



System performance in common business multitasking security-related scenarios

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to compare the performance in common business multitasking scenarios of Intel® vPro™ Technology platforms with that of two other earlier platforms. We ran a range of typical enterprise multitasking scenarios that included security tasks, such as virus and spyware scans, on four different Intel processor/platform combinations:

- **Intel Pentium® 4 630 Processor-based PC** (3.0 GHz) supporting Hyper-Threading Technology (HT) on the Intel D945GTP desktop board (with the Intel i945G Express chipset)
- **Intel Pentium D 930 Processor-based PC** (3.0GHz Dual-Core processor) on the Intel D945GTP desktop board (with the Intel i945G Express chipset)
- **Intel vPro Technology-based PC with Intel Core™ 2 Duo Processor E6300** (1.86GHz Dual-Core) on the Intel DQ965WC desktop board (with the Intel Q965 Express chipset)
- **Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700** (2.66GHz Dual-Core) on the Intel DQ965WC desktop board (with the Intel Q965 Express chipset)

KEY FINDINGS

- Intel vPro Technology-based desktop platforms yielded significant performance advantages for users simultaneously running productivity and security tasks, and these platforms were the fastest in all tests.
- The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 finished our tasks on average 2.20 times faster than the Intel Pentium 4 630 Processor-based PC and 1.64 times faster than the Intel Pentium D 930 Processor-based PC.
- The vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 finished our tasks on average 1.74 times faster than the Intel Pentium 4 630 Processor-based PC and 1.30 times faster than the Intel Pentium D 930 Processor-based PC.
- These performance improvements translate into multi-second time savings that would be noticeable to users.

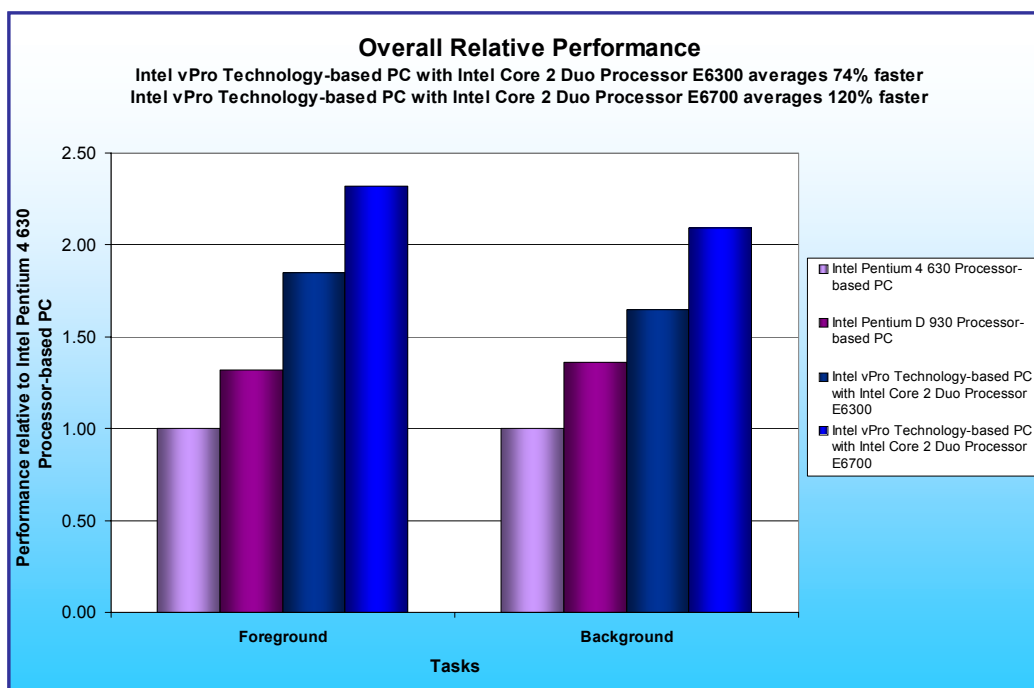


Figure 1: Overall average performance, relative to the Intel Pentium 4 processor 630-based system, on all foreground and background tasks on all four systems. Average performance is the geometric mean of the normalized times for each task. Higher numbers are better.

We selected four scenarios and created scripts that allowed us to automate our testing. Though each scenario involved a security function, we varied the number, type, and computational intensity of the tasks to reflect a range of user experiences.

As Figure 1 shows, both Intel vPro Technology-based PCs significantly outperformed the Intel Pentium 4 630 Processor-based PC and the Intel Pentium D 930 Processor-based PC on all our

tasks. Compared to the Intel Pentium 4 630 Processor-based PC, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 was from 1.33 times to 3.75 times faster on different applications and tasks and averaged 2.20 times faster across all the tasks. (In all comparisons in which we cite the average of task times, we use the geometric mean of the normalized times for each task.) Compared to that same Pentium 4 630 Processor-based PC, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 was from 1.20 to 2.87 times faster on our tests and averaged over 1.74 times faster.

Compared to the Intel Pentium D 930 Processor-based PC, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 was from 1.18 to 2.45 times faster on different applications and tasks and averaged 1.64 times faster. Compared to that same system, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 ranged from 1.03 to 1.82 times faster and averaged 1.30 times faster.

These performance improvements translate into multi-second time savings noticeable to users. The shortest task takes 19.7 seconds on the Intel Pentium 4 630 Processor-based PC but only 10.6 seconds on the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700. The longest task takes 128 seconds on the Intel Pentium 4 630 Processor-based PC but only 54.5 seconds on the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700.

So that we could make the four test systems as similar as reasonably possible while varying the processors and motherboards, we built the systems rather than purchasing them from vendors. Intel specified the general system types and supplied the processors and motherboards. We purchased such common components as RAM, hard disks, and optical drives. Each test system had the following basic components (see Appendix A for detailed configuration information):

- 1GB of the fastest RAM its motherboard supported
- 300GB SATA hard disk with an 8MB buffer
- DVD-RW optical drive
- Microsoft Windows XP Professional (Service Pack 2)

We used the following common enterprise security applications, which we list in alphabetical order:

- McAfee VirusScan Enterprise 8.0i
- Microsoft Windows Defender (Beta 2)
- Norton Internet Security 2006

We used the following common enterprise business applications, which we list in alphabetical order:

- Adobe Acrobat 7.0 Standard Version 7.0.8
- Microsoft Office Access 2003 (Service Pack 2)
- Microsoft Office Excel 2003 (Service Pack 2)
- Microsoft Office Outlook 2003 (Service Pack 2)
- Microsoft Office PowerPoint 2003 (Service Pack 2)
- Microsoft Office Word 2003 (Service Pack 2)
- Microsoft Windows Explorer in Microsoft Windows XP Professional (Service Pack 2)

The application scenarios we tested included such common functions as:

- Scanning for viruses
- Scanning for spyware
- Recalculating Excel spreadsheets
- Converting documents to .PDF format
- Opening files

To make it easier to test our scenarios repeatedly and accurately, we automated the hand-timed application functions using scripts we wrote using IBM Rational Visual Test 6.5. In our analyses we used the times from our tests of those scripts.

In the following sections we look more closely at our test application scenarios (Application scenarios), examine the results of our tests (Test results and analysis), and give detailed information about how we actually performed the tests (Test methodology). In the appendices, we present the configurations of the test systems, explain how to manually execute the application functions in our scenarios, and discuss some potential issues in the development of test scripts.

Application scenarios

To assess platform performance on typical user activities involving security applications, we developed a set of multitasking scenarios that employ leading productivity and security applications. We focused primarily on processor-intensive operations that often force users to wait, because users are likely to appreciate performance improvements on such operations.

Each scenario contains one to three timed tasks. Tasks are a combination of background computing tasks and foreground applications. Background computing tasks are typically activities that run unattended while users are performing other functions. In our scenarios, the security functions are backgrounds, as are other lengthy tasks on which users would be unlikely to wait. A foreground task is one whose completion users will typically await before moving to the next task. Some of our scenarios include multiple background tasks. In our results graphs and tables, we label each task as either FG (foreground) or BG (background).

