Refinery Stream Modeling Walkthrough

Agenda

- Introduction
- Refinery stream modeling overview
- Modeling exercise
  - Crude unit straight run naphtha 95%
- Feedback, Q&A

Our team

- 40 years refinery process engineering, control, and real time optimization experience
  - Crude/Vac, Alky, FCC, Hydrocracking, Light Ends, Olefins...
- Site Plans
  - Sequence of advanced project control
  - Benefit
  - Additional Instrumentation requirements
- Tuning
  - Poor regulatory tuning can reduce APC benefits by 40%-70%
- Honeywell experience
  - TDC, Experion, GUS, PHD, CL programming, APC
  - Upgrades, support

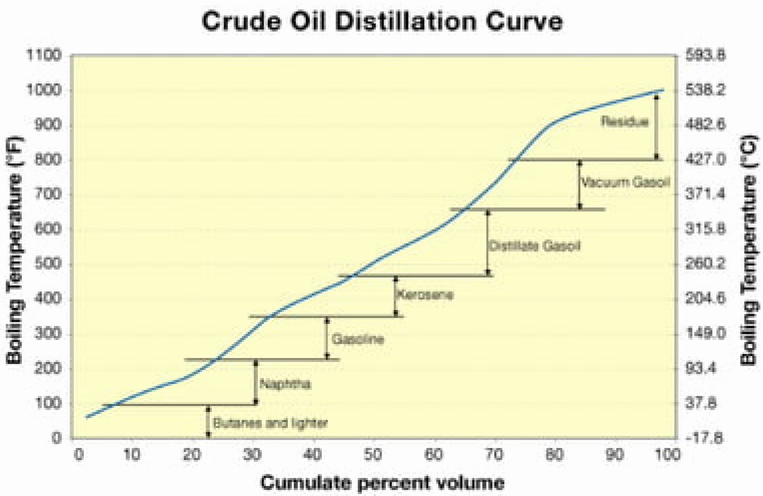
Inferentials are core in refinery advanced process control

- Distillation
- RVP
- Smoke
- Flash
- Cloud, Pour, Viscosity
- Colour
- Octane, Cetane
- Composition
- Drivability
- Penetration, Shear

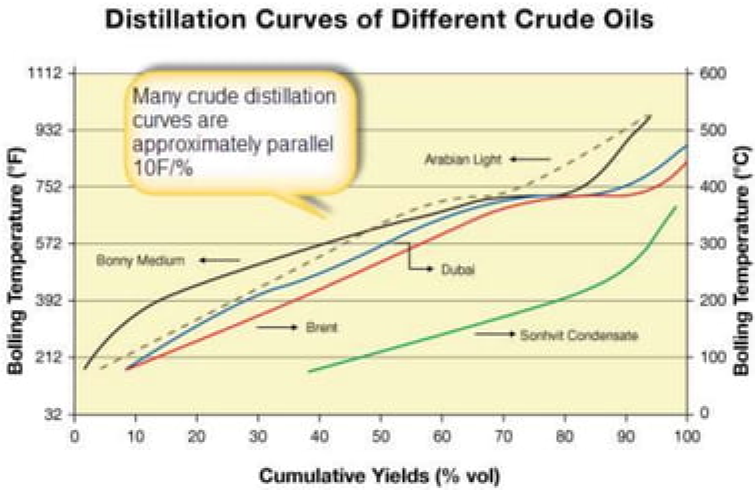
- Apply chemical engineering to select plausible variables and equation forms
  - Front end distillation = f(Bubble Point)
  - Tail end distillation = f(Dewpoint)
  - Flash $\propto$ ASTM 5%
  - Cloud $\propto$ f(50%, Aromaticity)
  - RVP $\ln(VP) = \dfrac{A}{B + CT}$

Modeling strategy

Crude Unit


Crude Oil Distillation Curve
Boiling Temperature (°F)
Boiling Temperature (°C)
1100
1000
900
800
700
600
500
400
300
200
100
0
593.8
538.2
482.6
427.0
371.4
315.8
260.2
204.6
149.0
93.4
37.8
-17.8
Residue
Vacuum Gasoil
Distillate Gasoil
Kerosene
Gasoline
Naphtha
Butanes and lighter
0
10
20
30
40
50
60
70
80
90
100
Cumulate percent volume

