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APPA U

535 BUILDING AUTOMATION SYSTEMS

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Credit(s) earned on completion of this course will be reported to American Institute of Architects (AIA) Continuing Education Session (CES) for AIA members.

Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Course Description

This course will provide an overview of a Building Automation System (BAS) utilized to monitor and control typical building HVAC systems. The course will cover typical architecture for web-based systems, industry terms, types of systems, system components, and communication protocols. Discussions will include the benefits and effective uses of BAS systems for facilities managers related to energy conservation and customer service as well as future trends in the industry.

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Learning Objectives

- Obtain an overview of Building Automation System (BAS) to monitor and control HVAC systems.
- Learn about typical architecture for web-based systems
- Learn about industry terms, types of systems, components and communication protocols
- Learn about the benefits and effective use of BAS systems for facility managers

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BAS Systems

- A system that optimizes the start-up and performance of HVAC equipment. A BAS greatly increases the interaction between the mechanical subsystems of a building, improves occupant comfort, lowers energy use, archives data, and allows off-site building control.
- Advanced Web-Based DDC = Building Automation System (BAS)

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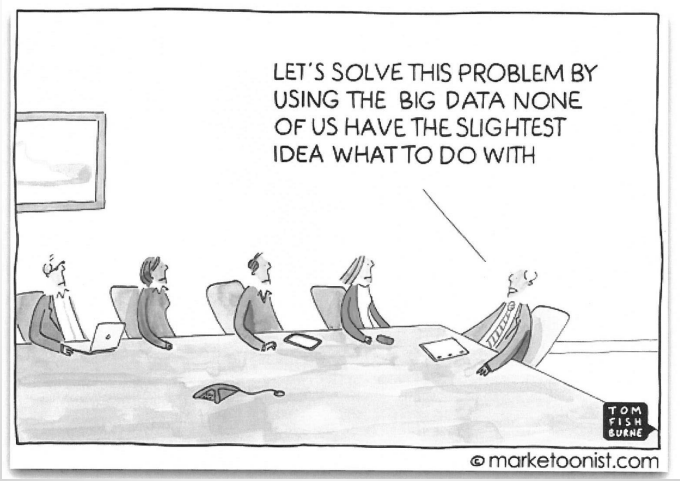
Automation/Technology = Facilities Management



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Building Controls/Automation Systems

- BAS = Building Automation System
- BMS = Building Management System
- BEMS = Building Energy Management System
- DDC = Direct Digital Controls
- DCS = Distributed Control System
- CMS = Central Monitoring System
- EMCS = Energy Management Control System

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HVAC Systems

- Self-contained package units
  - Converts primary energy source for heating/cooling
  - Rooftop units, heat pumps, geothermal, etc.
- Central systems
  - Central supply and multiple end use subsystems
  - Typical central chilled water and steam/hot water
  - CW and HW coils in AHU
  - Multiple fans
  - Various terminal units

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WHAT PARAMETERS ARE CONTROLLED

- Temperature & Humidity
- Pressure
  - Air moves from higher pressure to lower pressure
  - Typical offices/classrooms slightly positive: .01” wc
- Ventilation
  - ASHRAE “Ventilation for Acceptable Indoor Air Quality”
  - Min rates per person, typically 5 - 20 CFM/occupant
  - Air Change Rates(ACH=Air Changes per hour)
- Special requirements
  - Smoke control, ultra clean air(HEPA), hazardous effluent
  - Containment: Labs, Hospitals, Animal Care, BSLs

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Safe Operations

- Fume Hoods & Lab Exhaust
- Variable volume system
  - Lower energy usage
- Mnt & Operations
  - Safety verses high ventilation rate

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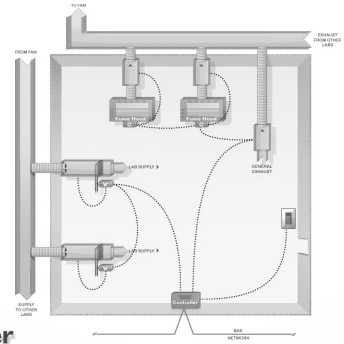
Laboratory Controls on BAS Native Controller



