Abstract

This paper presents a technical overview of the Microsoft® Windows NT® Embedded 4.0 and Microsoft® Windows® CE 2.12 operating systems. Together, these two operating systems provide unprecedented scalability for embedded systems development. This paper highlights the features and capabilities of both Windows NT Embedded 4.0 and Windows CE 2.12, so that developers can select the best operating system to address their design criteria.
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Introduction

Windows NT Embedded 4.0, which is available today, is the newest addition to the Windows family of operating systems. Windows NT Embedded 4.0 provides developers with a fast way to build rich functionality into their embedded applications and devices supporting 32-bit processors.

This document highlights the features and capabilities of both Windows NT Embedded 4.0 and Windows CE 2.12, which together, allow system designers to target systems ranging from low-cost, battery-powered consumer electronics to high-end server appliances.

Your design criteria for your embedded or dedicated application will determine the optimum Windows operating system selection.

Windows NT Embedded 4.0 Overview

Windows NT Embedded 4.0 is Windows NT 4.0 with embedded enabling features and tools. To ensure hardware and software compatibility, Windows NT Embedded 4.0 uses unmodified Windows NT 4.0 binaries.

Any application, device driver, or service that runs on Windows NT 4.0 will run on Windows NT Embedded 4.0—porting or recompiling is not required.

Any hardware that supports Windows NT 4.0 automatically supports Windows NT Embedded 4.0. It’s that simple.

With Windows NT Embedded 4.0, developers use off-the-shelf hardware and software to reduce their development costs and accelerate the time to market. Windows NT Embedded 4.0 supports all three Windows NT system roles — Workstation, Server, and Primary Domain Controller (PDC) — for products ranging from headless controllers to server appliances.

Windows NT Embedded 4.0 includes the following embedded enabling features and tools:

- Flash memory support for diskless operation.
- Flexible page file support, including support for “No page file.”
- CD-ROM boot support (El Torito).
- Windows NT filter driver, which makes read-only storage appear to be read-write—also useful for stateless reboot operation.
- Headless operation for systems without display, keyboard, and mouse.
- Remote management tools including a remote command shell and a remote GUI desktop.
- Enhanced error support for auto-handling and logging of error dialogs.
- Target Designer—a GUI tool for selecting the Windows NT Embedded 4.0 components your system needs.
- Component Designer—a GUI tool for making your application, or any software your application may need, a Windows NT Embedded 4.0 component.

Using Target Designer, developers can configure Windows NT Embedded 4.0 as a stand-alone system requiring only 8 megabytes (MB) of persistent storage and 12 MB of RAM.
Evaluating Windows NT Embedded and Windows CE

Developers or system integrators need to consider several factors when evaluating an embedded operating system. This document compares Windows NT Embedded 4.0 and Windows CE 2.12 in each of the following areas:

- Hardware requirements
- Application and device driver availability
- Application programming interfaces (APIs)
- Reliability
- Performance
- Networking and interoperability
- Security
- Manageability
- Expandability
- Scalability
- User interface
- Power management

