# Concept of SCADA System

# SCADA Terminology

- SCADA is an acronym for ***Supervisory Control and Data Acquisition***
- *Data Acquisition* :
  Gathers information from widely distributed processes
- *Supervisory Control* :
  Calculate and give limited control instructions to distant process facilities

# Terms & Terminology

- Field Instrumentation
- Data Acquisition
- Control Loop
- Supervisory Control
- Remote Terminal Unit (RTU)
- Master Terminal Unit (MTU)
- SCADA Server
- Communications Equipment

# Why SCADA?

- Saves Time and Money
  - Less traveling for workers (e.g. helicopter ride)
  - Reduces man-power needs
  - Increases production efficiency of a company
  - Cost effective for all systems
  - Saves energy
- Reliable
- Supervisory control over a particular system

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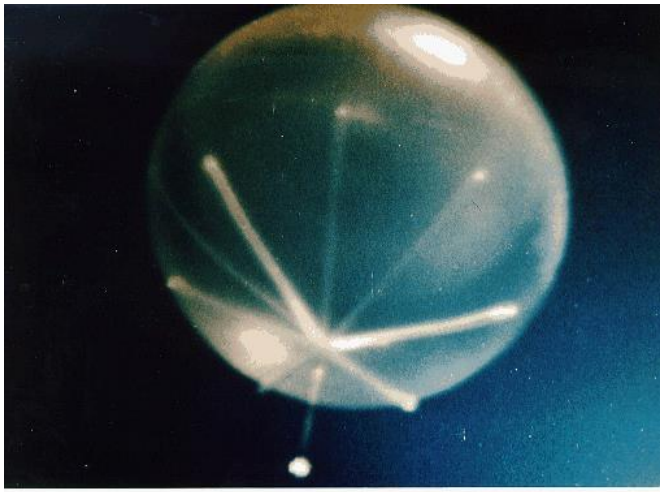
# What is SCADA?

- Supervisory Control and Data Acquisition
- Supervisory
  - Operator/s, engineer/s, supervisor/s, etc
- Control
  - Monitoring
  - Limited
  - Telemetry
  - Remote/Local
- Data acquisition
  - Access and acquire information or data from the equipment
  - Sends it to different sites through telemetry
  - Analog / Digital

# Use Case Diagram for SCADA System

- Description: The goal is to supervise, control, monitor and acquire data for critical infrastructure systems, operate from remote end and ensure security and safety
- Actors:
  - Field Devices
  - Local Control Center (LCC)
  - Remote Telemetry Units (RTU)
  - Master / Central Control Terminal Unit (MTU)
  - Operator
  - Supervisor

# Historical Background (1)



- 1960s:
  - *Radio Telemetry :* weather monitoring using unmanned balloon/rocket
  - *Hardwired Remote Monitoring :* oil & gas and processing industries
- 1970s :
  - *Two-way radio telemetry*
  - *Mini-computer*
  - *Distributed Process Control System (DCS)*
  - *Programmable Logic Controller (PLC)*

# Historical Background (2)

- 1980s :
  - *Low cost microcomputer (PC)*
  - *Satellite Communications*
  - *Cellular Telephone*
- 1990s :
  - *Local Area Network (LAN)*
  - *High Speed Communication Devices*
  - *Internet*

# Classifications

- Anatomy of a SCADA system?
  - Elements of SCADA
  - Levels of SCADA
- Where is SCADA used?
  - Different applications of SCADA systems?
- What types of SCADA are there?
- Component manufacturers and system manufacturers of the SCADA systems?
  - Automation Solutions
  - Software
  - Hardware

# Elements of SCADA

Elements of a SCADA system

- Sensors and actuators
- RTUs/PLCs
- Communication
- MTU
  - Front End Processor
  - SCADA server
  - Historical/Redundant/Safety Server
  - HMI computer
  - HMI software

# Sensors

Types of sensors:

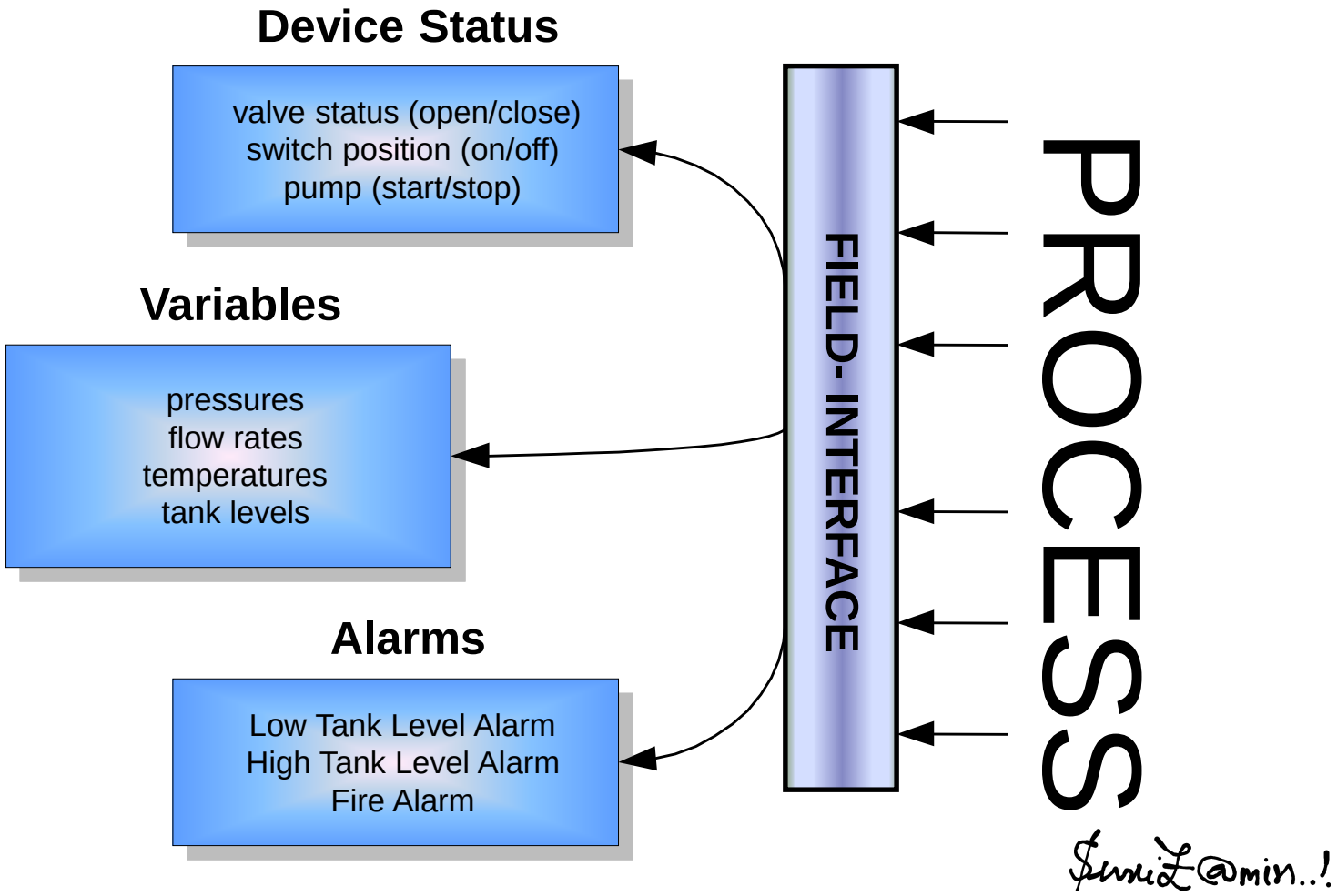
- Pressure sensors
- Temperature sensors
- Light sensors
- Humidity sensors
- Wind speed sensors
- Water level sensors
- Distance sensors

# Actuators

Actuators:

- Valves
- Pumps
- Motors

# Data Acquisition



# Alarms

- Types of alarms:
  - Good alarms
  - Critical failure alarms

# Safety Instrumented Systems

- Actions:
  - Override the normal control system
  - Take over the actuators

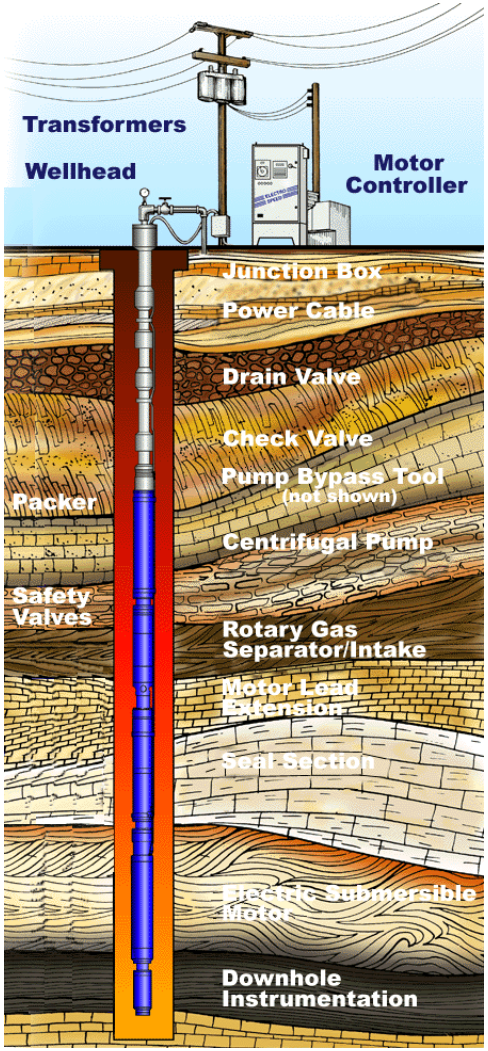
# Data Acquisition on an ESP System

Load Current (A)

Line Frequency (A)

Vibration (Hz)

Current Leakage (A)




ESP Compensator Pressure (Mpa)

Intake Pressure

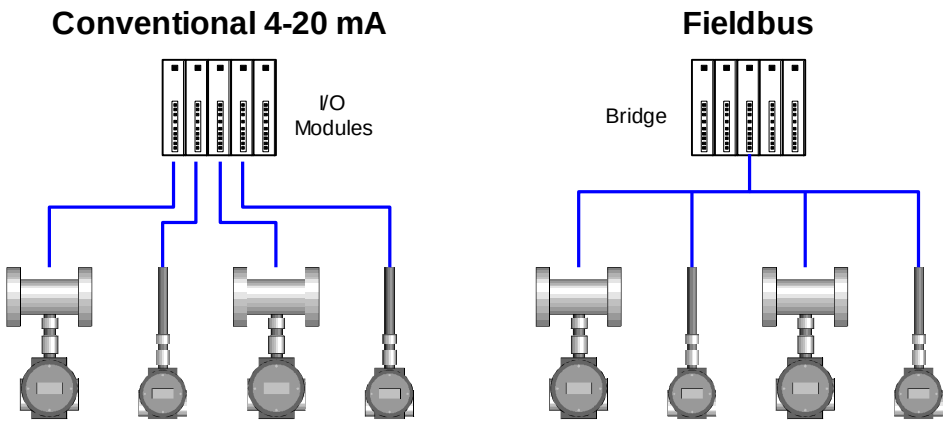
Intake Temperature (°C)

Motor Winding Temperature (°C)

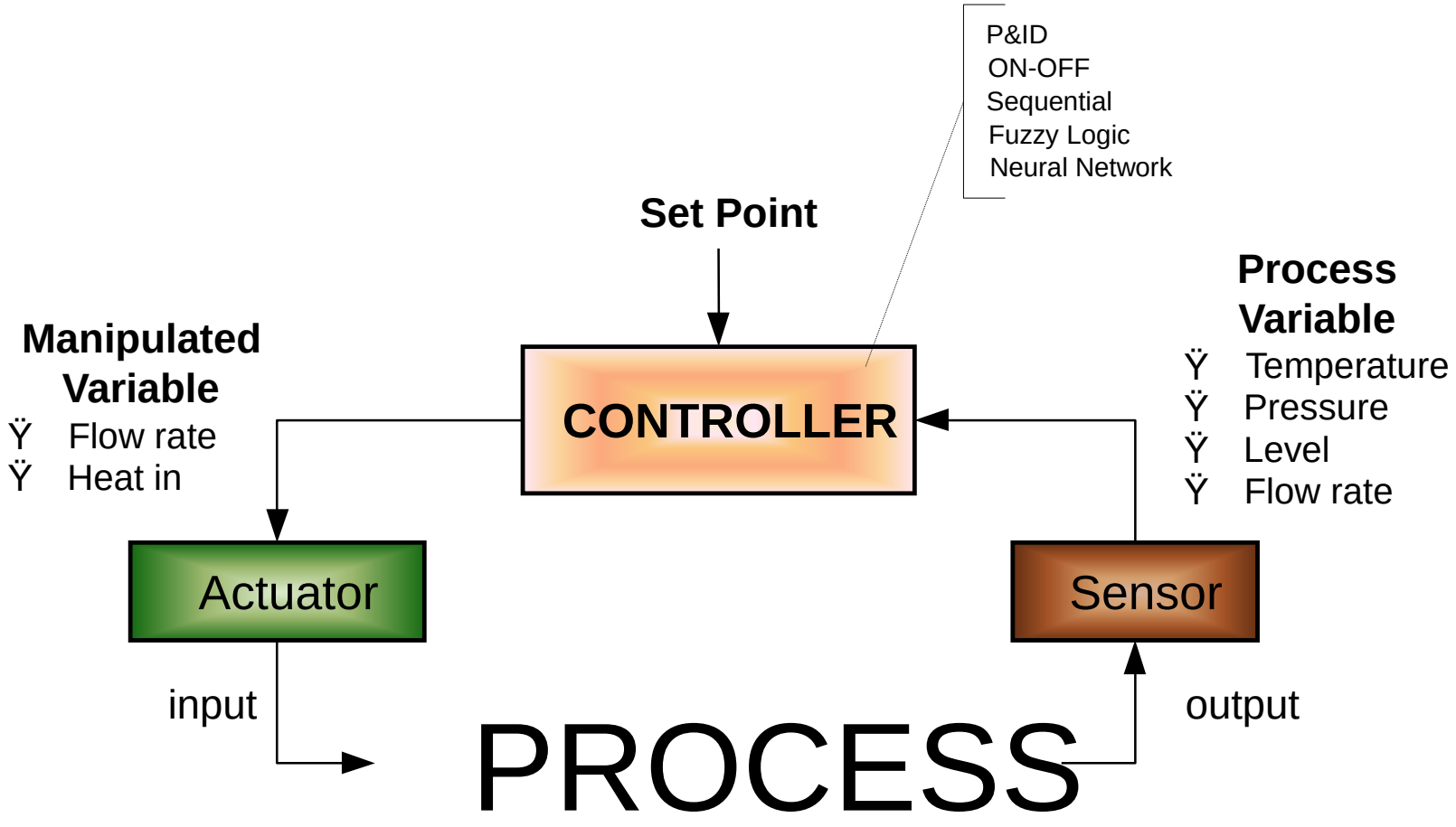
# Types of Field Devices

- Conventional
  - 4-20 mA analog signal
  - Discrete status (0/1)
  - Point-to-point configuration
  - Dedicated wiring for each devices

