AN804: Gaming Performance Analysis – 4GB vs 2GB

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Introduction

Corsair XMS2 DHX memory was used for testing

Adding memory is one of the best and most cost effective methods of improving your PC's performance. This application note examines the performance impact on today's popular PC games of upgrading system memory from 2GB to 4GB.

The tests were run on an Intel P965 Express chipset-based PC using 2GB and 4GB memory array sizes (both in dual channel mode), while keeping memory frequency and latency timings constant.

The results, described below, demonstrate that using 4GB of system memory provides significant performance improvements in today's popular PC games, in addition to providing secondary benefits such as improved loading times and increased multi-tasking flexibility.

Background

The system memory requirements of desktop and laptop computers have been increasing with each successive release of Microsoft's Windows operating system. Simultaneously, the memory requirements of new applications and games have also increased. Therefore, the end result is that 2GB of system memory is truly the realistic minimum memory specification for Windows Vista-based PCs. With the decreasing cost of DDR2 memory, upgrading total system memory to 4GB is now a very affordable option.

Due to differences in the way that 32-bit and 64-bit operating systems work (explained below), 4GB of system memory is most efficiently used in conjunction with a 64-bit operating system. Users with 32-bit versions of Windows will still be able to access up to 3.5GB of available memory, which is up to a 75% increase compared to 2GB.

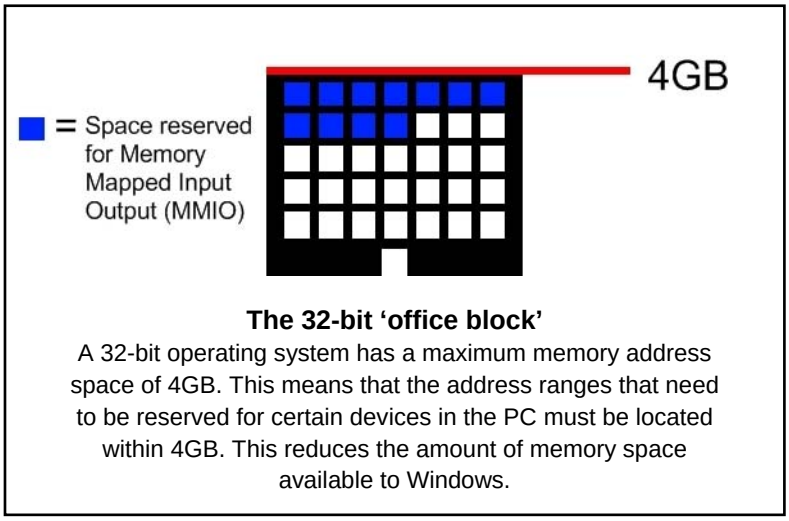
The system requirements to fully utilize 4GB are stated in the Microsoft Knowledge Base article 929605 (http://support.microsoft.com/kb/929605).

Memory usage in 32-bit operating systems

Since each binary bit in a 32-bit operating system can be used to represent the location of a byte of memory, a 32-bit operating system has a maximum 'memory address size' of 2^{32} bytes, which equates to 4,294,967,296 bytes (4,096MB or 4GB).

However, part of this 4GB 'address space' must be reserved for devices that require MMIO (Memory-Mapped Input Output). In simple terms MMIO is a process by which some devices in the PC exchange data with the CPU/memory. One such device is the graphics card, which requires an amount of address space equal to its frame buffer size (the amount of memory installed on the card) to be 'reserved' for such data exchanges. This reserved address space is therefore not available to Windows as accessible memory.

One way to visualise this is to think of each memory address as an individual office in a huge 'Windows' office block. Devices that require MMIO will therefore have a certain number of these offices 'reserved' exclusively for their use. Since the locations of these 'offices' are fixed, the CPU knows exactly where to go in order to exchange data with these devices. However, it also means that these offices are not available for other data exchanges, therefore reducing the total number of useable offices in the building (the total amount of memory available to Windows).



The 32-bit 'office block'

A 32-bit operating system has a maximum memory address space of 4GB. This means that the address ranges that need to be reserved for certain devices in the PC must be located within 4GB. This reduces the amount of memory space available to Windows.

While there are numerous devices in a PC that require MMIO, graphics cards have the most significant impact on available memory since they can be equipped with up to 1GB of on-board memory. This means that the available memory in a PC equipped with a 1GB graphics card will be reduced by at least 1GB. For systems with multiple graphics cards the total amount of memory on all cards installed in the system must be taken into account.