Table 1. Feature checklist for Windows NT Embedded 4.0 and Windows CE 2.12

<table>
<thead>
<tr>
<th>Feature</th>
<th>Windows NT Embedded 4.0</th>
<th>Windows CE 2.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported processors</td>
<td>Intel x86 compatible.</td>
<td>Multiple processor families.</td>
</tr>
<tr>
<td>Hardware design</td>
<td>PC system design recommended.</td>
<td>High degree of adaptability.</td>
</tr>
<tr>
<td>Memory and storage</td>
<td>12 MB to 32 MB RAM; 8 MB to 48 MB storage; FATFS, NTFS, and CDFS.</td>
<td>50 KB to 2 MB RAM; 256 KB to 4 MB storage; FATFS, ROM and RAM-based file systems; XIP supported.</td>
</tr>
<tr>
<td>Programming interfaces</td>
<td>Full support for Win32 APIs, OLE/COM, DCOM, NT RPC, TAPI 2.1, ATL, MFC, Winsock, WinInet, CryptoAPI, SSPI, ADO, and others.</td>
<td>A subset of Win32 APIs, OLE/COM, TAPI 1.4 outbound, ATL, MFC, Winsock, WinInet, CryptoAPI, SSPI, and ADO. DCOM and RPC not supported.</td>
</tr>
<tr>
<td>Applications and device drivers</td>
<td>Wide availability; automatically supports applications and drivers that run on Windows NT 4.0.</td>
<td>Limited availability when compared to Windows NT Embedded 4.0.</td>
</tr>
<tr>
<td>Performance</td>
<td>Optimized to maximize speed.</td>
<td>Optimized to minimize memory usage.</td>
</tr>
<tr>
<td>Networking and interoperability</td>
<td>TCP/IP, PPP, SLIP, HTTP, FTP, ICMP, PPTP, SNMP, IPX/SPX, AppleTalk, NetBEUI, CSLIP, and SNA protocols supported.</td>
<td>TCP/IP, PPP, SLIP, HTTP, FTP, ICMP, and IrDA protocols supported. Ethernet network adapters supported.</td>
</tr>
<tr>
<td>Secure communications</td>
<td>Both operating systems support secure communications and authentication using SSL 2.0, SSL 3.0, PCT 1.0, Crypto APIs, PAP, CHAP, MSCHAP, and NTLM.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 continued on next page
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<table>
<thead>
<tr>
<th>Feature</th>
<th>Windows NT Embedded 4.0</th>
<th>Windows CE 2.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manageability</td>
<td>SNMP, WMI, MMC, Telnet server, modem console, serial console, GUI remote administration, and performance monitoring.</td>
<td>Windows CE RAPI.</td>
</tr>
<tr>
<td>Expandability</td>
<td>Most standard PC bus architectures supported except for USB and AGP.</td>
<td>Most standard PC bus architectures supported except for 1394, SCSI, and AGP.</td>
</tr>
<tr>
<td>Scalability</td>
<td>Excellent upward scalability; symmetrical multiprocessing support (SMP) for up to 4 processors; no limit on number of processes; 2 GB of virtual memory per process; flexible page file support.</td>
<td>Excellent downward scalability; Windows CE uses component libraries to reduce the memory footprint of the OS for devices with limited memory resources.</td>
</tr>
<tr>
<td>User interface</td>
<td>Optimized for higher display resolutions.</td>
<td>Optimized for lower display resolutions.</td>
</tr>
<tr>
<td>Power management</td>
<td>N/A.</td>
<td>Aggressive power management for battery-powered consumer devices.</td>
</tr>
<tr>
<td>Windows services</td>
<td>RAS, RRAS, DHCP, DNS, WINS, HTTP, FTP, and Telnet.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>

This document is organized around each of the areas listed above. Some of these areas have been subdivided for organizational purposes.

- **Supported Processors**

  Windows NT Embedded 4.0 runs on Intel x86 and compatible processors. High performance processors (90 megahertz [MHz] or higher) are recommended. Several low-cost, highly integrated, embedded processors meeting these requirements are available today.

  Windows CE 2.12 runs on five different processor cores: ARM, MIPS, PPC, SuperH, and x86. With Windows CE, developers can select from processors providing low power consumption to processors providing high levels of performance. Typically, low power consumption and high performance are mutually exclusive because processors achieve low power consumption—in part—by running at low clock rates.

- **Hardware Design**

  Windows NT Embedded 4.0 runs on standard PC hardware, allowing developers to realize fast time-to-market. Non-standard hardware is also supported using a custom hardware abstraction layer (HAL) for added flexibility. A HAL Development Kit is available from Microsoft for this purpose. Developing a HAL requires a significant development effort using highly technical software developers. Therefore, it is expected that most OEMs will use the standard HAL that ships with Windows NT Embedded 4.0. The standard Windows NT loader and HAL require that the platform include a PC-compatible BIOS.

  Windows CE 2.12 is designed to be very flexible for hardware design. In addition to being able to run on a standard PC hardware design, Windows CE 2.12 can also run on custom hardware designs. Windows CE achieves this flexibility by requiring that the OEM implement a thin layer of code in the kernel called the OEM Adaptation Layer (OAL). Implementing the Windows CE OAL requires a small amount of development effort compared to that required for the Windows NT HAL. The OEM is also
responsible for implementing the Windows CE bootloader. Because the OEM implements both the 
OAL and the bootloader, a PC-compatible BIOS is not required. This allows Windows CE to achieve 
faster boot times than Windows NT Embedded.

- **Storage Considerations and Componentization**

Windows NT Embedded 4.0 and Windows CE 2.12 can both be configured using a process called 
*componentization*.

