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Pervasive Computing and its Impact on Next Generation Military Systems

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ABSTRACT

The former CEO of IBM, Louis Gerstner, once defined Pervasive Computing (PvC) as "…a billion people interacting with a million e-businesses with a trillion intelligent devices interconnected…" This is the vision of pervasive computing; a web of interconnected and interoperable devices, information, services and people. Enabled by the advent of broadband wireless and wired networks, the increased power and commodification of information technology (IT) components, and the emergence of a new class of software called middleware, technology companies around the world are spending trillions of dollars a year to make this vision of PvC a reality.

This paper examines PvC, or, as it is sometime called ubiquitous computing, within the context of the greater IT-based "convergence" phenomenon. It also reveals how the technologies and solutions supporting this new compute paradigm will soon impact our next generation military systems.

INTRODUCTION

Not long ago, verticals such as Information Technology (IT), Telecommunications, and Consumer Electronics, were all separate and distinct industries. What made them distinct was the fact that the products they produced were, for the most part, based on different foundation technologies. For example, there was a time when a camera, once a completely mechanical device, had virtually nothing in common with a cell phone. They not only had very different functions, but they had no component parts, or even foundation technologies, in common.

A close look at today's marketplace, however, will reveal that cameras are rapidly becoming powerful digital image acquisition, processing and storage systems, with the ability to store and transfer images through the use of plug-in flash memory modules. Moreover, some of the newer digital cameras also have the ability to capture, replay and store video clips, thereby giving them video-recorder like functionality. Digital cameras are also being linked to cellular or broadband wireless (e.g., WI-FI – IEEE 802.11b) networks in record numbers. These connections allow customers to send their pictures to friends and family, via the Internet, or to their home computer hard drives, instantly.

Conversely, In Japan, cell phones containing embedded optics and digital image acquisition capabilities have recently become a huge hit. These devices enhance a customers interactive-voice collaborative experience by allowing them to take and send digital pictures while they speak to their friends or family anywhere in the world. With this device you can share your vacation visually, and in real time, with anyone, anywhere, and at anytime.

Recent product trends such as these clearly indicate that as IT technologies, the foundation of these new devices, grow in power, even as their size and unit costs plummet, more and more functionality will be compressed into familiar, and on occasion entirely new, form factors [1]. As this happens the lines between historically separate and distinct products will vanish and competition within and across vertical industries will soar. This phenomenon is known as convergence.

CONVERGENCE

Broadly defined as the blurring of the lines between historically separate and distinct products, market segments and vertical industries, convergence is fundamentally changing the business landscape, on a global scale. It is not only changing the way that businesses function (i.e., their internal and cross-enterprise business processes), it is also changing the very foundations upon which they rest: the products and services that they produce.

At the heart of convergence are the technologies, standards and solutions generated by the IT industry. Once confined to the operational, or business side of corporations, these technologies have recently become powerful enough to support the more stringent processing and cost requirements of the embedded and

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real-time systems space. Now that these solutions have crossed a critical price-per-performance ratio, they are quickly being assimilated into the next generation products of other vertical industries. The impact of this watershed event promises to be enormous.

A significant facet of the convergence phenomenon is a growing trend to implement functionality in software as opposed to special-purpose hardware. As this trend reaches fruition, functionality can be added to network-enabled devices via Internet downloads of client software, and, if necessary, insertion of plug-in hardware modules. Additional examples that further illustrates the convergence phenomenon are as follows:

- Cell phones that are also cameras, Personal Digital Assistants (PDAs), pagers, MP3 players, interactive game players, etc.
- Cable set-top boxes that are also Personal Video Recorders (PVRs), Digital Video Disk (DVD) players, MPEG file players, streaming audio players (i.e., radios), and streaming video players (i.e., on demand video), etc.
- Routers that have server-like functionality and deaggregated server/storage farms that have router-like functionality
- Desktop phones that have basic computer-like collaboration functionality with the ability to send and receive email, download web pages, provide instant messaging (IM) capability, etc.
- Tablet PCs that contain additional capabilities (e.g., a cell phone, Bluetooth enable headset, digital phone based on emerging WI-FI standards, eBook, MP3 player, DVD player, MPEG player, etc.