Three of our scenarios include virus scanning as a security task; two use Norton Internet Security, while the third employs McAfee VirusScan Enterprise. Another scenario scans for spyware with Windows Defender (Beta 2).

Preparing market data for analysis

In the first scenario, Randi, the head of a district sales department, is working on tasks related to preparing market data for analysis. Randi maintains competitive sales data in a 12.1MB Access database. The marketing team wants some of that data in spreadsheet format because they want to analyze the data using Excel. Randi is about to start the export when the regularly scheduled weekly McAfee virus scan starts. As the scan runs, she opens Access and starts a macro to create and export the reports to XLS format. She waits for the Access status bar to show the Export is complete before she continues with her work.

We timed:

- the McAfee virus scan (BG) from the start of the scan until the scan status window shows the scan is complete
- the Access export (FG) from the time Randi starts Access until the status bar shows Access has completed the export

Preparing materials for a management presentation

In our second scenario, Floyd, an analyst in an engineering department, is preparing materials for a management presentation. Floyd has incorporated the final edits from his manager into a seven-page, 1.73MB Microsoft Word document and is now ready to convert the document to Adobe Acrobat PDF format and post it on the intranet site. He also needs to create charts in Excel for the next report on his plate. He is about to start these two tasks when a virus scan the IT department has scheduled starts. While the scan is running, Floyd opens the document in Word and starts the conversion by selecting Adobe PDF/Convert to Adobe PDF from the Word menu. He selects Save on the Save Adobe PDF File As dialog without changing the default file name. With the virus scan and Word open tasks still underway, he opens the 2.56MB Excel spreadsheet and waits for Excel to update the calculations in that file.

We timed:

- the virus scan (BG) from the time the scan displays its status window until that window closes at the end of the scan
- the PDF conversion task (BG) from the time Floyd presses Save until Adobe Acrobat displays the PDF
- the Excel task (FG) from when Floyd starts the open until the spreadsheet opens and recalculates all of its formulas

Collaborating on a marketing plan

In the third scenario, Lennie, a new member of the team, is working on a marketing plan. A few days ago, Lennie created a 10-page first draft in XML format. Her manager then edited the plan, added additional sections, and sent the new 42-page version back to Lennie. Lennie wants to compare her version and the rewrite using the Microsoft Word Compare and Merge Document option. She is about to start the task when a Windows Defender anti-spyware scan that the IT department has scheduled starts. As the scan runs, she opens the 10-page document in Word, selects Tools/Compare and Merge documents... from the Word menu, chooses the 42-page version of the document in the Compare and Merge Documents dialog, and presses the Merge button to start the compare and merge process. When the merged document displays she can review the changes.

We timed:

- the anti-spyware scan (BG) from the time the scan starts until the scan window closes at the end of the scan
- the compare and merge process (FG) from the moment that Lennie presses Merge to start the process until the merge process progress bar on the status bar ends and the status bar displays the page counter for the merged document showing that it has 42 pages

Locating information in response to an email inquiry

In the final scenario, Aiden, a project manager is locating information he needs to respond to an email inquiry. He has received an email requesting information that he needs to pull from three files: a 42-page Word document in XML format, a 7.44MB Excel spreadsheet, and a 36-slide PowerPoint presentation. The three files are in a compressed (zipped) folder. He leaves Outlook open, launches Windows Explorer, and locates the folder that holds the files. He selects all three files at once and presses Enter to open all of them. He waits for them to open, then continues with his work.

We timed how long the system takes to open all three compressed files; the combined open is the FG task. Opening the files triggers an automatic virus scan of each of them by Norton Internet Security, so the time those scans require is part of the file-open time.

For more details on how we executed and measured these scenarios, our specific test functions, and the files the scenarios use, see Appendix B.

Test results and analysis

In this section we examine the results of each of our tests. Figure 2 shows the times, in seconds, that each test system needed to complete each scenario. The times we show for each platform for each scenario are from the median run of the five test runs of that scenario on that platform. (We defined the median run as the one with the median sum of the times of its timed tasks.)

Tests	Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
Preparing market data for analysis				
Microsoft Access export XLS reports (FG)	72.3	41.2	25.2	19.3
McAfee virus scan (BG)	128	93.9	76.8	54.5
Preparing a management presentation				
Microsoft Excel open and recalc spreadsheet (FG)	25.7	20.8	11.4	8.5
Microsoft Word DOC to Adobe PDF conversion (BG)	70	43.9	39.2	30.4
Norton Internet Security virus scan (BG)	95.4	68.1	46.7	35.9
Collaborating on a marketing plan				
Microsoft Word XML file comparison (FG)	19.7	16.4	13.1	10.6
Windows Defender scan (BG)	41.4	36.8	34.3	31.2
Locating information in response to an email inquiry				
Windows Explorer open (and scan for viruses) files from compressed folder (FG)	26.6	22.8	22.1	19.4

Figure 2: Median test times, in seconds, for all four test systems on all four scenarios. Lower numbers are better.

In the following sub-sections we explore these results in more detail. To make comparisons easier, we always show results normalized to those of the slowest system in the group, the Intel Pentium 4 630 Processor-based PC. To compute those normalized results, we divided each system's time by the time it took the system with the Intel Pentium 4 630 Processor-based PC to perform the same task. The result for the Intel Pentium 4 630 Processor-based PC is thus always 1.00, because it's the comparison basis. Results higher than 1.00 indicate how much faster a system is than that system. Because of the normalization, higher result numbers are better. For example, a result of 1.80 would mean the system in question was 80 percent faster than the Intel Pentium 4 630 Processor-based PC.

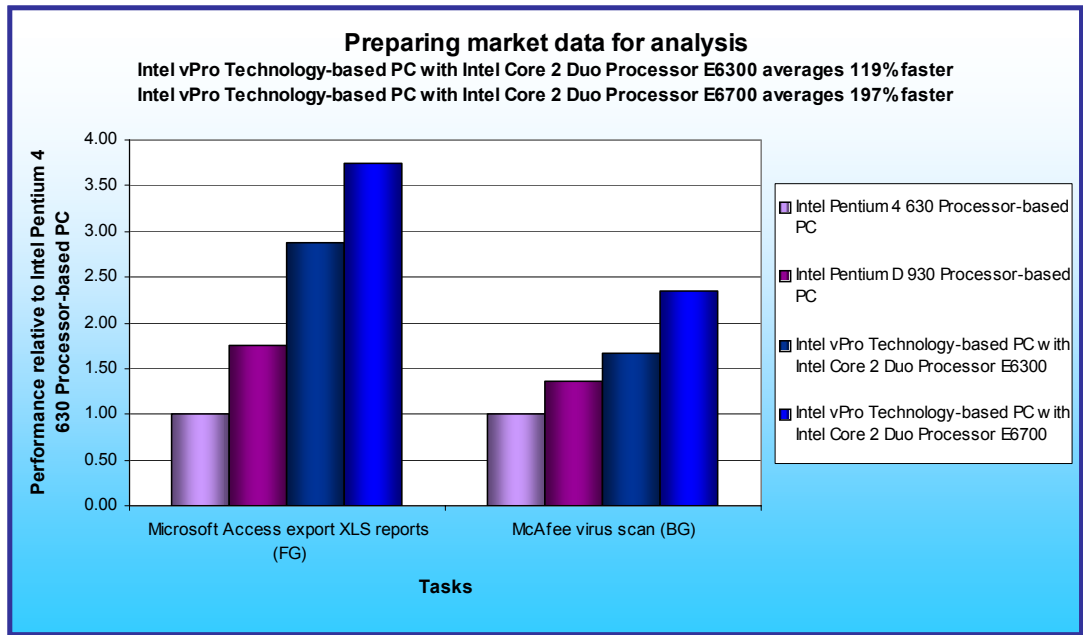
As part of our discussion of each scenario, we also show processor utilization curves that we captured with Windows XP's Perfmon utility. In all the processor utilization charts, we use a blue line for foreground tasks and a red line for background tasks. We use these charts to illustrate how demanding each task would be if we ran it alone. In multitasking scenarios, the system faces each of these same demands, but all at the same time, because the tasks run simultaneously. When each of the simultaneous tasks has minimal processor requirements, keeping them all executing smoothly in parallel may not be difficult. When one or more of the tasks has significant processor demands, meeting those demands at the same time can be extremely difficult for a processor without the added execution ability of the Intel Core 2 Duo Processor. We captured each task's processor-demand curve on the Intel Pentium 4 630 Processor-based PC with HT Technology disabled. We chose to capture this data on this system with HT Technology disabled to make it easy to see the processor demands; had we captured the processor utilization with HT Technology enabled or on one of the Dual-Core based systems, Perfmon would have capped each logical core at 50 percent utilization. (When we ran the scenarios on Intel Pentium 4 630 Processor-based PC, we of course took full advantage of the power of that system and had HT Technology enabled.)