Componentization enables the developer or systems integrator to control the size—or *footprint*—of the 
operating system by selecting only the operating system components required for an embedded or 
dedicated application. For example, if COM support is not required, the developer can choose not to 
include the COM component.

Because memory footprint is highly dependent on componentization, it is important to specify the 
operating system configuration when specifying memory requirements. For example, Windows CE can 
be minimally configured to include only the kernel and some rudimentary file system support (this 
configuration is called *Minkern*). The Minkern configuration can fit into 512 KB of storage and requires 
only 50 KB of RAM to run. This is very small compared to a fully configured Windows NT Embedded 
system functioning as a server appliance, which requires 40 MB of storage and 32 MB of RAM.

Without accounting for componentization, one might incorrectly conclude that Windows NT Embedded 
requires 160 times more storage and 820 times more RAM than Windows CE. For this reason, it is 
important to understand how componentization works for Windows NT Embedded 4.0 and Windows 
CE 2.12, which are built using discrete components and modules. As will be discussed, the module 
applies only to Windows CE.

**The Windows NT Embedded 4.0 Componentization Process Overview**

For Windows NT Embedded 4.0, each component consists of an unmodified Windows NT 4.0 binary 
or set of binaries accompanied by dependency information, registry settings, and related files. *Target 
Designer* is a tool you can use for selecting the Windows NT Embedded 4.0 components your 
operating system needs, and configuring them. Target Designer is also used to build the operating 
system image.

Windows NT Embedded 4.0 provides a tool called Component Designer to build custom components. 
Because the standard components are based on unmodified Windows NT 4.0 binaries, these binaries 
ultimately control the granularity of the componentization process. It is not possible, for example, to rip 
functionality out of a Windows NT 4.0 subsystem in an effort to reduce code size. This would require 
modifying the binary associated with the subsystem.

The benefit of this is that all Windows NT Embedded configurations—even the smallest configuration 
requiring only 8 MB of storage and 12 MB of RAM—support all of the base system services available 
in Windows NT 4.0. This includes full support for the Win32 application programming interface (API) 
(see Figure 1). As a result, 100 percent compatibility for software and hardware is achieved between 
Windows NT Embedded 4.0 and Windows NT 4.0.
The Windows CE 2.12 Componentization Overview

The Windows CE 2.12 componentization process is substantially more granular than the process used for Windows NT Embedded 4.0. This is because, unlike Windows NT Embedded, the base system services the operating system provides can be configured.

Each executable (.exe) and Dynamic Link Library (.dll) used in building an operating system image is called a module. Some modules are monolithic, in that they cannot be further componentized. Other modules can be componentized using component libraries.

These component libraries are simply called components. A componentized module is built by incrementally linking a specified set of components to produce an .exe or .dll.

Figure 2 shows how the module filesys.exe is built using the fsysram, fsreg, fsheap, fsmain, fspass, and fsdbase components. If password and database support are not required, the developer can simply choose to exclude the fspass and fsdbase components. In other words, multiple versions of filesys.exe can exist under Windows CE 2.12, each with varying capabilities.

The module Shell.exe, on the other hand, is monolithic and cannot be componentized.

```
...
...
set CE_MODULES=coredll filesys nk toolhelp shell
set FILESYS_COMPONENTS=fsysram fsreg fsheap fsmain fsdbase
...
...
```

Figure 2. Cesysgen.bat entry used by Windows CE to configure modules and components

Because the Windows CE componentization model is very granular, embedded systems with very small memory footprints can be targeted. Only the base functionally required to support the embedded or dedicated application is built into the operating system. As a result, storage and memory are not used for code that never gets executed.
From the application developer’s point of view, this means that the API depends on the operating system configuration. A full Windows CE configuration supports a subset of the Win32 API. As the number of components decreases, so does the number of Win32 APIs (see Figure 1). Windows CE effectively gives up some cross-platform compatibility to achieve good downward scalability.

Together with Windows NT Embedded 4.0, Windows CE 2.12 make it possible for Microsoft Windows to scale from systems with highly constrained memory requirements to servers with excess memory capacity, all with varying degrees of functionality (see Figure 1).

**Storage and RAM Requirements**

The memory requirements for Windows NT Embedded 4.0 depend on the operating system configuration. For a minimally configured OS, the memory requirements are about 12 MB RAM and 8 MB of storage (using NTFS with compression). A more fully configured system supporting networking requires about 16 MB of RAM and 12 MB of storage (see Table 2).

