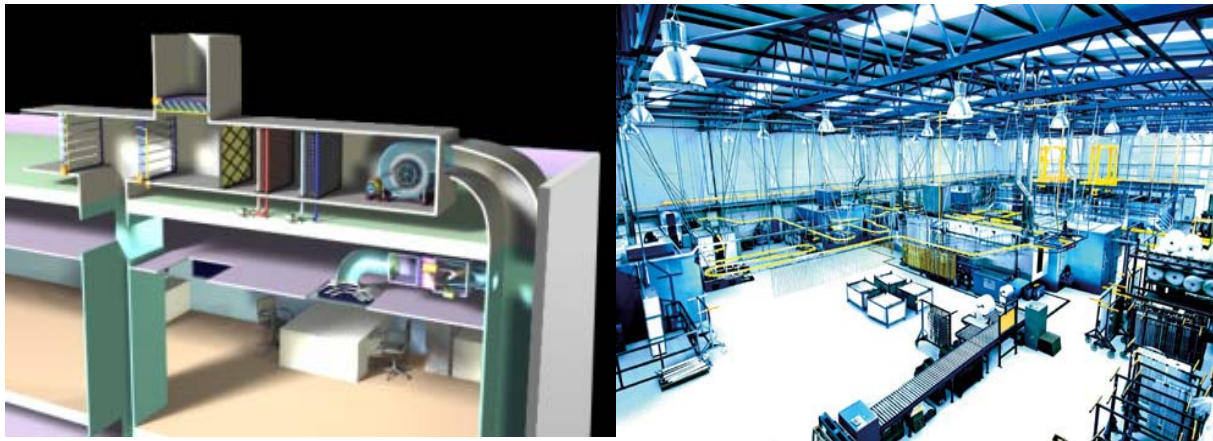


## Development of an Online Expert Rule based Automated Fault Detection and Diagnostic (AFDD) tool for Air Handling Units: Beta Test Results

**ICEBO 2013, MONTREAL, CANADA**

Ken Bruton, Daniel Coakley, Peter O'Donovan, Marcus M. Keane & D. T. J. O'Sullivan



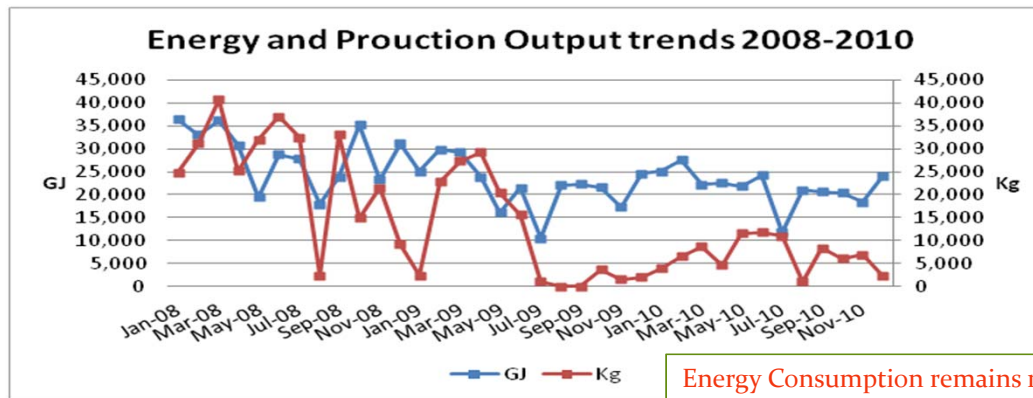


# Agenda

- Why does industry need this work?
- Why HVAC?
- An automated solution.....
- AFDD techniques
- Early Results



## Why does industry need this research work?



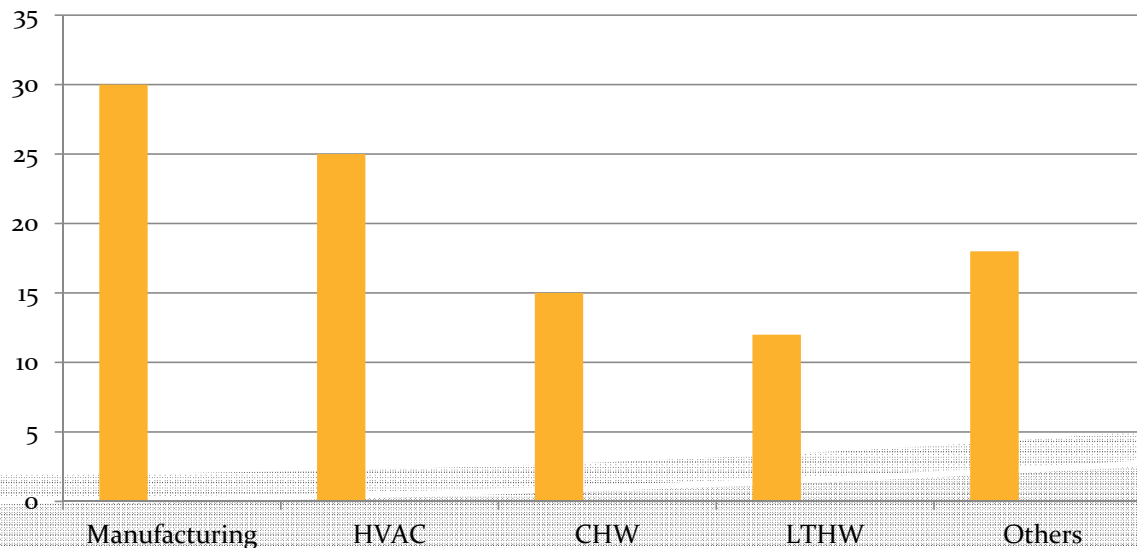
Energy Consumption remains relatively constant though production volume has decreased significantly



- Focus on production output in lieu of efficiency
- Difficult to track efficiency due to islands of information
- Competition from lower cost economies for investment

## Why Focus on HVAC Systems?

- Typically greater than 20% of an industrial site's energy consumption
- HVAC systems get less efficient over time
- 20-30% energy savings are achievable by re-commissioning HVAC