- Fieldbus based
  - Microprocessor and embedded system technology
  - Digital signal
  - Point-to-point or point-to-multipoint
  - Simplified wiring, drawings, and control engineering
  - Embedded control algorithm
  - example :
    - Foundation Fieldbus Transmitter
    - Profibus Transmitter
    - HART transmitter

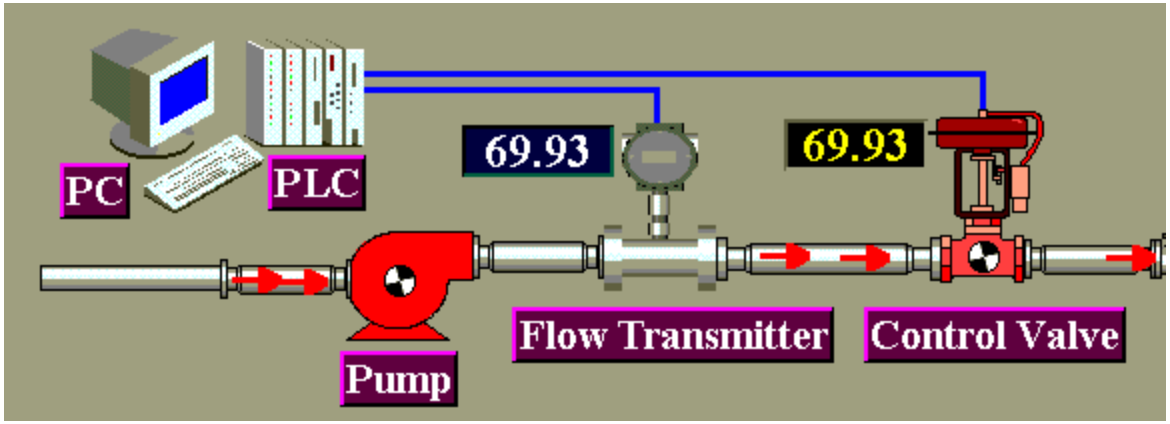


# Control Loop



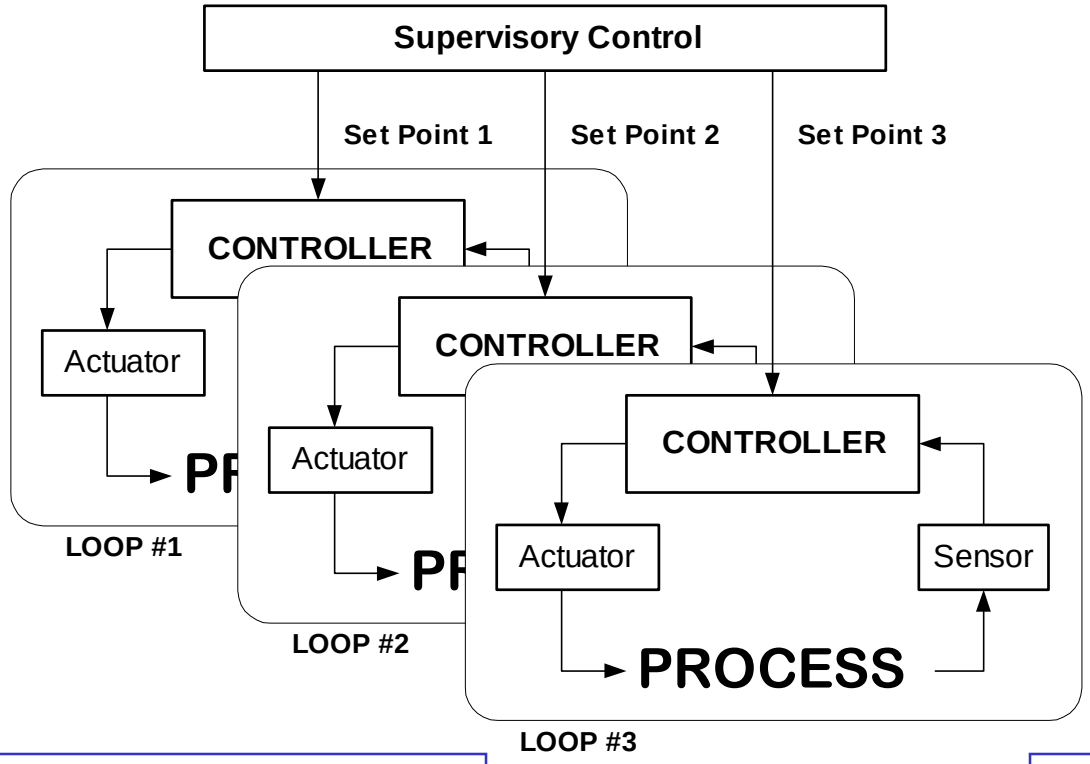
# Example : Flow Control Loop

- Objective :
  - maintain flow rate at a desired value (set point)
- Control elements :
  - Sensor : Flow Transmitter
  - Controller : PLC (PID)
  - Actuator : Control Valve



# Supervisory Control

- Set point management for several control loops
- Optimization to achieve “the best operating point”
- Use advanced control algorithm
  - cascade controller
  - ratio controller
  - override control
  - etc



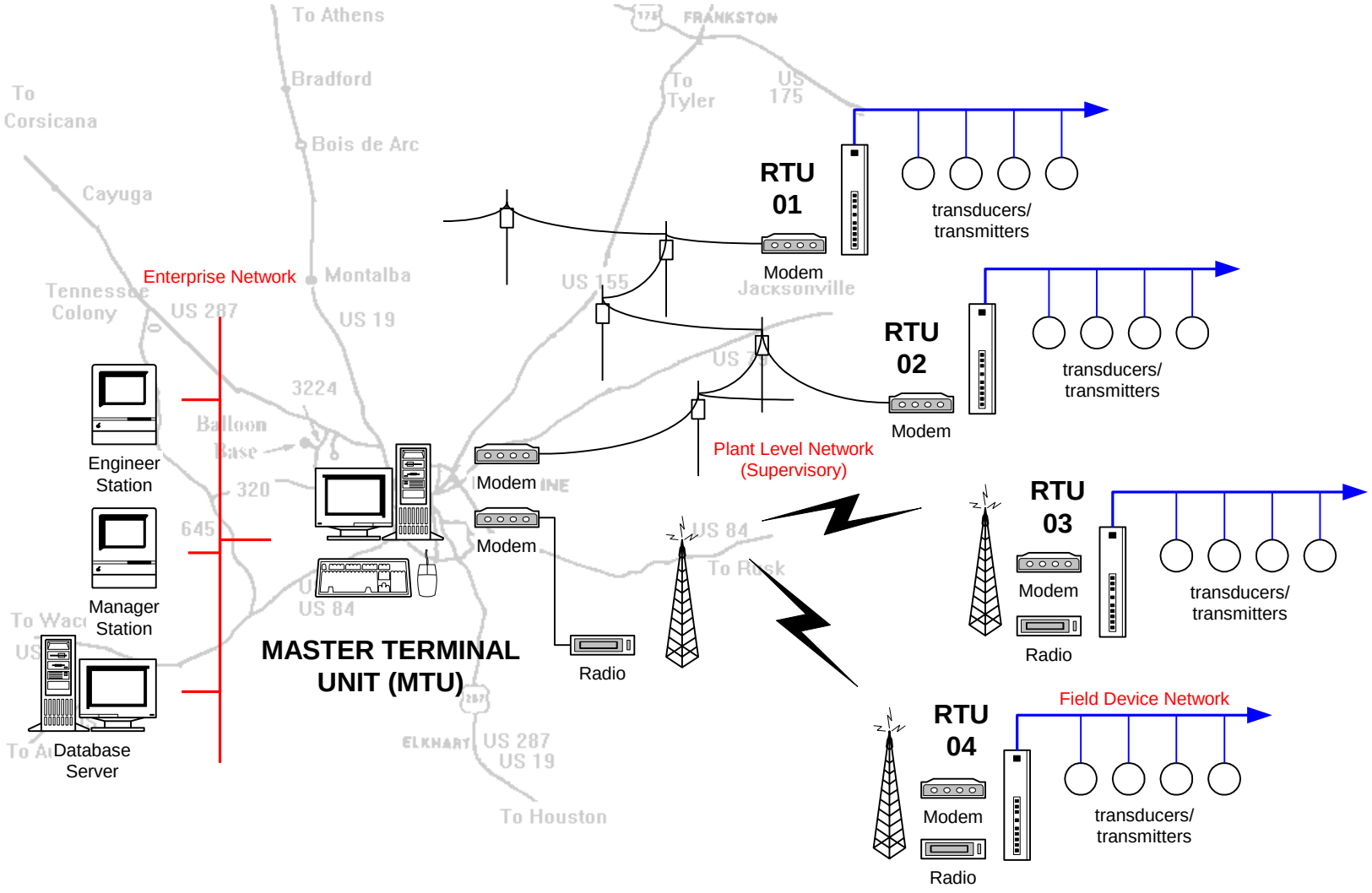
# Goals to Achieve

- Technical :
  - Safety
  - Increased productivity
  - Equipment protection and maintenance
  - Operational optimization
  - Energy saving
  - Immediate access to inventories, receipts, deliveries, etc.
- Economical :
  - Plant-wide optimization
  - Optimization of personnel utilization

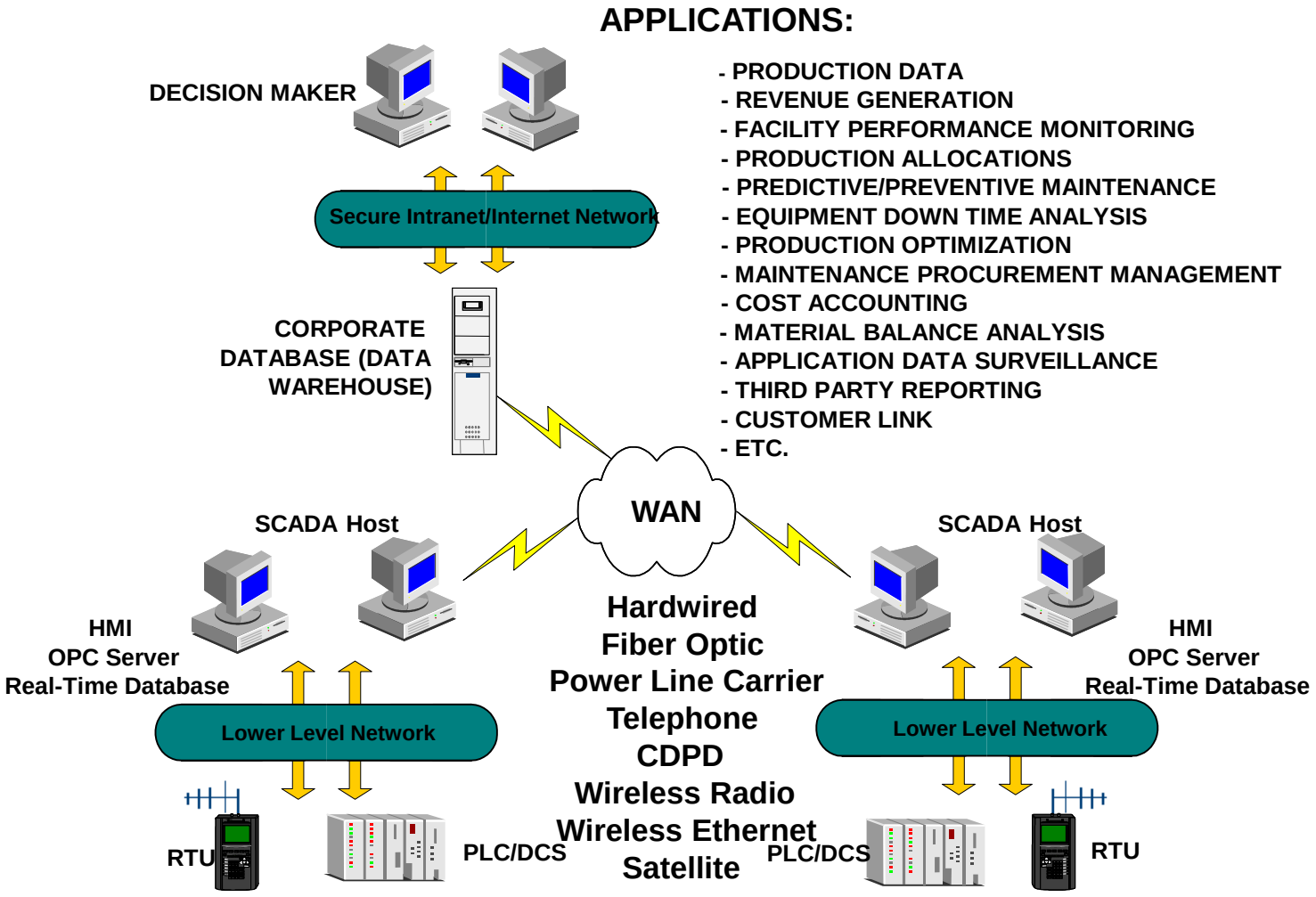
# Applicable Processes

- Widely distributed processes; spreading over large areas
- Require frequent, regular, or immediate intervention
- High cost of routine visits to monitor facility operation
- Examples :
  - Oil and gas production facilities
  - Pipelines for gas, oil, chemical, or water
  - Electric power transmission system
  - Railroad traffic
  - Feed water purification plant
  - Building automation

