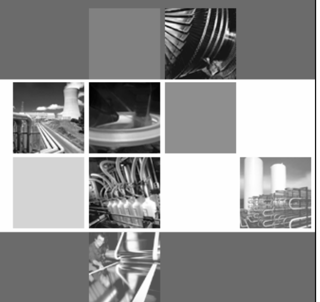
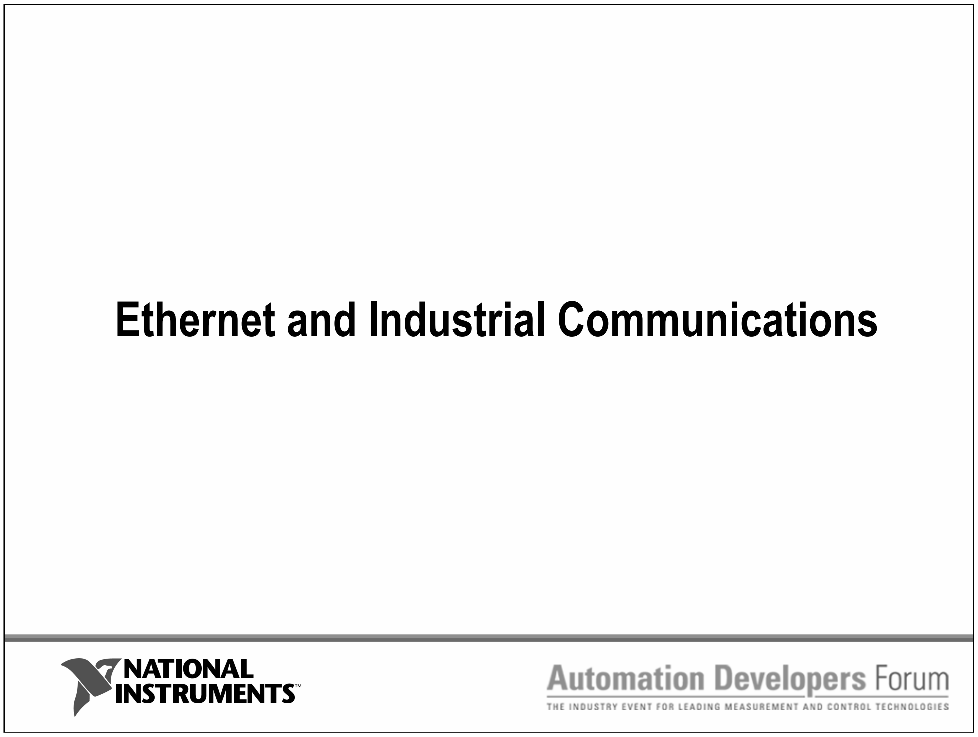
Automation Developers Forum

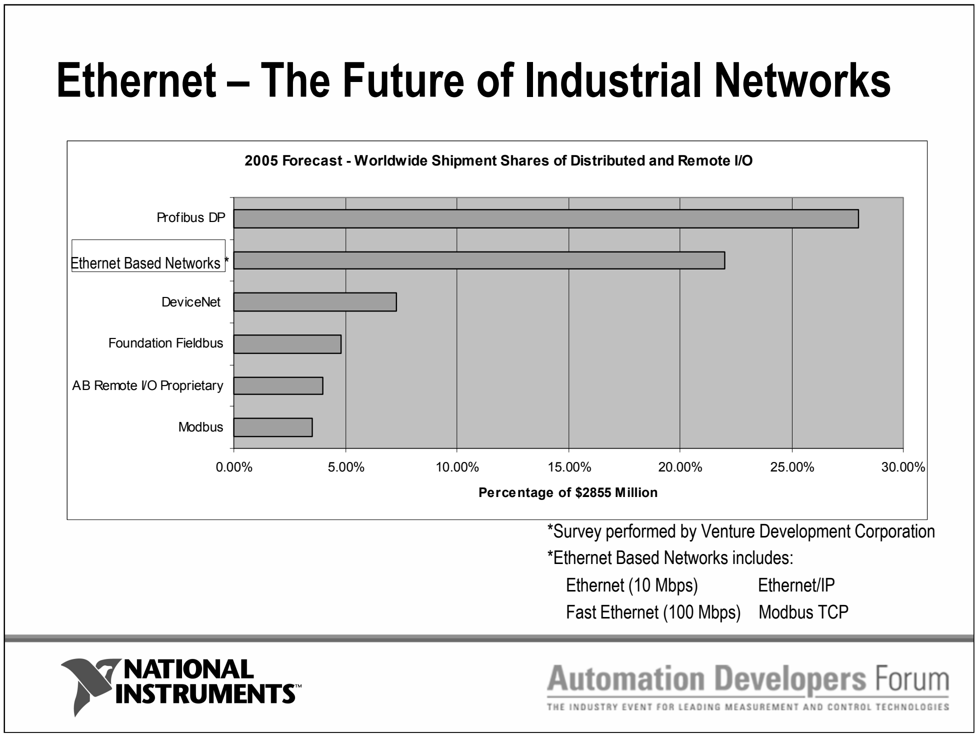
THE INDUSTRY EVENT FOR LEADING MEASUREMENT AND CONTROL TECHNOLOGIES





How many people in the room have used the Internet? How many have deployed Ethernet in your factories or plants?

It is obvious the Ethernet has become a "de facto" industry standard. Every PC, server, and handheld PDA ships with an Ethernet port or wireless Ethernet. But what about Industrial communication buses?



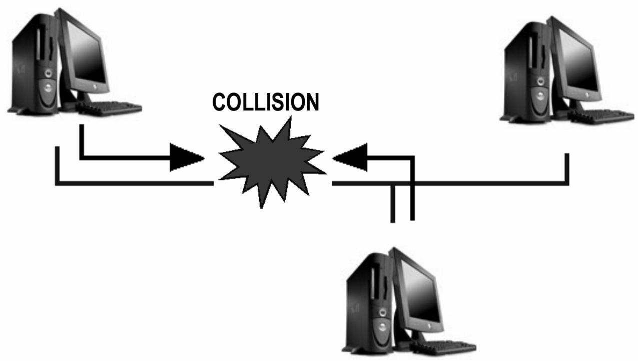
Ethernet has quickly increased its percentage of Shipment Shares of Distributed/Remote I/O for use with DCSs, PC-based control systems, and PLC systems worldwide. In 2002, the total percentage was 17%. This 5% increase is quite impressive considering the state of the economy during this time period—not as much money was invested in new technologies and products.

Also, all other Fieldbus network shares decreased during this same time period (with the exception of Foundation Fieldbus which grew .4%). This is further proof of the growing adoption of Ethernet as the replacement for existing Fieldbuses in industrial communications.

Bottom line numbers (As measured by Venture Development Corporation):

	2002	**2005**	**Category**	**Change**
Profibus DP	28.9%	28.0%	Fieldbus	declined
Ethernet (10 Mbps)	10.4%	12.0%	**Ethernet**	**grew**
DeviceNet	7.6%	7.3%	Fieldbus	declined
Foundation Fieldbus	4.4%	4.8%	Fieldbus	grew
Fast Ethernet (100 Mbps)	3.5%	4.1%	**Ethernet**	**grew**
ControlNet	3.5%	3.7%	Fieldbus	grew
AB Remote I/O Proprietary	4.4%	4.0%	Fieldbus	declined
AS-I	3.6%	3.6%	Fieldbus	same
Modbus	3.6%	3.5%	Fieldbus	declined
EthernetIP	not listed	1.0%	**Ethernet**	**grew**

Ethernet's Original Purpose

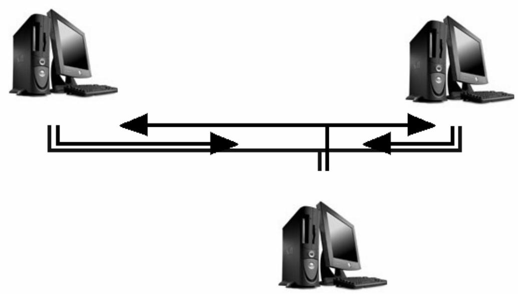


The physical medium of Ethernet—the cable and connectors that connect office PCs, printers, and other peripheral devices—handles a series of communication protocols such as IP (Internet Protocol), TCP (Transport Control Protocol) and numerous other ones. This group of protocols and connectivity is well suited for the office environment. It allows users to share files, access printers, send email, search the internet and perform all other communications used in an office environment.

Ethernet was originally designed as a bus topology. This meant that whatever device transmitted, owned the bus. If two devices transmitted at the same time, it would cause a collision and both sides would "back off" and wait for a random time interval to resend the data. Because the devices would wait random time intervals and then resend their data, collisions eventually resolve themselves in a non-deterministic manner. This is suitable for the office environment where the time between sending a print command to the printer and the printer actually starting the print job is not something that must happen in an exact amount of time.

This type of communication, however, is obviously not acceptable in an industrial environment, where deterministic communication is needed.