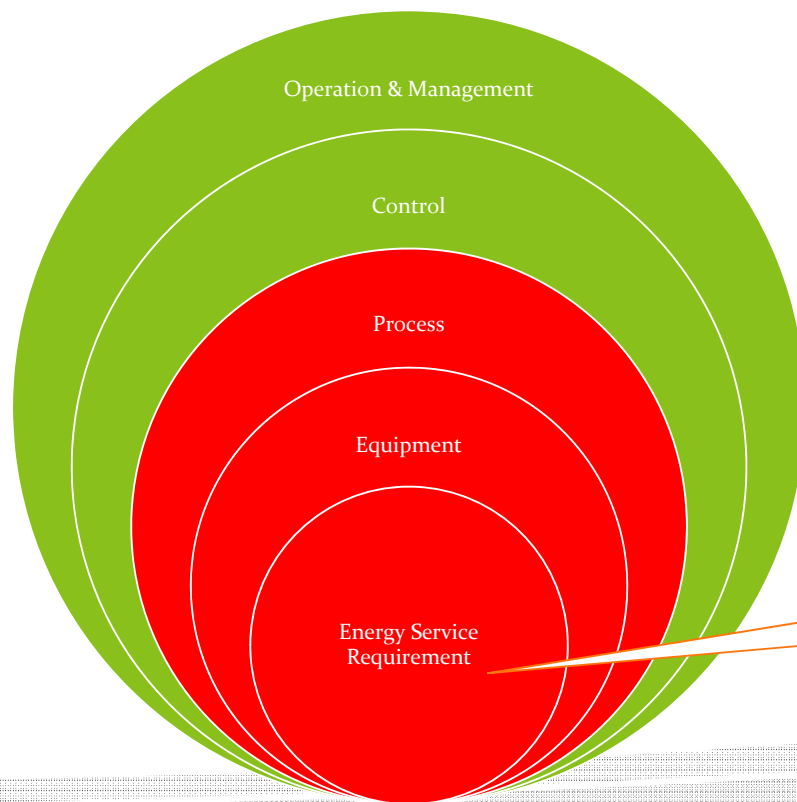


# How can AFDD help save HVAC Energy?





# How can AFDD help save HVAC Energy?

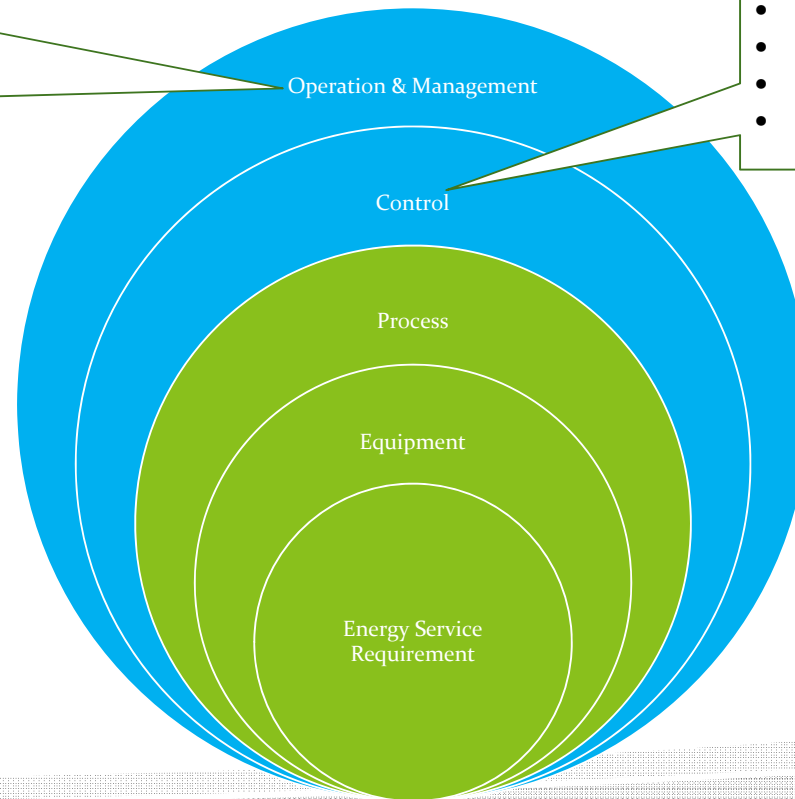


Air Change Reduction



## How can AFDD help save HVAC Energy?

- Simultaneous heating & cooling
- Set point adjustments
- Manual operation
- Sub optimal performance of equipment



- Inefficient control strategies
- Poor loop tuning
- Free cooling
- Incorporation of Deadbands