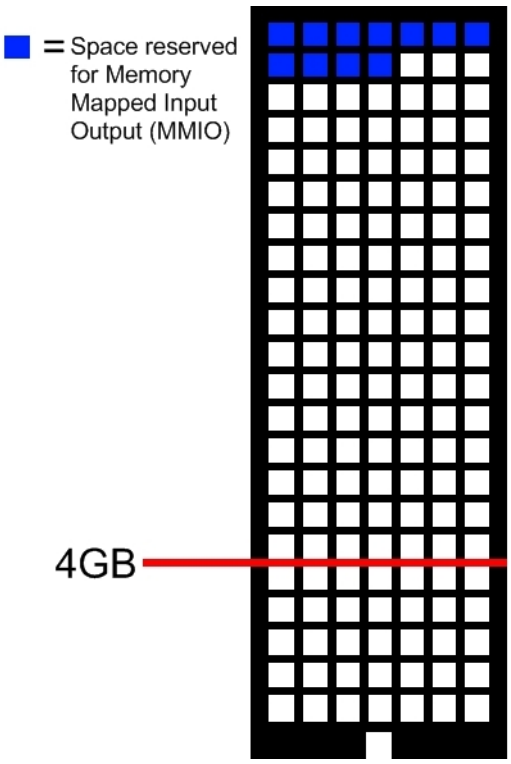
However, a typical PC with a 32-bit version of Windows and a single graphics card will still be able to access up to 3.5GB of memory. This is up to 75% more useable memory than is available to a PC with 2GB of memory installed.

Memory usage in 64-bit operating systems

With 64-bits available to represent the locations of bytes of memory the maximum theoretical memory address size increases to 2^{64} bytes, which equates to 16TB (terabytes) or 16,384GB (yes, gigabytes!). In reality the 64-bit versions of Windows Vista support 8 – 128GB+.

Therefore, for 64-bit systems, the address ranges for devices that require Memory Mapped Input Output can be set well above the 4GB address line. You can think of this as building billions of new offices on top of the original office block used in our earlier example, and then setting aside some of the new offices on the top floors exclusively for MMIO. This then frees up the office space at lower levels (below 4GB) meaning that all of these offices (the full 4GB) can now be used by Windows.

In summary, a 64-bit system with a 64-bit version of Windows Vista or XP will be able to utilise the full 4GB of installed memory. Users with a 32-bit operating system will also see a significant increase in useable memory of up to 75%.



The 64-bit 'office block'
The total theoretical amount of address space for a 64-bit operating system is 16TB. The addresses that need to be reserved for devices in the PC can therefore be located well above the 4GB address line.

Test Platform

To compare the performance of 4GB and 2GB memory sizes we used the following test system:

- Intel Core 2 Extreme QX6850 (multiplier-overclocked to 3.33GHz)
- Asus Commando P965 motherboard
- 500GB Seagate Barracuda 7200.11
- Windows Vista Home Premium 64-bit
- Nvidia ForceWare Driver 169.25 WHQL

Graphics configurations:

- 320MB Nvidia GeForce 8800 GTS
- 512MB Nvidia GeForce 8800 GT

Memory configurations:

- 2GB testing – Corsair TWIN2X2048-6400C5DHX
- 4GB testing – Corsair TWIN2X4096-6400C5DHX

What we tested

The test system uses a P965 motherboard and Intel Core 2 Extreme QX6850 processor

The focus of this application note is to assess the performance impact on modern games of upgrading from 2GB of memory to 4GB of memory.

However, as typical 3D graphics and game benchmarks are designed principally to analyse graphics subsystem performance, these tests are designed to work with 1GB or 2GB of system memory in order that they can be run on the widest possible range of systems.

Therefore, to be able to effectively examine the performance impact of upgrading from 2GB to 4GB of system memory we took a real-world benchmarking approach. This included performing the following tests:

Frame rate improvements

In these tests we will play through a repeatable section of several games and record the average and minimum frame rates using the "FRAPS" utility (www.fraps.com).

Multi-tasking

We call this test multi-tasking, although perhaps it would be better to describe it as 'task-switching'. While it's conceivable that some people will, for example, encode a video in the background while playing Counter-Strike, a more realistic scenario is simply Alt-Tabbing out of a game to send an email, check or post in a forum, or send an instant message.