# SCADA System Architecture



# SCADA SYSTEM ARCHITECTURE



# SCADA System Platform

- Discrete Pneumatic/Electronic System (Old Technology)
- Personal Computer (PC) Based System
- Programmable Logic Controller (PLC) Based System.
- Distributed Control System (DCS) Based

# RTUs

RTU – Remote Terminal Unit

- Intelligent to control a process and multiple processes
- Data logging and alarm handling
- Expandable
- Asks the field devices for information
- Can control IEDs (Intelligent Electronic Device)
- Slave/Master device

# PLCs

PLC – Programmable Logic Controller

- Ladder logic
- Industrial computer that replaced relays
- Not a protocol converter
- Cannot control IEDs
- Communication compatibilities
- Takes actions based on its inputs

# DCS

- DCS – Distributed Control System
  - Process oriented – tendency to do something
  - Not event oriented – does not depend on circumstances
  - Local control over the devices
  - Subordinate to SCADA

# Old Automation Technology

# New Automation Technology


Rendering courtesy of The Foxboro Company
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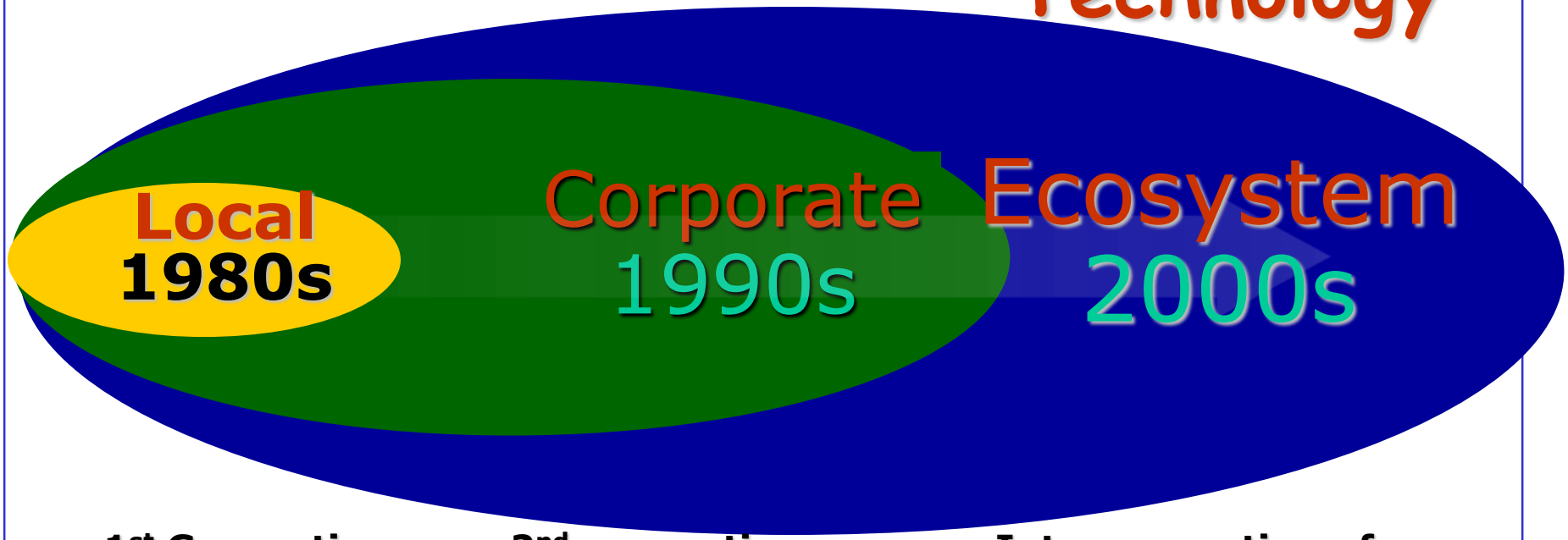
# Evolution of Automation Technology




- 1st Generation DCS / PLCs
- Proprietary systems/networks
- Introduction of workstations

- 2nd generation DCS/PLCs, starting to enable connections
- PC based supervisory systems
- Internet/Intranet
- Business process integration: ERP, CRM, SCM…

- Interconnection of:
  - Customers/Plants/Suppliers
  - All systems & workers
  - Workers in all roles
  - Business & manufacturing processes
  - Effective use of information

# Communication

Communication systems:

- Switched Telephone Network
- Leased lines
- Private Network (LAN/RS-485)
- Internet
- Wireless Communication systems
  - Wireless LAN
  - Global System for Mobile Communication (GSM) Network
  - Radio modems

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# Communication

- Protocols:
  - MODBUS
  - DNP 3.0
  - Fieldbus
  - Controller Area Network (CAN)
  - Profibus
  - DirectNet
  - TCP/IP
  - Ethernet

# Data Communications

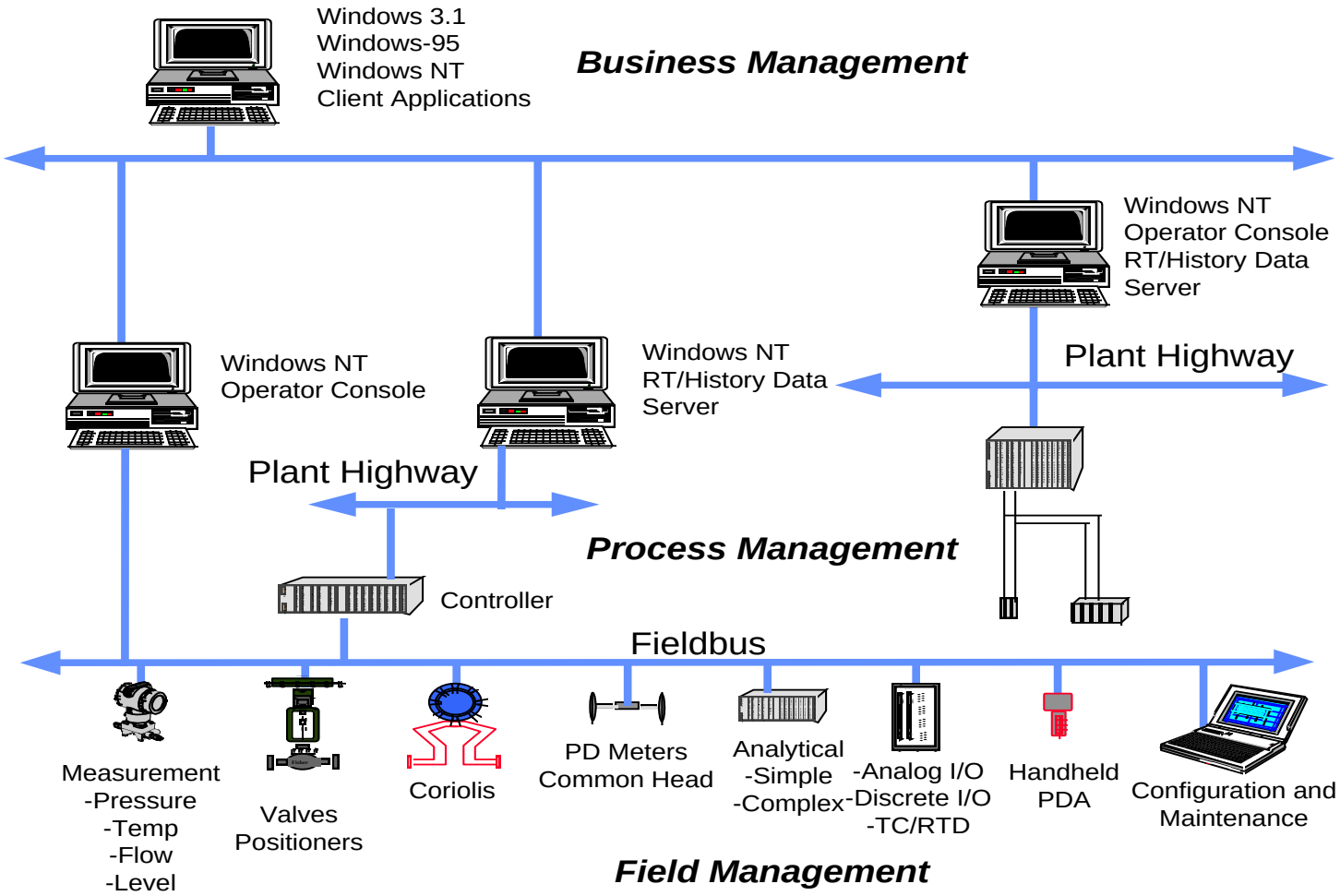
- One MTU can exchange data with one or more RTUs
- Data exchange within MTU and RTUs follows a pre-defined set of rules called *communication protocol*
- Data is encoded as *binary signal* (series of ones and zeros)
- This binary signal is modulated before it propagates through communication medium
- Two-way communications (half or full duplex)
- serial transmission (asynchronous/synchronous)
- Leased or non-leased line
- Guided or wireless medium :
  - radio link (UHF, VHF, microwave, satellite)
  - cable link (telephone, twisted pair, coaxial, power line carrier)
  - fiber optic
  - etc

# Remote Terminal Unit (RTU)




- Placed at remote plant location
- Integrated with instrumentation and control systems (PLC or DCS)
- Functions :
  - Gathers information from the field
  - Send the information to MTU
  - Process the supervisory control instruction from MTU