Preparing market data for analysis

This scenario exports reports from a Microsoft Access database using a macro (the foreground task) while McAfee VirusScan Enterprise scans an 86.8MB folder (the background task). As figures 3 and 4 show, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 is 3.75 times faster than the Intel Pentium 4 630 Processor-based PC on the foreground task and 2.35 times faster on the background task.

The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 also shows large performance improvements, coming in at as well as 2.87 times faster on the foreground task than the Intel Pentium 4 630 Processor-based PC and 1.67 times faster on the background task.

Figure 3 also demonstrates that both Intel vPro Technology-based PCs delivered better performance than the Intel Pentium D 930 Processor-based PC: the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 averaged 1.92 times faster on the two tasks, and the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 averaged 1.41 times faster.



As Figure 4 shows, these differences represent significant improvements in the time it takes to perform each task. Compared to the Intel Pentium 4 630 Processor-based PC, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 decreased the elapsed time from 128 to 54.5 seconds on the background task and from 72.3 to 19.3 seconds on the foreground task. The Intel vPro

Figure 3: Performance, relative to the Intel Pentium 4 630 Processor-based PC, of each of the four systems preparing market data for analysis. Larger numbers represent better performance.

Technology-based PC with the Intel Core 2 Duo Processor E6300 also showed significant gains over the Intel Pentium 4 630 Processor-based PC, completing background task 51.2 seconds faster and the foreground task 47.1 seconds faster.

PERFORMANCE RESULTS (seconds)				TASKS	COMPARATIVE RATING			
Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700		Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
72.3	41.2	25.2	19.3	Microsoft Access export XLS reports (FG)	1.00	1.75	2.87	3.75
128.0	93.9	76.8	54.5	McAfee virus scan (BG)	1.00	1.36	1.67	2.35

Figure 4: Results for each of the four systems preparing market data for analysis. Lower performance results are better. Higher comparative ratings are better.

The processor utilization curves in figures 5 and 6 help identify a key reason for these time savings. As they show, each of this scenario's tasks has very high processor demands and so benefits heavily from the vPro architecture and the Core 2 Duo processors.

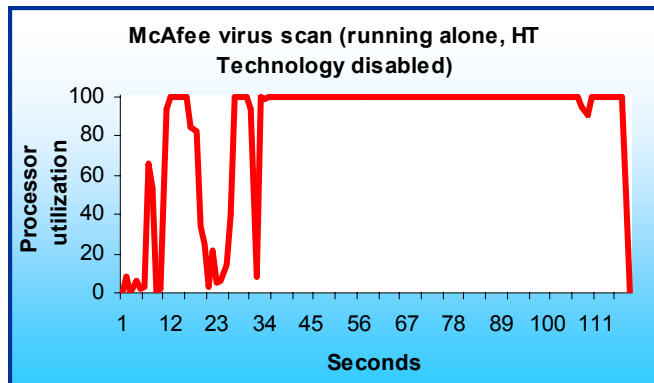


Figure 5: System processor utilization of the McAfee virus scan background task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

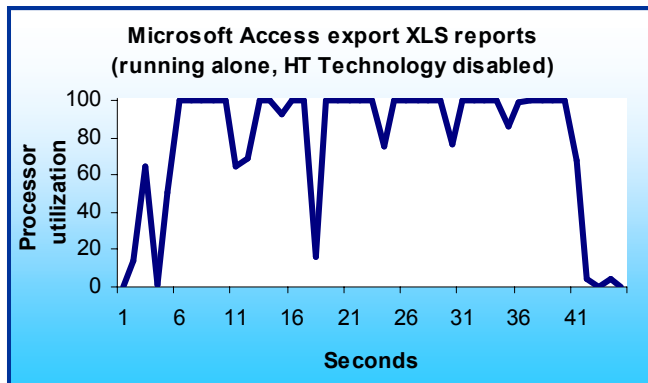


Figure 6: System processor utilization of the Microsoft Access export foreground task running alone on the Intel Pentium 4 630 processor-based PC with HT technology disabled.

Preparing a management presentation

In this scenario, the security task, the Norton Internet Security 2006 virus scan (the first background task), runs simultaneously with two other tasks: one that converts a Microsoft Word document to Adobe PDF format (the second background task), and one that opens and automatically recalculates an Excel spreadsheet (the foreground task).

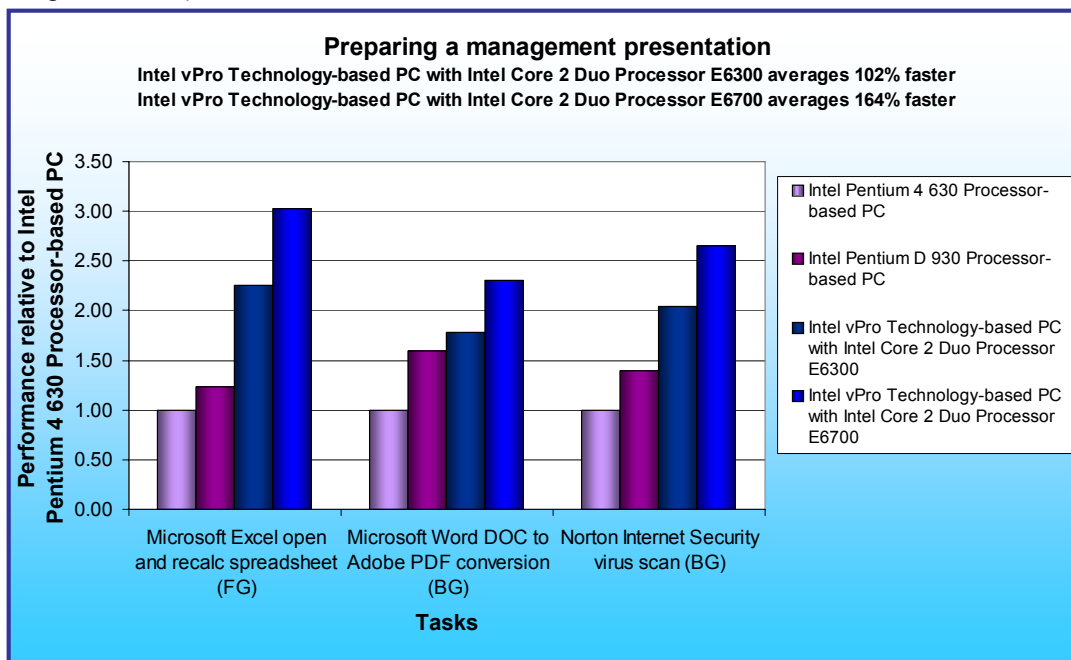


Figure 7: Performance, relative to the Intel Pentium 4 630 Processor-based PC, of each of the four systems preparing a management presentation. Larger numbers represent better performance.

As Figure 7 illustrates, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 was 3.02 times faster on the foreground task than the Intel Pentium 4 630 Processor-based PC, as well as 2.30 and 2.66 times faster on the two background tasks. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 also yielded large performance improvements,

coming in at 2.25 times faster on the foreground task than the Intel Pentium 4 630 Processor-based PC and 1.79 and 2.04 times faster on the background tasks.