As these new devices become more powerful, the desire to integrate them into enterprise networks, enabling their remote centralized control, monitoring and configuration management, will become overwhelming. Business organizations will integrate them in support of their cross-enterprise e-Business initiatives, and consumer electronics companies will provide interoperability with their own networks and services in order to form a tighter bond with their customers (e.g., to extend the branding of their products and to provide additional downstream services and device support). This trend, or conversely the trend to extend the enterprise outward to include these devices, is creating a new paradigm in computing: pervasive computing.

PvC: THE FINAL FRONTIER

The history of computing has been a natural progression from a centralized monolithic compute model, initially featuring large independent enterprise mainframe systems, to a more diversified and deaggregated model that includes low cost CPU-based systems over a much larger range of form factors. On the networking side, our initial highly centralized environments have evolved through a client-server phase, with limited connectedness and interoperability, to a completely distributed and loosely coupled multi-tiered and peer-to-peer compute model that is based on global networking standards (i.e., Internet standards).

This natural progression to a more ubiquitous and heterogeneous compute environment is being driven by three important IT trends:

- The increased power, commodification and miniaturization of hardware IT components (e.g., processors, RAM, storage drives, flash memory, etc.)
- The emergence of broadband wired and wireless (e.g., cellular, WI-FI, & Bluetooth, etc.) networks
- The emergence of powerful enterprise software that simplifies the integration of cross-platform processes

Consequently, PvC can be described simply as the emergence and proliferation of a new and increasing diverse class of network-aware digital devices. These new devices, sometimes referred to as pervasive devices, can draw functionality equally well from both local and network-centric services [2,3,4,5].

PERVASIVE DEVICES

Pervasive devices include any fixed or mobile device that contains the rudimentary components of a computer (e.g., a microprocessor, RAM, hard drive, flash memory, etc.), and that can, at some point in its life cycle, be linked to and communicate with an enterprise network.

It is interesting to note at this point that desktop systems also fit the description of a pervasive device. This is not surprising if we remember that historically, existing compute tiers are always radically changed by the new emerging tier. For example, mainframes were radically changed by the emergence of midrange computer systems; and in turn, these midrange systems were radically changed by the emergence of desktop systems.

From an enterprise IT perspective, a pervasive device can also be defined as any device that is part of the enterprise, but exists outside of the edge or enterprise servers that support it. Some additional examples of pervasive devices, over a broader market range, are as follows: laptop computers, Tablet PCs, PDAs, cell phones, digital cameras, GPS position reporting systems, navigation or routing systems, MP3 players, voice recorders, scanners, printers, routers, set-top boxes, stereos, Personal Video Recorders (PVRs), TVs,

home security systems, appliances, vending machines, automobiles, controllers, remote sensors or sensing suites, etc.

Since the real power of PvC is enabled only when pervasive devices are connected to, and interoperable with, enterprise networks and systems, the goal of PvC is to provide the hardware and software necessary to make that possible. Once this has been accomplished the following critically important scenarios become possible:

- Original Device Manufacturers (ODMs), business organizations, or services aggregators can remotely monitor, update and manage the device, and local software service set automatically, over the entire life cycle of the device
- Customers can access a constantly evolving and increasingly powerful set of cross-enterprise services and data, on demand
- Multi-media cross-enterprise collaboration can efficiently occur between individuals using a host of different devices

CONNECTIVITY & INTEROPERABILITY ARE KEY

Spurred by the rapid rise of data-hungry mobile pervasive devices, WI-FI access points (e.g., in homes, hotels, coffee shops, airports, universities, and businesses) are being deployed at unprecedented rates. Conversely, given the aggressive plans of a number of consortia to build national WI-FI networks (e.g., by Cometa Networks, a joint venture between IBM, AT&T, Intel, etc.), an increasing number of manufacturers are designing WI-FI capabilities into their next generation products.