# Why an automated tool?

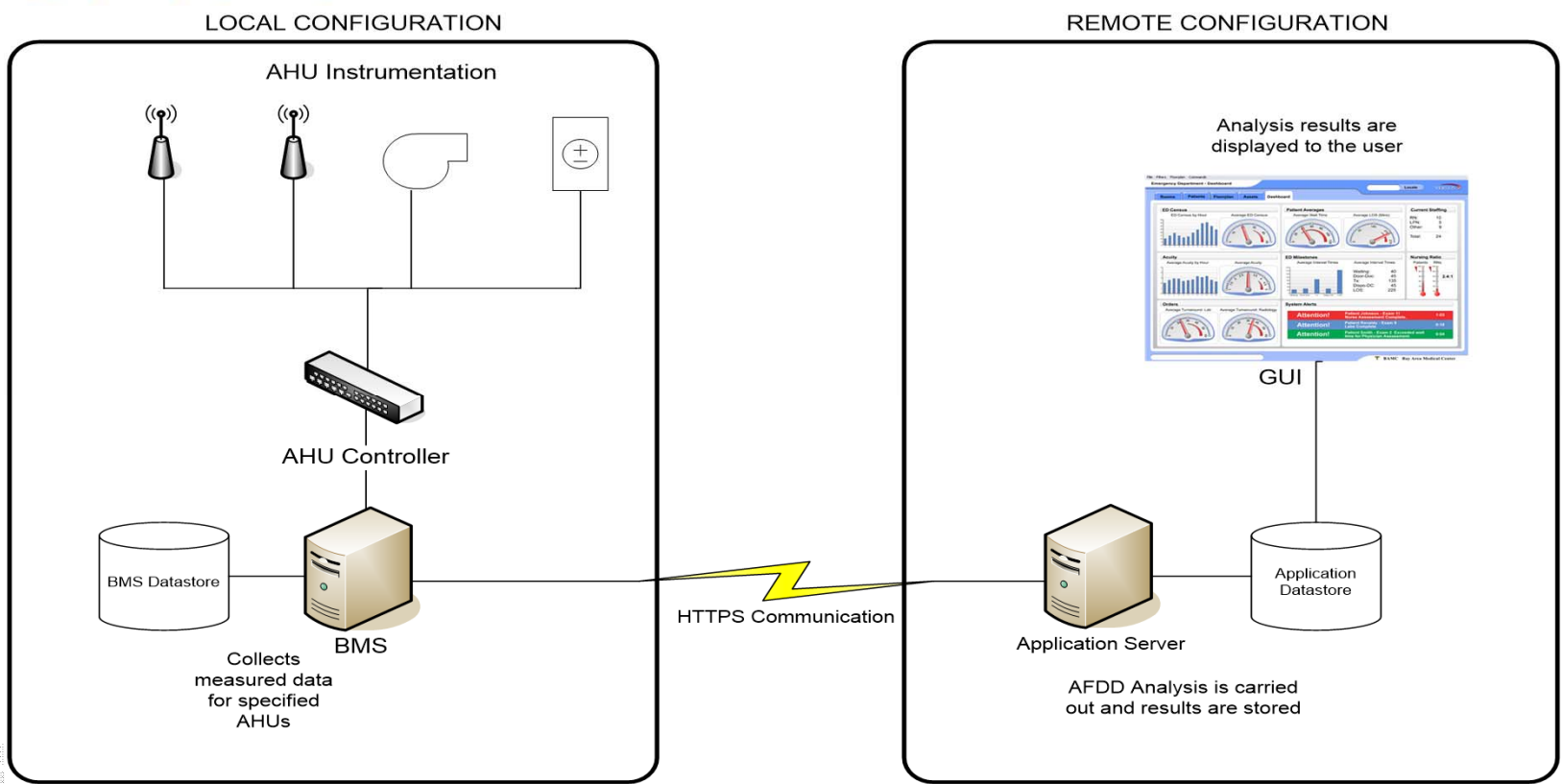
20 to 1  
Knowledge  
Complexity







# AFDD tool requirements

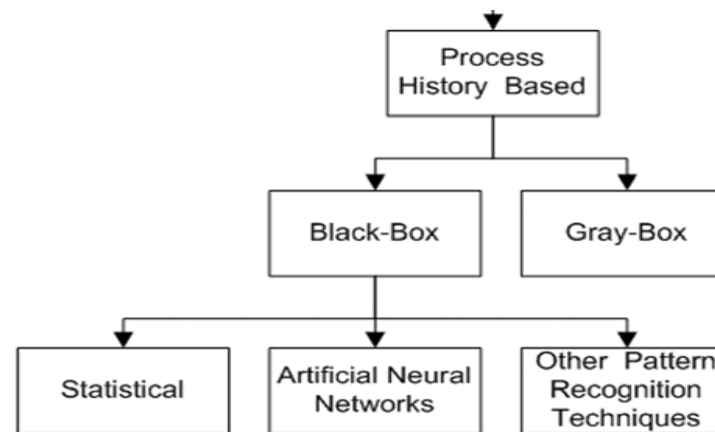
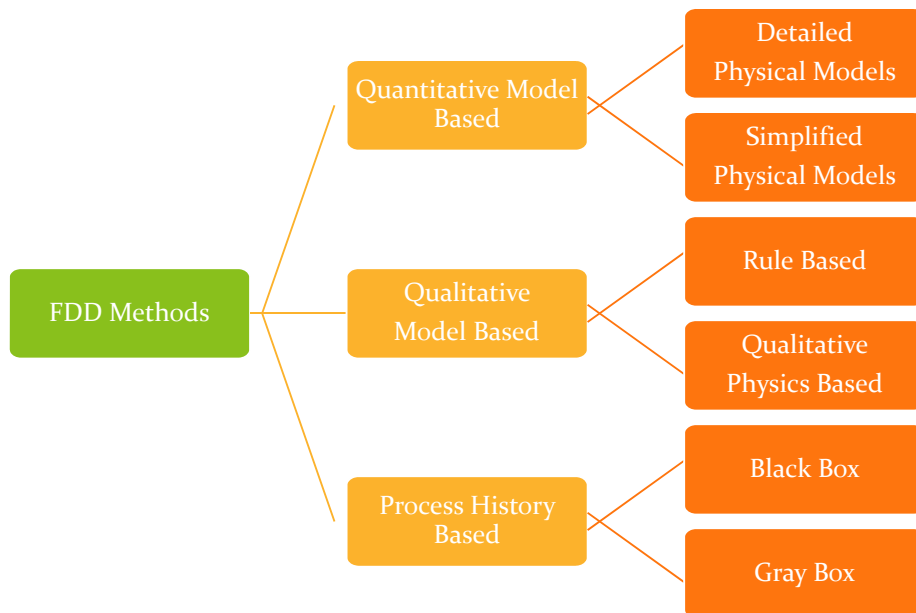