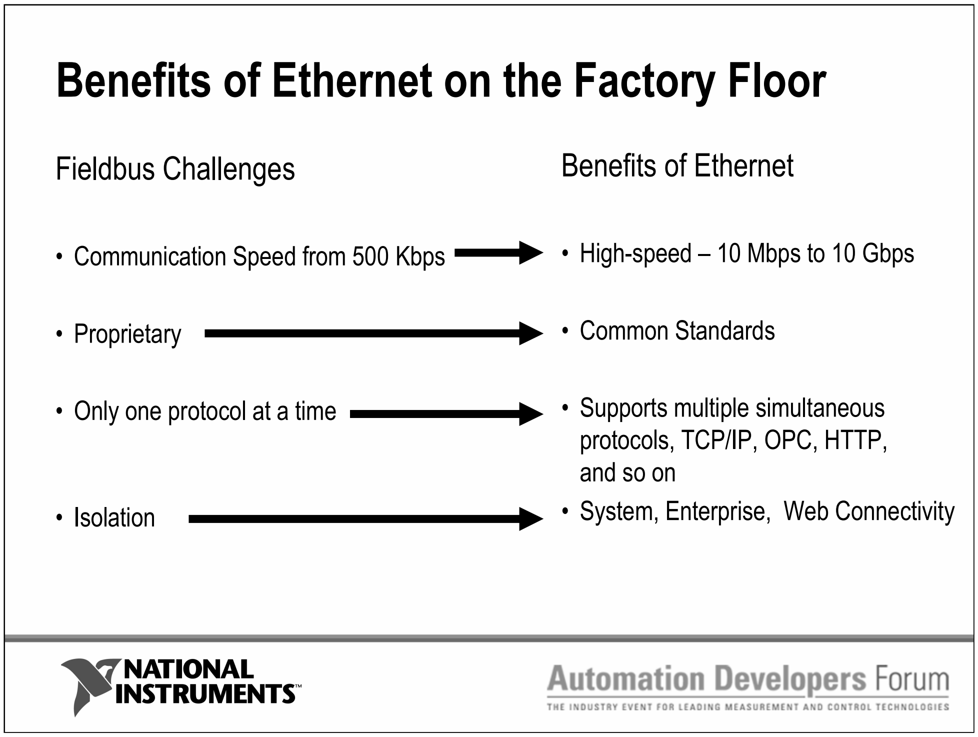
Advances in Ethernet Technology



- Ethernet Switches
  - Delivers Determinism
  - Each node has 10 Mbps
  - Multiple devices can send data at the same time
- Full Duplex Transmission
  - Transmit and Receive
  - Collision Free
  - Deterministic

Ethernet was originally designed as a half-duplex network, meaning that information could only be sent in one direction at a time. If multiple devices send data at the same time, collisions occur, as described on the previous slide.

One of the most important advancements in contemporary Ethernet networks is the use of *switched Ethernet*. Switched networks replace the shared medium of legacy Ethernet with a dedicated segment for each station. These segments connect to a switch, which can connect many of these single station segments. Some switches today can support hundreds of dedicated segments. Switched networks use either twisted pair or fiber optic cabling, both of which are implemented with separate conductors for transmitting and receiving data. In a switched network, devices do not have to go through the collision detection process and can transmit data at will, since they are the only potential device on that medium. This allows multiple devices to transmit data to the switch at the same time that the switch transmits data to them, achieving a collision-free environment.



What is Fieldbus?

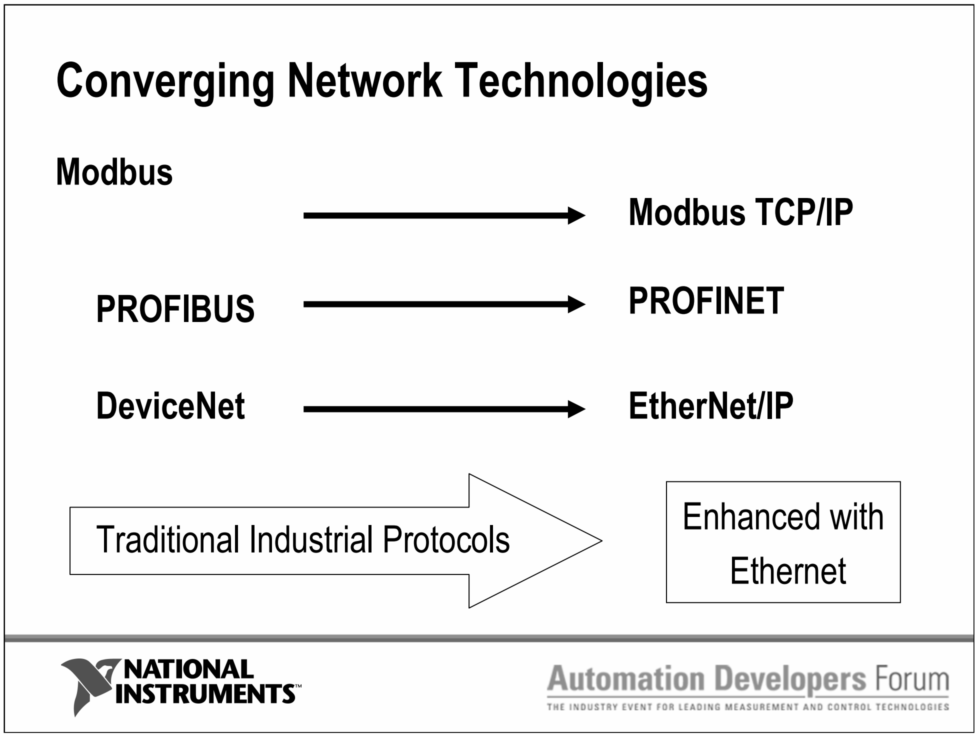
Fieldbus is conceptually identical to the local area network, but tailored for process control and measurement devices. It allows numerous devices in a system to be connected on a single network or “bus” cable. This allows data to be sent to and from the controllers (PACs, Industrial PCs, and so on), devices, and actuators on the network.

Unfortunately, there is no one FB standard to which all manufacturers of automation and control devices conform to. Like many communications standards there is a lot of politics involved between various groups of manufacturers and standard associations over which protocol is the true FB standard. Some of the most common Fieldbus standards of today are: DeviceNet, Profibus, Modbus, and CANopen.

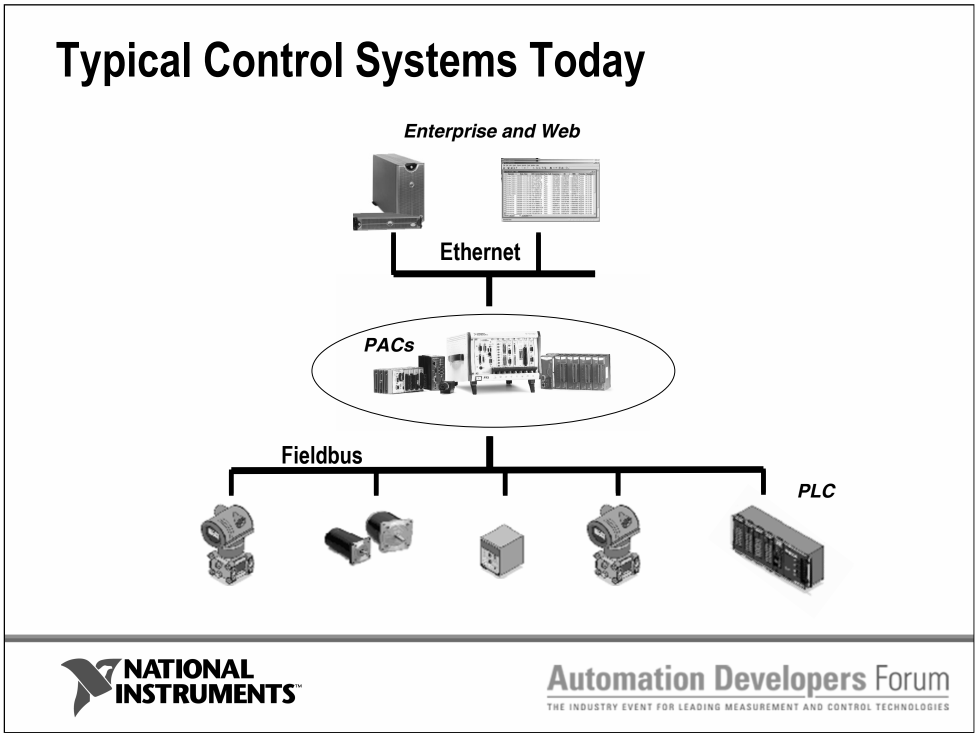
While Fieldbus networks have served the industry well, there are a lot of limitations associated with this technology. Ethernet offers a ton of advantages over Fieldbus.

Explanation of the proprietary versus common standards:

With massive adoption of Ethernet across the world for simple office and network applications, components and products are both widely available and low in cost. So, Ethernet for industrial applications, benefits from Ethernet economies of scale. Beyond the pricing advantages, Ethernet is a common standard that the majority of engineers are familiar with and understand.