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Student Initiative

- Not trying to solve this control problem

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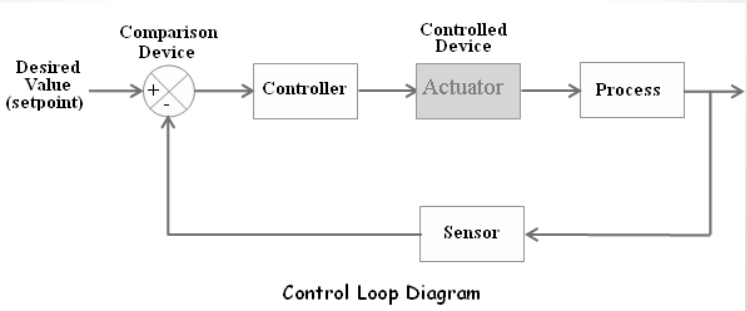
CONTROL LOOP



Control Loop Diagram

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CONTROL STRATEGIES

- On/Off Control
  - Short cycling
  - Operates at inefficient condition
  - Components wear quickly
- Modulation/Proportional Control
  - Equipment operates at a reduce rates
  - Equipment turn down ratios
- Staging
  - Multiple smaller units
  - Conditions require half of design capacity, then half of the units operate
- And lots of Hybrid variations

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History of HVAC controls

- Initial HVAC controls were pneumatic
  - Probably because mechanical engineers understood fluid control, hence use properties of air to control flow of heating and cooling
  - Use of electromechanical relays in ladder logic to switch dampers

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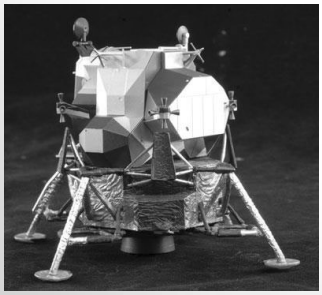
History of HVAC controls

- In the 70's & 80's, relays became electronic switches, as transistors could handle higher current loads



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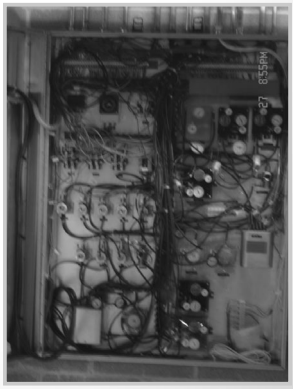
Pneumatics Control Panels



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History of HVAC controls (Con't)

- Mid 1980s, electronic switches cost effective
  - Pneumatic controls still common in older buildings

TRS-80 Personal Computer

- Around 2000, digital computerized controllers common
- Internet growth - Controllers accessed by web browsers allow monitoring and control remotely
- Use of Graphical User Interface (GUI)

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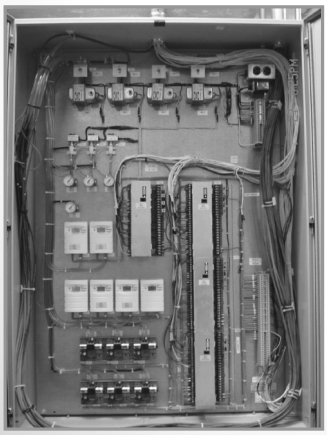
Typical DDC panel



1st Generation AHU Panel

1st Gen Bldg Controller/Network Device

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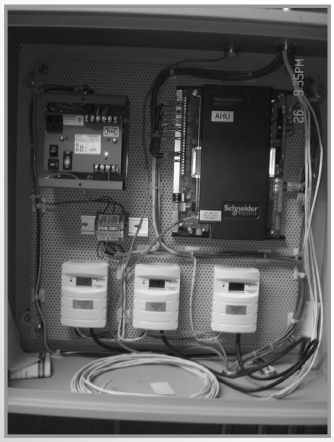
Typical DDC panel