# Communications



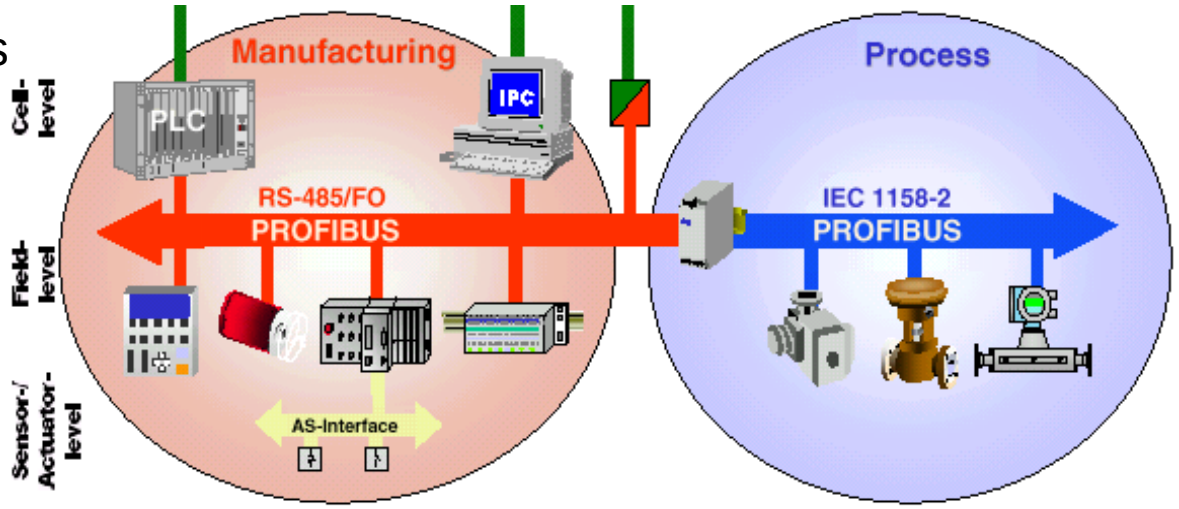
# Device Network

## Actuator/Sensor Level

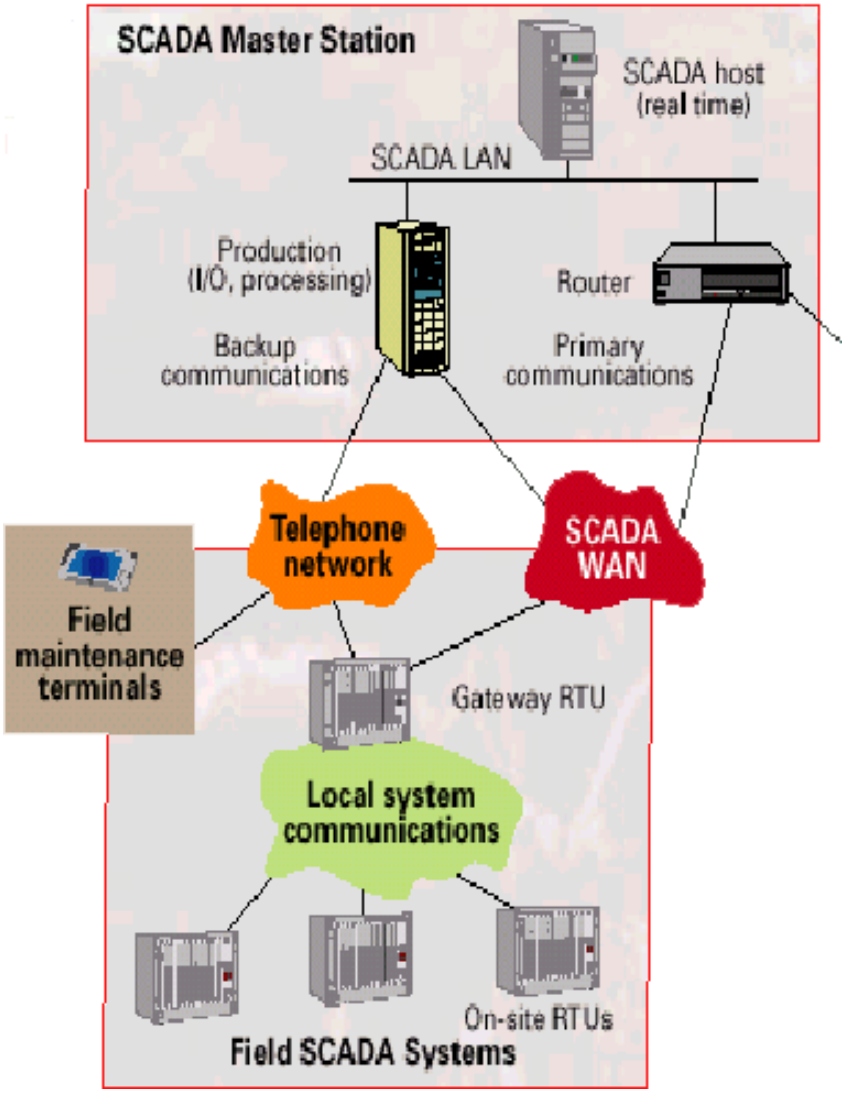
- Analog signals of the conventional sensors and actuators are transmitted via two-wire cable
- One dedicated two-wire cable is required for each sensor/actuator
- Analog-to-digital and digital-to-analog converters are required to enable interfacing and communications with other intelligent devices (programmable controllers, smart transmitter, fieldbus devices)

## Field Level

- Intelligent field devices are configured in multidrop/bus topology
- Single or multi-master mode is supported
- The numbers of field devices in a field level network is limited
- Interoperability issue



# Plant Network

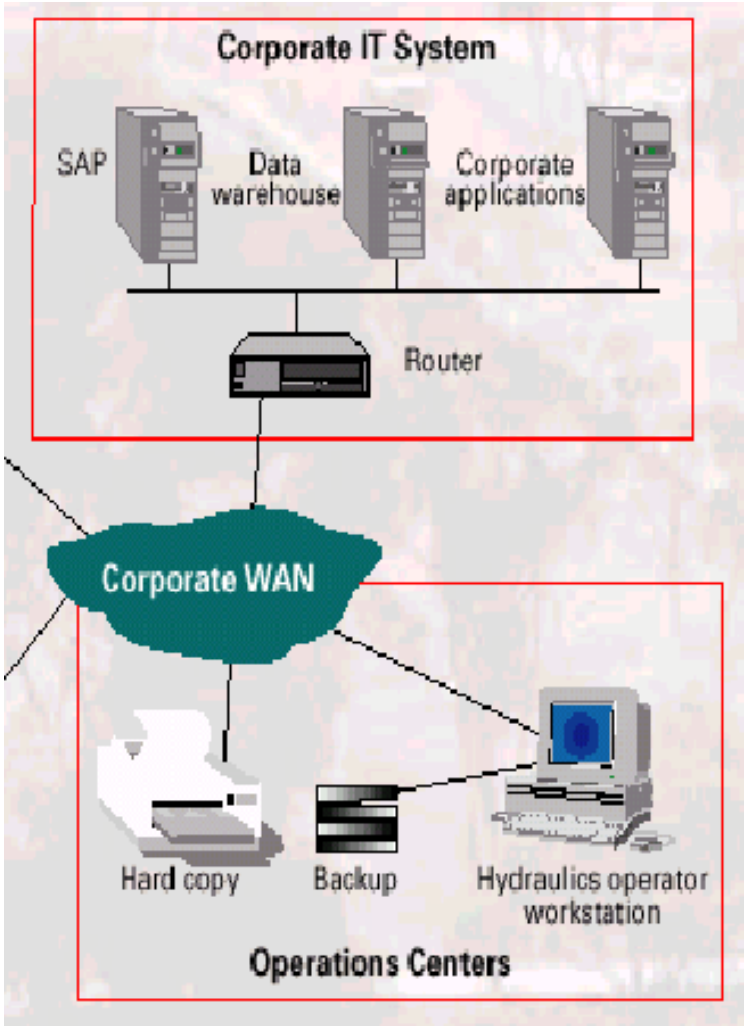



- RTU to Sub-MTU to MTU connection
- Medium
  - guided : cable, telephone, ISDN, optical fiber, etc.
  - wireless : broadcast radio, microwave, satellite
- Protocol
  - DH, DH+, DH-485, ControlNet
  - Modbus, ModbusPlus, ModbusTCP
  - Hostlink
  - DNP

Smile@min..!

# Corporate/Enterprise Network

- Ethernet
- TCP/IP
- Corporate Applications
  - Real time asset management
  - Business support
  - Marketing & sales
  - Procurement
  - Manufacturing
  - Distribution
  - Data warehouse



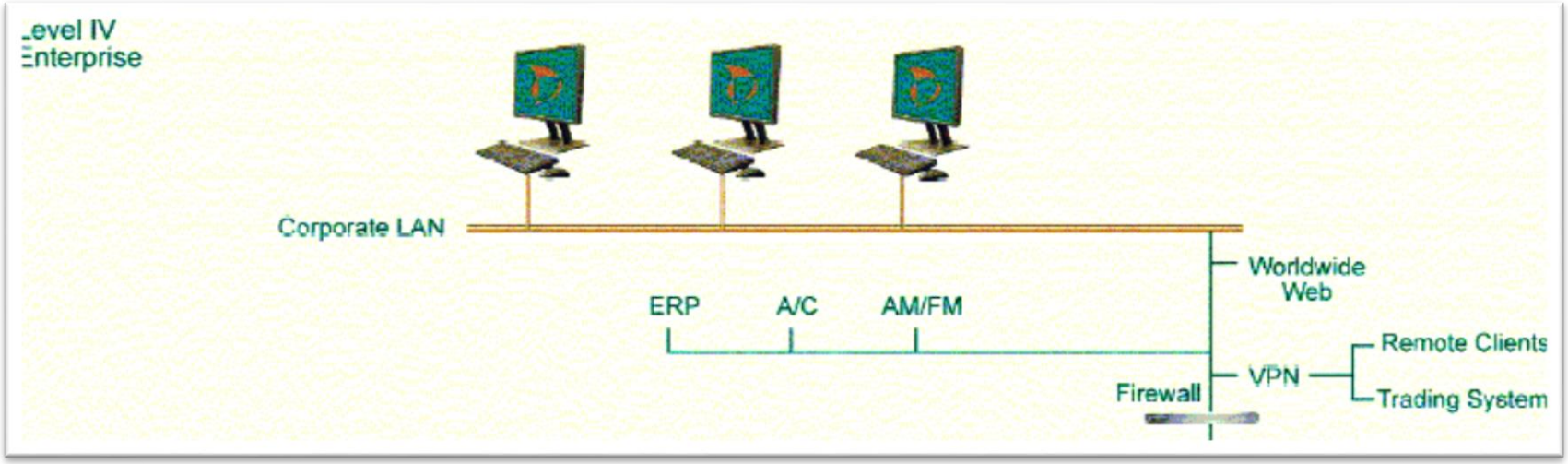
# Levels of SCADA

- Four levels of SCADA system
  - Level IV - Enterprise
    - Corporate LAN/WAN
    - World Wide Web
    - Virtual Private Network
    - Firewall for remote users
  - Level III – SCADA / MTU
    - Operator Workstations
    - Control
    - Engineering Workstations
    - Servers – Data logging

# Levels of SCADA

- Four levels of SCADA system
  - Level II – Telecommunication
    - Fiber
    - Radio
    - Telephone leased line
    - Protocols
  - Level I – Field
    - Devices
    - RTUs / PLCs
    - Sensors

# Level IV - Enterprise

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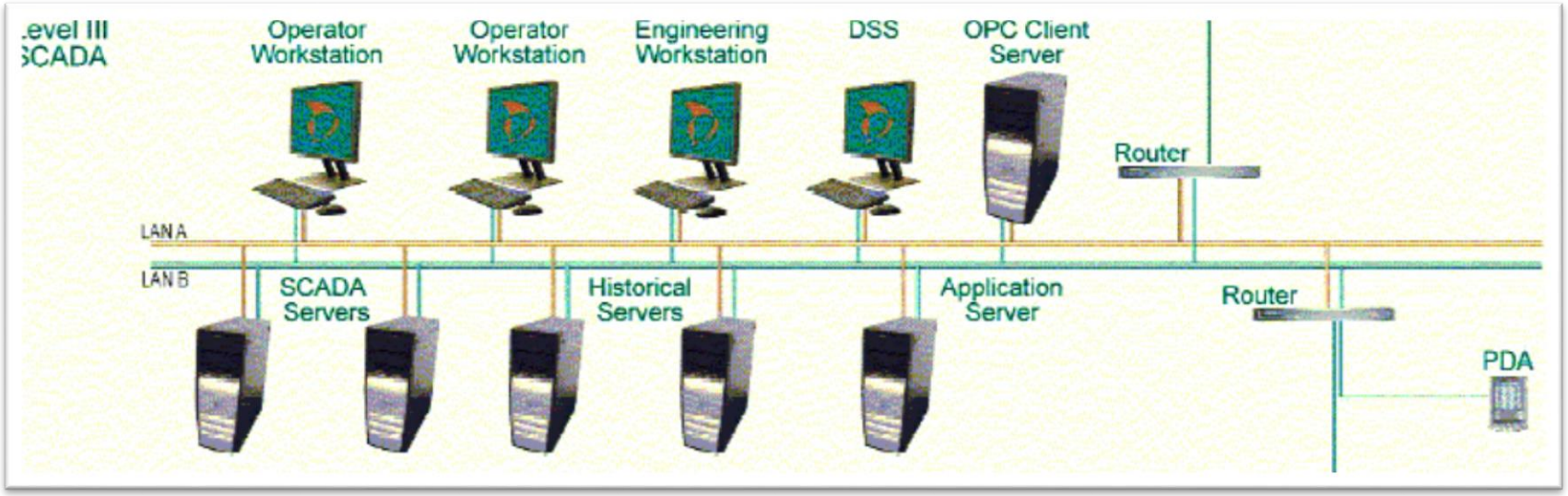
# Level III - SCADA

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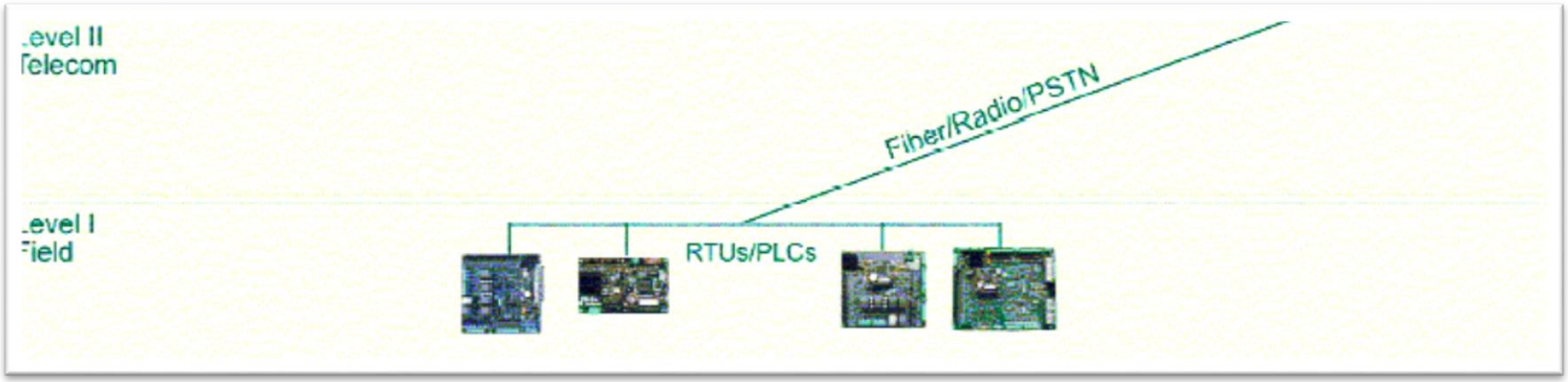
# Level II and I

- Telecommunication and Field




Samir..!