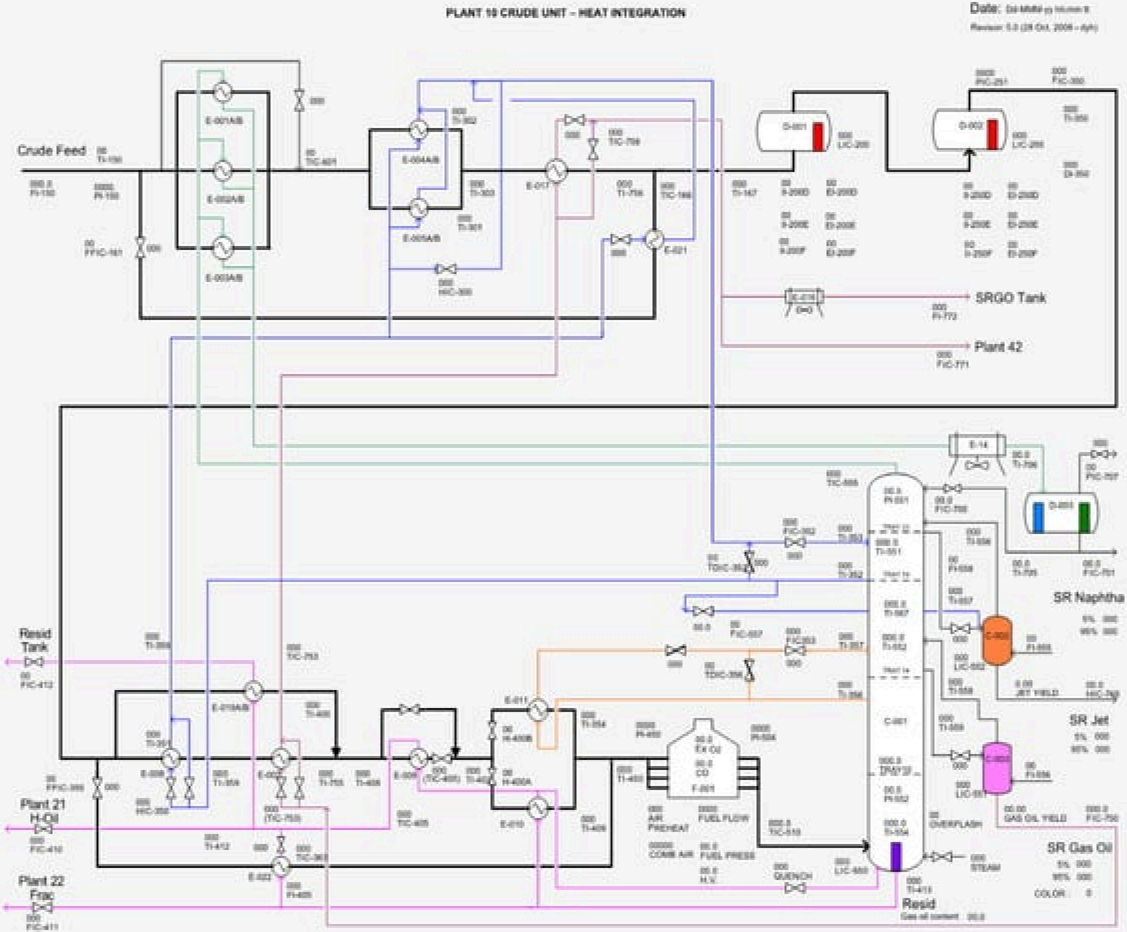
Crude Unit


Distillation Curves of Different Crude Oils
Many crude distillation curves are approximately parallel 10F/%
Arabian Light
Bonny Medium
Dubai
Brent
Snohvit Condensate
Boiling Temperature (°F)
Boiling Temperature (°C)
Cumulative Yields (% vol)
1112
932
752
572
392
212
32
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100