2nd Generation AHU Panel

2nd Gen Bldg Controller/Network

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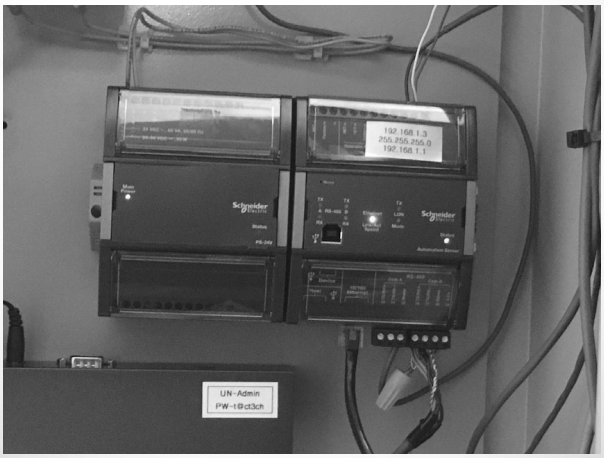

3rd Gen Bldg Controller/Network

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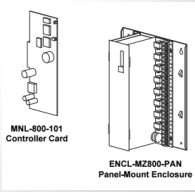
Microzone Conversion

- BUT, Generation I controllers that are 20+ years old???
- Replace Barber-Colman Microzone II circuit board w/ MNL-800 card
- Install new communications bus and replicate programming
- Preserve existing I/O investment



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History of HVAC controls

The Cloud – Mythical tool that holds data and images

"HVAC systems evolved from air control to direct digital control and are now return to 'air,' so to speak." **HPAC Engineering**, p.6, *Control Freaks*, October 2017

- **The Cloud –** A marketing term rather than an engineering term, which basically means other people's computer

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CLASS SURVEY – HVAC CONTROLS

- Campus Size - GSF
- % of Buildings HVAC Pneumatic controls
- % of Buildings with Local controller
- % of Buildings on campus Central Monitoring/Web Based DDC

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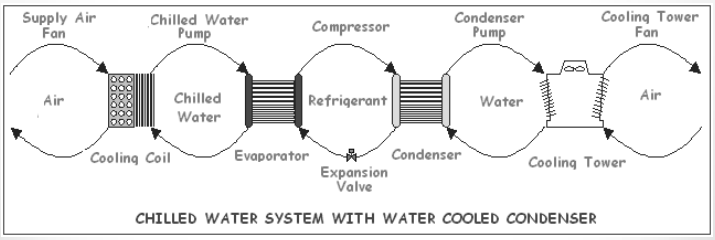
Central Cooling Cycle



Typically,

- Central systems = lower operating costs
- Central systems = more complex controls

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BAS COMPONENTS

- Local/Secondary Controllers
  - AHU or Terminal unit controllers
  - Limited software and data storage
- Building/Primary Controllers
  - High-end and communicate peer to peer
  - Full software compliment
  - Support global strategies
  - Buffer for alarms/messages/trends
- Web Servers/Data Repository
- Operator Interface
  - Desktop, laptop, Notebook, hand held

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BAS COMPONENTS AND FEATURES

- Central controllers, application specific controllers (VAV Box, AHU, Package unit)
- Controlled devices valves, dampers, and motors, actuators
- Time schedules
- Setpoints, logic, trend logs, alarms, points
- Data Storage
- Outputs start/stop equipment, voltage or current signals to control movement of medium (water, air, steam)
- Graphical User Interface (GUI)

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DDC System Controllers

- "Point"
  - Data origination location
  - Describes data storage location
  - Unique identification or address
- Inputs and Outputs send info
  - In the form of IO Modules
  - 0 to 5V dc, 0 to 10V dc, 4 to 20 mA
  - Output: 2 to 10V dc or 4 to 20 mA
- Microprocessor/Controller
  - Programmed to do a specific task

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BUILDING AUTOMATION SYSTEMS

- Vendors
  - Honeywell, Johnson Controls, Trane, Schneider Electric, Pheonix, Siemens, Carrier, Alerton, Andover, Automated Logic, Echelon, TAC
- Not right or wrong answer for type. Depends on existing equipment, where heading, IT environment, local providers, etc.