dependencies  
S Flexibility



# FDD Techniques

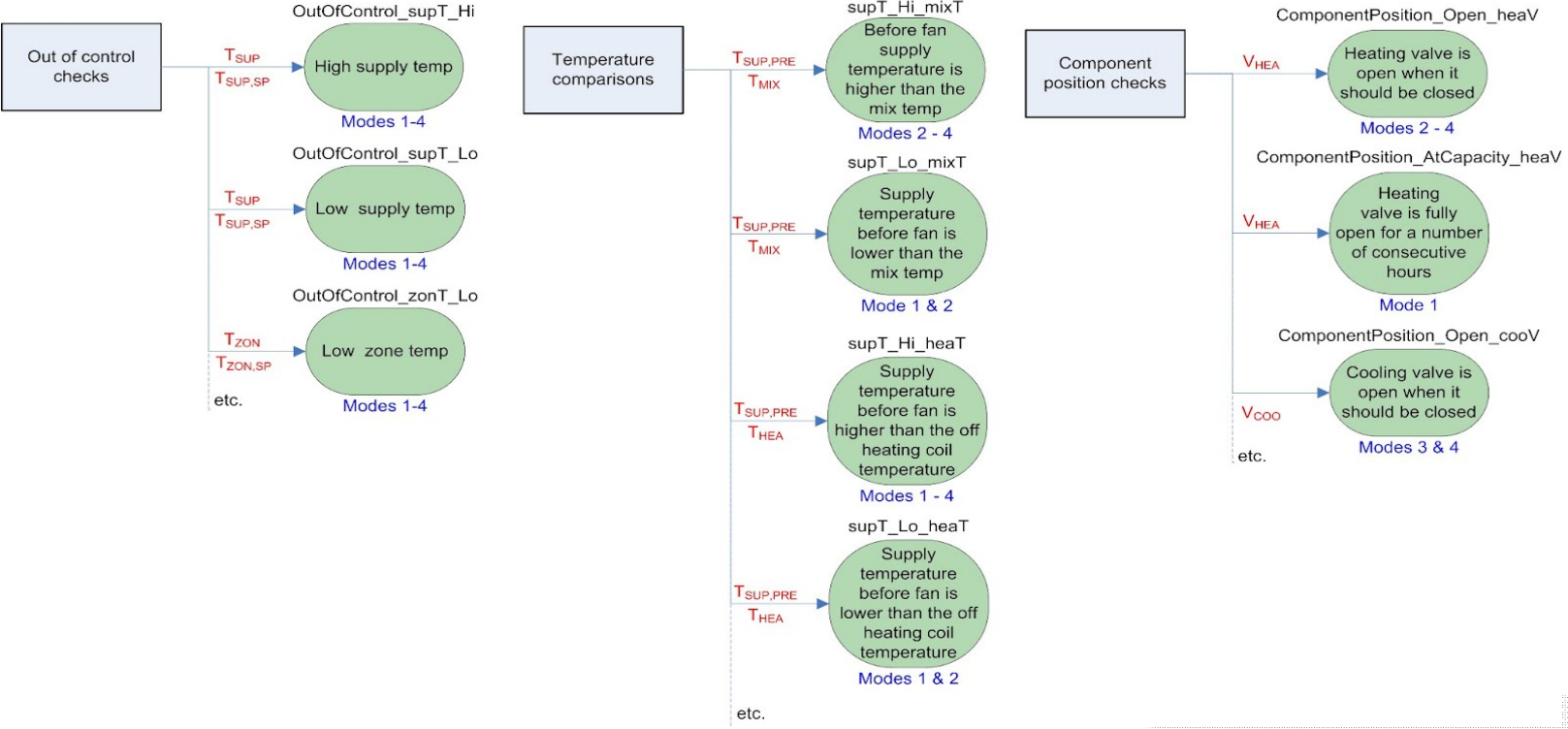
- FDD automates the process of detecting and diagnosing faults



- A rule based FDD tool can be developed and implemented in industry relatively quickly utilising existing equipment



# The Business Layer



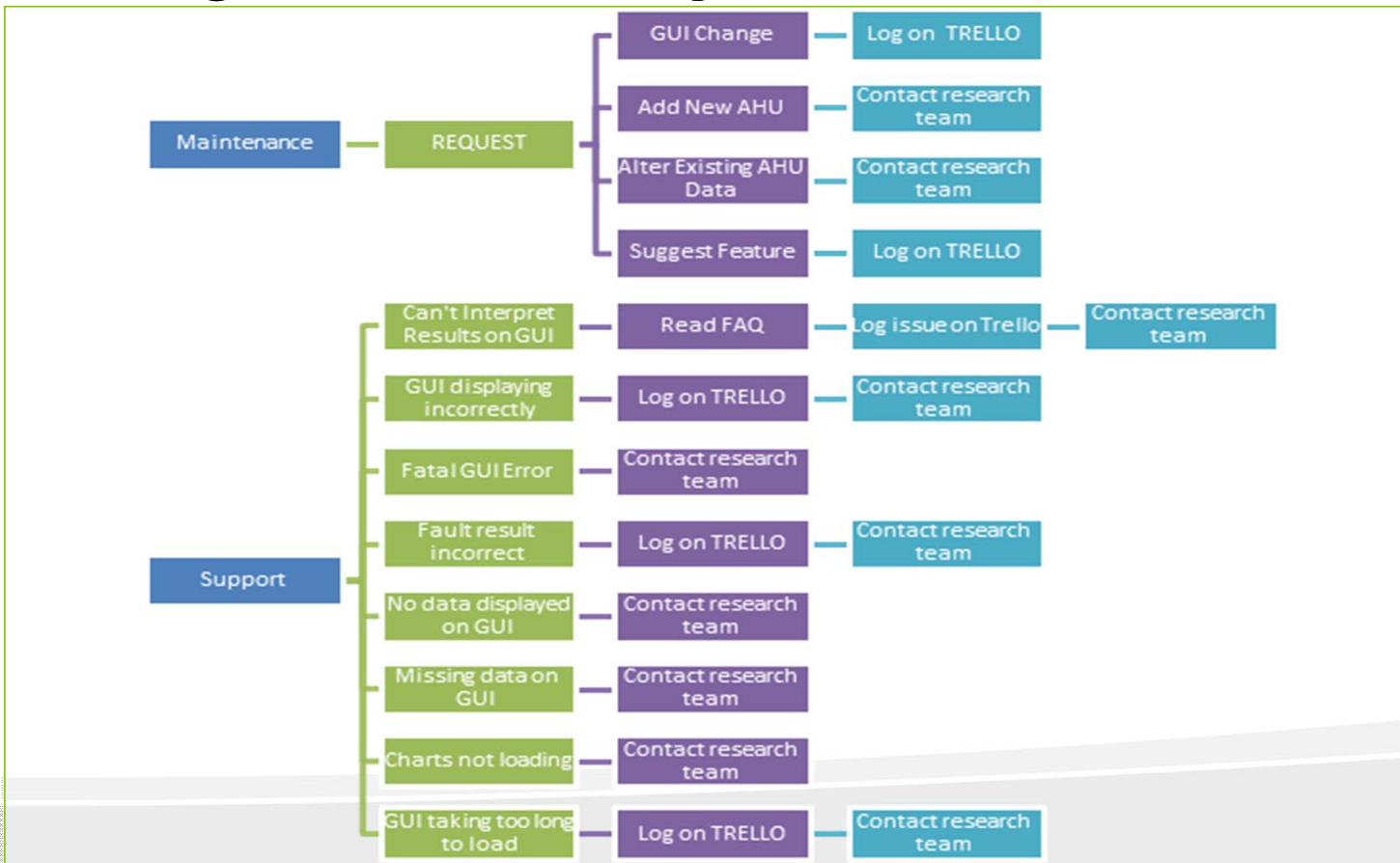
## Design of Test Study – AHU Selection

- > 200 AHU's available on 7 industrial and commercial sites
- AHU's were selected with
  - Different component and sensor layouts
  - Varying levels of instrumentation