Table 2. Windows NT Embedded 4.0 memory footprints for a stand-alone device, a router, and a server.

<table>
<thead>
<tr>
<th>Application</th>
<th>Features</th>
<th>RAM</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-alone device</td>
<td>Minimal OS + Command Console</td>
<td>12 MB</td>
<td>8 MB</td>
</tr>
<tr>
<td>LAN router</td>
<td>Minimal OS + Network</td>
<td>16 MB</td>
<td>12 MB</td>
</tr>
<tr>
<td>Server appliance</td>
<td>Minimal OS + Network + IIS + PDC + DHCP + WMI</td>
<td>32 MB</td>
<td>40 MB</td>
</tr>
</tbody>
</table>

The memory requirements for Windows CE 2.12 also depend on the operating system. Since Windows CE supports multiple processor families, memory requirements also depend on processor selection because CISC processors enable better code densities than RISC processors do (see Table 3).

Table 3. Windows CE 2.12 memory footprints for Minkern and Maxall.

<table>
<thead>
<tr>
<th>Application</th>
<th>Features</th>
<th>RAM</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minkern (x86)</td>
<td>Kernel + File System</td>
<td>50 KB</td>
<td>512 KB</td>
</tr>
<tr>
<td>Maxall (x86)</td>
<td>Full OS configuration</td>
<td>1.5 MB</td>
<td>9.5 MB</td>
</tr>
<tr>
<td>Maxall (MIPS)</td>
<td>Full OS configuration</td>
<td>1.5 MB</td>
<td>12.5 MB</td>
</tr>
</tbody>
</table>

When designing an embedded system, it is important to understand the RAM requirements for the operating system and applications. Depending on the application, the RAM consumed by the operating system may only be a small percentage of the total RAM required by the system.

Two applications that fall into the category are Microsoft Internet Explorer and Microsoft Terminal Server Client. Versions of these applications are available for both Windows NT 4.0 and Windows CE 2.12. Depending on the document being viewed, Internet Explorer can consume from 5 MB to 25 MB or more of memory, per instance. Microsoft Terminal Server Client requires 7 MB per instance for the bitmap cache it maintains. These applications can make the amount of RAM consumed by the operating system—whether Windows NT Embedded or Windows CE—appear small, especially when running multiple instances.
Figure 3 shows how the difference in the percentage of RAM used by Windows NT Embedded and Windows CE decrease as the number of application instances increases from 0 to 4. This is based on an application that consumes 8 MB of RAM per instance.

![Graph of RAM usage vs. application instances]

Figure 3. Depending on the application, operating system RAM requirements can have a varying impact on the overall RAM requirements of the system.

The logic shown in Figure 3 can also be applied to storage. For example, the Japanese font Mspgoth.ttf is over 4 MB in size. Incredibly, this is bigger than many Windows CE operating system configurations. For a system built using this font, the percentage of storage required for a system running Windows NT Embedded over a similar system running Windows CE decreases substantially.

- **Device Drivers**

  Windows NT Embedded 4.0 automatically supports all hardware supported by Windows NT 4.0. For supported hardware, there is no need to develop device drivers because they are already available and are distributed with the hardware. For example, developers wanting to incorporate the latest 2-D or 3-D graphics hardware into their design can simply obtain the latest driver from the hardware vendor.

  For a list of supported hardware, visit the Microsoft Windows Hardware Compatibility List (HCL) Web site at [http://www.microsoft.com/hcl](http://www.microsoft.com/hcl).

  For OEMs who must develop their own drivers, Windows NT Embedded 4.0 uses the Windows NT Driver Model, which is the basis for the Windows Driver Model (WDM) used by Windows 2000 and Windows 98.

  The flexibility that Windows CE provides in CPU selection and platform selection also means that OEMs typically end up doing most, if not all, of the device driver development. This is because a standard hardware platform does not exist for which hardware vendors can write device drivers. The exception is PC Card drivers. These are well-supported by hardware vendors as a result of the mobile products built using Windows CE, and because OEMs develop the PC Card socket driver to expose a
common set of interfaces for developing PC Card drivers. Windows CE has its own driver model, which is not compatible with other driver models.

