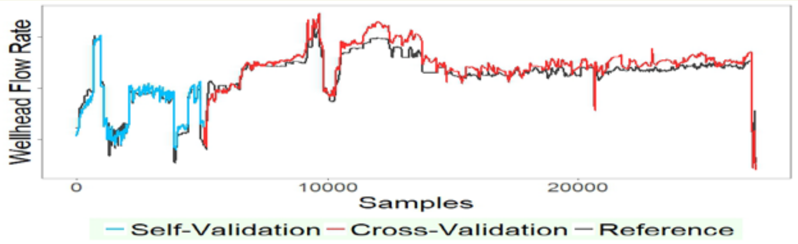
- The model structure is selected as **multiple linear regression** or **PLS**.

- The bias term is **updated** when **reliable test separator measurement** is **available**.

## ❖ Objective

Development and implementation of a **soft sensor** using test separator emulsion flow rate to provide **real-time estimation of the wellhead flow rate**.

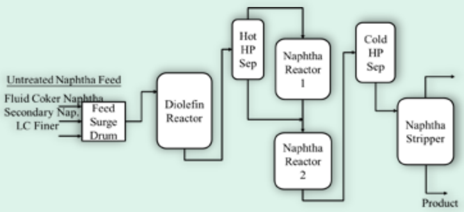
## ❖ Results

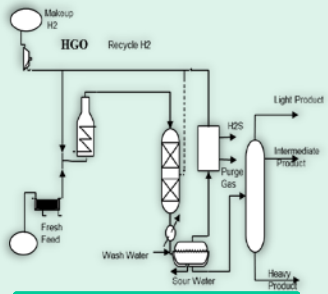
# Sulfur Content Soft Sensor in Upgrading Units

## ❖ Problem

Multivariate control is required for hydrotreater units in order to perform overall hydroreater optimization control strategy. Two main units considered are **HGO** and **Naphtha hydrotreaters**.




**Naphtha Hydrotreater**




**HGO Hydrotreater**

## ❖ Solution

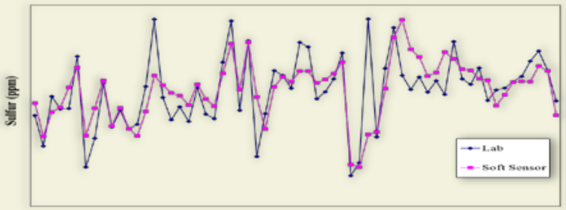
- Predictive models are developed using **influential process variables**.
- The bias term is **updated** using **reliable reference measurements**.

## ❖ Objective

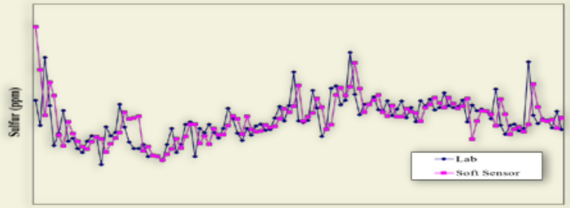
Develop **Sulfur inferential models** in order to:

- provide **sanity check** on the analyzers in case of failures.
- Improve the **availability of control solution** when the **analyzer** has **failed**.

## ❖ Results




**HGO Hydrotreater**



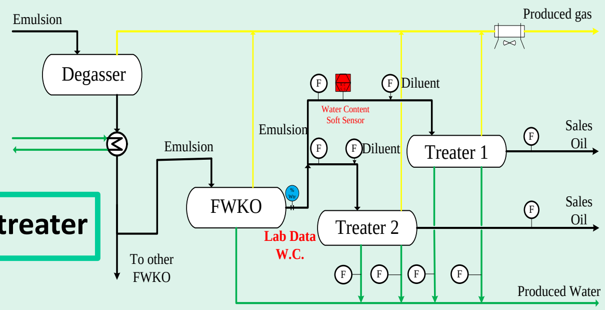

**Naphtha Hydrotreater**

# Water Content Soft Sensor in Oil Treating Systems

## ❖ Problem

**Water content** measurements are essential in order to **optimize the chemical injection**, **reduce OPEX cost** and ensure the **product specs**. However, these measurements are **not available on demand** or **not accurate**.