Site	No. AHUs in pilot	Type	Type of zone(s) supplied	Operating hours annum	BMS/Data logging Platform	Frequency of logged data
1	2	Constant volume	Office & canteen	8760	Trend	15 minutes
2	4	Constant volume	Manufacturing Floor	8760	Tridium	15 minutes
3	9	Variable Volume	Manufacturing Floor	6240	Cylon	15 minutes
4	4	Constant Volume	Commercial office space	6240	Cylon	7.5 minutes
5	3	Variable Volume	Commercial office space	6240	Schneider	15 minutes
6	2	Constant Volume	Manufacturing Floor	8760	Qlikview	15 minutes

# Design of Test Study - Feedback





# AFDD tool in Alpha testing

**Current display time**  
2011-12-07 07:00 Wed

Hour: 0  
Day: 1  
Week: 0

Reset schematic diagram

Temps  Other cond  
 Humid/Sec  Virtual valu  
 Valve/damper positio

List faults by...  
...frequency ...cost

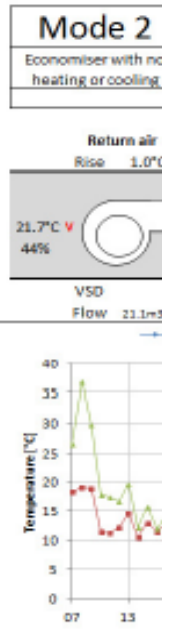
Fault selection  
DeltaT\_supT\_H\_maxT

Go to ... fault instance  
Oldest Next Newest Previous

Description of current fault

The supply temperature is higher than the mix temperature, when it should be identical (2) or lower (3,4).

No. fault hours... 92  
... as % of period 27%  
... as % of run hours 22%



**ENGINEER'S REPORT & DAYWORKS SHEET**

**ACE**  
CONTROL SYSTEMS LTD.

Ballycollig, Co. Cork  
Phone (021) 4873 003

New Road, Dublin 24  
Phone (01) 4036 202

REPORT NO. 31779

SITE	DEPUTY		
CUSTOMER	ALIGHTY		
SITE CONTACT	DAVE COYAREL		
ENGINEER	TOM DEASY		
PROJECT NO.	MOSS	P.M.	VC

JOURNEY ON OPERATIONS OF CONTROLS ON PRODUCTION FLOOR  
AHU'S 6, 7, 8, 9

- CHECKED ALL C.H.W + L.P.H.W VALVES FOR SIGN'S OF PASSING
- ALL TEMPERATURE SENSORS CHECKED CORRECTLY CALIBRATED AND ADJUSTED WERE REQUIRED
- CHECKED CORRECT OPERATION OF FRESH, RECIRC AND EXHAUST DAMPERS
- ALL ASSOCIATED FIELD EQUIPEMENT (IE V.S.D'S, ACTUATOR) CHECKED

FOUND FOLLOWING ISSUE'S

AHU 6 (A) CHECKED ~~DIFFUSER~~ DIFFUSER ON LEGS FOUND 3 AIR DIFFUSER ON LEG 3 NOT OPERATING.

AHU 7 (A) RETURN MOTOR FAULTY RECOMMEND REPLACING AS THIS IS EFFECTING OPERATION OF SYSTEM'S DAMPER'S AND IS CAUSING AREA TO OVERHEAT (B) ~~FRESH AIR DAMPER ACTUATOR ON UPPER DAMPER FAULTY~~

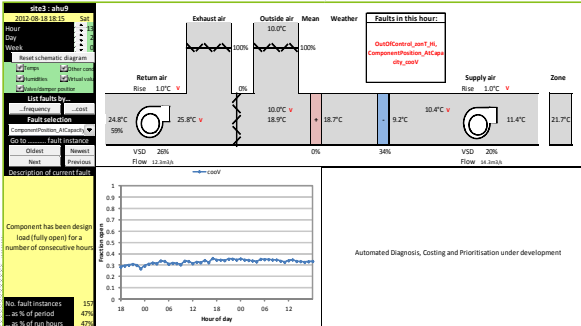
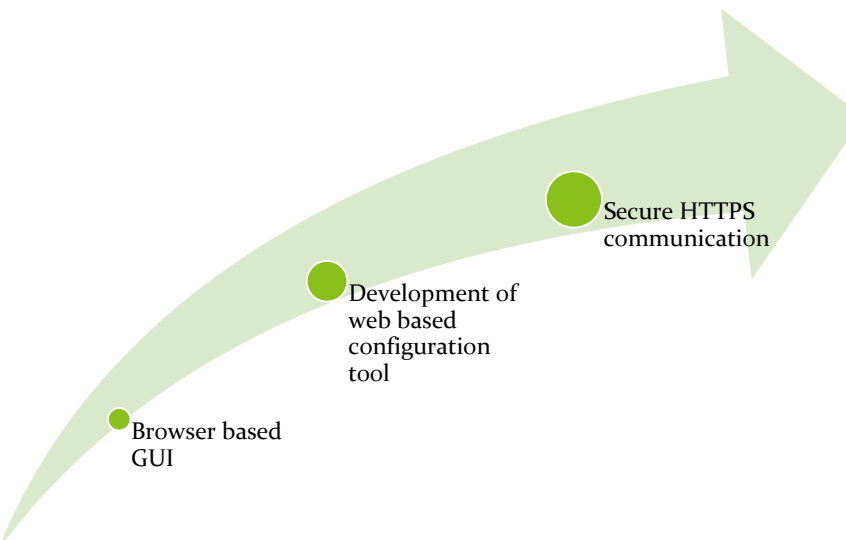
AHU 8 (A) RECIRC DAMPER NOT SEALING CORRECTLY LOUVERS DAMAGED (B) COOLING VALVE SLIGHTLY PASSING CLADDING AROUND VALVE TO BE REPLACED TO DEFECTING WHAT SIZE VALVE.