This test will look at the time taken to pause a game of Company of Heroes: Opposing Fronts and then 'Alt-Tab' to an IE7 web browser window in order to make a forum post. The test is timed from the moment 'Alt-Tab' is pressed to the point at which the web browser window is responsive (links can be selected and the page can be scrolled).

Loading times

This test will record the length of time taken for a game to load. The time will be recorded from the moment a game is launched until the game is ready to play. Please note that Windows Vista's SuperFetch feature was disabled during this test in order to ensure accuracy.

Memory usage analysis

In addition to the performance tests we will also record the memory usage of each game during play in order to investigate how memory usage differs for 2GB and 4GB configurations. This information could also be helpful when analysing the results of the benchmark tests.

To measure the memory usage of each process we used Process Explorer 11.1 (http://technet.microsoft.com/en-us/sysinternals/bb896653.aspx). We focused on three memory variables, which are as follows:

Virtual Size
The Virtual Size is the total amount of address space allocated to a process. Not all of this address space is necessarily mapped to memory (either physical RAM or in the paging file).

Private Bytes
The Private Bytes figure represents the total amount of memory allocated exclusively to a process (both physical memory and in the paging file).

Working Set Private
Working Set Private represents the total amount of physical memory allocated exclusively to a process (this differs slightly from Working Set, which includes data shared with other processes).

Results

Company of Heroes: Opposing Fronts

(Version 2.101)

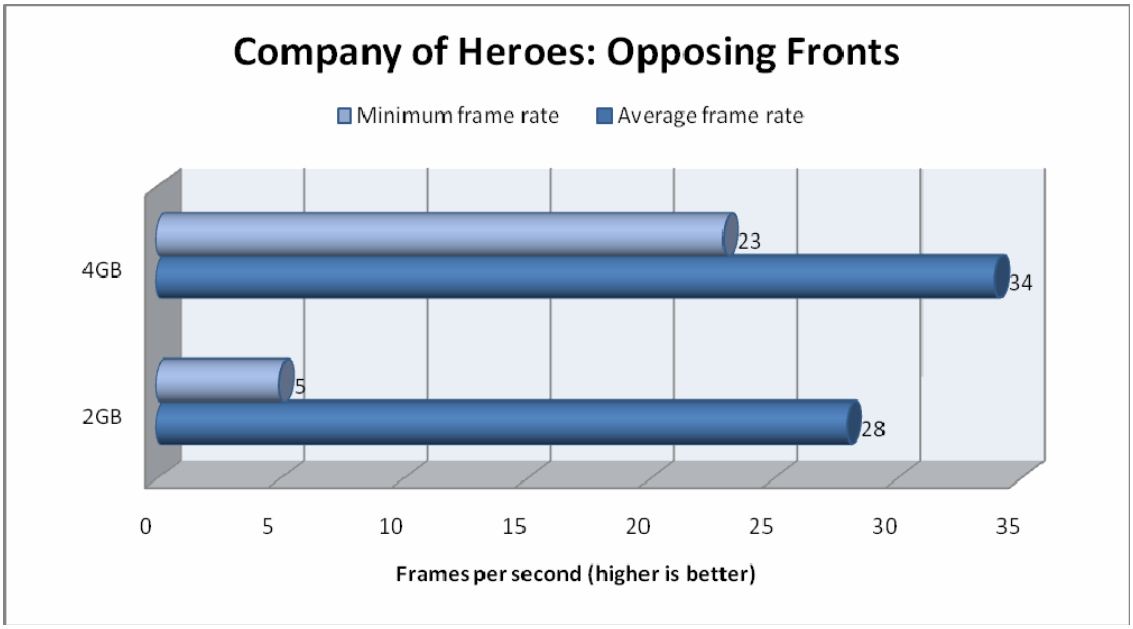
Company of Heroes: Opposing Front is a popular World War 2 RTS (real-time strategy) game. We tested using the Montargis Region, 8-player Skirmish map with 7 AIs and one human player.

We tested by loading a previously-saved Skirmish game and then moving around the map on a pre-determined path, recording the frame rate using FRAPs. Each test was run three times on each test system, rebooting after each test, and the average of the three runs is used as the final result. The game was set to maximum detail settings in DirectX 9 (High shaders) mode.