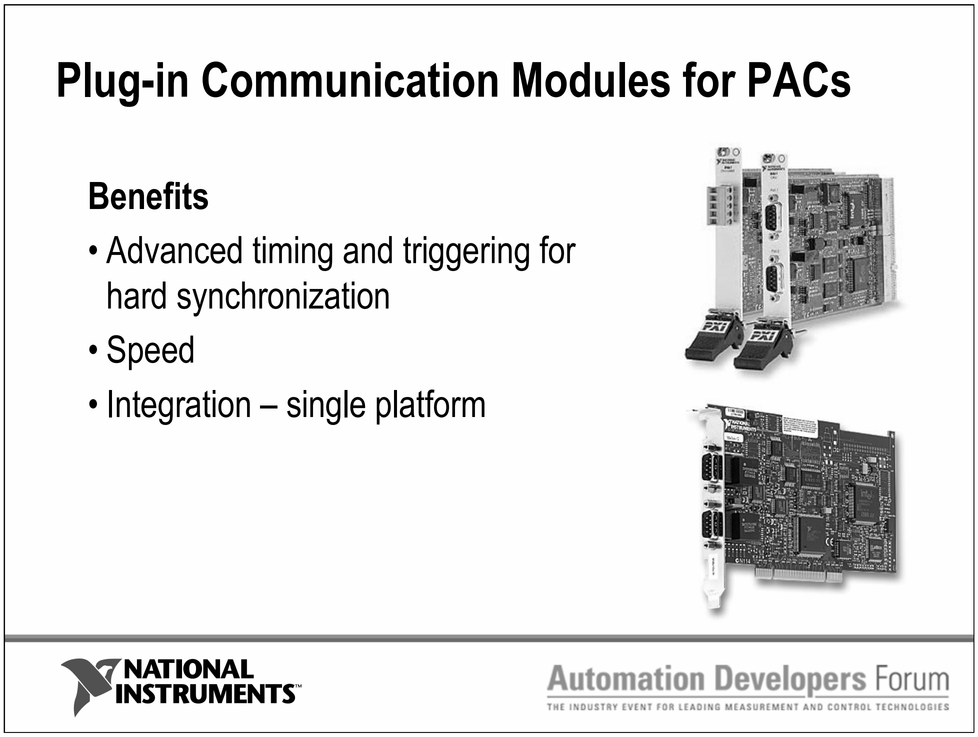
In addition to the adoption of Ethernet across the factory floor, a common trend that is occurring in the industrial communication market is the addition or enhancement of traditional busses with Ethernet technology. Basic protocols such as Modbus commonly implemented over RS-232 or RS-485 ports are now just as easily implemented over standard Ethernet ports, routers and cables. Popular busses such as PROFIBUS now offer version of the protocol implemented over an Ethernet based structure with PROFINET. And protocols such as DeviceNet used to communicate with field devices are evolving to new protocols such as EtherNet/IP that use some of the technology available from standard Ethernet.



While all trends are pointing towards Ethernet moving to the factory floor and eventually becoming the de facto network, typical control systems today are composed of many different sensors, actuators, and entire networks that are based on Fieldbus technologies.

If we take a look at the diagram now (orange network on the bottom), you will see that Ethernet is most commonly used to network the PC to the enterprise system. Often times, the PC will have some time of communication interface that allows it to speak to the devices on the fieldbus network.

A recent study by Venture Development Corporation forecasted the shipments of control devices, buses, and networks for 2005. As you can see, Fieldbus networks are still the vast majority of use cases today.

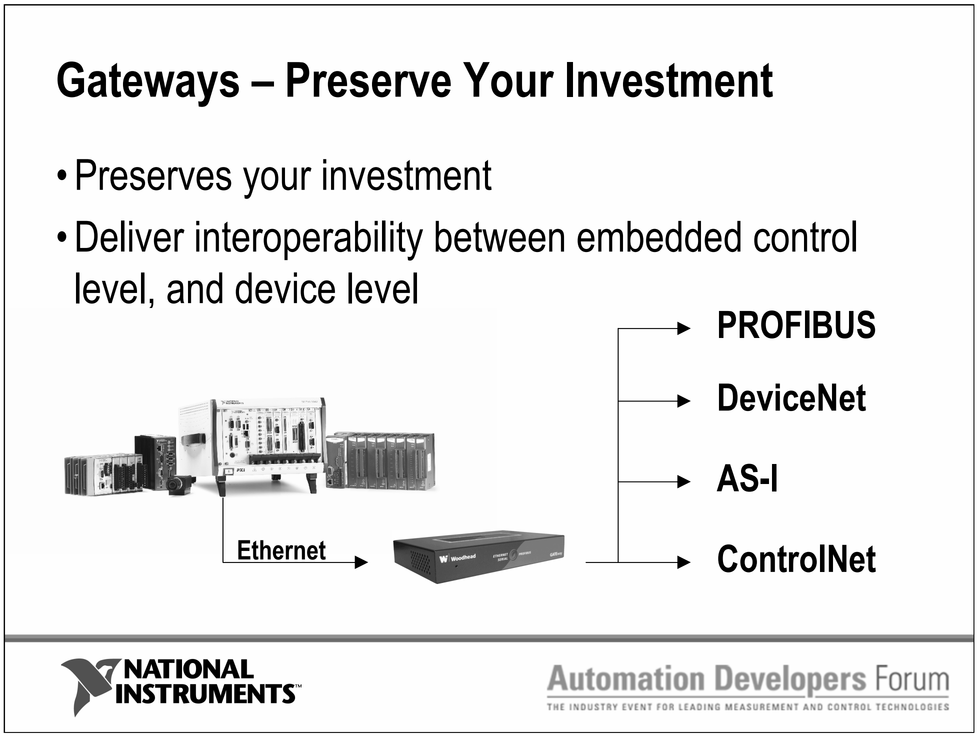


There are two ways to incorporate existing fieldbus networks and devices into your applications. Both of these methods are achievable with PACs. The first, which this slide focuses on, is using plug-in communication modules that allow your PAC to “talk” on the specific fieldbus network.

The advantages to this are:

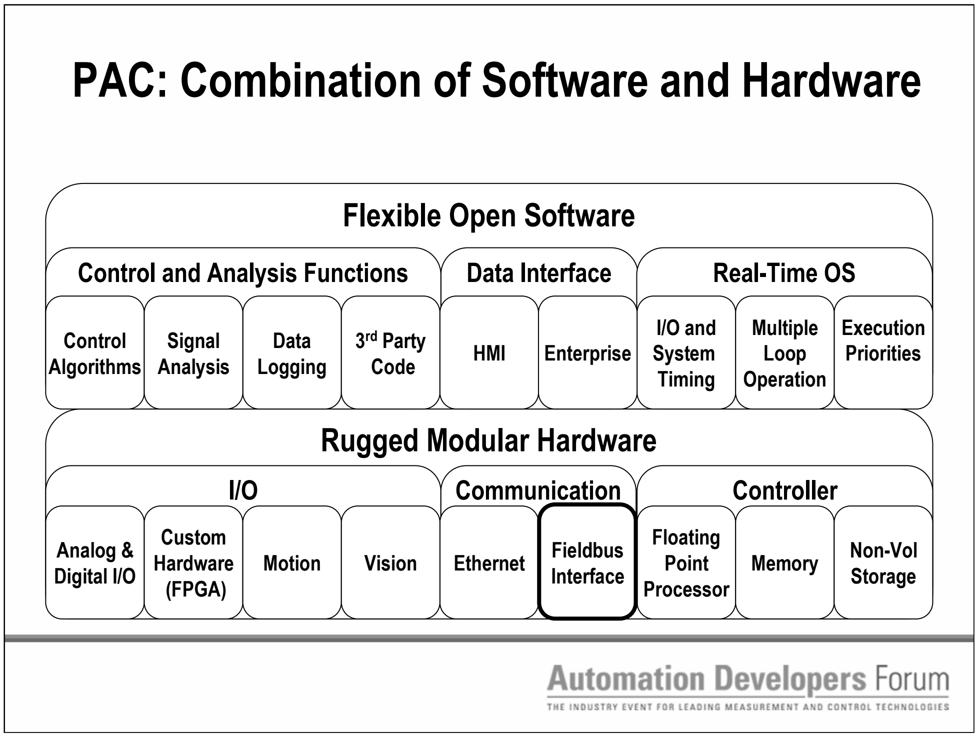
PXI – defines eight trigger bus lines for synchronization and communication between modules. Trigger, clock, and handshaking signals can be shared using the trigger bus lines. Triggers can be passed from one module to any number of modules, so you can distribute digital trigger signals from master to slave measurement devices. The trigger bus allows transmission of variable frequency sampling clocks, so multiple modules can directly share a sample clock or variable frequency time base.

Industrial PCs (and therefore PXI) – I/O Communication bus – as mentioned in Key Note under the PC Architecture slide



With gateways you can integrate your existing industrial devices into Ethernet-based systems. This preserves your investment in existing hardware while allowing you to add the functionality and processing performance of the latest PACs. By selecting an Ethernet backplane to build in your new systems and using gateways to interoperate with existing systems you can use the new technologies and easily integrate them.

In the future you will see new technologies based on Ethernet coming out such as deterministic Ethernet.



PACs are based on commercial technologies, with a network based on Ethernet it is easy to extend the distance between PACs and other factory nodes through the use of industrial wireless Ethernet. A gateway can connect different Fieldbus interfaces to a Ethernet backplane and then through the use of wireless modems engineers can extend the reach of industrial communication networks.

Gateways – Communicating Over Any Industrial Bus

Woodhead

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Interoperability Challenges

Despite trend to Ethernet there are challenges:

- Existing infrastructure does not support Ethernet
- Investment in existing equipment
- Multiple standards for industrial Ethernet protocols
- Some devices don't have Ethernet capabilities
- Lack of resources to implement products
- Industrial Ethernet management tools do not exist

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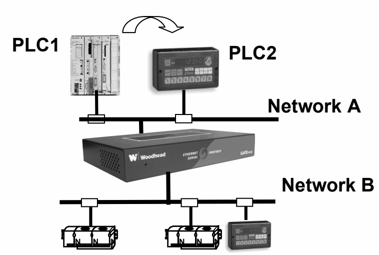
There are challenges to implementing Ethernet throughout the levels of factory communication.

- As Ethernet is making its way into the industrial automation world, customers are looking for ways to incorporate the benefits of Ethernet to the plant floor. Customers have already invested time and money in the existing equipment and it would be quite costly to replace it.
- Different PLC vendors are offering Industrial Ethernet and they are not interoperable with each other. It is confusing for a customer to determine which standard to implement.
- Customers may lack the resources to implement an Ethernet network in their factory or build Ethernet capabilities into their devices.
- As we introduce Ethernet into the manufacturing world, there grows a need for tools to help diagnose, troubleshoot and maintain an Ethernet network
- What is out there today that can help resolve some of these challenges. Gateways. They provide solutions to resolve the communications barrier that exist today between dissimilar networks. They help to leverage the existing equipment and "virtually" upgrade it to the Ethernet standards.
- Let's take a look at the typical gateway applications.