# Master Terminal Unit (MTU)

- Customized configuration for each applications
- Connected to Local Area Network (LAN)
- Equipped with auxiliary devices (data storage, console, pointing devices, etc)
- Functions :
  - Collect process information from RTUs and share the information on the LAN
  - Online operator interface (MMI)
  - Send supervisory control instruction to RTUs
  - Alarm management
  - Report generation
  - System security
  - Central data processing

# Front End Processor

Front End Processor

- Gathers all communications and converts them into SCADA friendly communication
- Communication interface between several RTU channels and the host Master Station computer

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# SCADA server

SCADA Server

- It can be a Web server
- Data logging
- Analyzing data
- Serve the clients through a firewall
- Clients connected in the corporation or connected
  outside through internet
- Real-time decision maker
- Asks RTU for information

# Historical server

- Historical/Safety/Redundant Server
  - Logs the data from the SCADA server and stores it as a backup, in case of a disaster
  - It is basically a safety server

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# HMI Computer

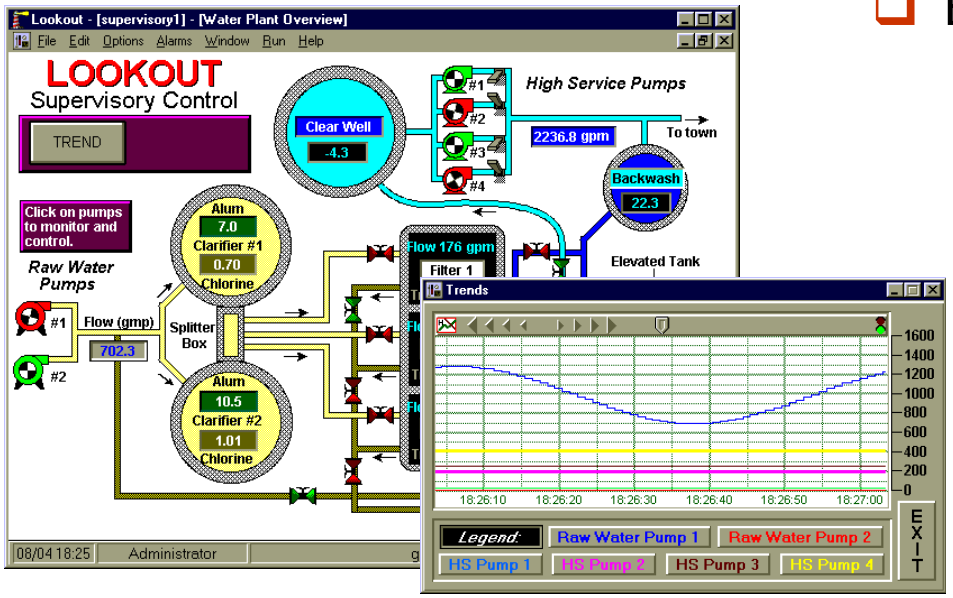
- Human Machine Interface Computer
  - Access on the SCADA Server
  - Control the system
  - Operator Interface
  - Software
    - User friendly
    - Programmable (C, C++)

# Man Machine Interface (MMI)

- Provides human access to field automation system
  - Operational
  - Maintenance & troubleshooting
  - Development
- Function :
  - Communicates with field I/O from Programmable Logic Controllers (PLCs), Remote Terminal Units (RTUs), and other devices.
  - Gives up-to-date plant information to the operator using graphical user interface
  - Translates operator instruction into the machine
  - Engineering development station
  - Operator station

# Man Machine Interface

- Plant information :
  - Process Variables
  - Device status
  - Alarms
  - Control Loops
  - etc

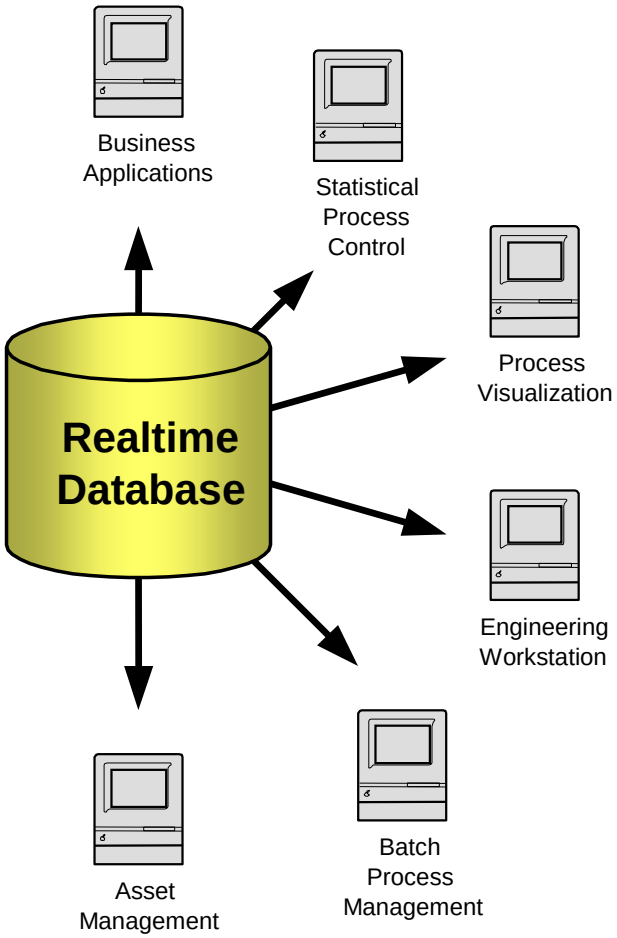



- Presentation Method :
  - Graphics Trending
  - Charts
  - Reports
  - Animation
  - etc
- Equipment :
  - Keyboard
  - Mouse or other pointing devices
  - Touchscreen or CRT
  - etc.

# User Applications

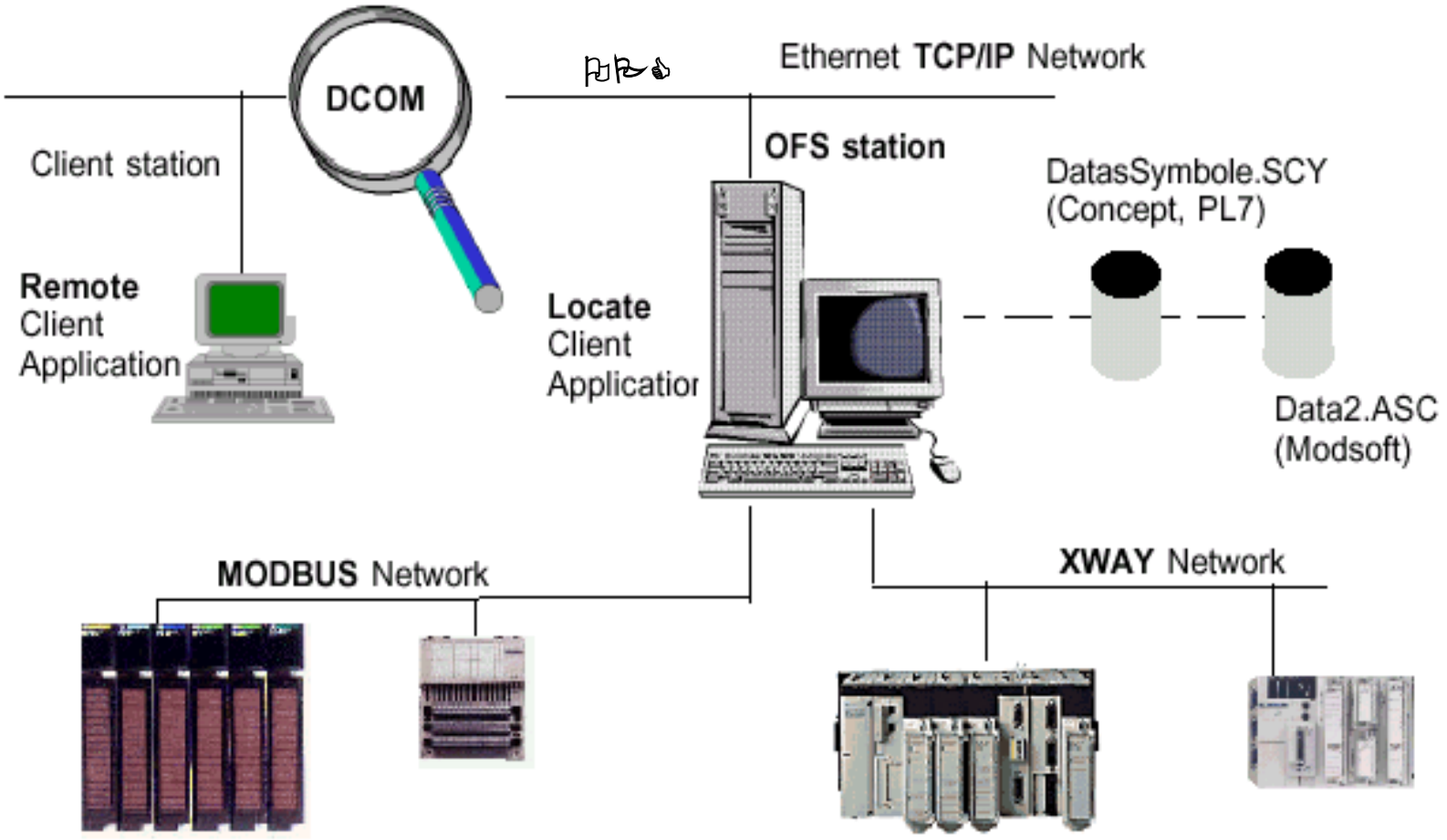
- Development tools is provided by SCADA system supplier (scripting tools)
- Examples :
  - Meter gross/net computation
  - Pipeline terminal display
  - Pipeline inventory
  - Transient modeling systems
  - Dynamic leak detection
  - Pipeline simulator
  - Compressor optimization
  - Automatic well testing
  - Well revenue calculation
  - etc.

# System Database




- Store historical process information for engineering, production, maintenance, and business purposes
- Features :
  - Engineering units conversion
  - Analog value filtering
  - Value limit checking
- Standardized Data Structure
  - Analog point structure
  - Status point structure
  - Accumulator point structure
  - Container points
  - User defined structure
- Each point in the database has a number of associated parameters, all of which can be referenced relative to a single tag name

# Industrial Automation Server



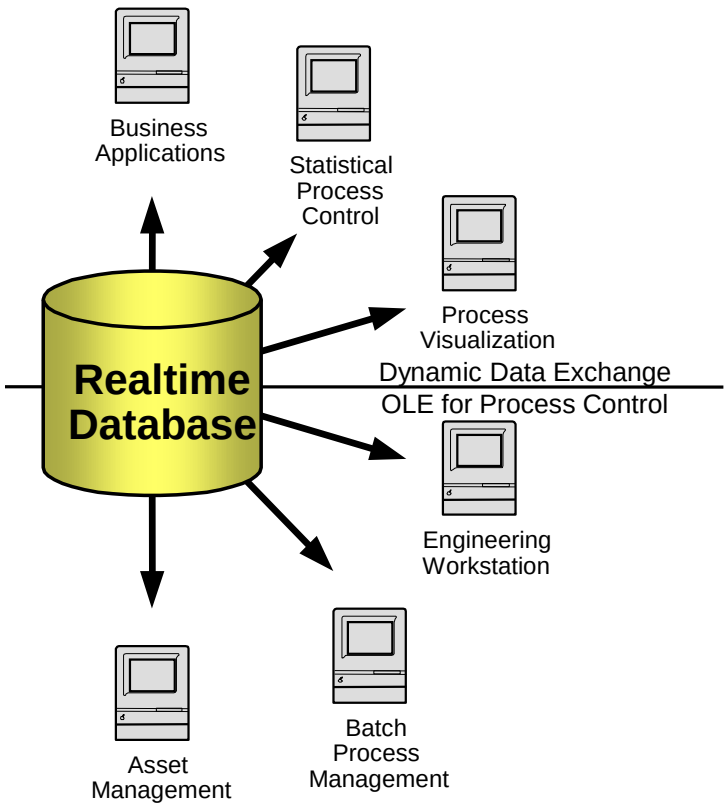
# OLE for Process Control (OPC)

- Object Linking and Embedding (OLE) for Process Control
- A standard for process automation (SCADA) communications
- A standard software mechanism for sharing data between process automation (SCADA) of different manufacturers
- OPC is based on Microsoft OLE (Object Linking and Embedding) and DCOM (Distributed Component Object Model)
- OPC advantage :
  - Simple to implement
  - Flexible to accommodate multiple vendor needs
  - Provide a high level of functionality
  - Allow for efficient operation

Sumi Z@min..!