**Naphtha Hydrotreater**




## ❖ Solution

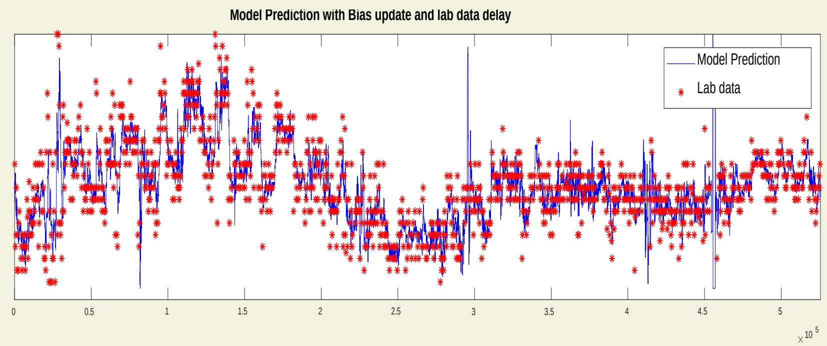
The considered analysis steps are:

- Data **pre-processing**
- **Mass balance** analysis on selected equipment
- **Bias update**
- **Robust test** on lab reference availability

## ❖ Objective

Develop **water content soft sensor (WCSS)** for Free Water Knockout **(FWKO) emulsion flows**.

## ❖ Results




| Model | MAE | CORR |
|---|---|---|
| No Bias update | 4.8631 | 0.5163 |
| + Bias update (α=0.435) | 3.9024 | 0.7031 |
| + Bias update (α=0.335) | 3.8825 | 0.7013 |
| + Lab value delay (120min) | 3.842 | 0.7049 |
| + Re-sample: rate=4 | 4.2737 | 0.618 |

Section 4:

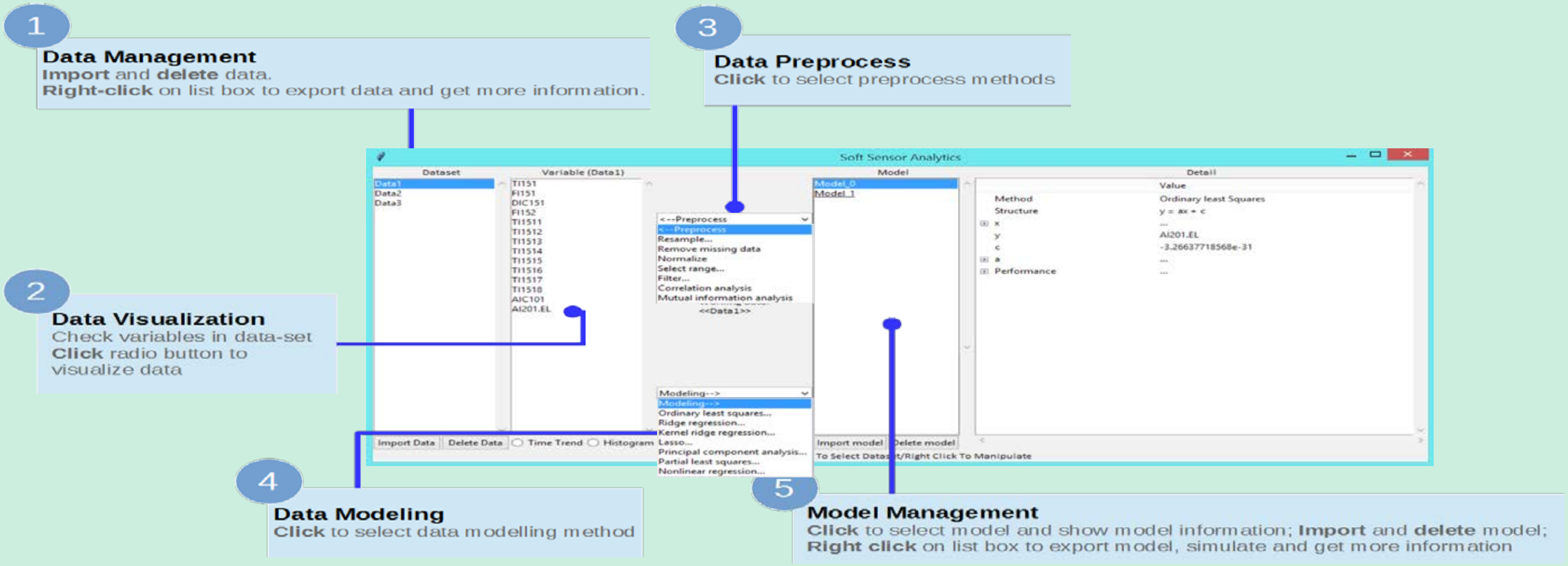
# SOFTWARE DEVELOPMENT

# Soft Sensor Analytics

## ❖ Objective

Develop a software with graphic user interface to assist users in **Soft Sensor Development**. The development environment is **Python** which is open-source software.

## ❖ Software Preview



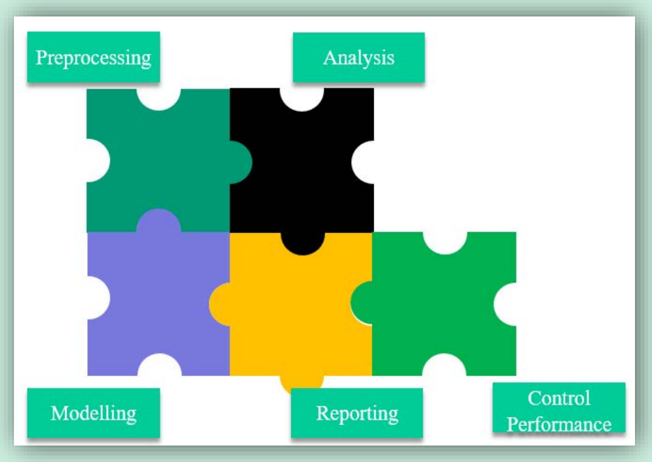
# Process Data Analytics

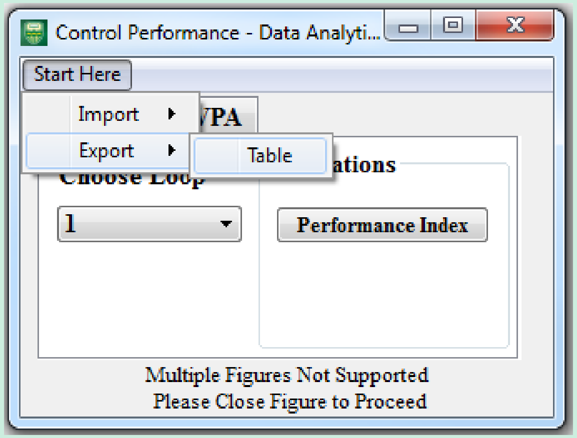
## ❖ Objective

Develop a package with graphic user interface to assist users in **Process and Control Monitoring** . The development environment is **Python**, and adding new features mentioned below is in progress:

- **Principal Component Analysis** based process monitoring
- **Slow feature analysis** based process monitoring
- Migration to **Kivy based natural human interface system** supporting **multiple platforms including Android/iOS**