Typical Gateway Applications

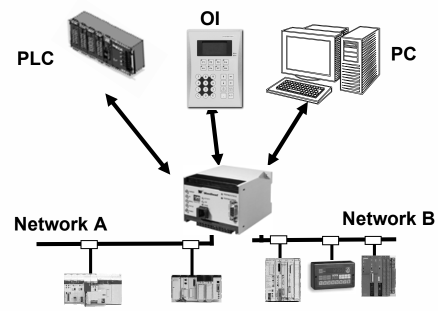
BRIDGING NETWORKS

- Data exchange between:
  - Dissimilar networks
  - PLCs with different messaging



CONNECTING DEVICE TO SOFTWARE

- Integrate unsupported devices or HMI/SCADA programs into your network



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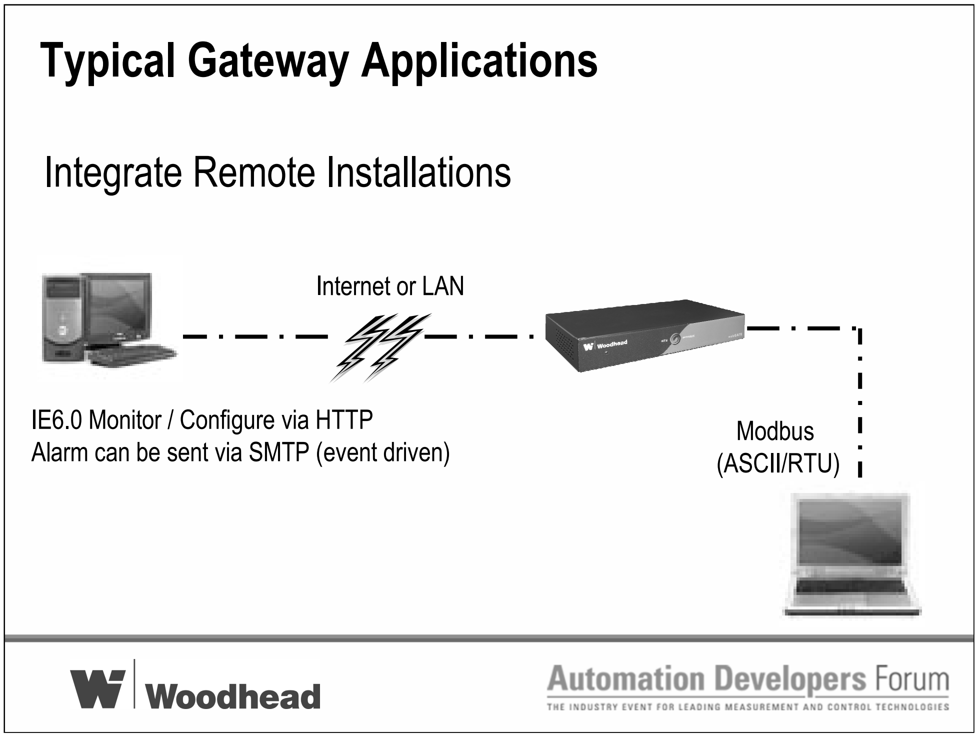
A Data Translator converts standard or proprietary device protocols to control center protocols



Gateways that house a modem can transfer data over alternative media.

Users can now access to the status and control information related to the devices connected through a thin client that supports a Web browser. Using an FTP server, customers can remotely update software and change configurations. And alarms can be sent through emails.

Other Typical Gateway Applications

- **Collecting** and **Storing** data
- Implementing network **Security** through a firewall
- Improving **Bandwidth** utilization
- Providing an **Access** point (portal)

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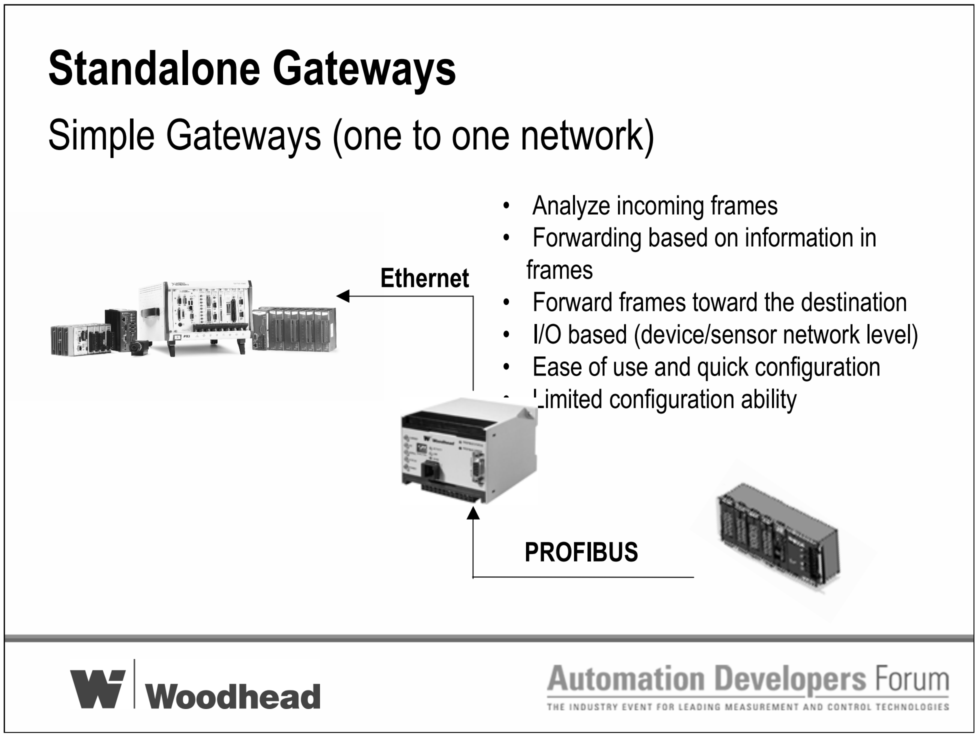
Gateways offer various solutions to customers.

- Collecting and Storing data – collect from multiple sources, concentrate and forward data
- Implementing network Security through a firewall – restrict access to specific network data
- Improving Bandwidth utilization – split a busy network to implement a high speed backbone
- Portal – an "access point" – to connect to the network to (i) flag alarms (ii) monitor (iii) visualize – to display data in graphical / textual form
- There are 2 types of gateways—PC gateways and standalone gateways.



There are simple and advanced standalone gateways. Most gateways have user-friendly configuration tools that does not require additional programming or network protocol knowledge.

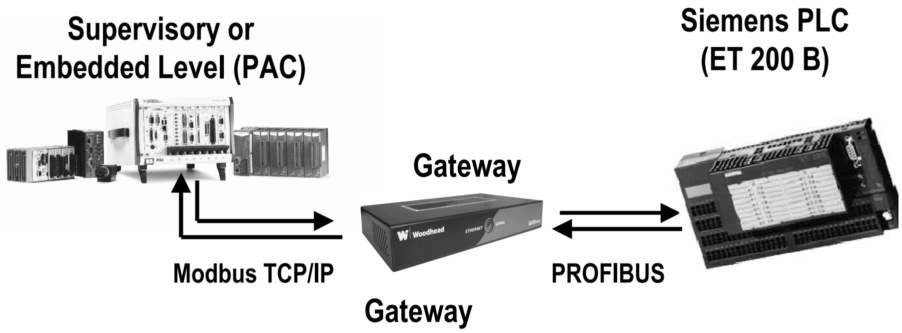
Simple gateways make it easy and inexpensive for a customer to translate data. Typically they are sharing data between two networks only. Messages between devices can be transferred using routing tables and/or data mappings.

Routing table – data is stored into a table in Network Protocol A and then the data is re-packaged and sent in Network Protocol B (for example, PROFIBUS DP to Ethernet)

Tunnelling – the network protocol is the same but the network transport layer is different (for example, Modbus TCP/IP to Modbus Serial). In this case, when the gateway receives an Ethernet frame, it removes the Ethernet portion (for example, TCP/IP address) and sends the information through the serial port using the same Modbus messaging.

Data mappings—information from all devices are stored into a database and then can be stored and/or sent out as needed by other devices.

Bridging the Network Gap – Demo



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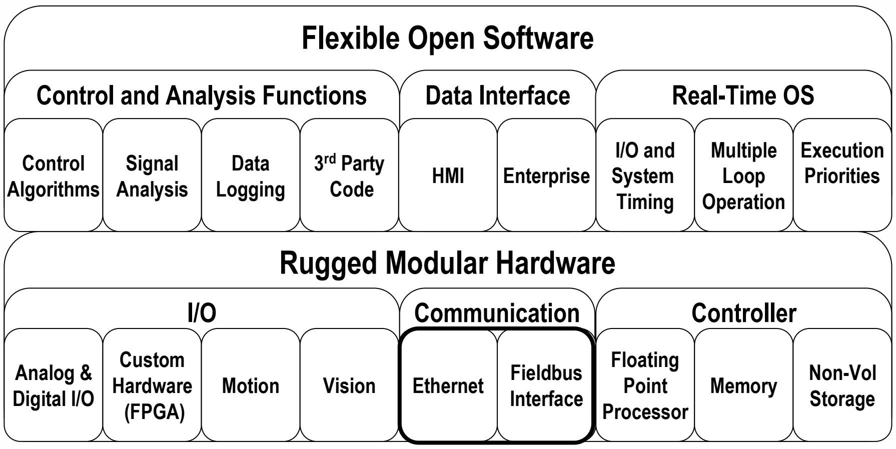
PAC – Combination of Software and Hardware



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Although Ethernet and field busses provide connectivity to the plant and to existing devices, sometime running cables is not feasible.