AHU 9 (A) RECIRC DAMPER NOT SEALING CORRECTLY LOUVERS DAMAGED



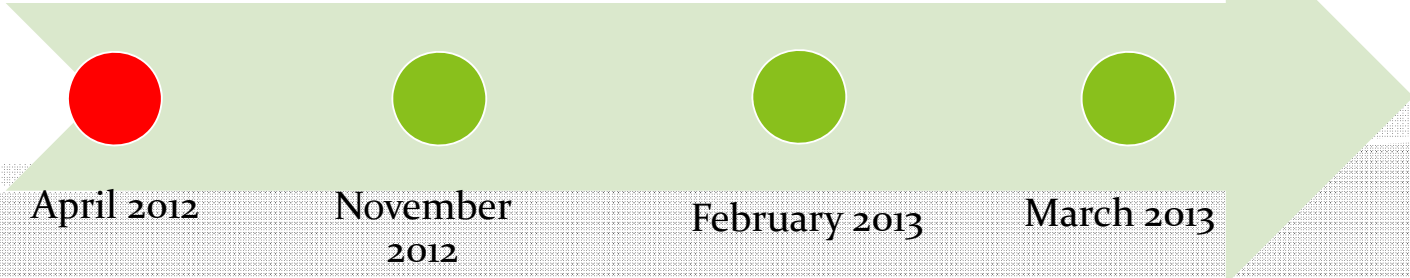
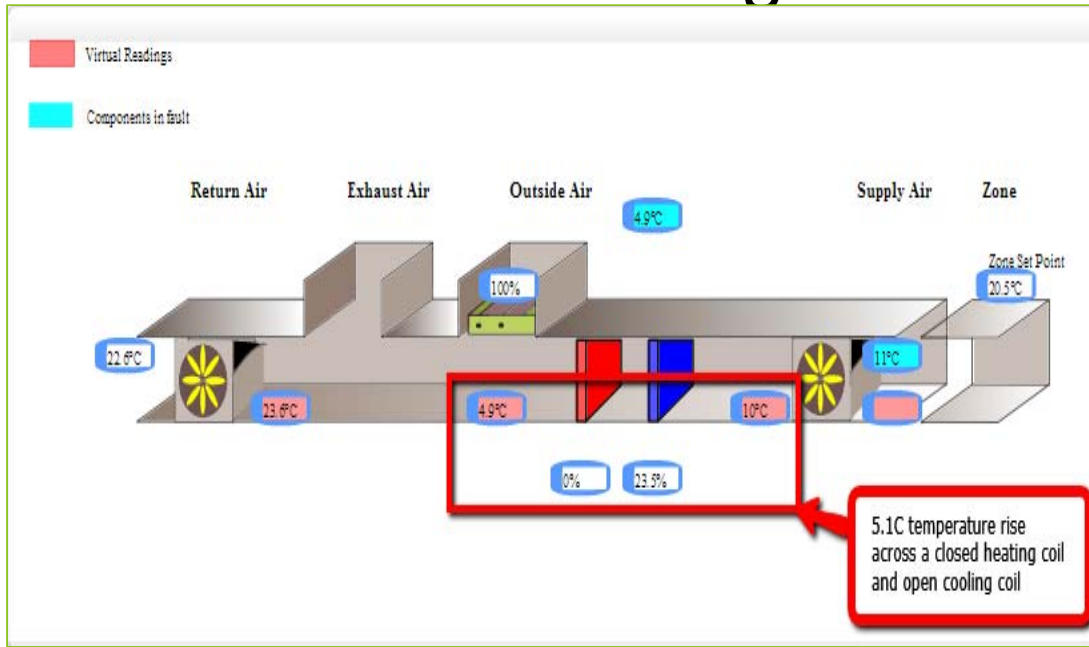