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BAS – INDUSTRY TERMS

- Air conditioning – Quantity, quality, temp & humidity of air
- Air Balancing - Distributing air through a system
- AHU - Air Handling Unit – Includes blower, coils, filters, and controls
- DDC – Direct Digital Control
- VFD - Variable Frequency Drive
- VSD – Variable Speed Drive
- TCP – Transmission Control Protocol
- IP Address – Internet protocol address

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BAS – INDUSTRY TERMS

- DI – Digital Input
- DO – Digital Output
- AI – Analog Input
- AO – Analog Output
- LAN – Local Area Network
- VLAN – Virtual Local Area Network
- VPN – Virtual Private Network

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COMMUNICATION PROTOCOLS

- Sets of rules for communication, like a language.
  - Very important to code writers.
  - Addressing scheme and associated value.
- Three types of Protocols
  - Closed
  - Open
  - Standard

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COMMUNICATION PROTOCOLS

- Closed Protocol
  - Proprietary used by a specific manufacturer
- Open System
  - Uses protocols open to anyone
  - Components from different manufactures co-exist
  - Do not need a gateway to communicate
- Careful with open protocol, sometimes only the monitoring device is plug and play. Application specific programmable devices may be more complicated

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COMMUNICATION PROTOCOLS - OPEN

- Modbus – Client-server communication between intelligent devices.
  - Truly open (but may need specific programming tools for a specific manufacturer)
  - Widely used network protocol in many industrial manufacturing
- Modbus TCP/IP – Modbus with a TCP Ethernet package
- Modbus II – Updated version; not widely adopted
- OPC
  - Open connectivity via open standards
  - Early open protocol language based on fundamental standard of general computing market (a bit level information protocol)

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COMMUNICATION PROTOCOLS

- Standard Protocol
  - Open to anyone
  - Created by standards organizations
  - Universally recognized engineering tool to allow anyone to interpret data
    - Example: BACnet Shareware web viewer makes information visible, but can not do anything with it
    - Example: Apogee BACnet engineering tool to interpret Siemens Lab control

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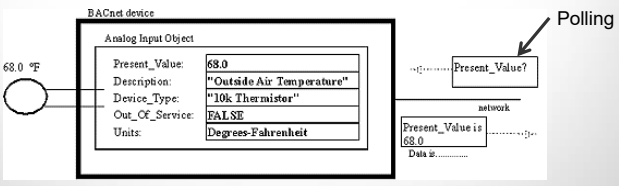
COMMUNICATION PROTOCOLS

- BACnet (Building Automation and Control Network)
  - Developed by ASHRAE to allow interoperability
  - Defines a standard set of "*Objects*", each of which has a standard set of "*Properties*"



The Language of BACnet-Objects, Properties and Services
By Bill Swan, Alerton Technologies, Inc.

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COMMUNICATION PROTOCOLS

- LonWorks
  - Created by Echelon
  - A standard for building controls ISO 14908-1
  - Uses a SNIVT (package of information) - well-defined interface for communication between devices
  - Each LON device has a Neuron ID Chip that identifies the type and address
- Johnson Controls Metasys N2 Field Bus – Defined around RS-485 communication standards (but very proprietary)

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COMMUNICATION PROTOCOLS

- Sets of rules for communication, like a language.
- No right or wrong vendor
  - Often depends on local service rep service
- Not right or wrong communication protocol
  - Depends on existing equipment, long term plans, IT environment, etc.
- No one protocol inherently better
  - Which is harder to learn Chinese or English?
  - Depends on which one you already know!