Although connectivity (e.g., mechanisms like WI-FI, cellular, satellite, etc.) between pervasive devices and enterprise systems are essential, mere connectivity (i.e., the ability to pass data from a device to an enterprise system, or vice versa) alone is not enough. This becomes obvious when one considers that every enterprise is, in essence, a mass of distributed data and processes. In order for pervasive devices to be truly useful, they must be able to securely and efficiently interoperate with any process or database within the extended enterprise (includes some of the processes and data owned and operated by their suppliers or customers). They must have access to potentially all enterprise services, whether that service is part of a well understood enterprise application, or an obscure piece of legacy code. This can only be accomplished through the use of a new category of software called middleware [6].

MIDDLEWARE: A FOUNDATION FOR PvC

Middleware refers to a collection of highly integrated and interoperable products, invariably provided by a single Independent Software Vendor (ISV), that is designed provide the foundation services required to build modern e-business applications, and to integrate them within existing corporate environments. The following are only some of the more common functional capabilities that are typically provided by today's powerful middleware suites:

- Security services and policy management
- Remote process monitoring and management
- Message queuing and transactions processing
- Application and Agent software abstraction, distribution and management
- Collaboration services
- Integration adaptors and network gateways

Much of the above functionality has been supporting the needs of enterprise IT organizations for years – running behind the scenes on enterprise servers as separate and distinct products. Only recently has much of it been reengineered, to include Internet technologies and standards, and repacked to support the cross-enterprise processing needs of today's global businesses. In addition to this lower-level functionality, the most powerful of today's middleware solutions (i.e., IBM's WebSphere solution) also provides the following:

- An Integrated Development Environment (IDE) supporting the efficient development of complex cross-enterprise applications
- A PvC Infrastructure supporting the seamless integration of pervasive devices and enterprise systems over a plethora of network protocols and technologies
- Enterprise Application Integration (EAI) tools, and adaptors enabling the integration of distributed processes across and between corporations

A FOUNDATION UPON WHICH TO BUILD

In the not too distant past, corporate IT organizations or ISVs had little choice but to build their applications on a particular platform (i.e., chip and operating system combination) and specifically for a particular market. For example, if the application was targeted for desktop system users, the developer would most likely use an IDE targeted for the most ubiquitous platform (e.g., WINTEL), and would put little resources into costly porting activities.

Today, however, with the advent of the Internet, and the need to deliver secure and scalable enterprise services via the network, developers have found that they can no longer afford to build such complex systems from the ground up. Rather, they are beginning to take advantage of the lower-level services and software abstraction layers that are being supplied by many ISVs. These capabilities, some of which are shown in Figure 1 below, allow developers to build complex cross-enterprise applications on the as easily as they build the monolithic, single platform applications of years past.

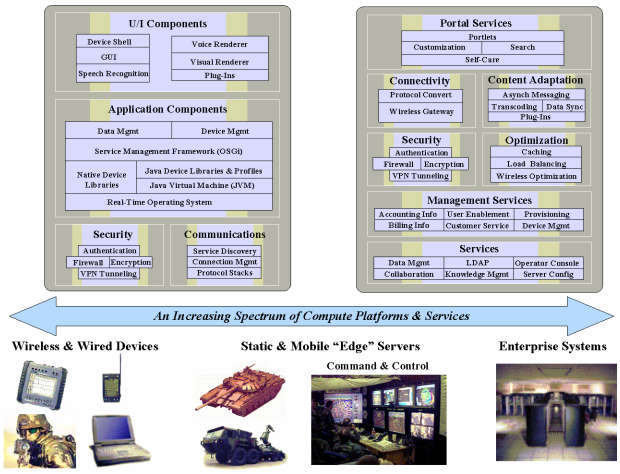

Figure 1: A Spectrum of Devices and Services

It should be noted that although many vendors have developed middleware products that support server-side enterprise application development, only IBM has developed a middleware stack (i.e., WebSphere Micro Environment, shown on the left in Figure 1) for pervasive devices. Moreover, only IBM has invested in the wireless gateway solutions required to provide wireless network and protocol abstraction. Using these wireless gateways, application developers using the IBM middleware need not concern themselves with lower-level networking issues of any kind – all of that is handled by the middleware itself.