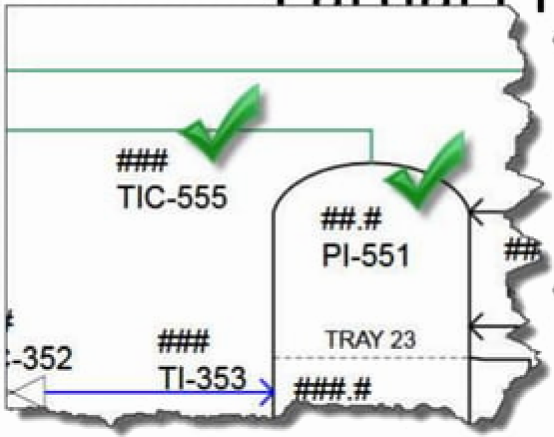
Model lab

- Straight run naptha 95%
  - Fit model
  - Accuracy
  - Compare different points (90%, 95%, FBP)

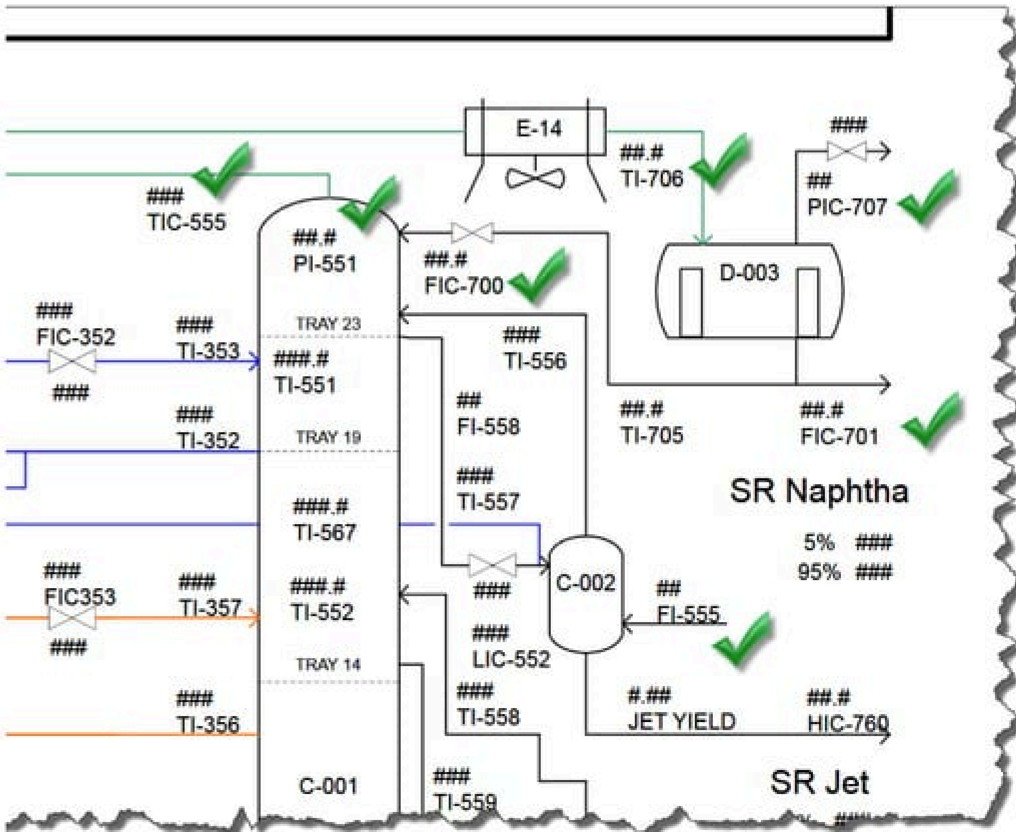
PLANT 10 CRUDE UNIT – HEAT INTEGRATION



Partial Pressure



- TIC-555 overhead dewpoint at the hydrocarbon partial pressure
- Convert PI-551 to absolute
  - Calculate naptha and steam moles to calculate HC partial pressure


E-14
###
TIC-555
##.#
TI-706
###
##
PIC-707
##.#
PI-551
##.#
FIC-700
D-003
###
FIC-352
###
TI-353
TRAY 23
###.#
TI-551
###
TI-556
###
##
FI-558
##.#
TI-705
##.#
FIC-701
###
TI-352
TRAY 19
###
TI-557
SR Naphtha
###.#
TI-567
5% ###
95% ###
###
FIC353
###
TI-357
###.#
TI-552
###
C-002
##
FI-555
###
###
LIC-552
TRAY 14
###
TI-558
#.##
JET YIELD
##.#
HIC-760
###
TI-356
C-001
###
TI-559
SR Jet