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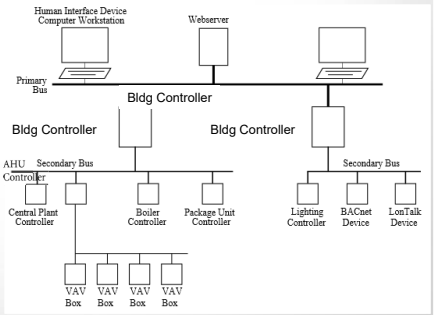
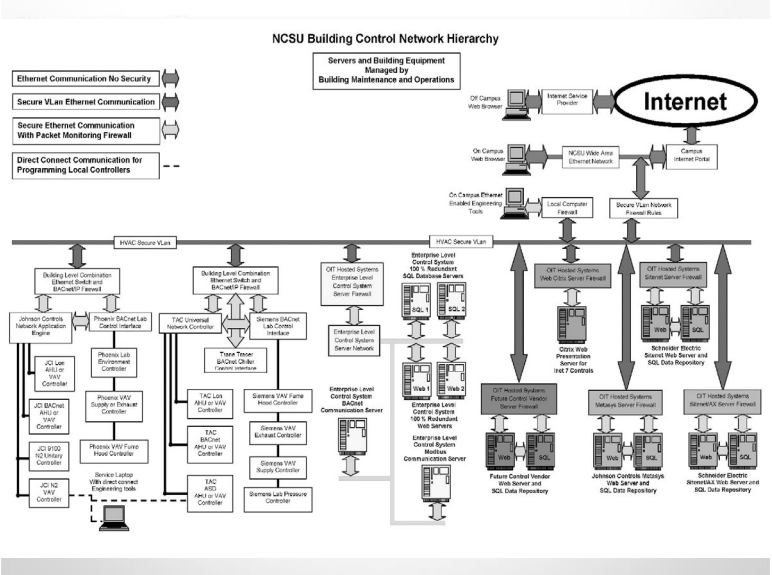
BAS ARCHITECTURE

- Secondary Bus – Within Building
  - Protocol to devices within Bldg
  - Could be normal ethernet or for BAS only
- Primary Bus – Campus Network(fiber, cable, wireless





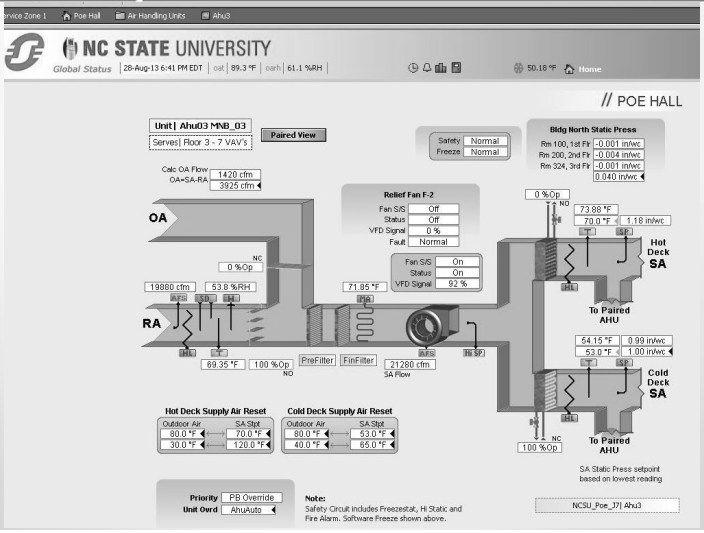
- Need a system that works, not just ‘check the block’ and say we met the requirements

OVERALL BENEFITS OF BAS

- Optimize indoor air quality
- Maintain thermal comfort
- Ensure safe operation
- Improve use for occupants
- **Optimize energy usage**
  - Efficient operation to match load (savings can be 10-50%)
- Complex Calculations
  - Anticipation of what will be needed/Predictive
- Maintenance & Operations benefits