Although all currently available middleware solutions offer powerful enterprise integration capabilities (i.e., all are providing EAI functionality), and IDE capabilities, only one, IBM's WebSphere, can be considered a true cross-enterprise information pipeline. This is true because only it currently provides a middleware software stack, for an ever-increasing number of pervasive devices, that enables these devices to become valuable members of the enterprise. That is, only they have extended their enterprise solutions and network services outward to include this last tier of computing: pervasive devices.

IBM's WebSphere Micro Environment software stack, composed of a number of loosely coupled software agents or components specifically designed to run in resource-challenged embedded systems, is designed to interoperate with its more capable server-side stack. For example, some more capable pervasive devices might have a need to organize and store data, locally. In cases such as this local embedded data base clients have been developed that not only provide a client-side foundation for the storage and retrieval of data, but also connect to enterprise data base systems for data replication and synchronization.

Once the pervasive device can be made interoperable with the network, it can be linked to a host of services and data bases – both inside the company and outside (e.g., with partners, suppliers, customers, etc.). The following services are examples of those that can be accessed remotely:

- Entertainment and Information (MP3, MPEG, text, image, gaming, audio streaming, etc.)
- Financial and Transaction Management
- Corporate (i.e., human resources, catalog, order entry, etc.)
- Collaboration (e.g., voice, text, image, etc.)
- Remote IT Asset Management (e.g., system monitoring, diagnostics, prognostics, update & configuration management, etc.)

ENTERPRISE SYSTEM MANAGEMENT

Although it is easy to manage one, a few tens, or even a few hundred pervasive devices using conventional means (i.e., an army of technicians deployed to access, troubleshoot, repair, and update these devices wherever they are located), it is quite another matter entirely to manage thousands, hundreds of thousands or perhaps even millions of devices without a high degree of automation and enterprise computer control. This is especially true given that pervasive devices are highly mobile and quite likely inaccessible to technicians for long periods of time. One only need consider the complexities and costs associated with maintaining desktop systems, the first and arguably most powerful of all pervasive devices, to see the difficulties we face in deploying and remotely maintaining pervasive devices.

Although remote system management is a critically important enterprise IT issue, it is only one of many. Other important issues, that also must be considered when building a 24X7 production-grade enterprise environment, are as follows:

- Scalability
- Reliably
- Availability
- Security

- Configuration Management (of data and software)

The IT industry, and especially those involved in creating enterprise IT hardware, software and networking systems, have dealt with these issues for some time. These companies understand the difficulties involved, and they are addressing them via the middleware layers that they are providing.

TELEMATICS: A SMALL SUBSET OF PvC

Rocked by explosive growth in the number of processors in contemporary vehicles, a customer base demanding increasingly more powerful and useful in-vehicle services (e.g., entertainment, diagnostics etc.), and a need to remain more connected to their products over their entire life cycle, the automotive industry is beginning to look at emerging PvC solutions with great interest. It is this interest that is giving renewed life to a fledgling industry – the Telematics industry.

Commercial Telematics solutions, although initially quite PC centric (e.g., the Clarion AutoPC) have evolved greatly in the last few years. Today, most solutions have embraced the Java platform (i.e., J2ME foundation software) which provides a common foundation and abstraction layer for the creation of vehicle-specific applications. In addition to the Java standards, automakers and their suppliers are also embracing other important standards, such as those developed by the Open Services Gateway Initiative (OSGi) [7,8]. These standards define how software can be downloaded and installed into remotely managed devices – such as next generation Telematics systems [9,10].

Although no one is quite certain how the Telematics hardware, software and services industries will evolve over time, we can make some predictions based on what has already happened in the consumer electronics markets (e.g., cell phone hardware and services market). For example, cell phone service companies (e.g., Nextel, Sprint, AT&T, etc.) in many cases will give away device hardware and software (i.e., the cell phone itself) in order to supply basic network services (i.e., access, digital services, etc.). Consequently, in a like manner, a company that wishes to supply diagnostic services to automakers might give away their on-board diagnostics hardware and software in order to sell back-end enterprise diagnostic services [11]. Such an approach could reduce the need for automaker investment – in this case, capital investment in subsystem development – and could allow companies to engage and switch vendors much more easily.