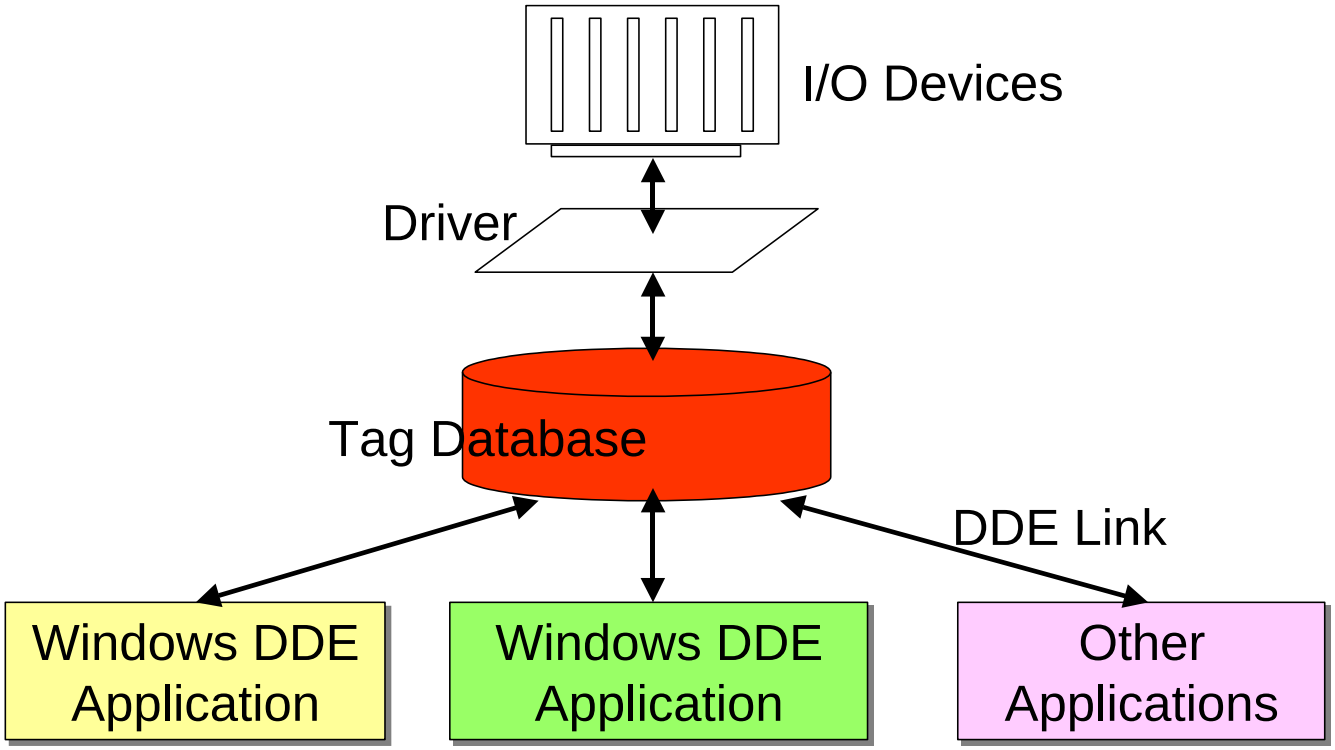
# Plant-Office Data Integration

- Networking has been successfully implemented from field device level up to management level.
- Data can easily be interchanged between applications in the same computer or different computers over a network.
- SCADA system can give an immediate response needed from field device to management system.
- Real-time plant information can be transferred to office application.
- Corporate information system must be designed to meet its business process.

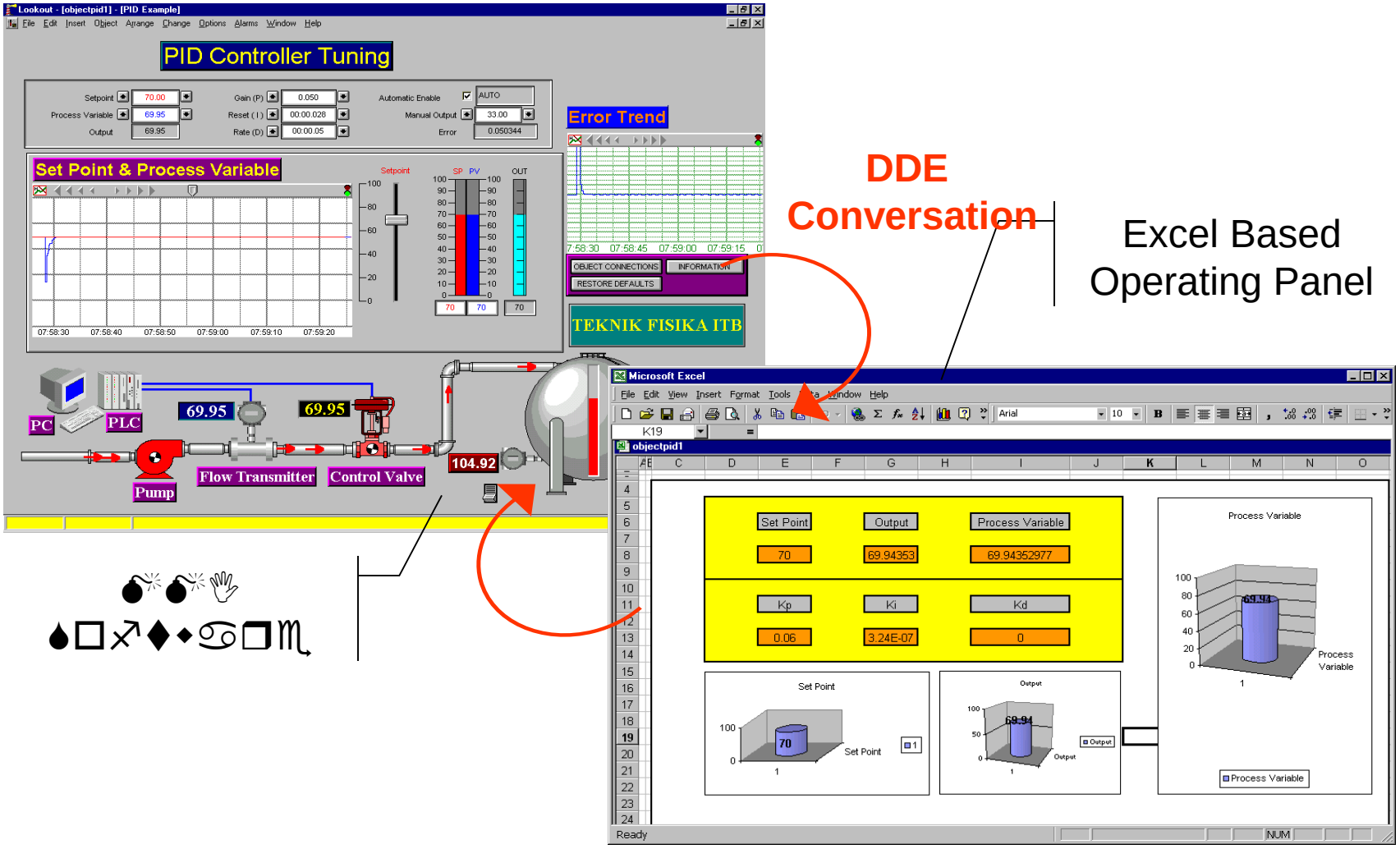


# Dynamic Data Exchange (DDE)

- An application protocol that allows data exchange on real-time basis on Windows/WindowsNT platforms
- NetDDE = Dynamic Data Exchange over network



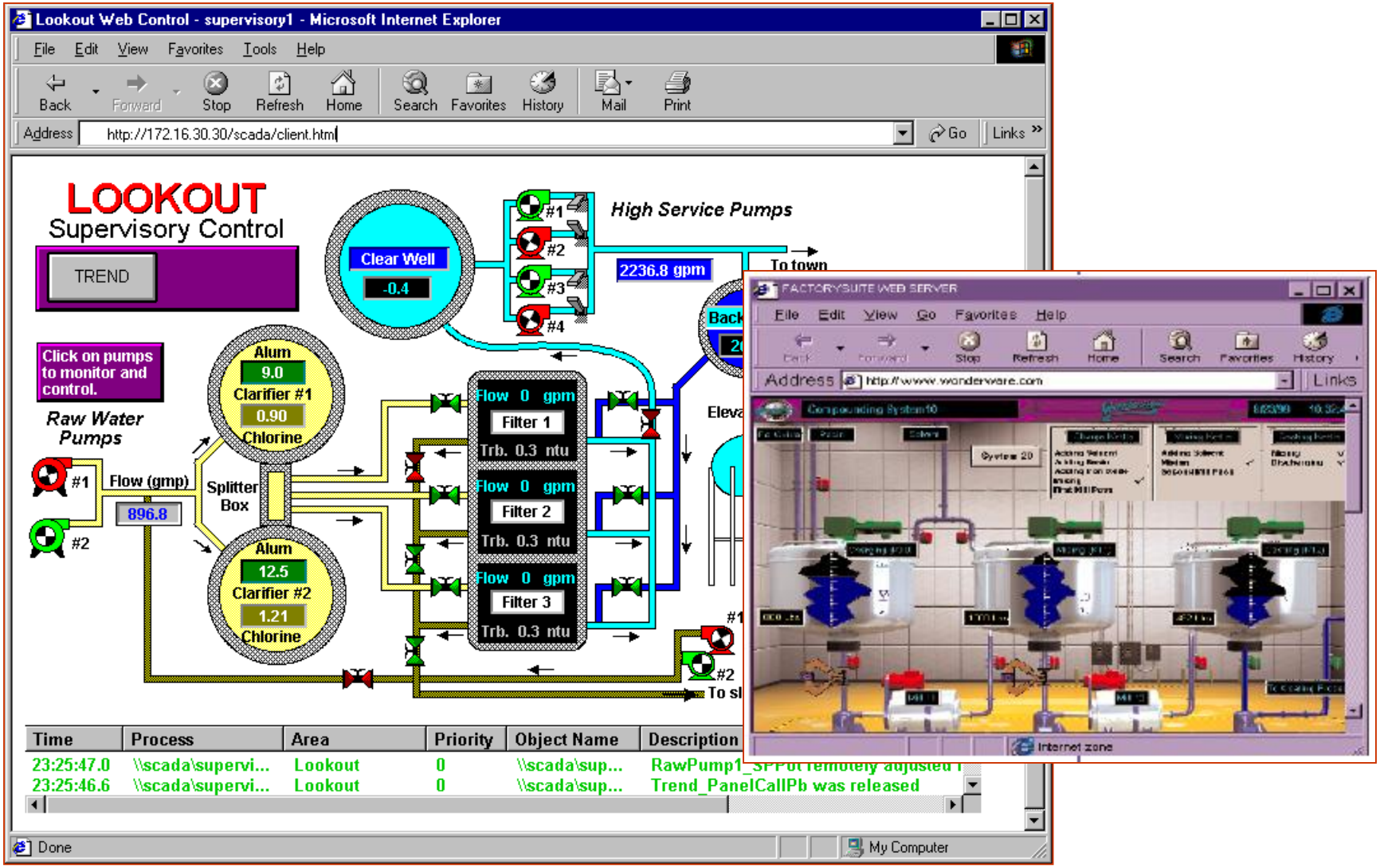
# Sample of System linked to Excel



# Web-based Process Monitoring

- Internet browser as an acceptable MMI standard will minimizes operator/user training by providing a familiar operating environment
- Many visualization techniques are available (JavaScript, Java, Shockwave/Flash, etc)
- Extra development effort is not needed since SCADA supplier software usually provide integrated web-based and application specific MMI development
- Allows the users (e.g. : supervisor/manager) to monitors process operation, documents and reports either in the Intranet or Internet
- Secured network design is a must to avoid cyber risk such as hacking attempts and virus