Industrial Wireless Solutions

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Since 1988, Data-Linc Group has provided industrial data communication solutions for control and data acquisition systems. In 1997 Data-Linc Group introduced license-free industrial wireless modems for automation systems using frequency hopping technology. In 1999, the technology was adapted for Ethernet creating the first highly reliable wireless Ethernet modem for industrial applications. Today, Data-Linc Group wireless modems are in operation in thousands of industrial plants.

Why Wireless?

Cheaper Solution

- Reduces wiring costs
  - Chemical Plant – typical wiring costs $40/ft
  - Nuclear Plant – typical wiring can cost up to $2,000/ft[1]
- Reduces costs to remote locations
  - Infrastructure not available or unreliable
  - Installing fiber-optic cable is cost-prohibitive

Only solution

- Wiring is impossible/impractical (for example, rotating machinery)
- Portable solutions – maintenance/process data where needed

[1] Using PCs for Machine Condition Monitoring, *Plant Engineering* December 6, 2004

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Wireless offers many advantages including significant cost reduction, improved productivity and plant maintenance.

Available Wireless Solutions

- Wide range of wireless technologies
  - Types: Cellular, satellite, private RF
  - Classes: Consumer, commercial, industrial
  - Data rate, range, and reliability
- Private RF
  - Customer “owns” system
  - Real time data exchange
  - No reoccurring subscription/usage costs

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There are many wireless technologies available today. Private RF systems are the most popular and the best choice for industrial systems.

Technical and Implementation Considerations

- Availability and range (propagation)
  - Bandwidth & latency (for example, Ethernet or serial)
- Performance
  - Reliability in high noise environments
  - Security
- Installation
  - Antenna placement and cabling
  - Environmental requirements
  - Safety issues
- Cost
  - Up-front and reoccurring costs
  - Licensing costs

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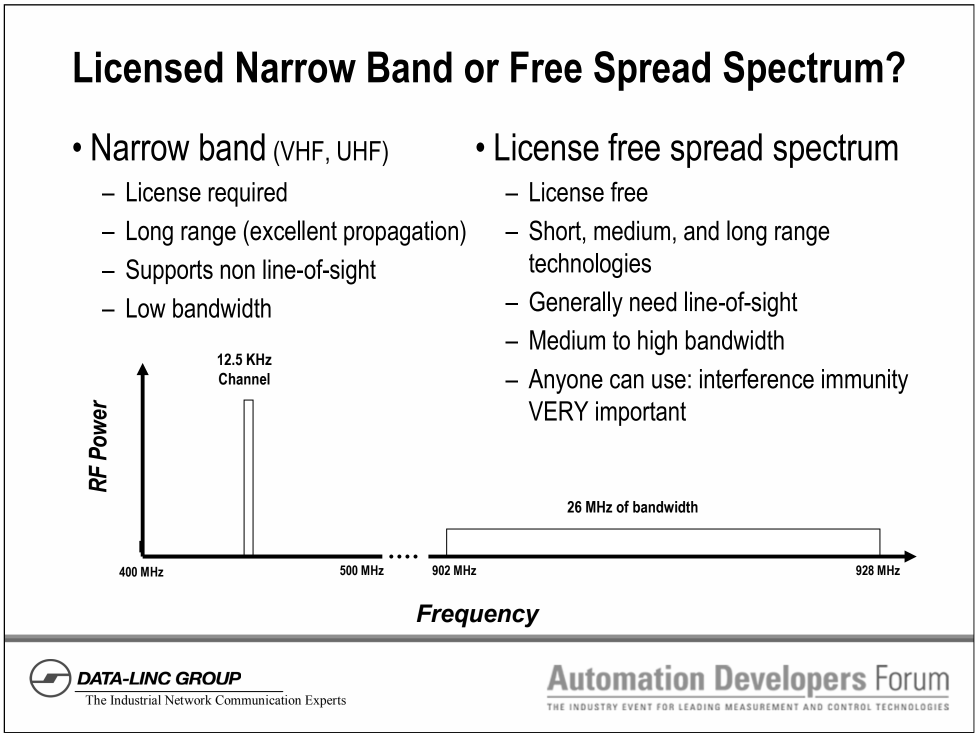
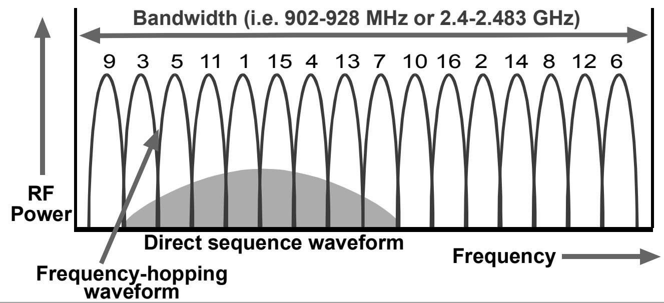
Industrial systems have unique demands on wireless communications. There are many considerations in choosing the right technology and ensuring reliable performance.



Spread spectrum offers many advantages over narrow band including license-free implementation, wider bandwidth and better interference immunity. However it is much more line-of-sight sensitive (no obstructions between antennas).

Frequency Hopping vs. Direct Sequence

- Direct sequence (DSSS)
  - High bandwidth (1 to 54 Mbps)
  - Range – 5 miles
  - 2.4 GHz or 5.8 GHz band
- Frequency hopping (FHSS)
  - Medium bandwidth (up to 200 Kbps)
  - Range – 25 miles
  - 900 MHz or 2.4 GHz band
  - Excellent interference immunity



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There are two spreading methods allowed by the FCC for spread spectrum radio systems: Direct Sequence and Frequency Hopping. Direct Sequence offers higher data rates and lower latency while frequency hopping offers longer range, excellent interference immunity but at lower data rates.

Spread Spectrum Technology Comparison

Technology	Type	Frequencies	Range	Data Rate	Industrial Maturity
Industrial FHSS	FHSS	902-928 MHz 2.4 GHz	30+ Miles	100 Kbps	Mature
802.11b Wi-Fi	DSSS	2.4 GHz	10 Miles	1 to 11 Mbps	Gaining Acceptance
802.11g	DSSS	2.4 GHz	5 Miles	54 Mbps	Emerging
BlueTooth	FHSS	2.4 GHz	300 ft	721 Kbps	Mostly Consumer
802.15.4 ZigBee	DSSS	902-928 MHz 2.4 GHz	200 ft	250 Kbps	Emerging