The Intel vPro-Technology-based PCs also out-performed the Intel Pentium D 930 Processor-based PC. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 averaged 1.89 times faster on the three tasks, and the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 averaged 1.44 times faster.

Figure 8 demonstrates that these differences represent significant improvements in the time it took to perform each task. Compared to the Intel Pentium 4 630 Processor-based PC, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 cut the elapsed time from 25.7 to 8.5 seconds on the foreground task, from 70.0 to 30.4 seconds on the first background task, and from 95.4 to 35.9 seconds on the second background task. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 also significantly beat the Intel Pentium 4 630 Processor-based PC, running 14.3 seconds faster on the foreground task and 30.8 and 48.7 seconds faster on the two background tasks.

PERFORMANCE RESULTS (seconds)				TASKS	COMPARATIVE RATING			
Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700		Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
25.7	20.8	11.4	8.5	Microsoft Excel open and recalc spreadsheet (FG)	1.00	1.24	2.25	3.02
70.0	43.9	39.2	30.4	Microsoft Word DOC to Adobe PDF conversion (BG)	1.00	1.59	1.79	2.30
95.4	68.1	46.7	35.9	Norton Internet Security virus scan (BG)	1.00	1.40	2.04	2.66

Figure 8: Results for each of the four systems preparing a management presentation. Lower performance results are better. Higher comparative ratings are better.

The Intel vPro Technology-based PCs with Intel Core 2 Duo Processors shine on this scenario, handling three simultaneous processor-intensive tasks with ease. The processor utilization curves in figures 9, 10, and 11 help illustrate the reason for these time savings. All three of these tasks are demanding, with each wanting 100 percent of the processor for significant lengths of time.

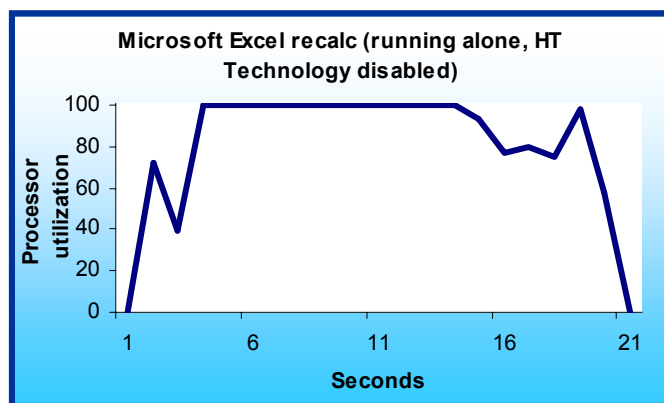


Figure 9: System processor utilization of the Microsoft Excel open and recalc spreadsheet foreground task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

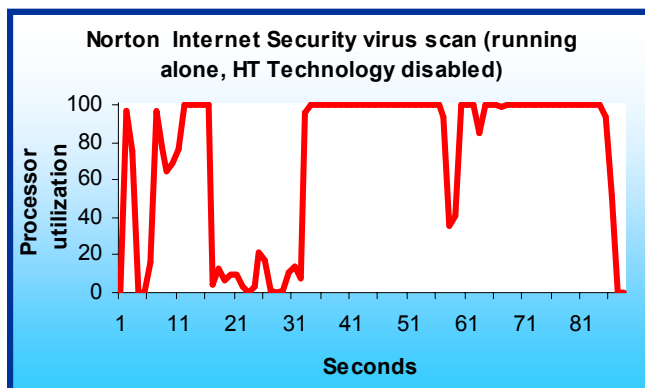


Figure 10: System processor utilization of the Norton Internet Security virus scan background task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

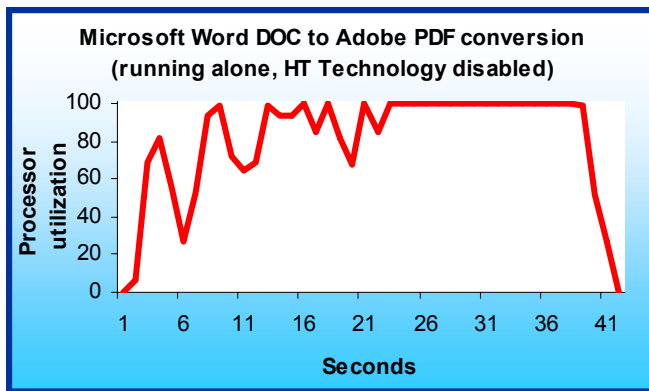


Figure 11: System processor utilization of the Microsoft Word .DOC to Adobe PDF conversion background task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

Collaborating on a marketing plan

This scenario uses the Compare and Merge Documents feature in Microsoft Word to compare a 1.27MB and an 11MB Word document (the foreground task) while a Windows Defender anti-spyware scan runs (the background task).

Figure 12 shows the improvement in performance of the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 on both the foreground and background tasks relative to the Intel Pentium 4 630 Processor-based PC. These results show that the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 was 1.86 times faster on the foreground task than the Intel Pentium 4 630 Processor-based PC and 1.33 times faster on the background task. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 ran 1.50 times faster on the foreground task and 1.21 times faster on the background task than

the Intel Pentium 4 630 Processor-based PC.

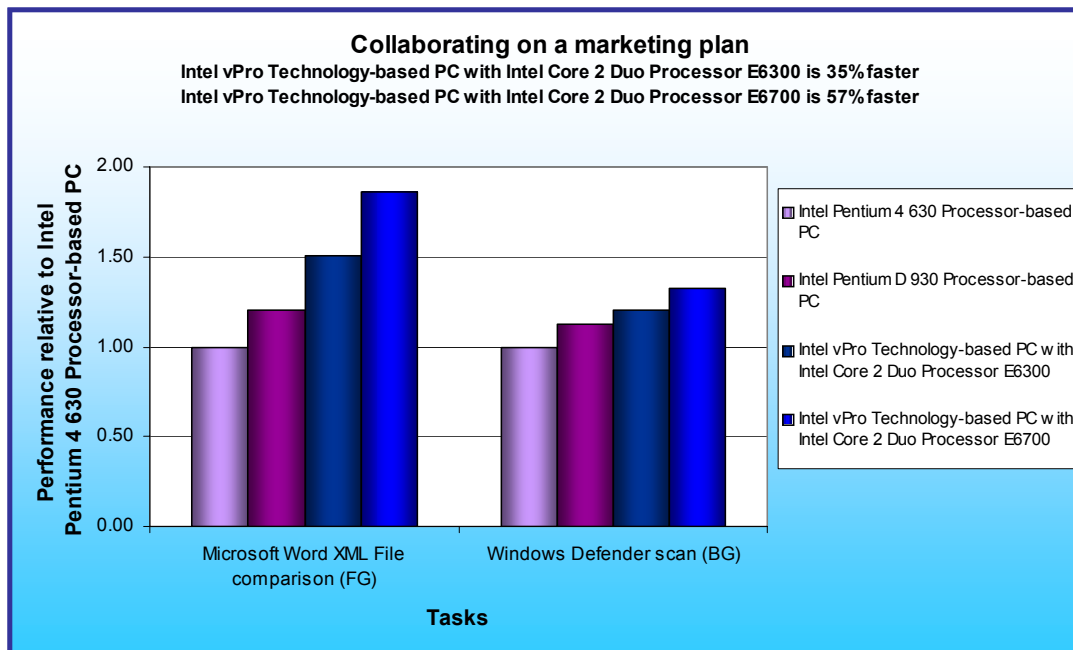


Figure 12: Performance, relative to the Intel Pentium 4 630 Processor-based PC, of each of the four systems collaborating on a marketing plan. Larger numbers represent better performance.

Both Intel vPro Technology-based PCs also outpaced the Intel Pentium D 930 Processor-based PC, with the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 averaging 1.35 times faster on the two tasks and the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 averaging 1.16

times faster.

Figure 13 shows that these percentage differences mean valuable time savings for users. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 finished the foreground task in only 10.6 seconds, vs. 19.7 seconds on the Intel Pentium 4 630 Processor-based PC, and it finished the background task 10.2 seconds faster. The Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 also beat the Intel Pentium 4 630 Processor-based PC, with a 6.6-second edge on the foreground task and a margin of 7.1 seconds on the background task.