Process Taglist

Tag	Description	Units
10FIC553	STRIP STEAM	kg/min
10FI555	STRIP STM TO C 2	kg/h
10FI556	STRIP STM TO C 3	kg/h
10TIC555	C 1 OVHEAD TEMP	deg C
10PI551	CRUDE TOWER TOP	kPag
10FIC700	C 1 REFLUX FLOW	m3/h
10PIC707	D3 RELIEF TO FLARE	KPAG
10FIC701	D 3 NAPHTHA FLOW	m3/h
10DI350	DESALTED CRUDE DENSITY	KG/M3
10FI350	DESALTED CRUDE FEED	MT/H
10TI551	CRUDE TOWER TRAY 23	deg C
10TI705	OVHD ACCUMULATOR NAPHTHA OUTLET	deg C
10TI706	C 1 OHEAD TO D 3	deg C

Lab Data

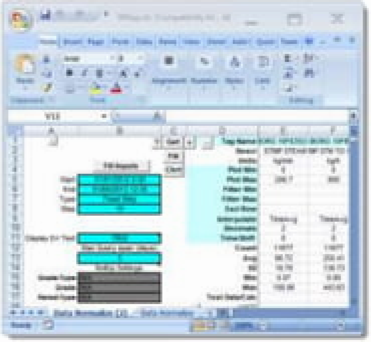
MW Calc

Tag	Units
STR RUN NAPHTHA, DENSITY [DENSITY]	kg/m^3
STR RUN NAPHTHA, SIMDIST(D2887) [IBP]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [5%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [10%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [15%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [20%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [25%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [30%]	°C
...	°C
STR RUN NAPHTHA, SIMDIST(D2887) [50%]	°C
...	°C
STR RUN NAPHTHA, SIMDIST(D2887) [90%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [95%]	°C
STR RUN NAPHTHA, SIMDIST(D2887) [FBP]	°C

Data Collection

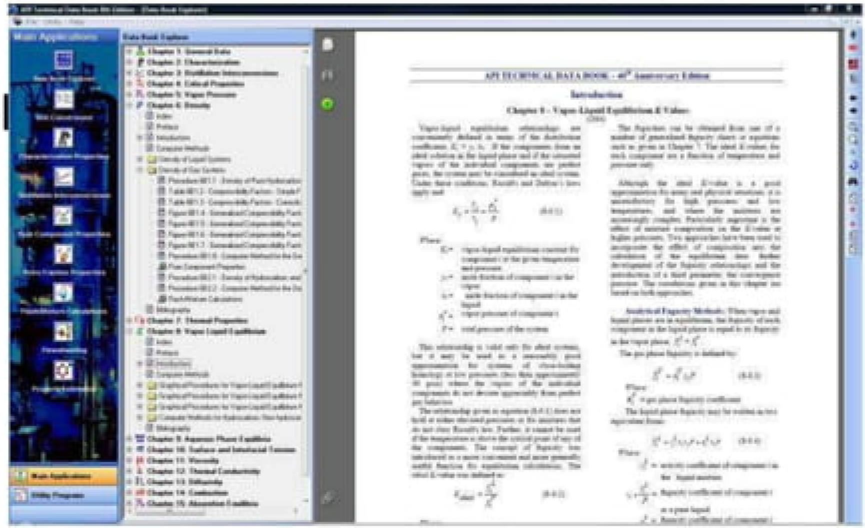
- Frequency
  - Lab data timestamps are usually only approximate
    - If the plant is steady the error this causes isn't serious
  - If data from historian, we make sure that compression is not excessive
  - For analysis, we typically work with averages of plant variables versus instantaneous readings
    - This eliminates high frequency noise
    - Crude unit, one hour average is usually effective

Client Dataset



Correlation sources

- API



Stream MW

$MW = 20.486*[\exp(0.000165*T_b - 7.78712*SG+0.0011582*T_b*SG)]*T_b^{1.26007}*SG^{4.98308}$

where:

MW = molecular weight of the fraction

T_b = mean average boiling point of the petroleum fraction degR

SG = specific gravity of the cut

Ref: 2B1.1 and 2B2.1

Modeling tool

- MACSEstimator modeling
  - Offline tool
  - Data visualization tool (PARCview)
    - Explore and filter data
    - Connect to your site sources and Excel
    - Test models
    - Fit models
    - Create calculated tags
  - Both use the same math libraries

Formulas and Calculations

- Comes with ASME steam tables
- Clients can create their own saved libraries of formulas/functions
- Calculated tags get named and saved
- Supports external DLL libraries
- Capstone physical property library available
- Formulas and library can be accessed by process engineers using Excel

Using Steam Tables

What is the saturation temperature of steam at 101.325 kPa, saturated vapour?