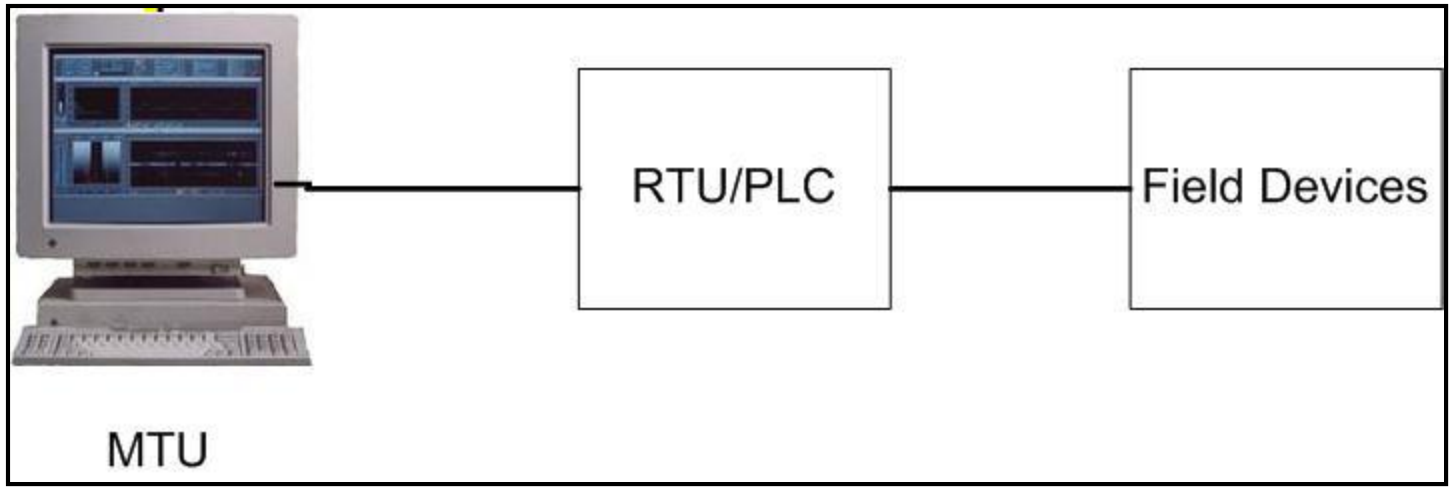
# Web Based Monitoring Example



# SCADA system types

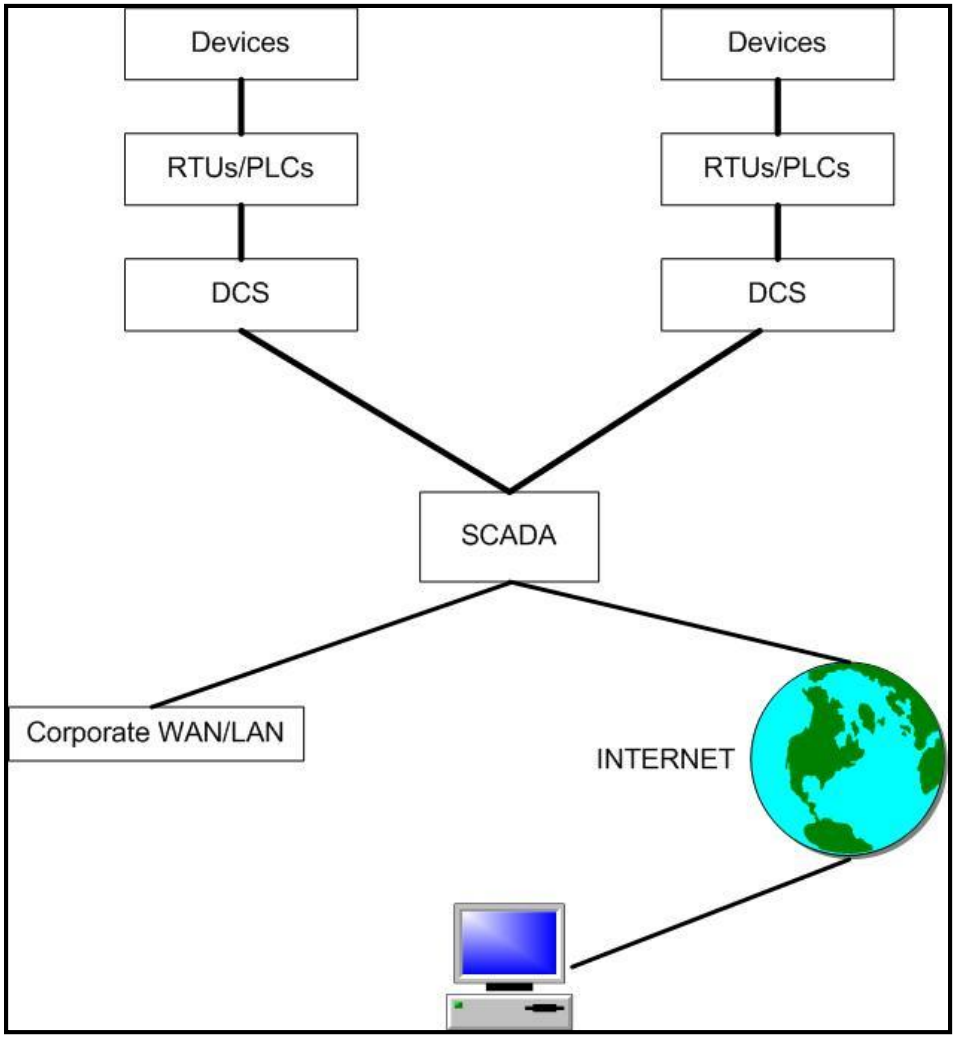
- Three types of basic SCADA systems:
  - Basic SCADA
    - One machine process
    - One RTU and MTU
  - Integrated SCADA
    - Multiple RTUs
    - DCS
  - Networked SCADA
    - Multiple SCADA

# Basic SCADA




- Car manufacturing robot
- Room temperature control

# Integrated SCADA




- Water systems
- Subway systems
- Security systems

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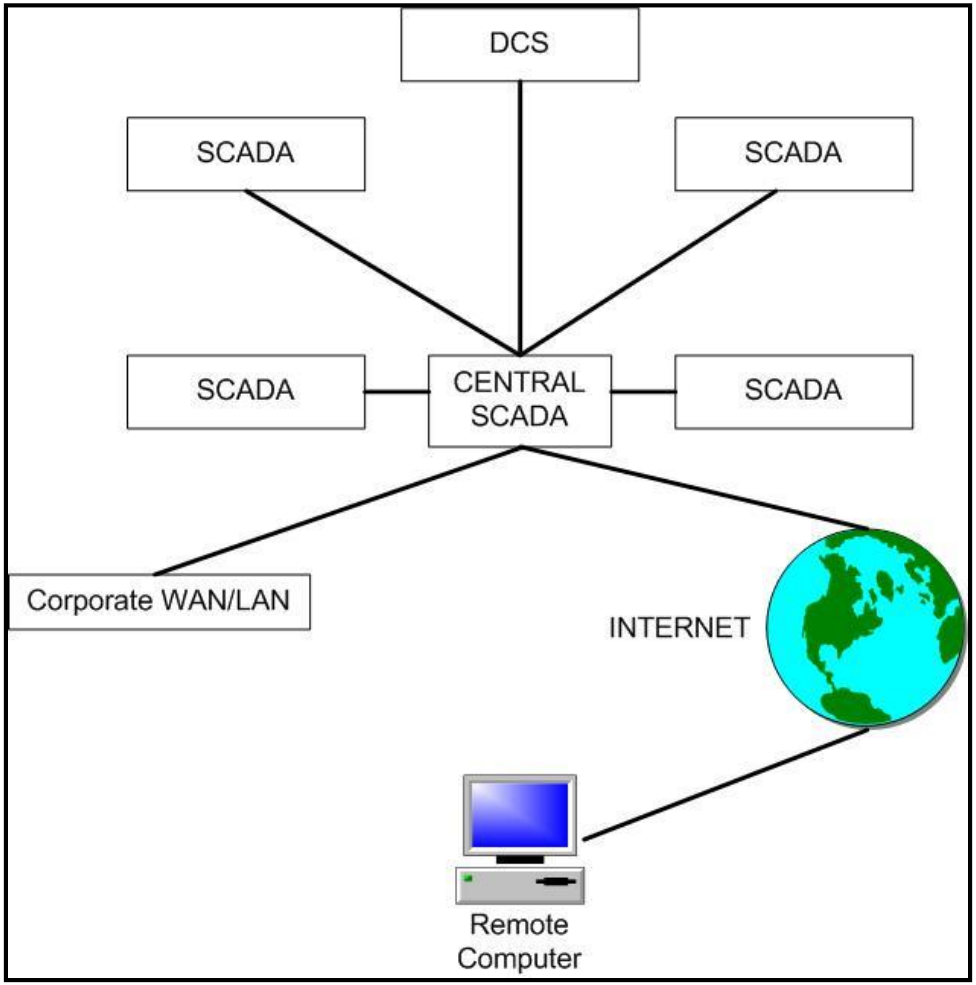
# Networked SCADA




- Power systems
- Communication systems

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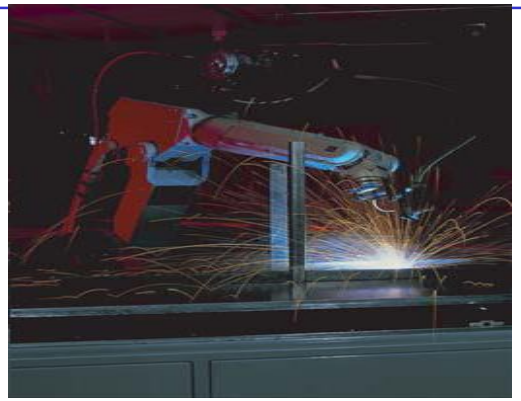
# Where is SCADA used?

- Main SCADA applications:
  - Water and Wastewater
  - Power
  - Oil and Gas
  - Research facilities
  - Transportation
  - Security systems
  - Siren systems
  - Irrigation
  - Communication control

**Electric power generation, transmission and distribution:** Electric utilities detect current flow and line voltage, to monitor the operation of circuit breakers, and to take sections of the power grid online or offline.



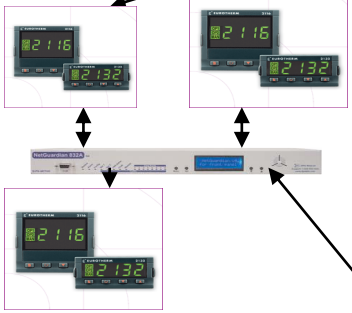
**Buildings, facilities and environments:** Facility managers use SCADA to control HVAC, refrigeration units, lighting and entry systems.

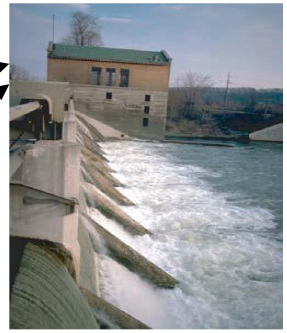
**Manufacturing:** manage parts inventories for just-in-time manufacturing, regulate industrial automation and robots, and monitor process and quality control.

**Mass transit:** regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.

**Water and sewage:** State and municipal water utilities use SCADA to monitor and regulate water flow, reservoir levels, pipe pressure and other factors.

**Traffic signals:** regulates traffic lights, controls traffic flow and detects out-of-order signals.





WATER
DISTRIBUTION
SYSTEM

POWER
DISTRIBUTION
SYSTEM

Remote Telemetry Unit (RTU)

SCADA MASTER UNITS

HUMAN COMPUTER INTERFACE

Remote Telemetry Unit (RTU)

TRANSPORT SYSTEM

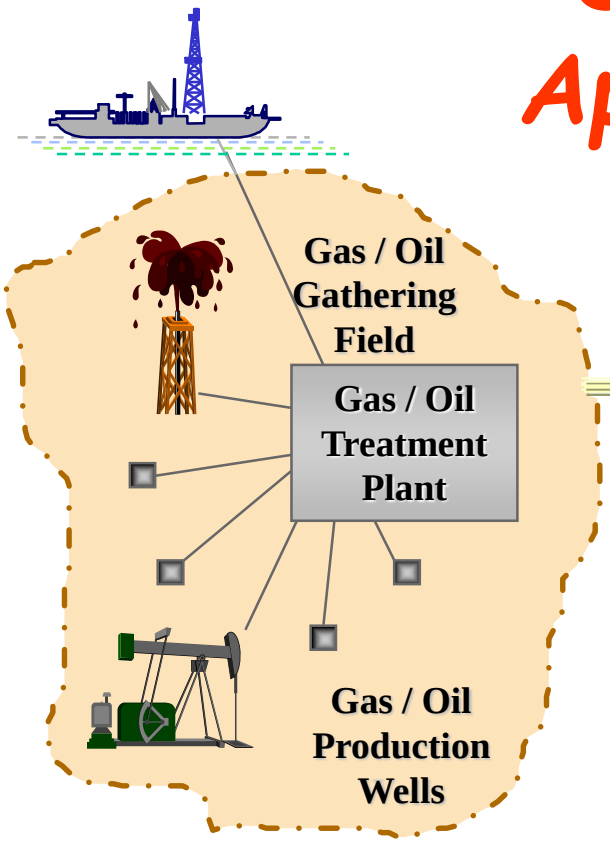
PETROCHEMICAL PLANT

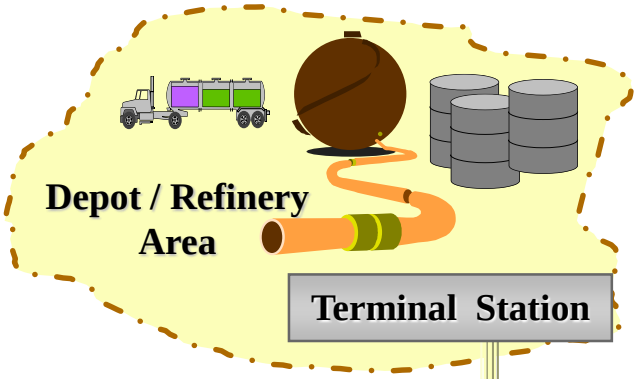
PROCESS
PLANT

# SCADA System Application Area:

- **OIL & GAS Production, Treatment, Gathering, Storage, Movement, Transportation, Pipelines and Distribution Networks**
- **OIL Tank Farms, Trucks Loading/Unloading facilities**
- **GAS Compressor & OIL Pumping Stations**
- **UTILITIES and Municipalities managing Water, Gas, Electric Power, Heating distribution Networks**
- **Drinkable WATER Purification & Transportation facilities, WASTEWATER Treatment plants, WATER Quality Monitoring**
- **INFORMATION Systems for Customers service, administration, General & Industrial Accounting, Inventory & Purchasing management in Utilities, Distribution Companies, Industry**
- **Electric POWER Industry: generation, transmission, EMS & DMS**