PERFORMANCE RESULTS (seconds)				TASKS	COMPARATIVE RATING			
Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700		Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
19.7	16.4	13.1	10.6	Microsoft Word XML file comparison (FG)	1.00	1.20	1.50	1.86
41.4	36.8	34.3	31.2	Windows Defender scan (BG)	1.00	1.13	1.21	1.33

Figure 13: Results for each of the four systems collaborating on a marketing plan. Lower performance results are better. Higher comparative ratings are better.

As you can see in figures 14 and 15, neither of these tasks alone fully taxes the processor for long. Despite this more modest processor utilization, the Intel vPro Technology-based PCs were significantly faster than the other two systems on both of this scenario's tasks.

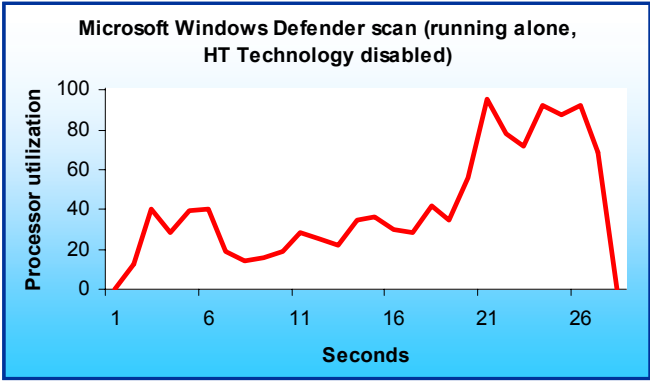


Figure 14: System processor utilization of the Windows Defender scan background task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

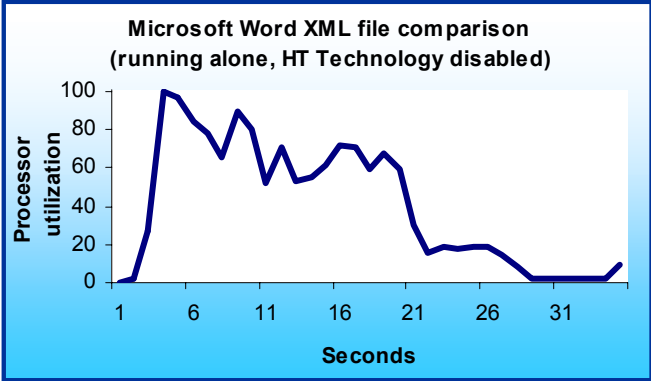


Figure 15: System processor utilization of the Microsoft Word XML file comparison foreground task running alone on the Intel Pentium 4 630 Processor-based PC with HT technology disabled.

Locating information in response to an email inquiry

The single task of this scenario opens three files in a 37.5MB compressed (zipped) Windows Explorer folder. As simple as it sounds, this scenario demonstrates how easy it is to end up running many applications simultaneously. In the course of running, this task actually involves five different applications:

- Windows Explorer, which the user is running when he opens the compressed folder
- Microsoft Word, which opens the document in the compressed folder
- Microsoft Excel, which opens the spreadsheet in the compressed folder

- Microsoft PowerPoint, which opens the slide show in the compressed folder
- Norton Internet Security, which is running in the background with the Norton Auto-Protect feature enabled and which consequently scans each of these files before an application opens it

The user also has Microsoft Outlook open, because an email message requesting information prompted his actions.

As Figure 16 illustrates, the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 was 1.37 times faster on this task than the Intel Pentium 4 630 Processor-based PC, while the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 was 1.20 times faster. Both Intel vPro Technology-based PCs

were also faster than the Intel Pentium D 930 Processor-based PC: the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6700 completed the task 1.18 times faster, while the Intel vPro Technology-based PC with the Intel Core 2 Duo Processor E6300 was 1.03 times faster. Figure 17 presents the time savings users would realize from these performance advantages.

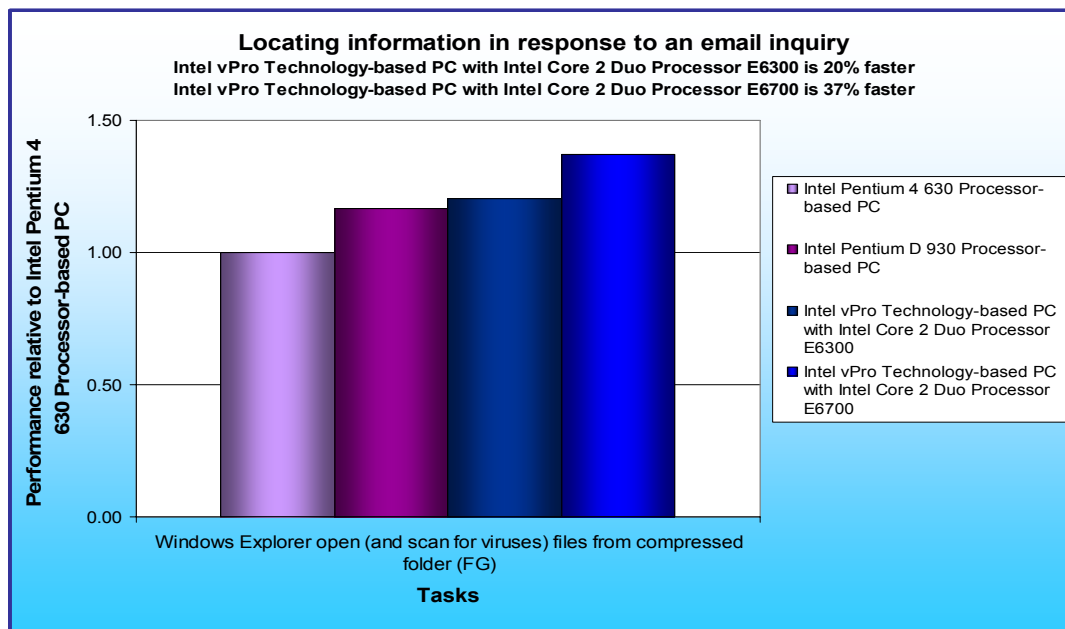


Figure 16: Performance, relative to the Intel Pentium 4 630 Processor-based PC, of each of the four systems locating information. Larger numbers represent better performance.

PERFORMANCE RESULTS (seconds)				TASKS	COMPARATIVE RATING			
Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700		Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
26.6	22.8	22.1	19.4	Windows Explorer open (and scan for viruses) files from compressed folder (FG)	1.00	1.17	1.20	1.37

Figure 17: Results for each of the four systems locating information in response to an email inquiry. Lower performance results are better. Higher comparative ratings are better.

As the processor utilization curve in Figure 18 shows, this scenario places significant demands on the system's processor, demands that the Intel vPro Technology-based PCs handle better than the other systems.

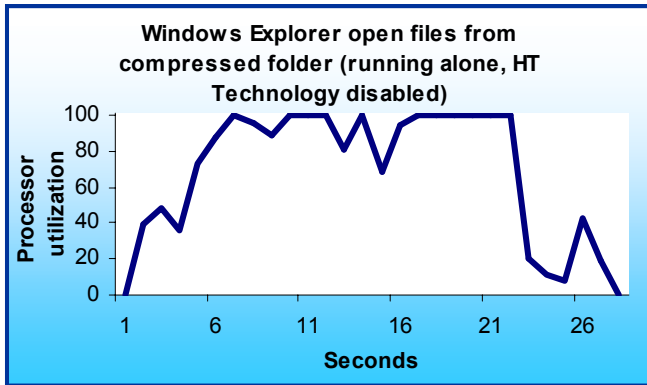


Figure 18: System processor utilization of Windows Explorer task opening (and causing the virus scanning of) files from a compressed folder, running alone on the Intel Pentium 4 processor 630-based PC with HT technology disabled.