It is important to understand that the Telematics industry is not a separate and distinct industry based on totally independent IT and networking issues and solutions. On the contrary, it is an integral and inseparable part of the much larger PvC market. That is, Telematics solutions across the globe are being supported and driven by the same set of hardware and software solutions that support the greater PvC market. Consequently, the Army can soon expect to leverage the technologies and solutions developed in that market pace as well.

THE ARMY OF THE 21ST CENTURY

As the convergence phenomenon continues to commodify computer hardware and software components, including the middleware foundation layers, and as pervasive technologies and devices continue to proliferate across all vertical industries, the vision articulated by IBM's Louis Gerstner will quickly become a reality. This phenomenon will greatly impact our next generation systems.

For some time now the Army has been under increased pressure to develop and field next generation systems that have unprecedented levels of interoperability, and that are cheaper and more reliable and maintainable then their predecessors. These systems must not only be seamless linked and interoperable on an operational level (i.e., C4ISR), they must also be interoperable with enterprise systems (e.g., LMP, ePDM, etc.). Cost effective connectivity of this kind can not be accomplished after the fact; it must be an intrinsic part of the system developed. Consequently, in the future, the Army must consider enterprise architecture and integration issues before it selects additional enterprise applications (e.g., SAP, Windchill, etc.), not afterward.

THE IMPACT OF CONVERGENCE ON THE DOD

As the convergence phenomenon continues to radically alter commercial vertical industries the world over, it will also fundamentally change the greater military industrial base, and the DoD as well. The first phase of this impact is starting to be felt now, given that military-industrial-base players are beginning to use commercial middleware in some of their next generation applications (e.g., GCSS–A and GCSS–AF, FCS, etc.). This is good news and bad. It is good in the sense that these companies are leveraging commercial solutions that provide a plethora of services that will grow and become more robust with time. However, it is bad in the sense that in addition to the plethora of competitive enterprise applications instantiated across the Army, there will soon be a plethora of middleware solutions as well. As a result, our enterprise integration problems will grow considerably more complex, and the cost of interoperability will skyrocket.

Some will undoubtedly say that the advent and use of Web services will solve all of our interoperability problems. This is not the case. Web services will clearly help, especially at the application layer, but the level of granularity of these services will be quite course for the foreseeable future. Stated another way, it will be

some time before Web services penetrate the middleware layer of enterprise computing and even longer before we see any true commodification at that level.

Simply stated, convergence is a disruptive phenomenon that will take a disorganized enterprise with stove-piped organizations, and will make it even more disorganized by allowing any organization to build and deploy competitive enterprise systems. Consequently, without significant top-down control of enterprise IT directions, and a common middleware foundation upon which to build, competition between DoD IT organizations will escalate to a higher level. The result will be a financial and IT-organizational nightmare.

A COMMON ARMY MIDDLEWARE FOUNDATION

Everyone would agree that virtually all of our applications need the services of an operating system (OS) of some kind, but few of us would be foolhardy enough to develop one ourselves as part of our application development effort. The reasoning behind this conclusion is obvious: firstly, there are a plethora of powerful and stable operating systems in the commercial sector, systems that took years and billions of dollars to build and debug; and secondly, these software solutions continue to become more powerful every year, with absolutely no support from the government. Moreover, thanks to the open source movement, some of them are even free!