Results

512MB GeForce 8800 GT
1,920 x 1,200

Company of Heroes: Opposing Fronts	2GB	4GB
Average frame rate	28 fps	34 fps
Minimum frame rate	5 fps	23 fps

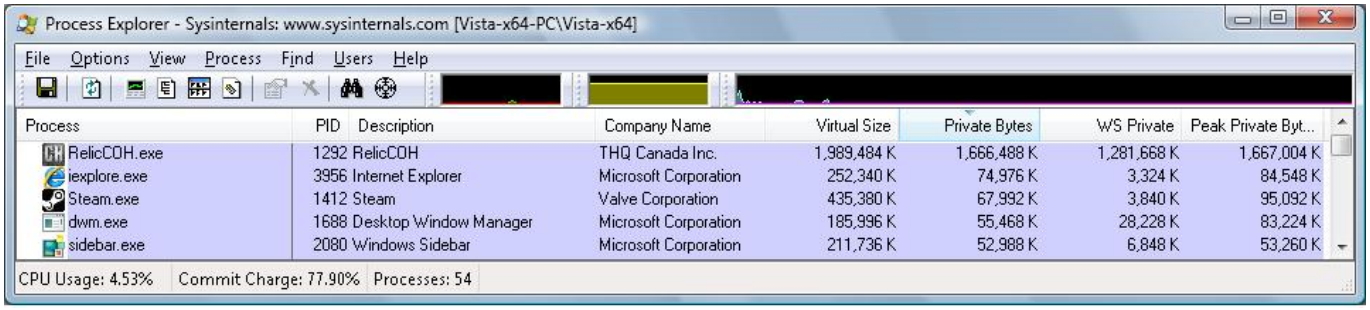


The results show that 4GB provides a significant performance benefit, particularly with regards to the minimum frame rates, which are over 4x higher with 4GB installed. During this test the low minimum frame rates are sustained over a long enough period to affect the average frame rate, which is 6fps lower with only 2GB installed.

To illustrate this difference we created a video that shows the performance of Company of Heroes: Opposing Fronts with 2GB and 4GB memory sizes. This video can be viewed at http://www.corsair.com/cinema/movie.aspx?id=507445.

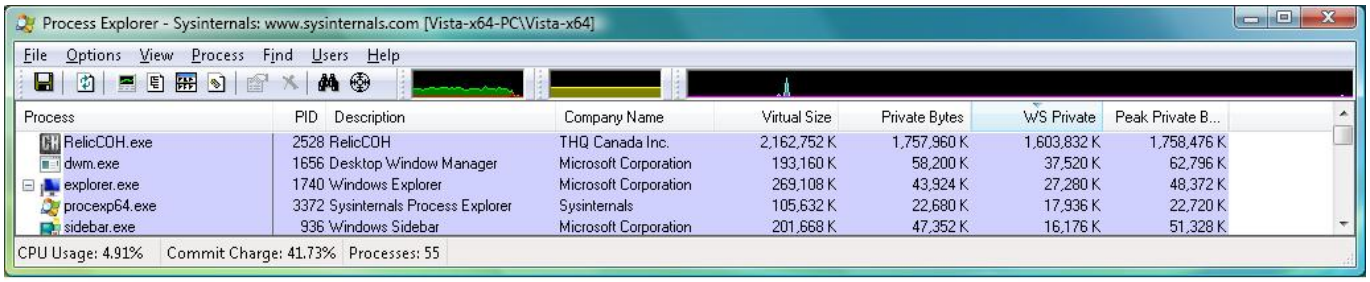
Company of Heroes: Opposing Fronts memory usage

2GB system memory installed



With 2GB of system memory installed Windows Vista has actually set a Virtual Size of nearly 2GB for the Company of Heroes process (RelicCOH.exe). Nearly 1.7GB of memory has been allocated exclusively to RelicCOH.exe, although only 1.3GB is comprised of physical RAM, meaning that a significant chunk of data is stored in the paging file. Loading data from the paging file could explain the stuttering frame rates and low minimum frame rate.

4GB system memory installed



With 4GB of system memory installed the Virtual Size of the Company of Heroes process has grown to nearly 2.2GB, and 1.75GB of memory is exclusively in use by the game. Importantly, the amount of physical memory (WS Private) that the game is using has risen to over 1.6GB. As a result, there are hardly any occurrences of stuttering or stalling, leading to the higher frame rates, particularly the higher minimum frame rates.

Company of Heroes: Opposing Fronts Analysis

Company of Heroes: Opposing Fronts performs significantly better with 4GB of memory installed compared to 2GB. Directly after loading an 8-player Skirmish game there were significant delays and stutters with only 2GB installed, to the point where the game occasionally ground to a complete standstill, but with 4GB installed the game was responsive and playable almost instantly.