BAS BENEFITS – Mnt & Operations

- Global perspective of how a facility is functioning
- Real time operating data
- Employee awareness of system
- Troubleshooting
  - More efficient use of time
  - Old Pneumatics – “make an adjustment and come back tomorrow to see how it worked”



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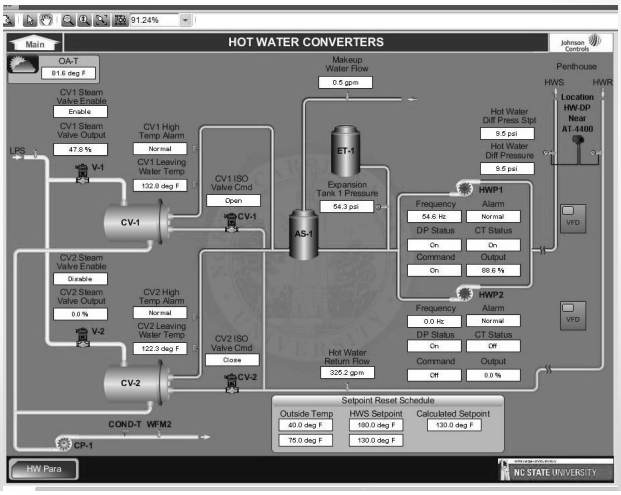
GRAPHICS- STEAM/HW CONVERTER



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Troubleshooting HVAC Systems Rule To Live By

- Turning manual valves for HVAC temperature control is at best a very temporary solution and at worst a ***long term pain in the neck for you***

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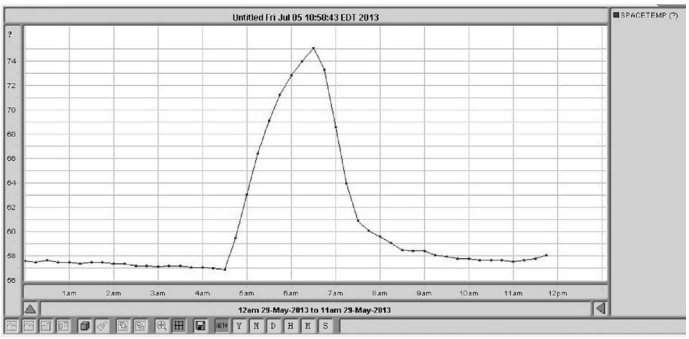
BAS BENEFITS – Mnt & Operations

- Alarm Management
  - Building Rounds from a screen
  - Focus effort of staff
- Direct Connect at Controller Level
- Distribute software to remote controllers
  - Eliminate need for continuous communications
  - Function in front end failure modes/Disasters
- Analysis with Trends

Chilled Water Outage at Data Center 2 – May 29, 2013



- Between 4:30 am and 6:30 am, space temperature rose from about 57 F to about 75 F (temperature may actually be higher because T-Stat mounted adjacent to CRAC unit on a cold wall)

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BAS BENEFITS – CUSTOMER SERVICE

- Alarm Management
  - Email notification on critical parameters
- Trends to document research requirements
- Troubleshooting
  - Faster response to problem
- Safe Operation/Better IAQ

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Indoor Air Quality (IAQ) - HVAC

- General duty clause – Workplace must be free from RECOGNIZED hazards that are likely to cause death or serious physical harm
- IAQ Affects productivity, comfort, health and safety
- **If comfort issues not resolved, they are perceived as health and safety problem and productivity will suffer!**

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BAS BENEFITS – ENERGY MANAGEMENT

- Metering, Data Management, Reporting
- Technician awareness of energy issues
- Scheduling
  - Occupied/Unoccupied/Load Shed

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ORGANIZATIONAL CONSIDERATIONS

- Who is responsible for HVAC Systems?
- Challenges
  - Occupancy sensors controlling lighting and HVAC
  - Scheduling lighting through HVAC BAS
  - Who manages building schedule?