Test methodology

We evaluated the performance of each of the application scenarios (see “Application scenarios”) both by hand and with automated test scripts, which we developed with IBM’s Visual Test 6.5. Appendix B details the steps we followed when we hand-timed the scenarios. In this paper, we concentrate our discussions on the results of the automated scripts, because those results are generally more repeatable than hand timings.

We collected results for five runs of each script in each system configuration. (If any test or script failed, we discarded that test’s results and ran the test again.) We refer in this paper only to the median results of those runs on each system configuration. The scripts produce times (in milliseconds), with lower times to complete a given function indicating better performance. We round those times to tenths of seconds in this report.

Appendix A provides detailed configuration information on the test systems. We set up each of those systems using the following process:

1. Install Microsoft Windows XP Professional.
2. Using the standard Microsoft Windows Update Web site, apply all current (as of August 18, 2006) Windows XP critical updates, including Windows XP SP2—but not including optional updates, such as Windows Media Player 10 or Windows Media Connect, that were totally unrelated to the goal of this paper.
3. Install Microsoft Office 2003 (with Access 2003).
4. Using the standard Microsoft Office Update Web site, apply all current (as of August 18, 2006) Office 2003 updates.
5. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Security Center.
 - c. Click Change the way Security Center Alerts me on the left.
 - d. Uncheck Firewall, Automatic Updates, and Virus Protection.
6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Automatic Updates.
 - c. Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
 - a. Open the Control Panel.

- b. Choose System.
 - c. Choose the System Restore tab.
 - d. Select Turn off System Restore on all drives.
8. Turn off all Power Management settings. Doing so prevents power-saving options from starting during testing and affecting results.
 - a. Open the Control Panel.
 - b. Choose Display.
 - c. Choose the Screensaver tab.
 - d. Select None as the Screensaver.
 - e. Choose the Power button.
 - f. Select the Power Schemes tab, and choose Never to Turn off monitor, Turn off hard disks, and System standby.
 - g. Select the Hibernate tab, and uncheck the Enable Hibernation option.
9. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk of each system.
10. Using Symantec's Ghost utility, make an image of each system's hard disk. (This image lets us return to a clean and consistent starting point whenever necessary.)
11. Install the additional software, using the versions current as of August 18, 2006, that each scenario requires:
 - Preparing market data for analysis
 - Network Associates' McAfee VirusScan Enterprise version 8.0i
 - Preparing a management presentation
 - Adobe Acrobat 7.0 Standard Version 7.0.8
 - Norton Internet Security 2006
 - Collaborating on a marketing plan
 - Microsoft Windows Defender (Beta 2)
 - Locating information in response to an email inquiry
 - Norton Internet Security 2006

To obtain the results for each application scenario, we followed the same basic process:

1. Reboot the system.
2. Wait 10 seconds after the Windows hourglass disappears and Windows XP has completed its startup sequence. This delay ensures the system is in a consistent starting state.
3. Run the test script or hand-timed application functions, as appropriate.
4. Record the results.
5. Repeat the above three-step process five times.

If any test or script failed, we discarded that test's results and ran the test again.

Appendix A – Test system configuration information

This appendix provides detailed configuration information about each of the test systems, which we list in alphabetical order by processor name.

Processors in the systems	Intel Pentium 4 630 Processor-based PC	Intel Pentium D 930 Processor-based PC	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6300	Intel vPro Technology-based PC with Intel Core 2 Duo Processor E6700
General				
Processor and OS kernel: (physical, core, logical) / (UP, MP)	1P1C2L / MP	1P2C2L / MP	1P2C2L / MP	1P2C2L / MP
Number of physical processors	1	1	1	1
Single/Dual-Core processors	Single (with Hyper-Threading Technology enabled)	Dual	Dual	Dual
System Power Management Policy	Home/Office Desk	Home/Office Desk	Home/Office Desk	Home/Office Desk
CPU				
System type	Intel	Intel	Intel	Intel
Vendor	Pentium 4	Pentium D	Core2Duo	Core2Duo
Name	630	930	E6300 (pre-production)	E6700 (pre-production)
Stepping	3	2	5	5
Socket type	LGA775	LGA775	LGA775	LGA775
Core frequency (GHz)	3.0	3.0	1.86	2.66
Front-side bus frequency (MHz)	800 MHz	800 MHz	1066 MHz	1066 MHz
L1 Cache	16 KB + 12 Kμops	16 KB + 12 Kμops	32 KB + 32 KB	32 KB + 32 KB
L2 Cache	2 MB	2 MB	2 MB	4 MB
Platform				
Vendor	Intel	Intel	Intel	Intel
Motherboard model number	D945GTP	D945GTP	DQ965WC	DQ965WC
Motherboard chipset	Intel i945G Express	Intel i945G Express	Intel Q965 Express (pre-production)	Intel Q965 Express (pre-production)
Motherboard revision number	A2	A2	01	01
Motherboard serial number	AAC97837-301	AAC97837-301	AAD41834-300	AAD41834-300
BIOS name and version	Intel NT94510J.86A.39 43.2006.0707.140 5	Intel NT94510J.86A.39 43.2006.0707.140 5	Intel CO96510J.86A.44 62.2006.0804.205 9	Intel CO96510J.86A.44 62.2006.0804.205 9
BIOS settings	AHCI Enabled	AHCI Enabled	AHCI Enabled	AHCI Enabled

Memory module(s)				
Vendor and model number	Micron 8HTF6464AY-667D7	Micron 8HTF6464AY-667D7	Corsair CM2X512A-6400	Corsair CM2X512A-6400
Type	PC5300	PC5300	PC6400	PC6400
Speed (MHz)	667	667	800	800
Speed in the system currently running @ (MHz)	333	333	400	400
Timing/Latency (tCL-tRCD-tRP-tRASmin)	5-5-5-15	5-5-5-15	5-5-5-12	5-5-5-12
Size	1 GB	1 GB	1 GB	1 GB
Number of sticks	2 x 512 MB	2 x 512 MB	2 x 512 MB	2 x 512 MB
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided
Channel	Dual	Dual	Dual	Dual
Hard disk				
Vendor and model number	Maxtor 6B300S0	Maxtor 6B300S0	Maxtor 6B300S0	Maxtor 6B300S0
Size	300 GB	300 GB	300 GB	300 GB
Buffer Size	16 MB	16 MB	16 MB	16 MB
RPM	7200	7200	7200	7200
Type	SATA 150 MB/s	SATA 150 MB/s	SATA 150 MB/s	SATA 150 MB/s
Controller	Intel 82801GB (ICH7)	Intel 82801GB (ICH7)	Intel 82801HB (ICH8)	Intel 82801HB (ICH8)
Driver	Intel 5.5.0.1035	Intel 5.5.0.1035	Intel 6.1.0.1002	Intel 6.1.0.1002
Operating system				
Name	Windows XP Professional	Windows XP Professional	Windows XP Professional	Windows XP Professional
Build number	2600	2600	2600	2600
Service pack	2	2	2	2
Microsoft Windows update date	NTFS	NTFS	NTFS	NTFS
File system	ACPI Multiprocessor PC	ACPI Multiprocessor PC	ACPI Multiprocessor PC	ACPI Multiprocessor PC
Kernel	English	English	English	English
Language	DirectX 9.0c	DirectX 9.0c	DirectX 9.0c	DirectX 9.0c
Microsoft DirectX version	Windows XP Professional	Windows XP Professional	Windows XP Professional	Windows XP Professional
Graphics				
Vendor and model number	Intel GMA 950	Intel GMA 950	Intel GMA 3000	Intel GMA 3000
Chipset	Integrated	Integrated	Integrated	Integrated
BIOS version	Intel 82945G Express Chipset	Intel 82945G Express Chipset	Intel Q965 Express Chipset	Intel Q965 Express Chipset
Type	1295	1295	1345	1345
Memory size	128 MB Shared	128 MB Shared	128 MB Shared	128 MB Shared
Resolution	1024 x 768	1024 x 768	1024 x 768	1024 x 768
Driver	Intel 6.14.10.4497	Intel 6.14.10.4497	Intel 6.14.10.4624	Intel 6.14.10.4624
Sound card/subsystem				
Vendor and model number	SigmaTel High Definition Audio	SigmaTel High Definition Audio	SigmaTel High Definition Audio	SigmaTel High Definition Audio