## ❖ Software Preview



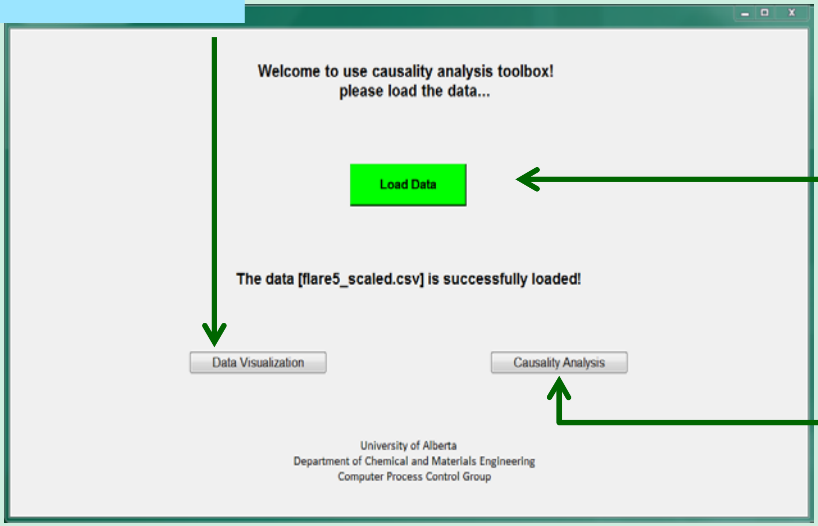
# Causality Analysis

## ❖ Objective

Develop a software package with graphic user interface to assist users in **Causality Analysis** by providing data visualization and various time series data analysis options. The development environment is **Python**.

## ❖ Software Preview

2 **Data Visualization**

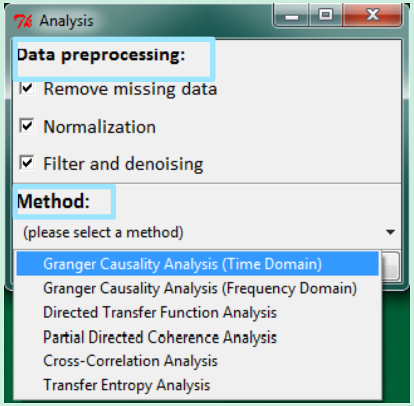



1 **Loading Data**

Click to load a data set from a **.csv** file

3 **Causality Analysis**

Click to directly perform causality analysis



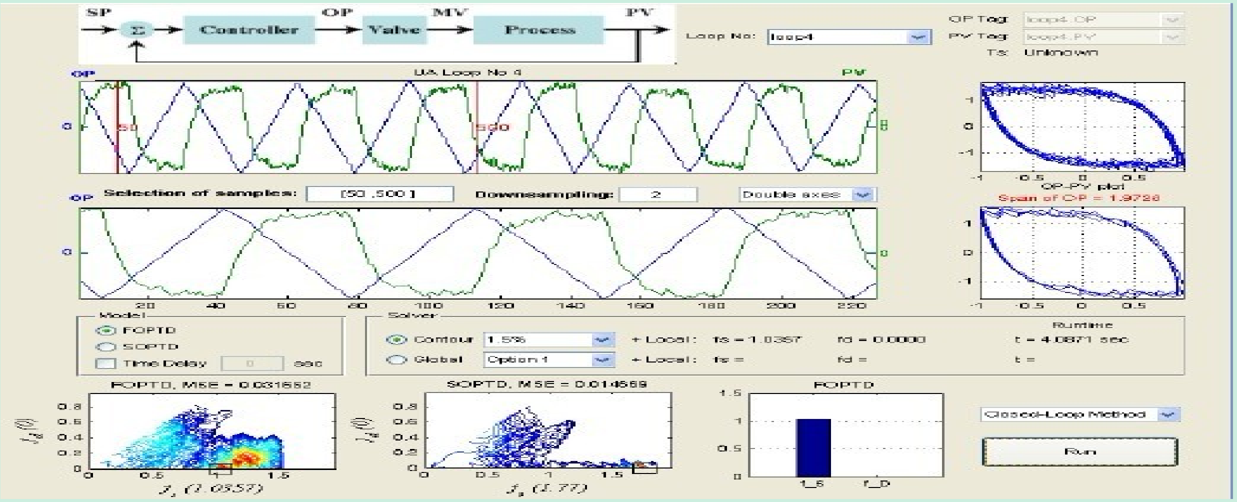
# Valve Stiction Detection and Compensation

## ❖ Objective

- The **Stiction Detection and Quantification package** detects **static friction (stiction)** in control valves and **estimates** the **numerical values** of the parameters used in the **data-driven stiction models**. This package allows users to combine stiction detection and quantification.