Microsoft Flight Simulator X

(Service Pack 2)

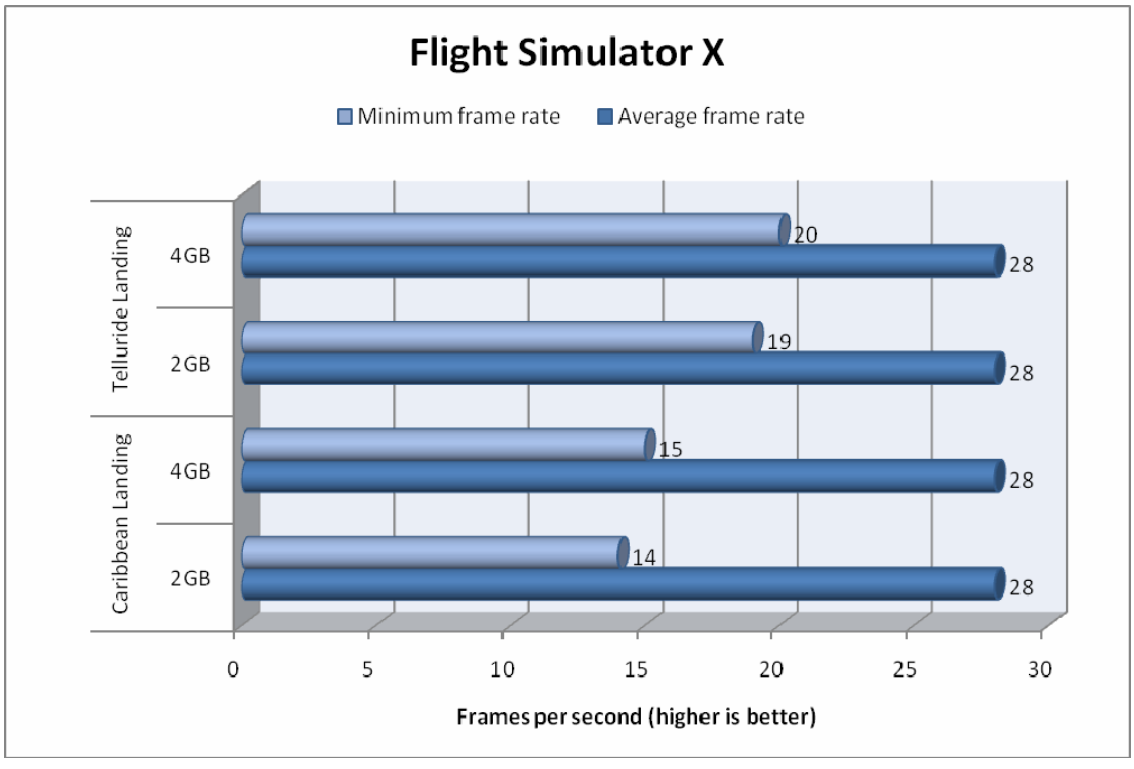
Microsoft Flight Simulator X is a highly realistic and extremely resource-hungry flight simulator. The latest Service Pack (SP 2) adds support for DirectX 10 graphics card (support is still in BETA) and the game is heavily optimised for multi-core processors.

We tested using the 'Caribbean Landing', 'Telluride Landing' and 'Swiss Outing' missions, which are simple and easily repeatable missions that last about 10 – 15 minutes. We recorded the frame rate using FRAPS, timing from the point at which the mission begins to immediately after touchdown on the runway. We repeated each test three times, rebooting after each test, and took the average of the three runs.