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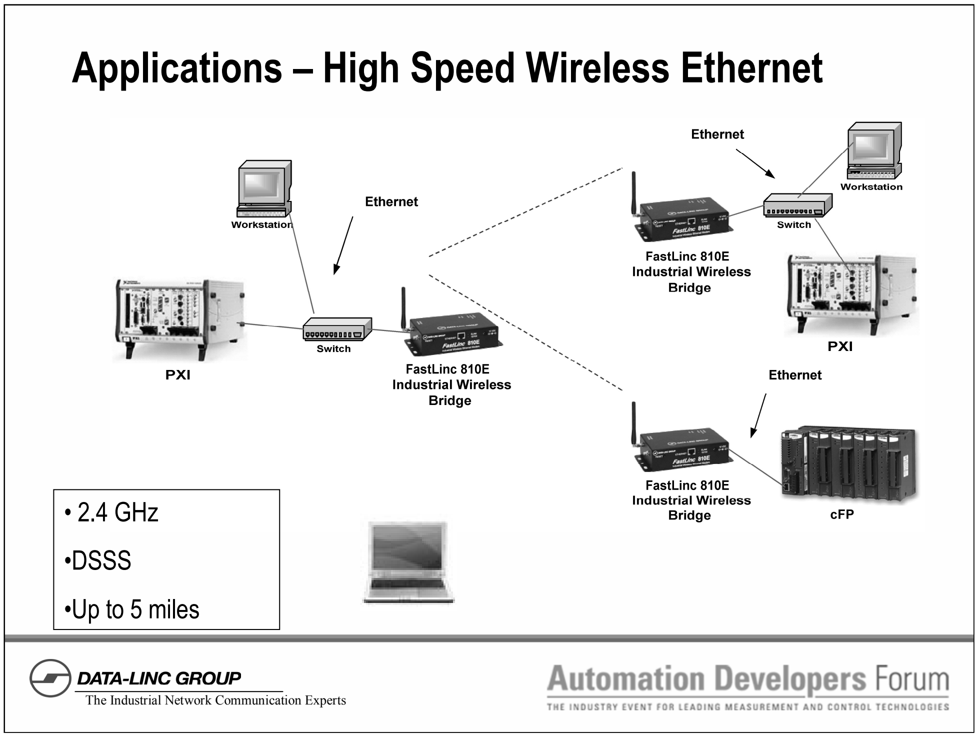
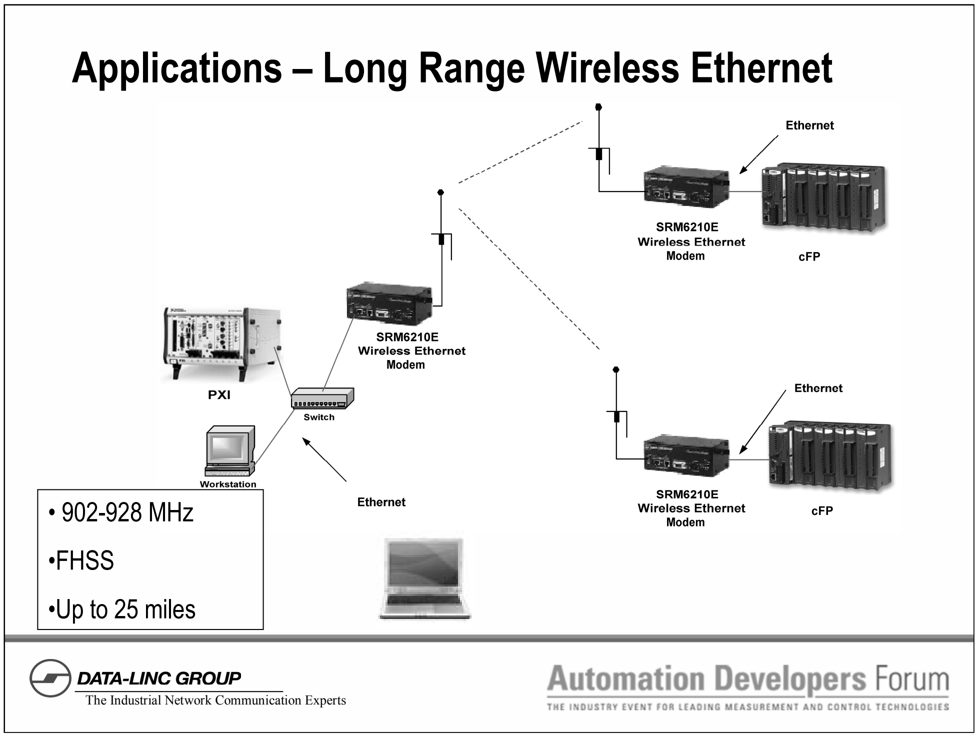
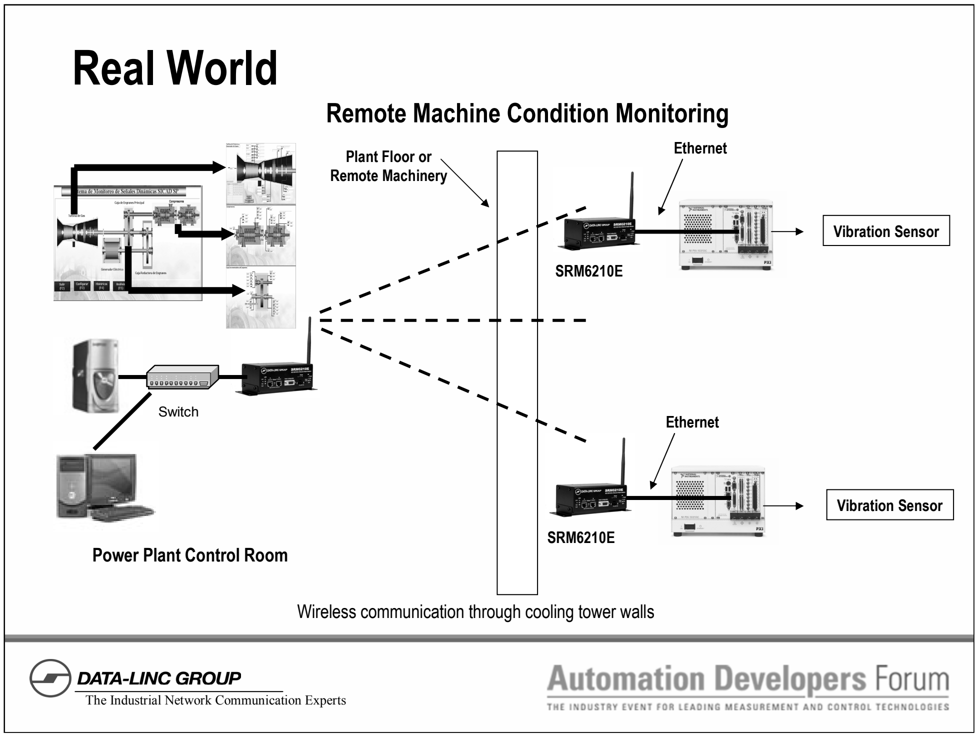
This chart compares several existing wireless technologies used in industrial systems and several emerging technologies. It is organized by range.



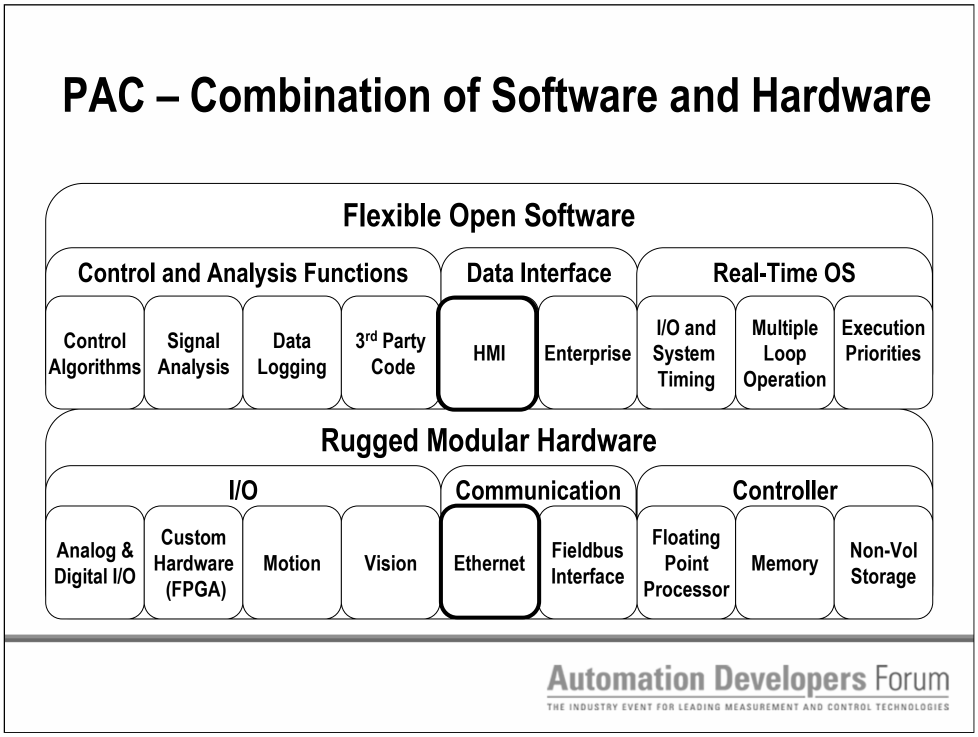
This diagram shows how wireless Ethernet technology can be used to bridge separated networks in a plant while maintaining high speed communication.



This diagram shows how industrial-grade wireless frequency hopping technology can be used to connect plant networks up to 25 miles away. This eliminates the need for leasing telephone lines from the telephone company.



This diagram shows a real world application where industrial wireless technology is used to link vibration monitoring equipment at a power plant. The vibration sensors are used for detecting impending failures of motors used to drive cooling fans in the cooling towers. The wireless Ethernet modems eliminated the high costs of running fiber optic cable in the harsh environment.



We have seen the pervasive spread of standard off-the-shelf technology such as Ethernet to industrial measurement and control. With wireless we have seen that it is also possible to expand the reach of Ethernet to cover distant or mobile installations. Because of Ethernet's coverage it is also possible to distribute operator interfaces through the plant. QSI will now discuss the options and technologies available for operator interfaces.

Adding Local and Remote Operator Interfaces to Any Control System

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Overview

- What is an “Operator Interface”?
- Market Segments
  - Consumer Grade
  - Industrial Grade
  - Military Grade
- Displays
- Input Devices
- Interfaces
- Operating System / Software
- The O.I. Decision Process
- Example Application

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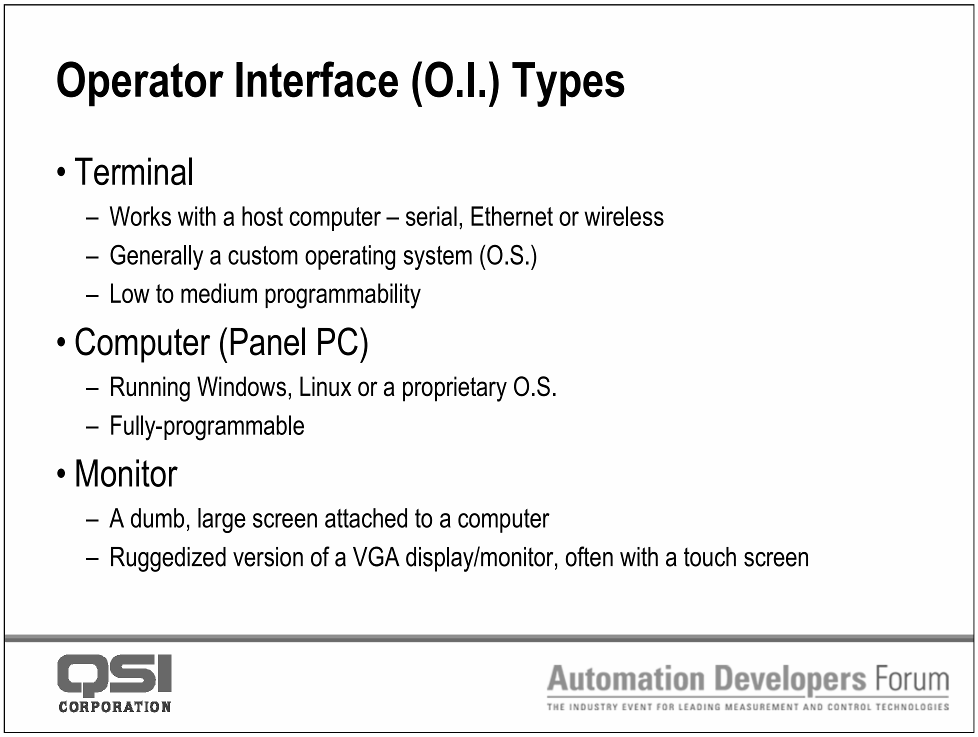
QSI Corporation designs and manufactures operator interface terminals for industrial, commercial and vehicle applications. We specialize in making both graphical and character terminals for applications where high reliability and excellent durability are a necessity. Customers have used our terminals for industrial and production machinery control panels, plant floor data and collection terminals, commercial public-access terminals and for numerous other applications.