Answer: 99.96429585 °C, or 211.9496461 °F

	A	B	C	D	E
1	function	pressure	units	Result Formula	Result Value
2	fnTSatFromP(Pressure, Units)	101.325	SI	=fntsatfromp(B2, C2)	99.96429585
3		14.7	AE	=fntsatfromp(B3, C3)	211.9496461

rty Library

	A	B	C
1	Formula	Property	Result
2	CH4	MW	=Pureprop(A2,B2)
3	N2	Tb	=Pureprop(A3,B3)
4	CO2	MW	=Pureprop(A4,B4)
5	H2	MW	=Pureprop(A5,B5)
6	O2	MW	=Pureprop(A6,B6)
7	CO	MW	=Pureprop(A7,B7)
8	ClH	MW	=Pureprop(A8,B8)
9	C7H8	Omega	=Pureprop(A9,B9)
10	CH4	Tc	=Pureprop(A10,B10)
11	CH4	Pc	=Pureprop(A11,B11)
12	CH4	Vc	=Pureprop(A12,B12)
13			
14			

	A	B	C
1	Formula	Property	Result
2	CH4	MW	16.043
3	N2	Tb	77.35
4	CO2	MW	44.01
5	H2	MW	2.016
6	O2	MW	31.999
7	CO	MW	28.01
8	ClH	MW	36.461
9	C7H8	Omega	0.264
10	CH4	Tc	190.56
11	CH4	Pc	45.99
12	CH4	Vc	98.6
13			

468 Compounds in library

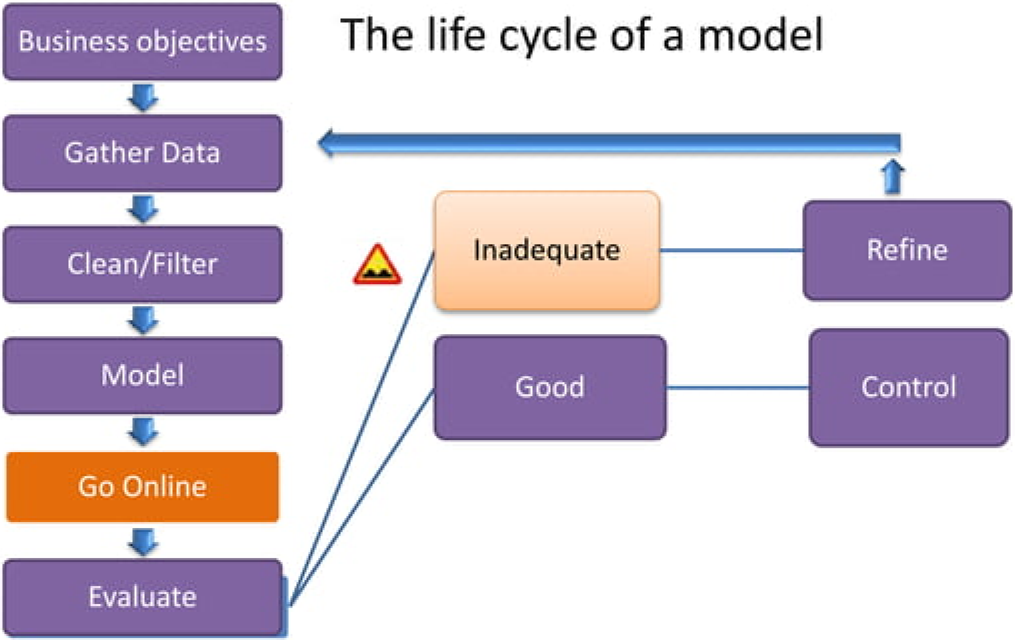
Pure properties or thermodynamic properties such as Cp, Enthalpy, …