# Oil & Gas Applications



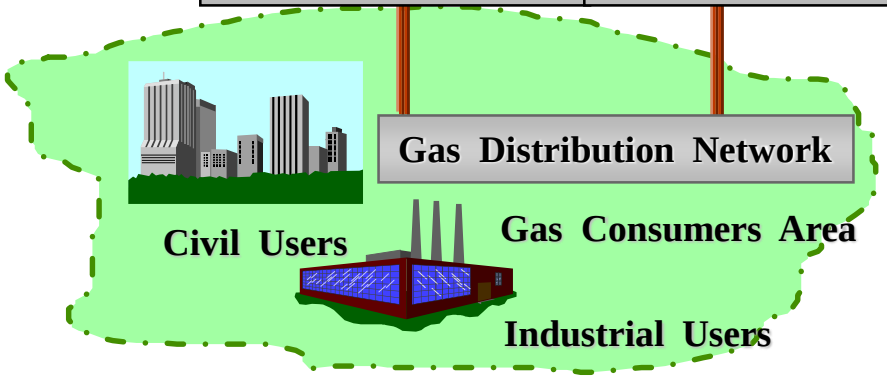

Compressor or Pumping Station

Gas / Oil Pipeline

Compressor or Pumping Station

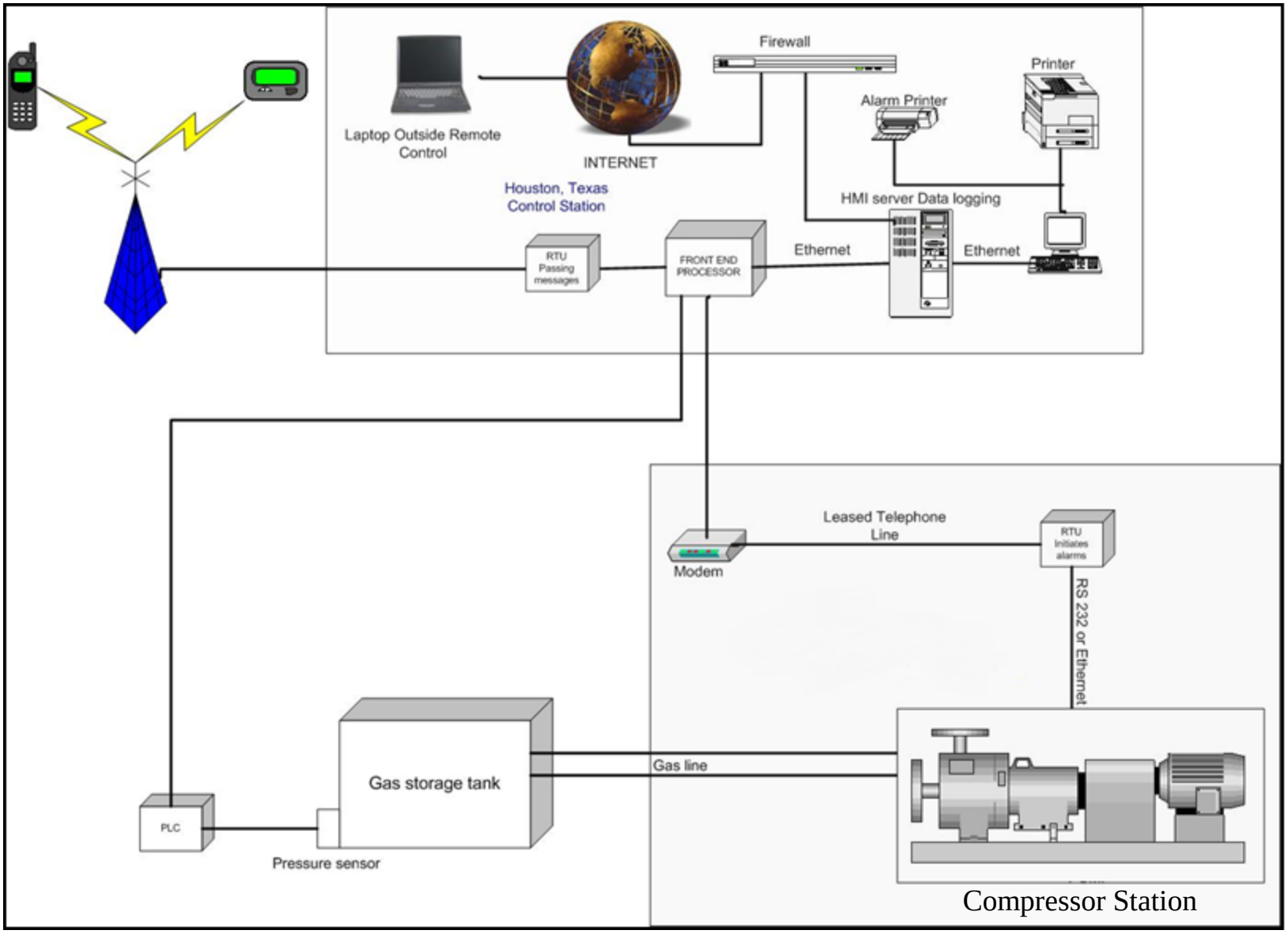
Gas Reducing & Metering Station

Gas Reducing & Metering Station

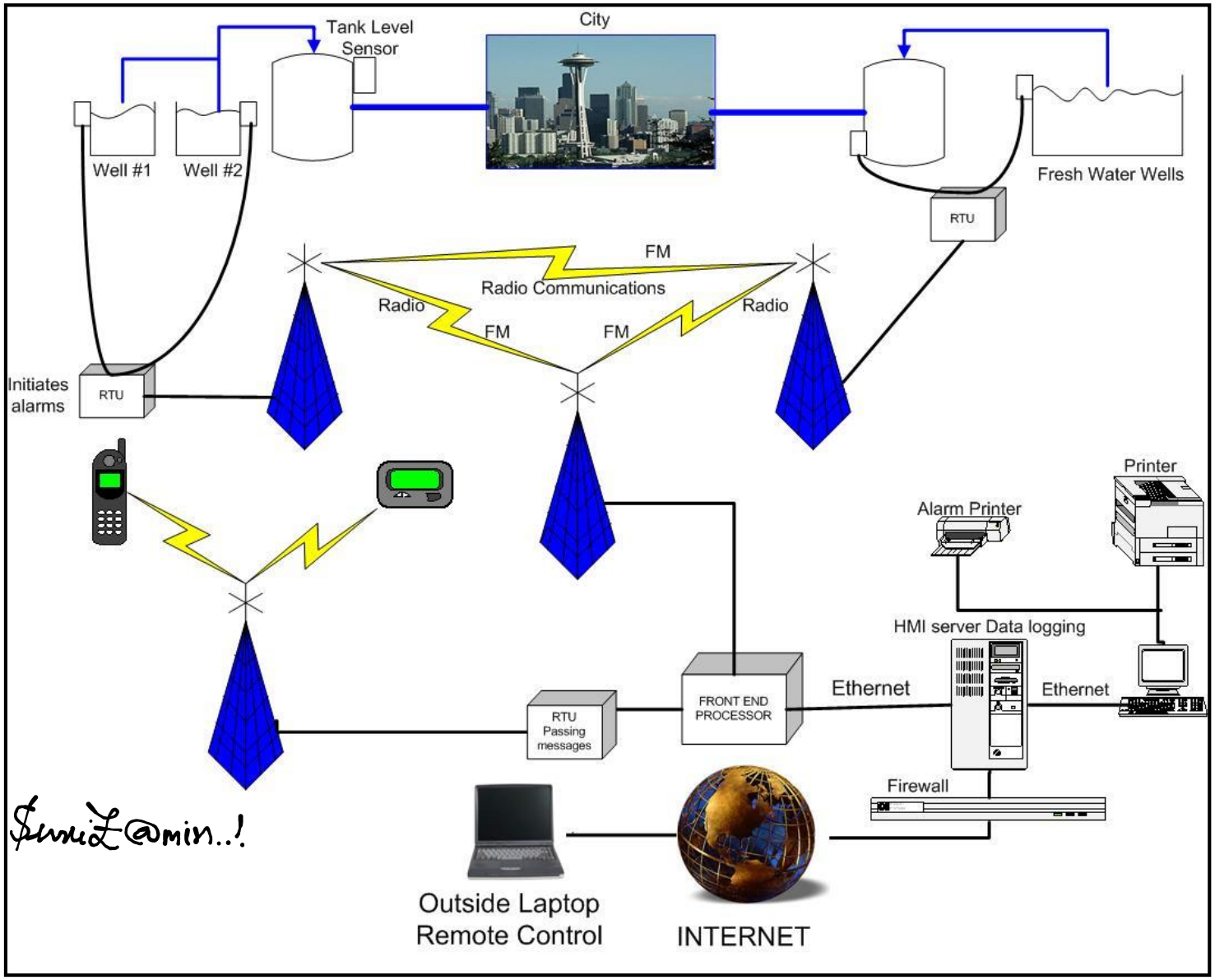



**Automation from wells to end users**

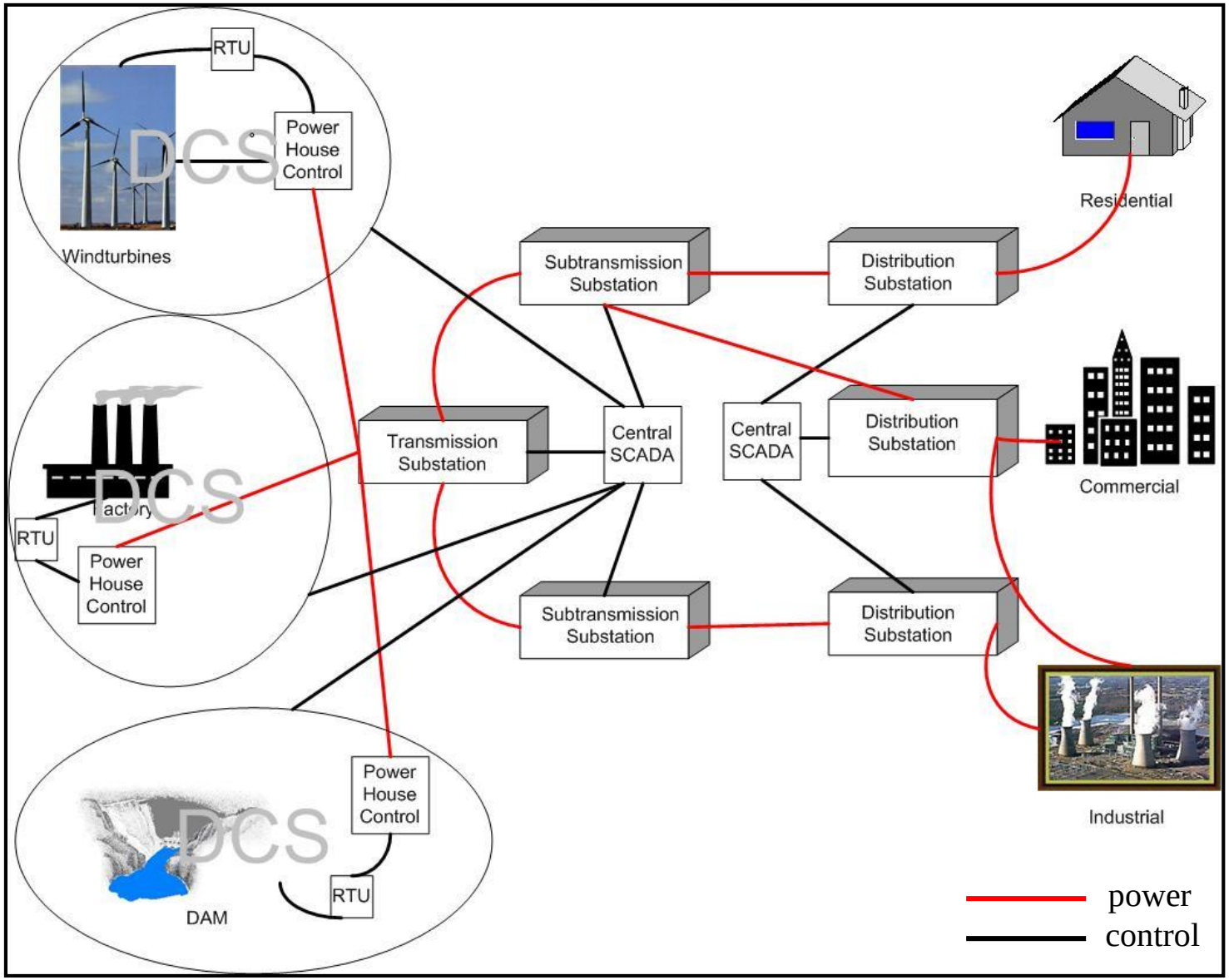
# Gas SCADA


Laptop Outside Remote Control
INTERNET
Firewall
Printer
Alarm Printer
Houston, Texas
Control Station
HMI server Data logging
RTU
Passing
messages
FRONT END
PROCESSOR
Ethernet
Ethernet
Leased Telephone
Line
RTU
Initiates
alarms
Modem
RS 232 or Ethernet
Gas storage tank
Gas line
PLC
Pressure sensor
Compressor Station

# Water SCADA


Tank Level Sensor
City
Well #1
Well #2
Fresh Water Wells
RTU
FM
Radio Communications
Radio
FM
FM
Radio
Initiates alarms
RTU
Printer
Alarm Printer
HMI server Data logging
Ethernet
Ethernet
FRONT END PROCESSOR
RTU Passing messages
Firewall
Outside Laptop Remote Control
INTERNET

# Power SCADA


RTU
Power House Control
DCS
Windturbines
Residential
Subtransmission Substation
Distribution Substation
Transmission Substation
Central SCADA
Central SCADA
Distribution Substation
Commercial
RTU
Power House Control
DCS
Subtransmission Substation
Distribution Substation
Industrial
Power House Control
RTU
DCS
DAM
power
control

# Automation Solutions

- SCADA system manufacturers
  - Modular SCADA, UK
  - MOSCAD, Motorola
  - Rockwell Automation
  - ABCO
  - ABB
  - Lantronix

# SCADA Hardware

- SCADA Hardware manufacturers
  - Rockwell Allen Bradley
  - General Electric (GE)
  - Emerson
  - Siemens
  - Schneider Electric

# SCADA Software

- SCADA Software manufacturers
  - Fix Intellution
  - Iconics
  - Wonderware (InTouch)
  - Citect (CitectSCADA)
  - National Instruments (Lookout SCADA)
  - Cimplicity (GE Fanuc)
  - Siemens WinCC

# Summary

- SCADA is a *two-way system* : remote monitoring & controlling
- Applicable to widely distributed processes
- Two way communication system is required
- Basic Elements of SCADA :
  - *Master Terminal Unit (MTU)*
  - *Remote Terminal Unit (RTU)*
  - *Communications Equipment*