“Operator Interface” is also called: HMI - Human Machine Interface, MMI - Man Machine Interface, Touch screen, Industrial PC



Venture Development Corporation (VDC), an industrial market analysis firm, defines the operator interface market in the following way in their study *North American Markets for Industrial Electronic Monitors and Operator:*

- Terminals - alphanumeric, graphic
- Monitors - alphanumeric, graphic
- PC Based Terminals
- Web Browser Terminals
- Portable OI Terminals

We have consolidated their categories as follows:

- Terminals - Alphanumeric, Graphic, Portable Terminals
- Monitors - Alphanumeric, Graphic
- Computer - PC Based Terminals, Web Browser Terminals

Market Segments

Consumer Grade (e.g., Dell, iPaq)

- High volume (10,000+), low-cost
- Not rugged, office environment
- Short lifetimes due to breakage or obsolesce
- Off-the-shelf only, no customizing

Consumers often try to compare our handheld terminals with PDAs (Palm, iPAQ) that they use every day. This is like comparing an Army vehicle to one that you can buy at your local car dealership. Army vehicles are designed for the environment in which they will operate and are more rugged.

Buying an industrial terminal is not like going to Best Buy and picking out a new desktop computer. You have to consider the environment (temperature, humidity, shock, vibration, etc.) in which the terminal will operate.

Market Segments

Drop Test Video

- Industrial Grade (e.g., QTERM-G70)
  - Low to moderate volume (100-5,000), moderate cost
  - 10+ year lifetimes
  - Some customizing (e.g., legends) is common
  - Industrial environments (sealed, wide temperature range, drop resistant
    - Video shows QTERM-G55 being dropped from 3.5 meters (12 feet) onto concrete
- Military Grade (e.g., EL displays)
  - Low-volume, high cost
  - Military environments & specifications (e.g., wind-blown sand, fungus)
  - Project lifetimes can be decades
  - Often entirely custom

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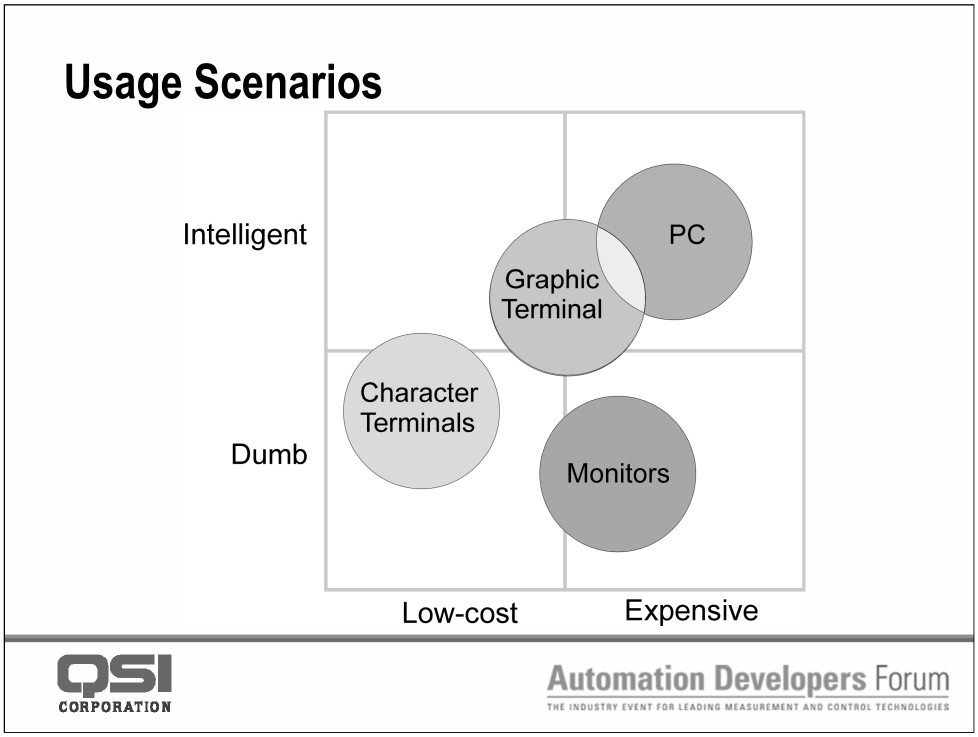
QSI focuses on the industrial and military markets due to our core competencies.

Industrial and military terminals have a 10+ year life cycle. We still have customers buying the first terminal(s) that we produced almost twenty years ago, although, we have had to redesign it twice due to electronic part obsolescence.

Many of our the OEM customers in the industrial market will customize portions of the terminal so that looks like it is part of their machinery. This can range from simple keypad graphics to completely new terminals built to the customers specifications.

The drop test video shows the QTERM-G55 handheld terminal being dropped from 3.5 meters (~ 12 feet) onto concrete.



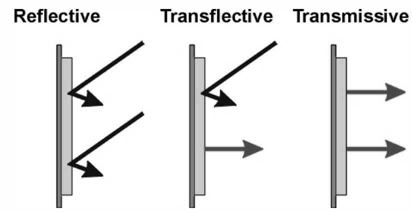
With a “dumb terminal”, each key stoke is sent to the host and then the host sends the information back to the terminal so that it can be displayed. There is no decision-making capability. These types of terminals work great when the controller you are using has all of the intelligence and when cost is the determining factor.

Because graphic terminals and PCs have many of the same hardware components, each has a processor and each can be programmed, the markets often overlap in features, application and price.

Many times a full PC is not needed when the intelligence is housed in another device like the FieldPoint.

In some of our installations with National Instruments customers, the terminal and the controller share the intelligence. The I/O is controlled by FieldPoint and the user interface by a terminal (QSI Qlarity-based terminals). The information that is sent over the serial and Ethernet cable is simply the data points to update on the display and the new set points for the controller.

Displays for O.I.



- LCD, VFD or EL
- Type
  - Technology – STN, DSTN, TFT, eTFT
  - Construction: reflective, transflective, transmissive
  - Environmental (temperature, shock/vibration)
  - Brightness (viewable in factory or outdoor)
  - Viewing angle
- Selection criteria
  - Budget
  - Environment (lighting conditions, temperature)

Definitions

- STN - Super Twist Nematic
- DSTN - Dual Super Twist Nematic
- TFT -Thin Film Transistor

Color TFT and Enhanced TFT are often used for direct sunlight applications because they typically have a brighter display backlight, contrast ratio (difference between the lightest and the darkest pixel) and a wider viewing angle.

Because a reflective display reflects the ambient light, they have poor visibility in low light situations but excellent visibility in high ambient light. Conversely, transmissive displays work best in low-light environments.

Wide temperature displays are available for harsh environments outside the standard temperature range (-10 to 60 °C)

Input Devices

- Keypad / Keyboard
- Touchscreens
- Pointing Devices – mouse, track ball, directional arrow keys
- Industry-specific – live-man, E-stop, jog dials, and so on.

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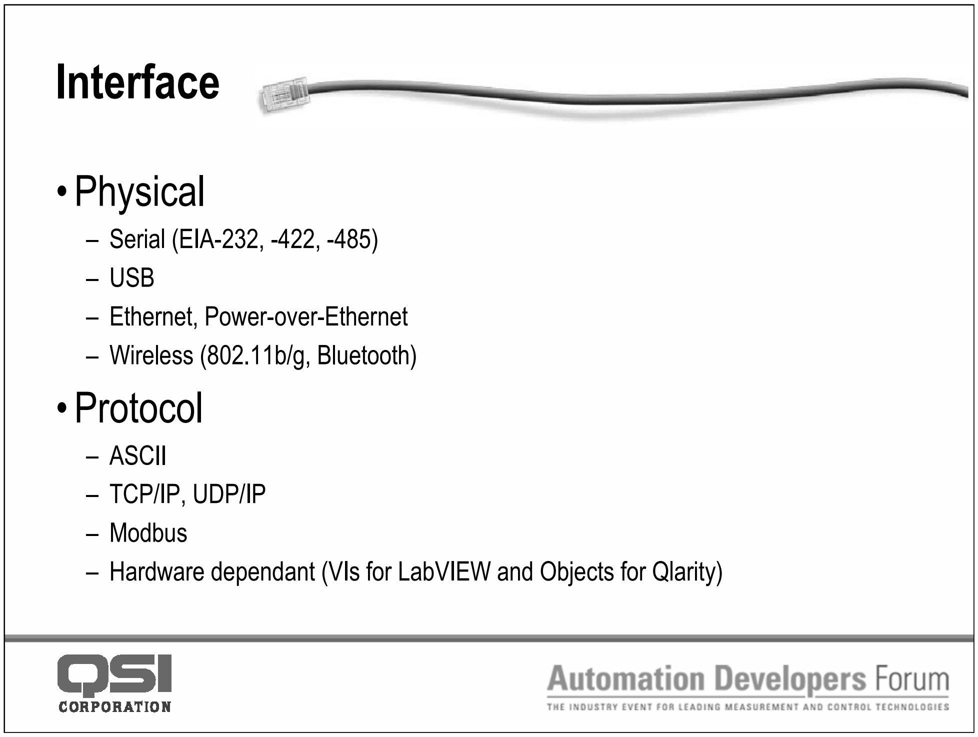
Input devices are used to interface with the terminal.