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ORGANIZATIONAL CONSIDERATIONS

- Central Shops
  - Trades: HVAC Mechanical, Electric, Plumbing
- Zone Maintenance Shops - Multi-skill shops
- Hybrid Central and Zone
  - Central automation shop
- Energy Management Department
- Utility Department – Thermal plants
- Different Departments
  - Academics, Housing, Athletics

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ORGANIZATIONAL CONSIDERATIONS

- Discussion at your Table about different organization options
  - Central vs. Zone
  - Control Shop
  - Housing, Athletics, Academic, Dining
- Advantages and Disadvantages

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STAFF CONSIDERATIONS

- Employees
  - Skills and training (The best understand all trade)
  - Proper classification and pay
  - May need someone with network skills
- Employees may modify the system to their level of understanding
  - System Over-rides
  - Defeat automation by placing in Manual
- Knowledge is Power
  - Must share information and not horde it

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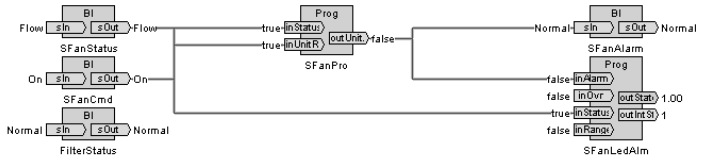

BAS Logic Diagram for a Fan Stop/Start

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A WAY - 4 LEVELS OF USERS/TECHNICIANS

1) Basic User/Technician
   - Use graphics to see what is going on – Look Only

2) Intermediate User/Technician
   - Understands system, manage operations schedules, troubleshooting, operation mode, setpoints

3) Advanced Technicians/Building Engineer
   - Software tools, sequence of operations, programing, Advanced troubleshooting

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A WAY - 4 LEVELS OF USERS/TECHNICIANS

4) Does not work with DDC Systems
   – Those that don't know and don't want to know
   – May be able to press reset button
   – Definitely can put the VFD in Manual

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Wave of the Future

SMART BUILDING

Class Work
– What does "***Smart Building***" mean to you and your campus?

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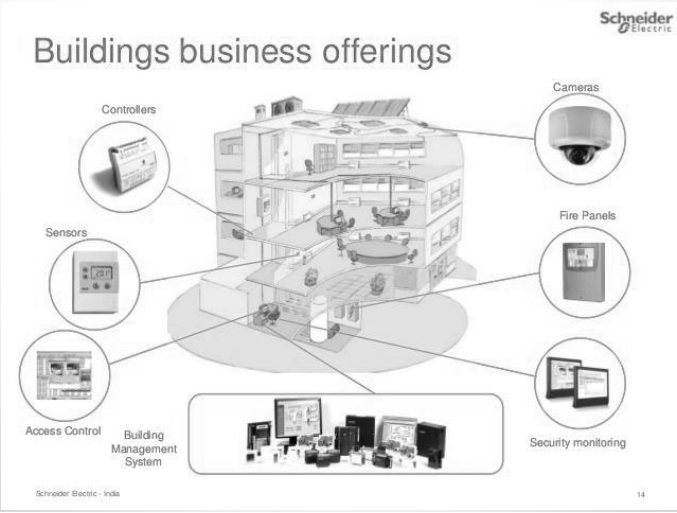
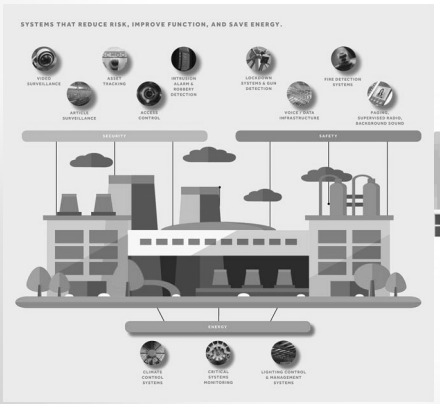
Definition of Smart Building:

"A building that provides a productive and cost-effective environment through optimization of its four basic components - structure, systems, services and management - and the interrelationships between them."

Source: Intelligent Buildings Institute (IBI)





CHALLENGES WITH SMART BUILDINGS

- Any Success Stories?
- Any Significant Issues?