Going Online

- Components
- Data Flow

MACSEstimator

A simple online calculation is not enough of a solution

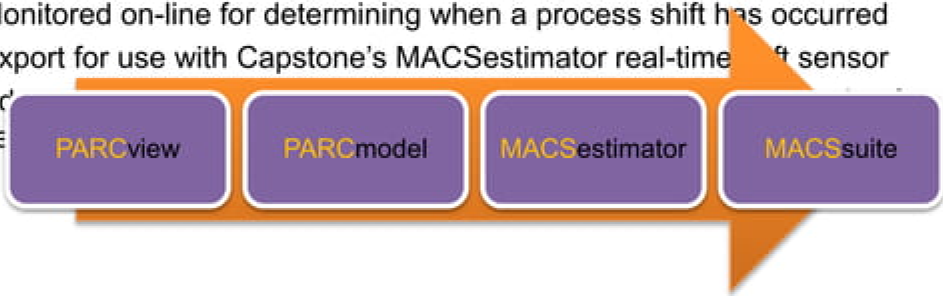


PARCmodel is an ideal tool in your plant analytics tool box

PARCmodel results can be used in any number of ways

- Monitored on-line for determining when a process shift has occurred
- Export for use with Capstone's MACSestimator real-time soft sensor
- Ad
  se

Process Information



Capstone's suite of process tools will significantly shorten the cycle time from project conception, to project implementation

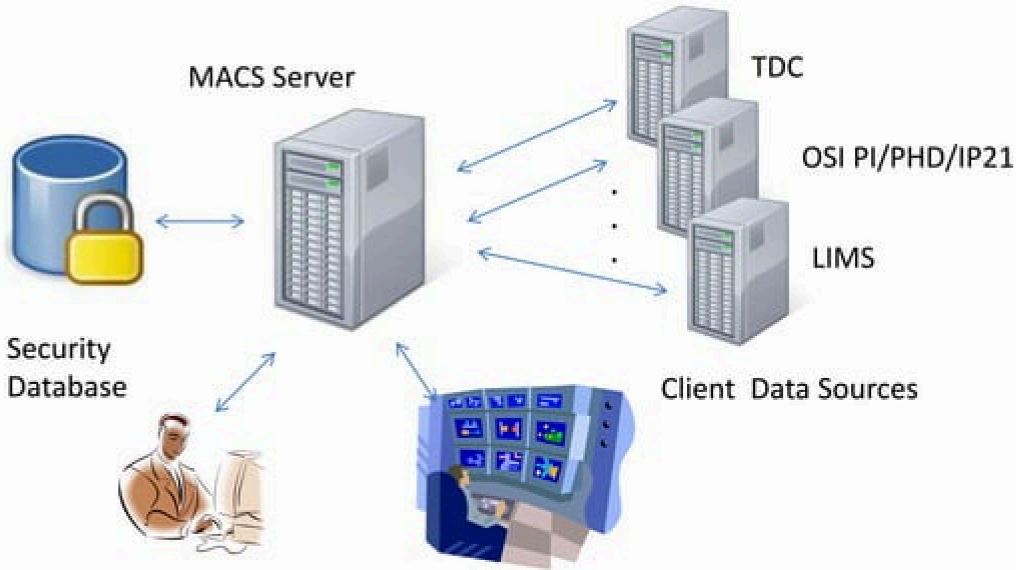
Calculation in DCS blocks

- Cons
  - Challenging to debug, maintain and support
  - Very rare that model is so good that lab feedback not required
  - Handling lab timestamps

MACSestimator

- Features
  - Runs models in real time
  - Handles filtering of data
  - Validity checking
  - Diagnostics
  - Lab feedback
  - Add calculations or new models on the fly
  - Seamless integration with MACS controller
    - Interlock/shed control
    - Operator reset capability

MACSEstimator Architecture



MACS Server Components

- MACS
- MACSEstimator calculation engine
- MSSQL engine (server 2005 or greater)
  - Security database and site data source connection information
- Alarm Engine
  - Monitors tags for alarm conditions
  - Optional notification via email, OPCDA
- Health Engine
  - Monitors server and application health (disk space, memory, loss of data)