Application Availability

Windows NT Embedded 4.0 is binary-compatible with Windows NT 4.0, and therefore automatically supports any software developed for Windows NT 4.0. This includes applications, device drivers, and system services. Using Windows NT Embedded, developers retain the full functionality of the applications and no porting or recompiling is required. For example, the following fully featured applications will run unmodified on Windows NT Embedded 4.0:

- Microsoft Internet Explorer 5
- Microsoft Windows Media Technologies
- Microsoft Terminal Server Client
- Wealth of third-party applications

Unlike Windows NT Embedded 4.0, Windows CE 2.12 cannot run software developed for PCs running other Microsoft Windows operating systems. This holds true even for Windows CE devices having x86 processors. Most of the third-party software available for Windows CE today has been developed for the Handheld PC and the Palm-sized PC. Other platforms may be able to use existing software if the operating system configuration and CPU selection meet the requirements of the software. For example, an application developed for the Handheld PC will not run on a platform running a minimal operating system configuration (Minkern).

Application Programming Interfaces (APIs)

For Windows NT Embedded, componentization has no effect on application compatibility because the full Win32 API is available for all operating system configurations. Developers write to the API, not to the platform. Any application written using the Win32 API exclusively will run on Windows NT Embedded 4.0. If other APIs for services such as the Component Object Model (COM), Document Object Model (DOM), and Open Database Connectivity (ODBC) are used, the developer must include the required component in the operating system configuration.

For Windows CE, a subset of the Win32 API is supported. Additionally, the percentage of Win32 APIs supported depends on the level of componentization. Developers also need to consider the level of support each API provides, not just the percentage of APIs supported. As an example, Windows CE supports the CreateWindowEx API, but the following extended window styles are not supported:

- WS_EX_ACCEPTFILES
- WS_EX_LEFT
- WS_EX_LTRREADING
- WS_EX_NOPARENTNOTIFY
- WS_EX_RIGHT
- WS_EX_RTLREADING
- WS_EX_LEFTSCROLLBAR
- WS_EX_MDICHILD
- WS_EX_PALETTEWINDOW
- WS_EX_RIGHTSCROLLBAR
- WS_EX_TRANSPARENT
- WS_EX_APPWINDOW

When developing Windows CE applications, developers need to understand how the platform they are developing for has been componentized. For example, an application developed for a handheld PC will not run on a product running the Windows CE Minkern configuration. The Windows CE Platform Builder includes a tool for creating Platform SDKs (software development kits) to make the application development process easier.
Reliability

Windows NT Embedded 4.0 is designed to actively protect itself and applications from errors and external damage—whether accidental or deliberate—and to respond predictably to software and hardware errors. For example, every application (including legacy 16-bit applications) can be configured to use its own private memory space. This means that if one application fails, it does not impact the other applications or the operating system. Core system components (executive) run separately from the many subsystems, so backdoor entry points cannot compromise security or damage the system in any way. In an embedded environment where the OEM controls the software and hardware, much greater reliability can be achieved over Windows NT 4.0, because poorly written applications and device drivers can be installed on a PC.

Windows CE 2.12 also provides excellent reliability, but architectural differences with Windows NT Embedded preclude an equivalent level of robustness. Windows NT Embedded 4.0 is based on a mature code base and uses unmodified Windows NT 4.0 binaries, which have been deployed to millions of users throughout the world. Windows NT Embedded 4.0 is currently based on Windows NT 4.0, Service Pack 5.

Performance

It is outside the scope of this document to provide a head-to-head comparison of Windows NT Embedded 4.0 versus Windows CE 2.12 performance because such measurement is specific to each application. For designs where performance is critical, it is recommended that developers benchmark the performance of a target application running on both operating systems and a common hardware platform. The Windows CE Platform Builder provides sample code for Windows CE 2.12 running on a PC (CEPC). This section briefly discusses points to consider when evaluating performance.

Windows NT Embedded 4.0 is optimized for performance, not code size. This includes both the software algorithms used in the operating system code and the optimization flags used to compile the code. Additionally, because Windows NT 4.0 supports only a limited number of processor families, developers take full advantage of processor-specific instructions to improve performance.

Windows NT Embedded supports 32-thread priority levels based on process priority, thread priority, and 32 interrupt request (IRQ) levels. For an embedded or dedicated application, the developer can tune the application for the system without having to consider the requirements of a general-purpose platform like the PC. To help developers analyze and tune performance, Windows NT Embedded has a powerful performance-monitoring infrastructure.

Finally, developers can take advantage of the symmetric multiprocessing (SMP) support available in Windows NT Embedded to improve system performance and reduce interrupt latencies where the need for performance outweighs the desire for low cost.