CHALLENGES WITH BAS ON CAMPUS

- Staffing Models
  - In-house staff verses vendor
  - Single or multiple vendors on campus
  - Shop organization and staffing levels
- Sensors controlling multiple systems
  - Areas of responsibility
- Integration and control of package units
- Who manages building schedule?

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CHALLENGES WITH BAS ON CAMPUS

- M & O costs of system
  - IT/Server costs – Behind the scene work
  - Calibrations and maintenance required
  - Preventive Maintenance tasks and frequency
  - Specialty items: control valves, dampers, DDC
  - Proprietary systems that talk to the BAS
- Software upgrades
  - Web browsers
  - JAVA – security issue
  - Windows OS being phased out
- Public vs. Private IP addresses

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CHALLENGES WITH BAS ON CAMPUS

- Network security
  - Firewalls
  - VLANs
  - Switches
  - Use Building Internet or an intranet
- Backwards Compatibility
  - How many other industries have to communicate with devices/software built 30 years ago???

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OPTIMIZE VALUE OF WEB-BASED BAS

- Occupied/Unoccupied Scheduling
  - Integration with classroom scheduling system
  - Unoccupied mode reduces energy up to 80%
- Alarm Management
  - Critical alarms/Critical systems
  - Not get overwhelmed with data
- Optimize use of personnel
  - Building Rounds from computer screen
  - Troubleshooting

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OPTIMIZE VALUE OF WEB-BASED BAS

- Remote/off site monitoring
  - Critical facilities; Hospitals, data centers
  - Key data with a quick read (CW, steam systems, Boss's office, Chancellor's Residence)
- Energy Management
  - Metering & sub-metering
  - Reporting features

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OPTIMIZE VALUE OF WEB-BASED BAS

- Optimize sequences of operations
  - Outside air reset
  - Economizer cycles
  - CO2 monitoring for outside air quantities
  - Supply air temperature reset
  - Failure mode operation (power, equipment, etc.)
- Reporting
  - Meet accreditation requirements
    - AAALAC, Joint Commission Standards
  - Support Critical Research

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Future of BAS

- Interoperability – Plug & Play
  - BYOD
  - Aps and Mobile Devices
- Wireless
  - Ease of relocation of sensors
  - Reduced installation costs
- More sensors or fewer better sensors?
  - Aircuity (Centralized suite of sensors)
  - Improved sensors reliability and functionality
- Analytics and Re-Commissioning

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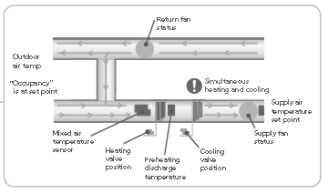
Control Logic/Analytics Lite/Smart Rules

- Analytics built-in to BAS system
  - Instrumentation/sensors must be in place
- Identify central equipment anomalies
- Simultaneous heating/cooling
- Valves not closing off properly



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Future of BAS

- Cyber Security
  - Segregated networks/enclaves
- System Integration - SMART BUILDINGS
  - Fire Alarm, lighting, HVAC, AV, electrical, card access, security, specific equipment
  - Reduce costs of multiple systems
  - CMMS, IWMS, and BAS integration

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- System Integration

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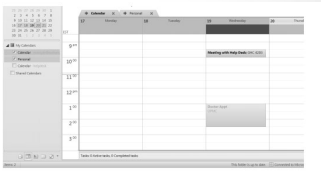
Future of BAS – Schedule Integration

- Registrar class scheduling integration (AD ASTRA)
- Google calendar scheduling integration
- Third party software application – Events 2 HVAC



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Future of BAS

- Artificial Intelligence

- Division 25 (Integrated Automation) verses standard Div 26(Lighting) & Div 23(Mech/HVAC)
- Enterprise Level Systems
  - Power Quality, Meters, Central Thermal Plants & thermal distribution system

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SURVEY SHEETS QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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