Driver	SigmaTel 5.10.5067.0	SigmaTel 5.10.5067.0	SigmaTel 5.10.5067.0	SigmaTel 5.10.5067.0
Ethernet				
Vendor and model number	Intel PRO/1000 PM	Intel PRO/1000 PM	Intel 82566DM Gigabit	Intel 82566DM Gigabit
Driver	Intel 9.4.17.0	Intel 9.4.17.0	Intel 9.4.6.0	Intel 9.4.6.0
Optical drive(s)				
Vendor and model number	Lite-On DVDRW SHOW-1673S	Lite-On DVDRW SHOW-1673S	Slimtype DVDRW SLW-8315	Slimtype DVDRW SLW-8315
Type	DVD-RW	DVD-RW	DVD-RW	DVD-RW
Dual/Single layer	Dual	Dual	Dual	Dual
USB ports				
Number	6	6	8	8
Type	USB 2.0	USB 2.0	USB 2.0	USB 2.0
IEEE 1394 ports				
Number	1	1	2	2
Monitor				
Type	Plug & Play	Plug & Play	Plug & Play	Plug & Play

Figure 19: Detailed system configuration information for each of the four test systems.

Appendix B – Instructions for running the application scenarios

This appendix summarizes the script for each application scenario and explains how we manually tested and timed each of those scenarios. Though the vast majority of our discussions in this report focus on the results of the automated tests, we verified that manually performing the same functions yielded results similar to those of the automated scripts.

As the instructions below reflect, to get the most consistent possible timings and to make our hand-timed actions more like the ones the automated scripts perform, we sometimes chose to follow procedures for launching applications that were different from those typical users would follow. (See Appendix C for additional information on scripting issues.) When we made such choices, we also independently verified that the typical user procedures would still show similar results.

Consequently, we are confident that the performance benefits the Intel vPro Technology-based PCs delivered in these scenarios are benefits that users can expect to realize in real work situations and are not artifacts of the measurement or scripting technology.

We ran all application scenarios five times on each of the four systems under test, and we reported the median of those runs.

The following subsections, which assume you have already completed all of the setup work in the Test methodology section, describe how to run each of the individual scenarios.

Preparing market data for analysis

The applications involved

- McAfee VirusScan Enterprise 8.0i
- Microsoft Office Access 2003 (Service Pack 2)

The data files involved

- CompetitiveSalesData-reports.mdb, a 12.1MB Access database
- C:\Windows\Driver Cache folder, an 86.8MB folder. To keep the script short, we scanned only this one folder, which contains a large compressed (CAB) file.

The script

The script for this scenario performs the following tasks:

1. Start the timer for the background task, and start McAfee VirusScan with options that instruct it to scan the C:\Windows\Driver Cache folder and to close VirusScan when it finishes the scan.
2. Start the timer for the foreground task, and open the Access database. The macro runs automatically when Access opens.
3. Stop the timer for the foreground task when the Access macro finishes exporting data and displays a finished message in the status bar.
4. Stop the timer for the background task when the McAfee VirusScan window closes.
5. Close the open files and applications. (We did not time this task, because it occurs outside the multitasking section of the script.)

The manual process

First, prepare each system by following these steps once:

1. Copy the scenario folder to C:\Averill.
2. Create a shortcut on the desktop for C:\Program Files\Network Associates\VirusScan\scan32.exe.
3. Right-click the shortcut, and choose Properties.
4. Append the following, preceded by a space, to the Target: entry on the Properties dialog: "C:\WINDOWS\Driver Cache" " /ARCHIVE /AUTOEXIT".
5. Double-click the shortcut you created to test it. It should open McAfee VirusScan, scan the folder you specified in the target, and then close VirusScan.

6. Create a desktop shortcut to the CompetitiveSalesData-reports.mdb file in the Content\TaskContent\Access folder. If the file is not there, copy the file from the CleanContent folder.

To execute the test, follow these instructions. You will need two stopwatches.

1. Reboot the system.
2. Start the first stopwatch, and double-click the Desktop shortcut that you created for VirusScan.
3. Start the second stopwatch, and double-click the Desktop shortcut that you created for the Access database. The report macro starts when the database opens.
4. Stop the second stopwatch when the Access status bar shows Access has completed the export.
5. Stop the first stopwatch when the McAfee VirusScan finishes and the VirusScan window closes.
6. Record the time for the VirusScan from the first stopwatch and the time for the Access export from the second stopwatch.
7. Close all open applications.

Preparing a management presentation

The applications involved

- Adobe Acrobat 7.0 Standard Version 7.0.8
- Microsoft Office Excel 2003 (Service Pack 2)
- Microsoft Office Word 2003 (Service Pack 2)
- Norton Internet Security 2006

The data files involved

- C:\Windows\Driver Cache folder, an 86.8 MB folder, and C:\Program Files\Adobe\Acrobat 7.0\Setup Files\Acrostan\ENU, a 164MB folder. To keep the script time reasonable, we scanned only these two folders. The folders contain large compressed (CAB) files.
- ProjectA.doc, a 1.73MB Word document
- Excel2min.xls, – a 2.56MB spreadsheet

The script

The script for this scenario performs the following tasks:

- Open the Word document. (We did not time this task, because it occurs outside the multitasking section of the script.)
- Start the timer for the Norton Internet Security scan and start a Norton Internet Security scan of the two folders.
- Start the timer for the Adobe Acrobat PDF conversion and start the conversion of the Word document.
- Start the timer for the Excel open and open the Excel file. We set the file and Excel to recalculate automatically, so Excel performs the recalculation as a part of the open process.
- Stop the timer for the PDF conversion when the conversion finishes and Adobe Acrobat displays the PDF file.
- Norton Internet Security closes its window when it completes the scan, so stop the timer for the virus scan when the Norton Internet Security window closes.
- Close all the applications. (We did not time these tasks, because they occur outside the multitasking section of the script.)

The manual process

First, prepare each system by following these steps once:

1. Copy the scenario folder to C:\Averill.
2. Verify that C:\Program Files\Adobe\Acrobat 7.0\Acrostan\Setup Files\ENU folder exists and is 164MB in size.
3. Create a shortcut on the desktop for C:\Program Files\Norton Internet Security\Norton AntiVirus\NAVW32.exe.

4. Right-click the shortcut, and choose Properties.
5. Append the following, preceded by a space, to the Target: entry on the Properties dialog: /NoResults /HEUR:3 "C:\windows\driver cache" "C:\Program Files\Adobe\Acrobat 7.0\Setup Files\Acrostan\ENU".
6. Double-click the shortcut you created to test it. It should open Norton AntiVirus, scan the two directories you specified in the target, and then close Norton AntiVirus.
7. Create shortcuts for ProjectA.doc and Content\TaskContent\Excel\Excel2min.xls in the Content\TaskContent\Word folder in the script folder.
8. Create a shortcut to that Word folder.
9. Open Word, and size it so it fills less than half of your desktop. Click the Convert to Adobe PDF icon in the Word toolbar.
10. Reposition the Norton AntiVirus scan shortcut that you created if either the Word window or the Save Adobe PDF File As dialog covers it. Close the Save Adobe PDF File As dialog.
11. Open Excel, and position it in the other half of the desktop.
12. Close Word and Excel.

To execute the test, follow these instructions. You will need three stopwatches to time three different tasks.