For these same reasons it is unwise to try to recreate the newly emerging middleware layer, the next major step in the abstraction of software, as well. Middleware can be thought of as a software layer that occupies the space between the OS and the application, on both enterprise and embedded systems. Its purpose is to provide the services (e.g., communications, security, messaging, transaction, etc.), gateways, adaptors, and APIs necessary to enable the efficient and cost effective:

- Development of next generation net-centric applications
- Acquisition, processing, storage and dissemination of cross-enterprise information
- Integration of existing legacy applications and data

If one stops for a moment to consider precisely what our C4ISR systems are actually trying to do (e.g., acquire, access, process, store, and disseminate information within a secure network environment) the use of middleware within the Army enterprise takes on a deeper meaning. Continuing this line of reasoning, it should be obvious to most that a single robust enterprise middleware, and PvC solution could provide seamless support and information flow within and between all of the following functional areas:

- C4ISR
- Procurement
- Logistics
- Readiness
- Maintenance
- Supply
- IDE (Integrated Digital Environments)

For these reasons, and many more, it is imperative that the Army move to a common middleware foundation such as the one outlined in Figure 2 below. A foundation such as this would ensure interoperability throughout Army enterprise systems and would provide all developers a common set of enterprise services upon which to build our next generation applications. Only in this way can costs be dramatically reduced even while the capability of our next generation systems are greatly enhanced.

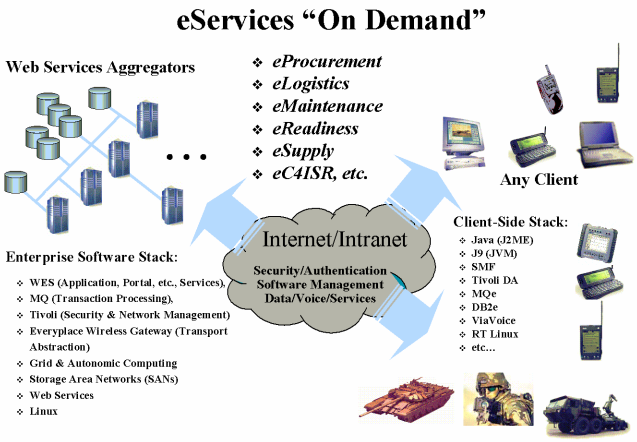

Figure 2: The IBM Middleware Software Stack

ARMY PERVASIVE DEVICES

PvC is essentially about integrating, as much as possible, digital CPU-based systems with back-end enterprise servers, and about the seamless movement of information and processes throughout the enterprise. Consequently, any electronic device used by the military, including all commercial systems from the desktop on down, could potentially be considered a pervasive device. Some examples of pervasive devices in the Army could potentially include the following: warfighter-based systems (e.g., wearable computer systems); all ground and airborne vehicles (include robotic or unmanned systems) and sensor systems; C4ISR systems; and all weapon systems – from the most brilliant down to the most intellectually challenged.

Once these devices contain an OSGi-compliant platform, services (i.e., applications designed to perform specific functions, such as a particular diagnostics check) can be

dynamically downloaded, unbundled, registered, instantiated and then executed as required. Using this approach system monitoring or diagnostics agents, for example, can be continuously updated over the life of the system. When the system requires an update, the new software can be automatically deployed, via wired and wireless networks, to an entire series of devices (i.e., all those systems in inventory that are considered to be of the same type – with regard to the system update in question) automatically, and wherever the devices may reside – instantly.

Even though all pervasive devices are different, there will undoubtedly be a subset of common services that can be accessible remotely. The following list of platform-centric services could potentially be accessed through common interfaces:

- Current Position and Operating State Information
- Readiness State Information
- User Profiles
- Platform Diagnostics
- Central Computer System Diagnostics
- Prognostics Analysis Data Dump
- Operational Data Base or Log Dump

Keep in mind that the actual code, or implementation, behind these interfaces would be different for different devices, but the syntactical interfaces could be the same. Such a common set of APIs would undoubtedly help reduce C4ISR and some enterprise BPM (Business Processes Management) system development costs.

THE e-BUSINESS OF WAR FIGHTING

The diverse set of business, technical and operational activities that support our ability to create superior weapons systems, to optimally wage war, or to efficiently execute a police action designed to monitor and control the occupants of a particular geographic region, is, at its most fundamental level, a business. And in the deadly business of war, our ability to create, transfer, process and react to information faster and with greater fidelity is much more important than any commercial business matter. The only difference between the "business of defense" and the "business of commerce," is that in the commercial space failure is measured by lost market share or lost opportunity, in the defense space, failure is measure by the loss of life.