- The **Valve Stiction Compensation** Tool compensates for valve stiction in a single-loop control system. The tool offers a convenient way to **resolve the valve stiction problem without interrupting the process** or **adding any extra costs**.

## ❖ Software Preview

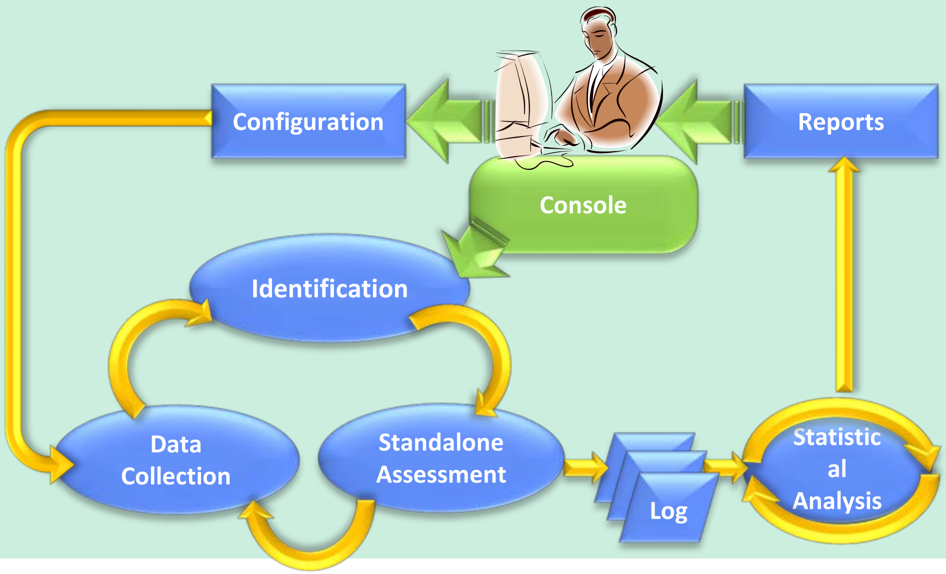


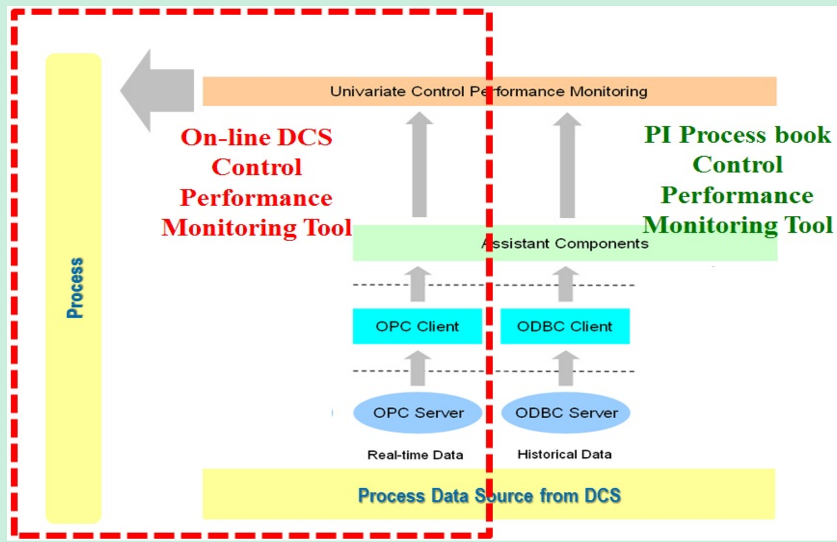
# Control Performance Monitoring

## ❖ Objective

Open Process Control **(OPC)** as well as **PI-ProcessBook** based Univariate Performance Assessment **(UVPA)** modules and functions based on **MATLAB®** assist users in **collecting process data from equipment periodically** and **automating the analysis of the control loop's performance**.