Keypads and touch screens are the most common, but in some industries input devices are required. In the robotics industry, a 3-position live man switch (off-on-off) is required for handheld terminals in case the user is pinned by the robot. The robot will only function when the switch is depressed half way.



Each communication physical interface has its own advantages and disadvantages. The distance from the host to the terminal helps determine the serial interface:

- EIA-232 - 15 meters
- EIA-422 - 1000 meters
- EIA-485 - 1000 meters multidrop

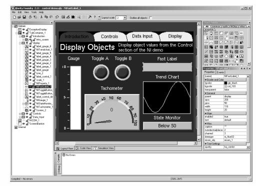
Terminals can be daisy chained (multidroped) together using an EIA-485 serial interface.

Power-over-Ethernet (802.3af) is a fairly new standard which allows power and data to communicate over the same CAT5 cable. This significantly reduces the cost of wiring.

`www.poweroverethernet.com`

Terminal O.S. and Software

- Terminal
  - – Low end – Generally not programmable
  - – High end – Programmable (for example, Qlarity)
- Computer (Panel PC)
  - – Windows, Linux
  - – Visual C++, Visual Basic, BASIC, C
- Monitors
  - – Generally not programmable



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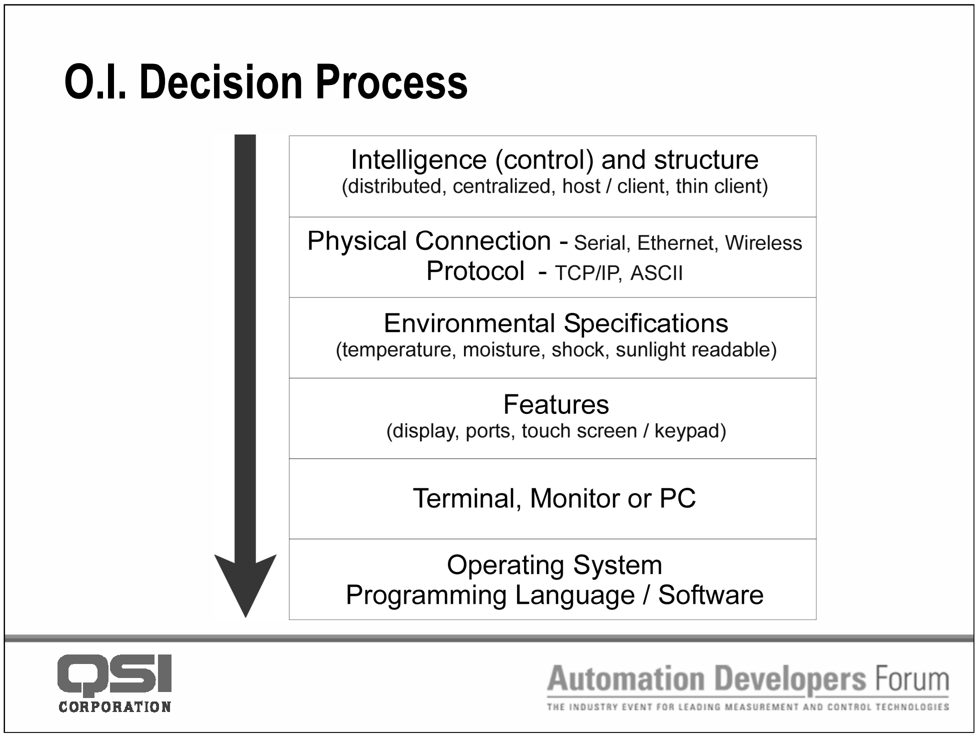
QSI's Qlarity™ software is an object-based programming language. It is like Visual Basic with objects, properties and methods. It is very simple to use, even a marketer like me can easily create applications. Go to www.qlarity.com

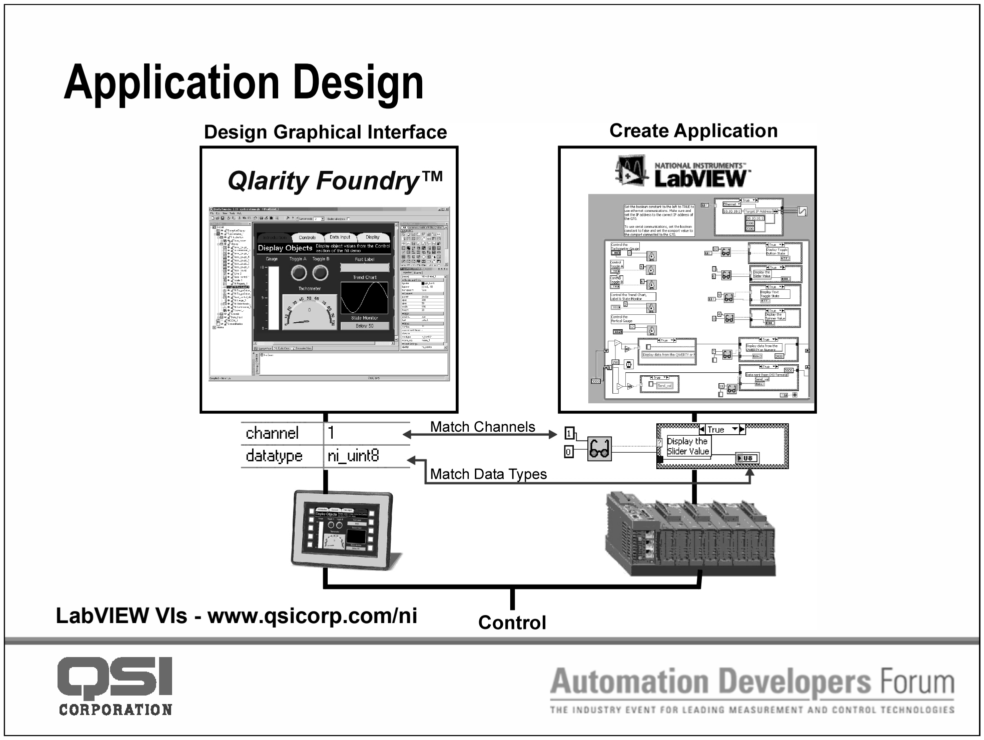
Qlarity Foundry™ is a Windows-based program used to design the screens and program the terminal. Available for free at www.qlarity.com

Computers (PC Based) use many of the same programming languages that are used to create applications for your desktop computers (Visual C++, Visual BASIC, etc.)



This slide shows the decision process that control system architects and machine builders use when choosing an operator interface terminal for their control system.

After answering the questions (top to bottom), the choice of a terminal, computer or a monitor is evident.



QSI terminals can be connected to many National Instrument control platforms that use LabVIEW (FieldPoint, Compact FieldPoint, Compact Vision, PXI, etc.) Simply match channels and data types in LabVIEW to the channels and data types in Qlarity Foundry. Communicate via Ethernet or serial.

For LabVIEW VIs and documentation visit: www.qsicorp.com/ni

Qlarity Foundry and documentation download (free) from `www.qsicorp.com`

Applications

- Example Applications
  - Autoliv ASP, Inc.
  - Stress Engineering Services
- National Instruments
  - Compact FieldPoint introduction – ISA 2003
  - Compact Vision – NMW 2004

cFieldPoint and G70 - Environmental Chamber

FieldPoint and G70 - Semiconductor Monitor

QTERM-G70 and Compact Vision Oil Sorter

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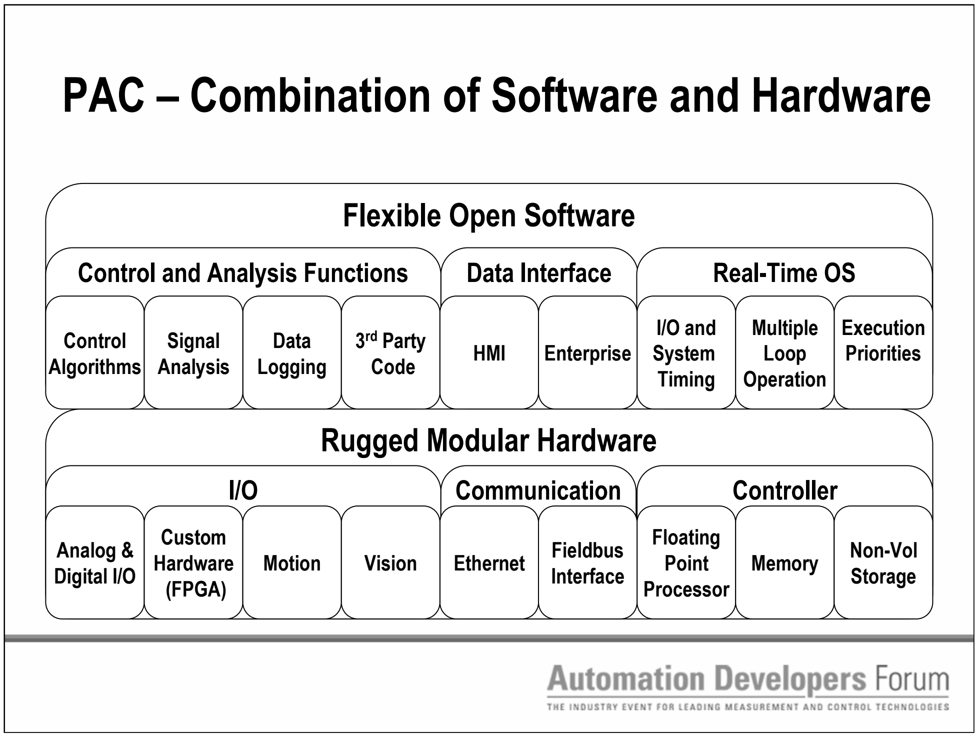

End of sessions.

ni.com/forum/presentations.htm