Our failure then, to reduce our costs while providing an ever expanding set of services to DoD organizations and ultimately the warfighter, will directly map to fewer assets (both human and materiel) in the field, and the possibility of greater loss of life. It's just that simple.

The Army, like any business in today's Internet-centric IT environment, must leverage the commercial e-business applications and middleware that will support the functionality required by our next generation applications. Only in this way can we provide the expanded functionality required at a price we can realistically afford to pay. Moreover, we must stop our current propensity to build overlapping and stove-pipe applications and move to a common foundation that will insure the creation and deployment of secure, reliable and scalable information services. Services that are truly enterprise systems and that are accessible to all who need them.

CONCLUSION

Driven by the convergence phenomenon, PvC is the next major step in network and enterprise computing, and a final step in a natural progression that has lead us from centralized monolithic mainframe computers to a more ubiquitous and fully distributed compute paradigm. Enabled by the increased power and commodification of IT components, the emergence and deployment of broadband wired and wireless networking solutions, and increasingly powerful middleware services, convergence will soon fundamentally change the way that we live, work and play in the 21st century.

Supported by literally trillions of dollars of investment by IT, telecommunications, consumer electronics, and manufacturing, companies across the globe, PvC will fundamentally changing virtually every vertical industry in the world economy. Moreover, given the progress made to date, and the momentum that continues to build in the commercial sector, it is easy to see that these emerging trends and solutions will have a profound impact on next generation Army systems (e.g., FCS).

Given that a major portion of FCS deals with the efficient access, processing, and movement of unprecedented amounts of information, and on an extended enterprise scale, commercial middleware must be used to ensure that these systems are cost effective, maintainable and supportable. That is, FCS must be build on a common commercial middleware foundation. Only in this way can we build the powerful services for tomorrow in a way that is not only cost effective, but also sustainable.

In an effort to demonstrate the affordability and power of PvC solutions, and the need for a single middleware environment, the NAC, working closely with the TACOM and greater Army Logistics communities, is supporting the development and demonstrations of a PvC- and middleware-based eLogistics solution. The enterprise system will make maximum use of IBM's PvC infrastructure and the WebSphere family of technologies.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

API:	Application Programmers Interface
BPM:	Business Process Management
CPU:	Central Processing Unit
C4ISR:	Command, Control, Computers, Communications, Intelligence, Surveillance, and Reconnaissance
DVD:	Digital Video Disk
EAI	Enterprise Application Integration
FCS:	Future Combat System
GCSS-A:	Ground Combat System Support – Army
GCSS-AF:	Ground Combat System Support – Air Force
GPS:	Global Positioning System
IDE*:	Integrated Digital Environment
IDE*:	Integrated Development Environment
IP:	Internet Protocol
ISV:	Independent Software Vendor
IT:	Information Technology
J2:	Java 2 Platform Specifications
J2EE:	Java 2 Enterprise Edition Specifications
J2ME:	Java 2 Micro Edition Specifications
J2SE:	Java 2 Standard Edition Specifications
LMP:	Logistics Modernization Program
MP3:	MPEG, Audio Layer 3
MPEG:	Motion Picture Experts Group
ODM:	Original Device Manufacturer
OEM:	Original Equipment Manufacturer
OS:	Operating System
OSGi:	Open Services Gateway Initiative
PC:	Personal Computer
PDM:	Product Data Management
PvC:	Pervasive Computing
PVR:	Personal Video Recorder
TCP:	Transmission Control Protocol
WAN:	Wide Area Network; Wireless Area Network
WI-FI:	IEEE Standard 802.11b

*: Integrated Development Environment is a commercial industry term referring to the class of visual software development tools and APIs that aid in the development of software applications (e.g., Borland's J-Builder, IBM's WebSphere Studio, etc.). Integrated Data Environment is an Army specific term that refers to Army e-Business processes, data and applications.