## ❖ Software Preview



Section 5:

# LAB RESOURCES

# Process Control Lab

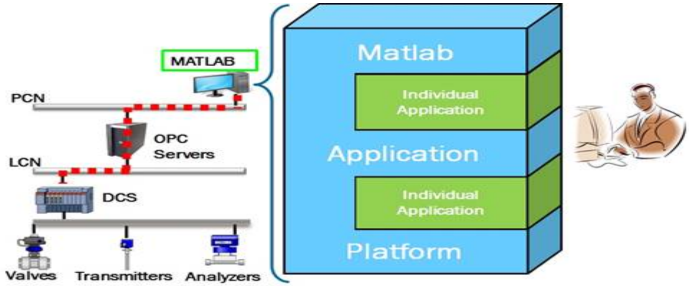
# Control Systems and Communication Devices

## ❖ Control Systems

The Process Control Lab is equipped with **Emerson DeltaV DCS** which helps to construct a process control simulation environment for university research that is as real as industrial process control applications. Currently, all engineering work such as control strategy design and configuration and soft sensor implementation are performed on DeltaV Professional Station.

## ❖ Communication Devices

In the lab, there are two OPC servers: **DeltaV OPC server** and **OPTO 22 Server**. There is one OPC client: MATLAB OPC client. Since all lab experimental devices can communicate with MATLAB, DeltaV DCS can communicate with lab experimental devices through DeltaV OPC server and MATLAB OPC client.



# Primary Separation Vessel (PSV)

- The lab is equipped with a plant to simulate and study the interface level monitoring for the **primary separation vessel (PSV)** in industry. Two immiscible process liquids, purified water and sunflower oil, are filled in the vessel to form an interface. Since sunflower oil which has relative low density represents **the froth layer** in real PSV and purified water represents the **middling layer**.
- Interface level is monitored using a **DP cell** as well as an **online camera** and is controlled to be maintained at a relatively constant position by manipulating water drainage pump rate. The plant is built up and can be operated using **LabView**. It is also connected with **MATLAB and DeltaV through OPC**. The captured images are analyzed using statistical methods to estimate the interface.

# Hybrid Tank and Multi-Tank Systems

❖ **Hybrid Tank System:**

In any industry, being able to control the level of a liquid in a tank is crucial for safety purposes, as well as for the optimization of a process. The Hybrid Tank is used to find control algorithms to regulate liquid heights in tanks. This plant is used for research on multi-input multi-output (MIMO) plant control and control of hybrid systems.

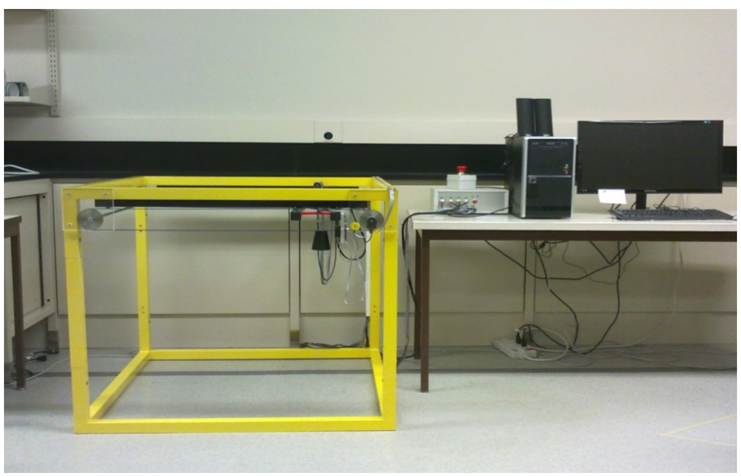
❖ **Multi-Tank System:**

The purpose of the Multi-Tank system experiment is to study different control systems for nonlinear processes. The varying shapes of the tanks in the Multi-Tank system leads the process to be nonlinear. In addition, the system introduces a measurement technique called Camera Fusion.