# Alpha to Beta Testing





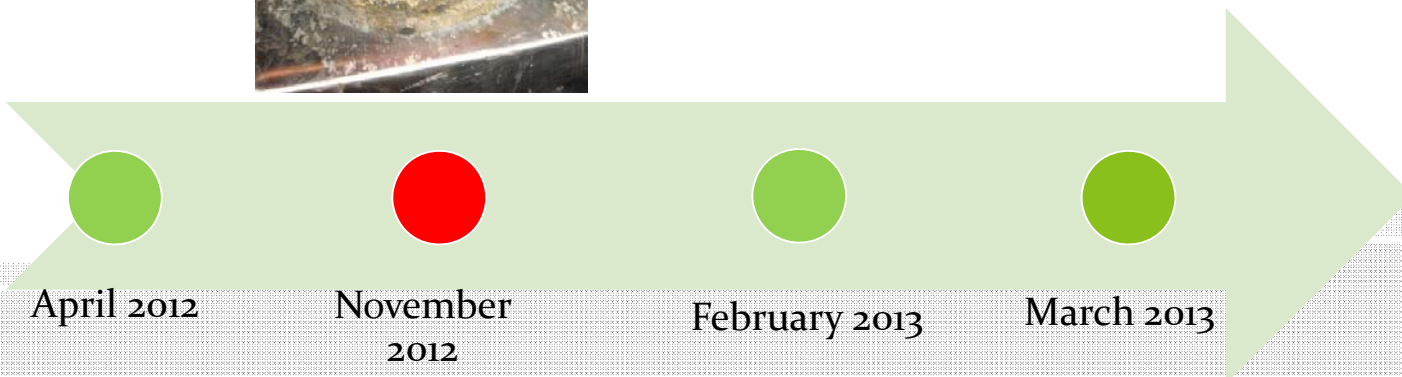
# AFDD tool in Beta testing





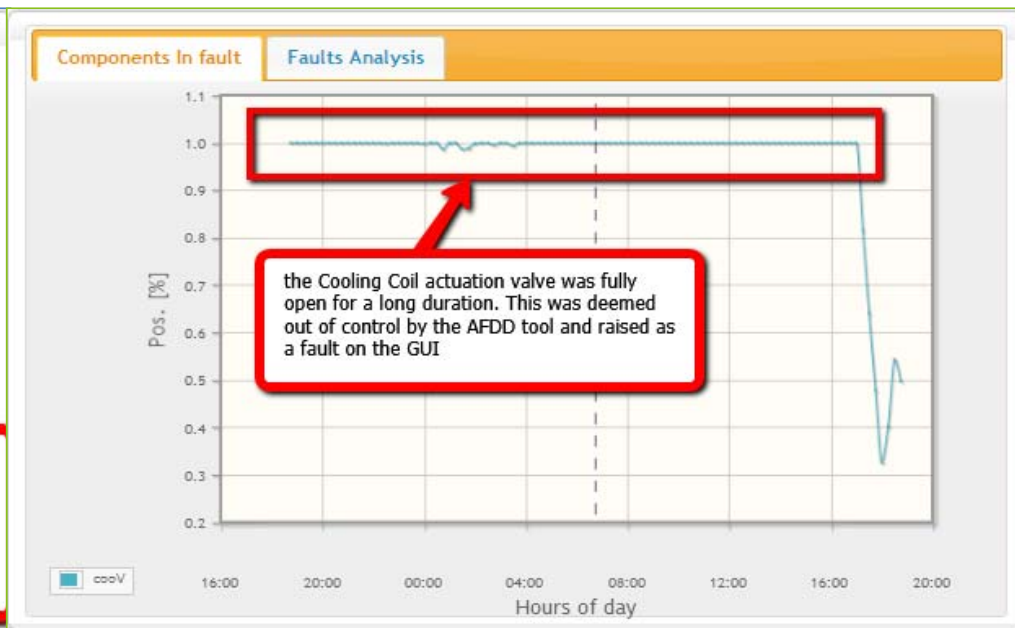
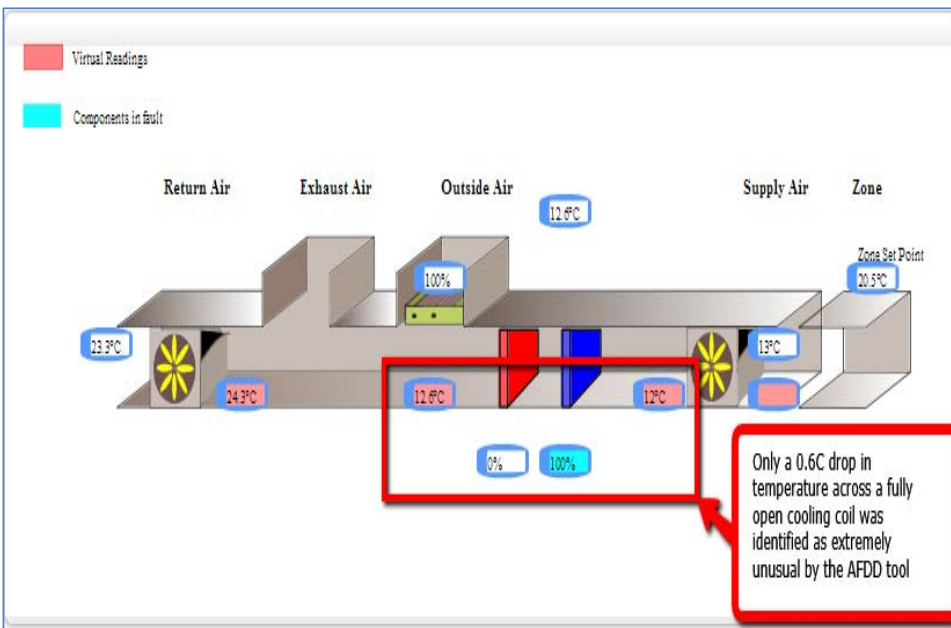


# AFDD tool in Beta testing





# AFDD tool in Beta testing



April 2012

November 2012

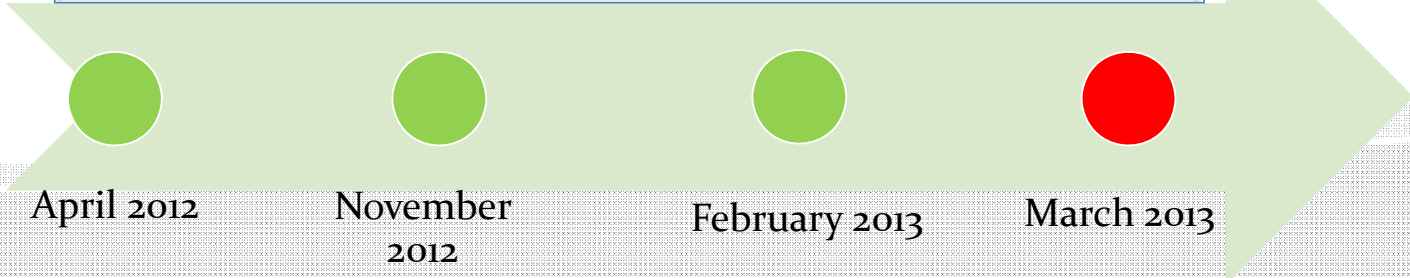
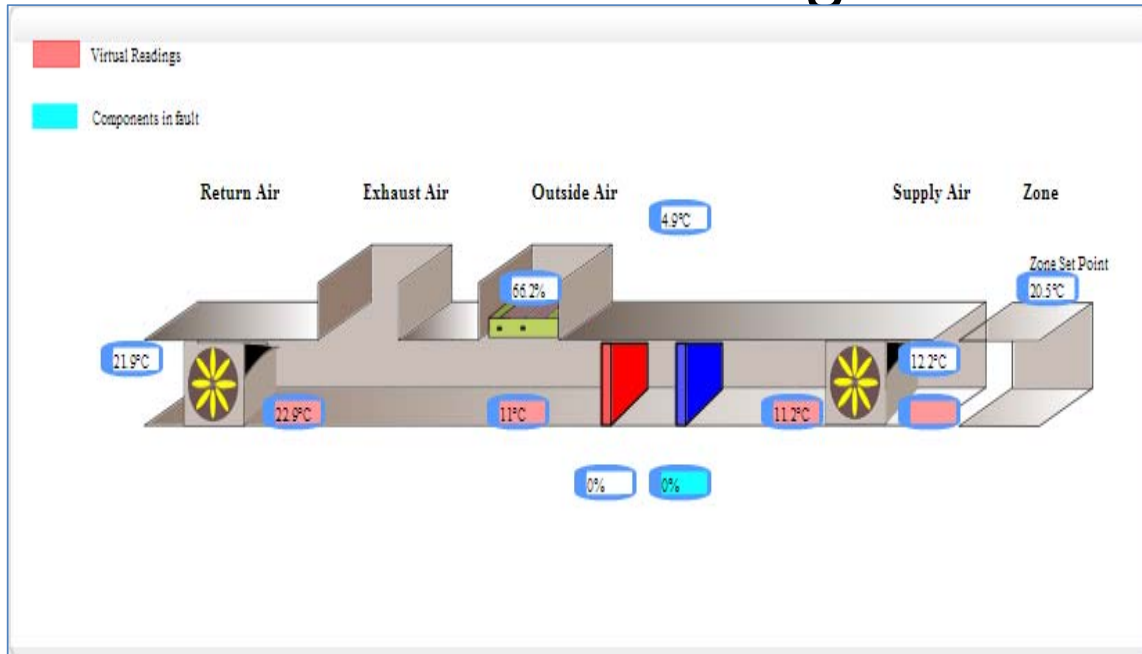
February 2013