One way that Windows CE achieves its low memory footprint is to optimize for it. This does not mean that Windows CE cannot perform well in applications requiring high levels of performance. Windows CE 2.12 provides 8 priority levels for threads.

Note: Windows CE 2.12 does not support SMP.

Networking and Interoperability

Windows NT Embedded 4.0 and Windows CE 2.12 both offer a wide range of networking options for communicating with other computers on a local area network (LAN), a wide area network (WAN), and
the Internet. Both operating systems support TCP/IP, PPP, and SLIP for local and dial-up networking. Further, they both support the protocols HTTP, FTP, and ICMP for Internet and intranet communications. A server message block (SMB) redirector is supported for access to remote file systems.

Windows NT 4.0 Embedded provides the following added features for enhanced connectivity options:

- Point-to-Point Tunneling Protocol (PPTP) for Virtual Private Networks (VPNs).
- Dial-up networking, multi-link channel aggregation for combining two or more dial-up lines for faster data transfer speeds.
- Full network driver interface specification (NDIS) 4.0 support.
- IPX/SPX, NetBEUI, CSLIP, and AppleTalk protocols for legacy environments and interoperability in mixed environments.
- ISDN, Token-Ring, Ringnode, LocalTalk, X.25, Frame Relay, EIA-232, and FDDI network adapters for interoperability in mixed environments and for WAN access.
- Telephony API (TAPI) 2.1 for client and server
- Broad range of services including HTTP, FTP, RAS, RRAS, WINS, DNS, and DHCP.

Windows CE 2.12 also provides IrDA protocol and IrSock extension to the Windows sockets (Winsock) interface for infrared communications. This feature enhances connectivity options.

Security

Windows NT Embedded 4.0 is a secure operating system. Depending on the application, varying levels of security are required in embedded devices. It is important not to confuse operating system security with network protocols used for secure communications and application-enforced security. Both Windows NT Embedded and Windows CE support SSL 2.0, SSL 3.0, Private Communications Technology (PCT) 1.0, and Crypto APIs. This support is independent of base operating system security.

Windows NT has earned a C2 security rating by the National Computer Security Center (NCSC). Windows NT earns this rating by implementing the following features:

- Secure logon facility
- Discretionary access control
- Auditing
- Object reuse protection

A secure logon facility requires users to enter a unique identifier and password before they are granted access to the computer. Once logged on to the computer, Windows NT uses discretionary access control to specify which users have access to shareable operating system resources. Each resource or object has an access control list (ACL) associated with it, which can be modified by authorized users. The ACL controls who can access the object. Auditing lets authorized users record failed or successful attempts by users to access operating system resources. Object reuse protection prevents users from seeing data that another user has deleted or from accessing memory that another user previously used and released.

Windows NT also meets two of the requirements for B-level security: Trusted Path functionality and Trusted Facility Management functionality. Trusted Path functionality prevents Trojan horse programs from intercepting a user’s name and password as the user logs on. Windows NT implements a Secure
Attention Sequence (SAS) to enable this feature. Trusted Facility Management supports separate account roles for administrative functions. For example, Windows NT provides separate accounts for administration, accounts charged with backing up the computer, and standard users.

Windows NT also supports multiple forms of logon including custom GINA, MSGINA, and auto-logon. By default, Windows NT uses the Microsoft Graphical Identification and Authentication (MSGINA) component to obtain user credentials using a keyboard. A custom GINA can be developed to support other forms of authentication, for example, authentication using a smart card, a voiceprint, a fingerprint or palmprint, or a retinal scan. Auto-logon bypasses the need to enter credentials by automatically logging the user on with a predefined set of credentials.

Windows CE does not support any of the security features required for C2 security compliance. Simple password support is provided to prevent unauthorized access to the system, but this support is not intended to protect sensitive data or prevent unauthorized system access using a hard attack.

- **Manageability**

  Windows NT Embedded 4.0 provides several services, protocols, and tools aimed at device manageability. Depending on the application, varying levels of manageability are required in embedded devices. Simple Network Management Protocol (SNMP) and Windows Management Instrumentation (WMI) are both supported by Windows NT Embedded 4.0 and are based on industry-accepted standards for remote computer management. WMI uses the Distributed Management Task Force’s (DMTF’s) Common Information Model (CIM) as the basis for exposing and interacting with management data provided by the hardware platform, device drivers, and applications.