# 3D Crane Control and Ball in Tube Systems

❖ **3D Crane Control System:**

The purpose of 3D crane is to develop control algorithms used to reduce the swinging of a play load while moving towards a desired position as fast as possible. Industries use cranes to move heavy objects, and it could be very dangerous if the swinging of the load is not kept under control. Moreover, reducing the swinging will improve the efficiency of the work being done.



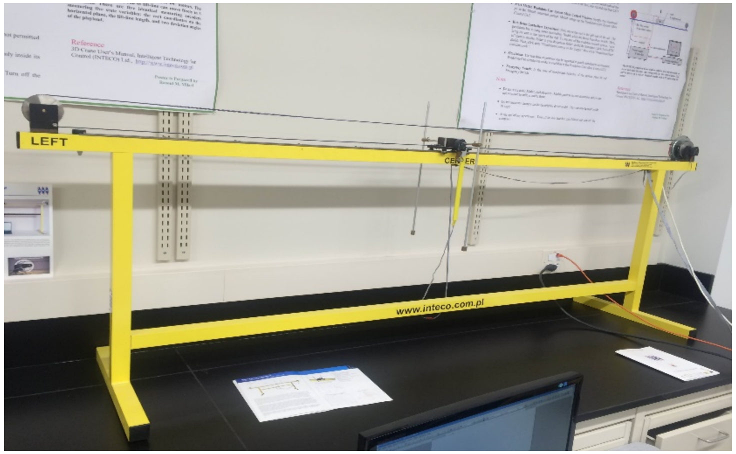
❖ **Ball in Tube System:**

The Ball-in-Tube experiment is aimed to be a test bed for the implementation of resource allocation strategies and control methods for a multi-input multi-output system. The experiment can be set up to study balancing the balls inside the tubes at a fixed position, balancing or allocation in the presence of plant changes, using inlet size changes or flow obstruction , Identification of system dynamics, etc.

# Inverse Pendulum and Thermal Chemical Reactor

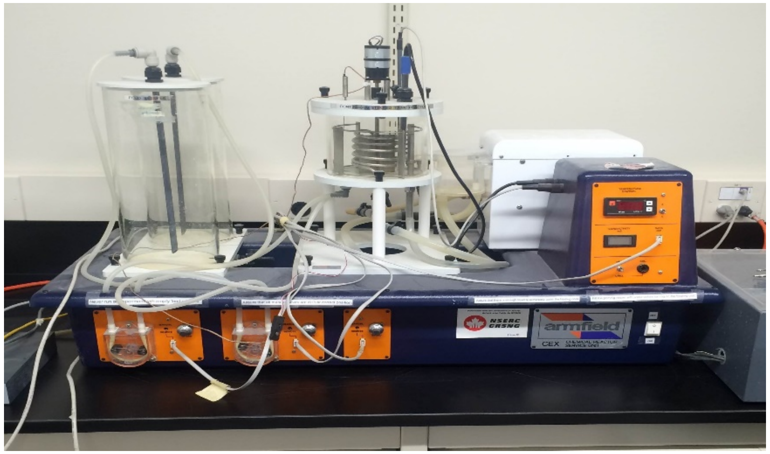
### ❖ Inverse Pendulum:

Control of a link using steering force is one of the basic problems in robotic. This laboratory experiment is used as a benchmark to test control algorithms (PID and Fuzzy). It is used to develop control algorithms to swing-up and stabilize the pendulum in the most efficient way possible; which involves time efficiency, rail limitations, and centering the cart while stabilizing the pendulum.




### ❖ Thermal Chemical Reactor:

The Armfield CEX Chemical Reactors Teaching Equipment demonstrates the characteristics of some of the important types of chemical reactor such as batch stirred tank reactor (batch reactor), continuous stirred tank reactor (CSTR) and tubular reactor. The purpose of this device is to implement different control strategies to control the temperature in the experimental reactors.



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