March 2013

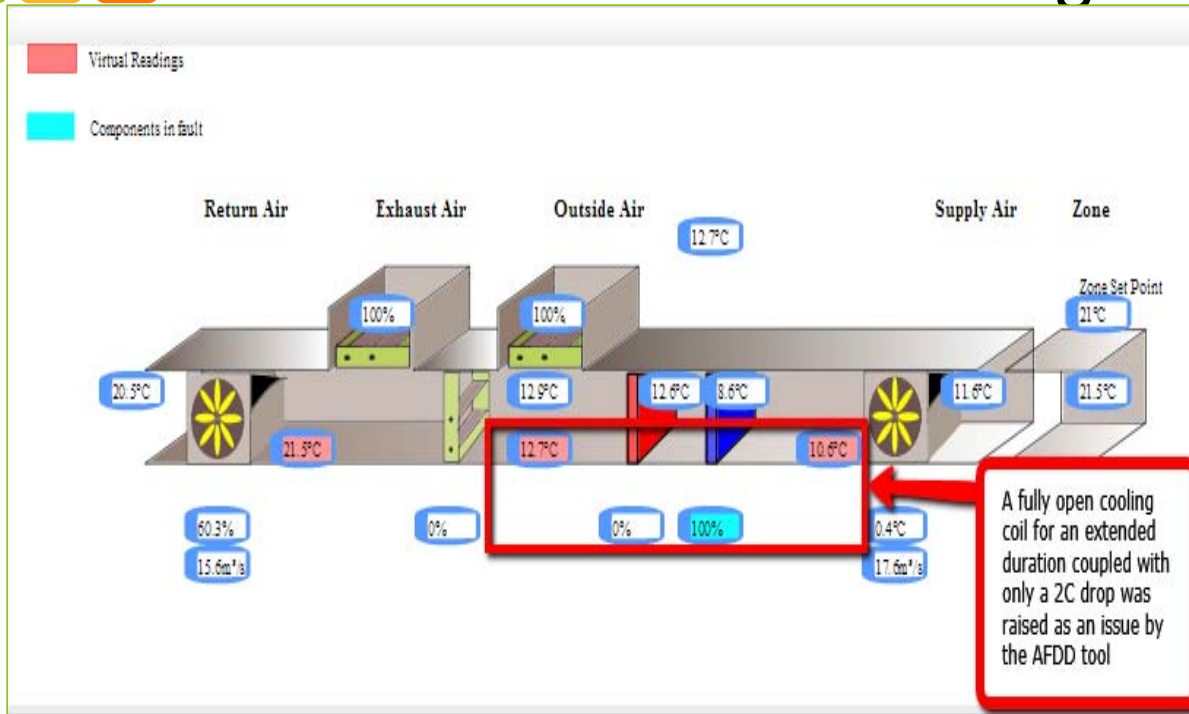




# AFDD tool in Beta testing



# AFDD tool in Beta testing



# Requirements Versus Developments

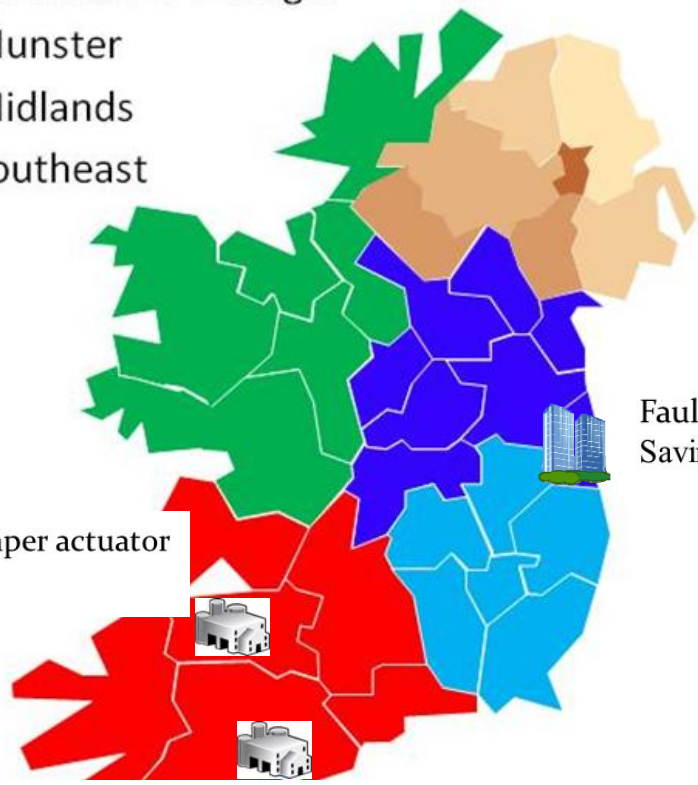
Rationale	Requirement(s)	Framework/Tool Developed
Data Access Layer Flexibility	Compatibility with any BMS type or age	A generic data access tool was developed
Business Layer Flexibility	Compatible with various combinations of sensors and components	Calculation of virtual values coupled with “rule libraries”
Reliability	Low number of false positives/negatives	A error threshold applied to each rule based on rule makeup
Usability	User friendly graphical user interface (GUI)	A browser based GUI was developed
Fault Priority	Quantification and prioritisation of the diagnosed faults	Each fault is prioritised in terms of cost and frequency of occurrence
Scalability	Rapid setup time per AHU	A web based site configuration tool was developed
Low Cost	Ability to use existing measurements	First principal techniques and engineering computation utilised to calculate readings where none are present





# Results

- Connacht & Donegal
- Munster
- Midlands
- Southeast



Faults: Passing heating coil, stuck damper actuator  
Savings: €74,000

Faults: Passing coils, design issues  
Savings: €26,000

Faults: Damaged dampers, high supply temperature, passing cooling coil  
Savings: €53,000





## Next Steps

- Develop OPC functionality to expand data capture capability
- Expand the business layer to incorporate humidity control AFDD
- Further develop the fault costing & prioritisation methodology
- Improve diagnostic and future prognostic capabilities
- Automate the link to planned maintenance systems





If we knew what it was we were doing, it would not be called research, would it?

Albert Einstein

Ken Bruton

i2e2 Researcher

Department of Civil & Environmental Engineering,

University College Cork

[k.bruton@ucc.ie](mailto:k.bruton@ucc.ie)