  Using CIM, WMI enables applications, platforms, and consoles to perform the following types of management tasks:
  - Monitoring and reconciliation of hardware or software faults and alerts
  - Preemptive maintenance
  - Upgrade management and version control
  - Capacity planning and performance management
  - Enhanced security and asset management
  - Operations management
  - Automated management

  Other Windows NT Embedded 4.0 management features include system policies and user profiles, Telnet service, remote shell service, remote GUI desktop, and Microsoft Management Console (MMC).

  Windows CE does not support any of the manageability features described for Windows NT Embedded 4.0. Windows CE does support one-way remote API (RAPI), which can be used to provide some level of remote management support.

- **Scalability**

  Together, Windows NT Embedded 4.0 and Windows CE 2.12 make Microsoft Windows-based operating systems a highly scalable platform that can run on devices raging from low-cost, memory-constrained consumer devices to high-end, performance-driven server appliances. This section briefly discusses the scalability characteristics of Windows NT Embedded 4.0 and Windows CE 2.12.

  Windows NT Embedded 4.0 has excellent upward scalability. The number of processes that Windows NT Embedded supports is limited only by the amount of available memory. Additionally, each process
running on Windows NT Embedded has access to 2 GB of virtual memory. For virtually unlimited memory capacity, Windows NT Embedded also supports up to 16 page files for paging the contents of memory to disk when physical memory becomes overly committed. Finally, Windows NT Embedded 4.0 supports SMP for systems requiring additional CPU capacity or improved interrupt latencies.

Windows NT 4.0 Embedded has limited ability to scale down because of how it is componentized. For example, it is not possible to run Windows NT Embedded on a hardware platform with only 2 MB of storage and 1 MB of RAM. On the other hand, this is more than enough memory to support running Windows CE.

Windows CE 2.12 scales down much better than Windows NT Embedded 4.0. This is because Windows CE is built using component libraries that allow the developer to control what services the operating system provides. As a result, Windows CE can easily run on platforms with as little as 512 KB of storage and 50 KB of RAM, and still provide plenty of room for applications.

The ability for Windows CE to scale up, however, is limited. This is because Windows CE is limited to 32 processes, although there is no limit on the number of threads supported. Additionally, each process is limited to 32 MB of virtual memory. Additional memory can be accessed using memory-mapped files, but this slows performance and places an additional burden on the application developer.

Because Windows CE only supports paging in, page files are not supported. Windows CE does not support multiprocessing. For these reasons, Windows NT Embedded offers better upward scalability than Windows CE.

- **User Interface**

Windows NT 4.0 is designed for use on PC workstations and servers. Workstations typically have display resolutions ranging from 1024 x 768 to 1600 x 1200. Because of this, the Windows NT Embedded 4.0 user interface is optimized for use on display resolutions of 640 x 480 and higher.

Windows CE, on the other hand, was originally designed for use on handheld devices with small displays. As a result, Windows CE is optimized for display resolutions running at 640 x 480 and lower. Screen real estate is a precious resource on a handheld device, so several user interface optimizations are present in Windows CE to support devices with small displays. For example, the Windows CE message box places the OK button in the title bar instead of the client area. The client area is used only to display the message text. This is a deviation from the standard Windows-based user interface but helps save screen real estate. Again to save screen real estate and code size, Windows CE does not support 3-D buttons and controls. The default show window behavior used when creating windows is maximized. Windows CE supports sizing windows, but the sizing controls are not as varied as for Windows NT Embedded 4.0. Thus, Windows CE applications typically run maximized or full screen.

- **Power Management**

Windows NT Embedded 4.0 offers no built-in power management support and is not recommended for battery-powered devices.

Windows CE, on the other hand, was designed for use on battery-powered devices and therefore has aggressive power management features. Windows CE power management functions include instantaneous powered off and then turned on instantly if the device has non-volatile (battery-backed) RAM. Power management functions in the OAL enable the OEM to turn off
unnecessary hardware components in conjunction with the operating system’s state transitions from full-on, to standby, and ultimately suspend. The processor must support these states to take advantage of the power management that Windows CE provides.

**Conclusion**
This document has shown how Windows NT Embedded 4.0 and Windows CE 2.12, together, offer unprecedented scalability for Microsoft Windows running on embedded systems. By focusing on some of the key differences between these two operating systems, developers can select the one that best addresses their design criteria.