1. Double-click the shortcut for the Word folder. If the folder includes a PDF file, delete the file.
2. Reboot the system.
3. Double-click the shortcut for the Word document.
4. Click the Convert to Adobe PDF icon in the Word toolbar. Word displays a Save Adobe PDF File As dialog.
5. Start the first stopwatch and double-click the desktop shortcut for the Norton AntiVirus scan.
6. Start the second stopwatch and click the Save button in the Save Adobe PDF File As dialog.
7. Start the third stopwatch and click the desktop shortcut for the Excel file. Excel recalculates the spreadsheet when you open it.
8. Stop the third stopwatch when the file opens and the window title for Excel displays "Ready" in its status bar.
9. Stop the second stopwatch when Adobe displays the completed PDF.
10. Stop the first stopwatch when Norton AntiVirus completes the scan and closes the Norton AntiVirus window.
11. Record the time for the Norton Antivirus scan from the first stopwatch, the time for the PDF conversion from the second stopwatch, and the time for the Excel file open and recalc from the third stopwatch.
12. Close all open applications.

Collaborating on a marketing plan

The applications involved

- Microsoft Office Word 2003 (Service Pack 2)
- Microsoft Windows Defender (Beta 2)

The data files involved

- ProjectA1.xml, a 10-page (1.27MB) Word document
- ProjectA2.xml, a 42-page (11MB) Word document

The script

The script for this scenario performs the following tasks:

1. Open Windows Defender. (We did not time this task, because it occurs outside the multitasking section of the script.)
2. Start the timer for the background task, and press the Scan button in Windows Defender to start the scan.
3. Open the 10-page Word document.
4. From the Word Tools menu, select Compare and Merge documents.
5. Enter the name of the 42-page Word document.
6. Start the timer for the foreground task, and press Enter.

7. Stop the timer for the foreground task when the merged document displays and the page counter at the bottom of the document shows 42 pages.
8. Stop the timer for the scan when Windows Defender displays the scan status window showing that it has finished the scan.
9. Close Windows Defender and Word. (We did not time these tasks, because they occur outside the multitasking section of the script.)

The manual process

First, prepare each system by following these steps once:

1. Copy the scenario folder to C:\Averill folder.
2. Create a shortcut for ProjectA1.xml in the Content\TaskContent\Word folder in the script folder.
3. If there isn't a shortcut for Windows Defender on the desktop, copy the shortcut from the Start menu to the desktop.
4. Double-click the Windows Defender Desktop shortcut and then the shortcut for the XML document. Position the two windows so that you can see at least the left third of the Windows Defender window. You will need to monitor this area to see when Defender completes its scan.
5. Close all open applications.

To execute the test, follow these instructions. You will need a stopwatch.

1. Reboot the system.
2. Double-click the shortcut for the XML document.
3. Wait for the document to open in Microsoft Word, then select Compare and Merge Documents... from the Tools menu.
4. In the Compare and Merge Documents dialog, locate the Content/TaskContent/Word folder in the script folder, and highlight the name of the ProjectA2.xml file.
5. Double-click the Windows Defender shortcut on the Desktop.
6. Start the stopwatch, and click the Merge button in the Compare and Merge Documents dialog.
7. Stop the stopwatch when the Spelling and Grammar status icon on the Word status bar shows an X. (This icon resembles an open book.)
8. Wait until Windows Defender finishes the scan and reports the scan status.
9. Record the time for the Windows Defender scan from the status area of the Windows Defender window and the time for the Word merge from the stopwatch.
10. Close all open applications.

Locating information in response to an email inquiry

The applications involved

- Norton Internet Security 2006
- Microsoft Outlook 2003 (Service Pack 2)
- Microsoft Office Excel 2003 (Service Pack 2)
- Microsoft Office Word 2003 (Service Pack 2)
- Microsoft PowerPoint 2003 (Service Pack 2)
- Microsoft Windows Explorer for Windows XP Professional (Service Pack 2)

The data files involved

- Threefiles.zip, a 43.7MB compressed (zipped) folder
- Excel2MinLarge.xls, a 7.44MB Excel spreadsheet
- Content.PPT, a 33.4MB PowerPoint presentation
- ProjectA.doc, an 11MB Word document
- Outlook.pst, a 217MB Outlook database

The script

The script for this scenario performs the following tasks:

1. In Windows Explorer, open the compressed (zipped) folder

2. Open Outlook.
3. Start a timer, select the three files in the Explorer window, and press enter. . (We did not time these first two tasks, because they occur outside the multitasking section of the script.)
4. Stop the timer when all three files are fully open. The Excel file is open when Ready appears in its status bar. The Word document is open when the Word status bar shows it has completed the grammar check. The PowerPoint presentation is open when it displays all of its thumbnails. The background task for this test is the Norton Internet Security automatic scan of the three files. (We do not time this background task separately, because there is no way to know exactly when it begins.)

The manual process

First, prepare each system by following these steps once:

1. Copy the scenario folder to C:\Averill.
2. Copy the Content\CleanContent\Outlook folder in the script folder to C:\Documents and Settings\User\Local Settings\Application Data\Microsoft. If your user name is different from User, substitute that name for User in this path.
3. Create a shortcut to Outlook.
4. Create a desktop shortcut ThreeFiles.zip in the Content\TaskContent\Explorer folder in the script folder.
5. Double-click the desktop shortcut for ThreeFiles.zip.
6. Select all three files.
7. Press Enter to open the three files.
8. Arrange the windows for the three applications so that PowerPoint consumes roughly the left third of the screen and displays 21 slide snapshots. Fill the top right of the screen with Word and the bottom right with Excel.
9. Close all the open applications.

To execute the test, follow these instructions. You will need a stopwatch.

1. Reboot the system.
2. Double-click the desktop shortcut for ThreeFiles.zip
3. Select all three files.
4. Double-click the desktop shortcut for Outlook.
5. Start the stopwatch, go to the Explorer Window, and press Enter to open the three selected files.
6. Stop the stopwatch when all three files are open. PowerPoint is open when the bottom slide snapshot appears. Word is open when the Spelling and Grammar Status icon shows an X. Excel is open when its status bar shows "Ready".
7. Record the stopwatch time that the system needed to open the compressed files.
8. Close all open applications.

Appendix C – Issues in script development

To the best of our knowledge, despite its age IBM's Visual Test 6.5 remains the tool most widely used today for constructing application-based benchmarks and performance tests for PCs running various versions of Microsoft Windows. We have used this product (and previous versions of it) for many years to build performance tests. The tool does, however, have some stated limitations that unavoidably affect the way one develops performance tests with it.

First, the product's own documentation notes that its primary goal is to be a tool for automating application testing, not for benchmark development. Consequently, the granularity of some of its functions and the way some of its functions behave are not ideal for benchmark development.

IBM also does not officially support Visual Test 6.5 for the Windows XP operating system. Because Windows XP is the leading and most current desktop version of Windows today, we nonetheless felt it was essential to use that operating system in our tests.

The presence of any scripting tool has the potential to affect the performance of a system. The tool unavoidably must, for example, occupy some memory and consume some processing power. Consequently, developing a performance-measurement script with such a tool involves maintaining a delicate balance between using the tool to automate typical real user behavior and minimizing the effects of the tool on system performance. To make sure the results of our scripts were accurate, we also hand-timed each of the functions we scripted.

To minimize these limitations and problems, we sometimes had to use scripting techniques that would achieve the same results as typical user behavior but not exactly mirror that behavior. Such techniques include inserting delays to mimic user think time and launching applications by clicking the OK button of a pre-filled Run command line. The hand timing instructions we provide in Appendix B reflect those techniques, so following those instructions will yield results similar to those the scripts produce. Whenever we had to use one of these alternative techniques, we manually verified that doing so did not materially alter the way the system behaved and that real users performing the same actions in more typical ways would see the type of performance benefits we describe.

The timings the scripts produce also inevitably contain some variability. This variability is a result of the combination of the tool's limitations and the generally asynchronous nature of the many processes Windows XP and other modern operating systems have running at any given time.

Finally, though one of the goals of this effort was to produce reliable scripts, we were not trying to build bulletproof benchmarks for wide distribution and use. We developed the scripts to mimic user behavior on our specific test systems; on different systems the scripts might show different levels of performance benefits or even fail to work. So, although the scripts are as reliable, self-contained, and free of system dependencies as we could reasonably make them within the project's timeframe, they do sometimes fail or encounter problems. Should a problem occur, rebooting the system and running the script again will generally yield a good result.



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