Results

512MB GeForce 8800 GT
1,920 x 1,200, Ultra High, DirectX 10

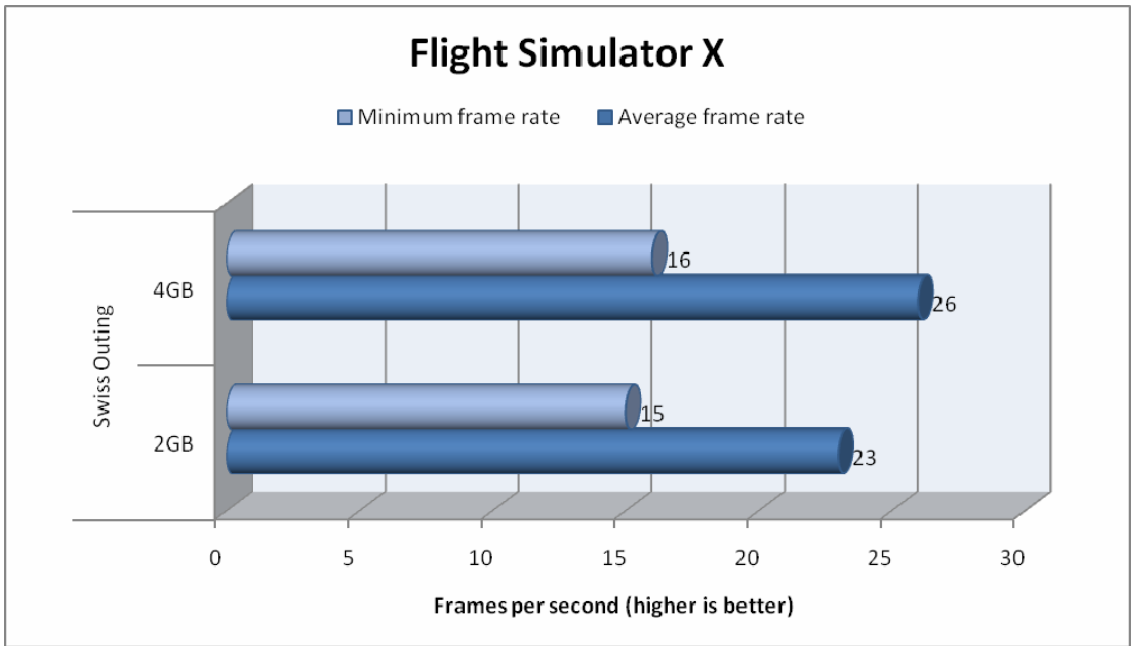
Microsoft Flight Simulator X	Caribbean Landing		Telluride Landing	
	2GB	4GB	2GB	4GB
Average frame rate	28 fps	28 fps	28 fps	28 fps
Minimum frame rate	14 fps	15 fps	19 fps	20 fps



Initially, we tested using the 'Ultra High' in-game settings and found that there was relatively little difference in performance between 2GB and 4GB. However, the level of detail can actually be enhanced above the 'Ultra High' setting by customising the detail options. We tried increasing the Ground Scenery detail settings to see if increased detail levels resulted in higher memory usage.

512MB GeForce 8800 GT
1,680 x 1,050, anti-aliasing enabled. Ultra High, DirectX 10
Plus 'Ground Scenery' maximum, Ground Scenery Shadows enabled

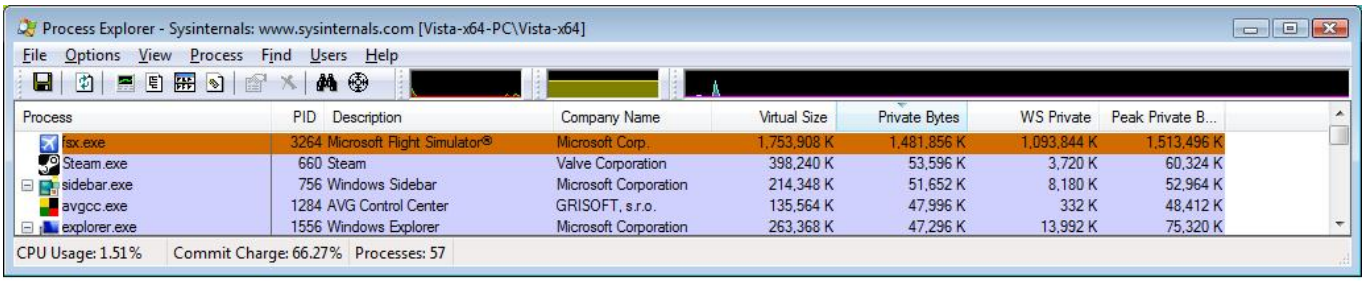
Microsoft Flight Simulator X	Swiss Outing	
	2GB	4GB
Average frame rate	23 fps	26 fps
Minimum frame rate	15 fps	16 fps



With the 'Ground Scenery' sliders set to maximum the extra level of detail led to additional memory requirements. In the 'Swiss Outing' mission the performance difference between 2GB and 4GB was subtle but noticeable, averaging a 3fps gain with 4GB.

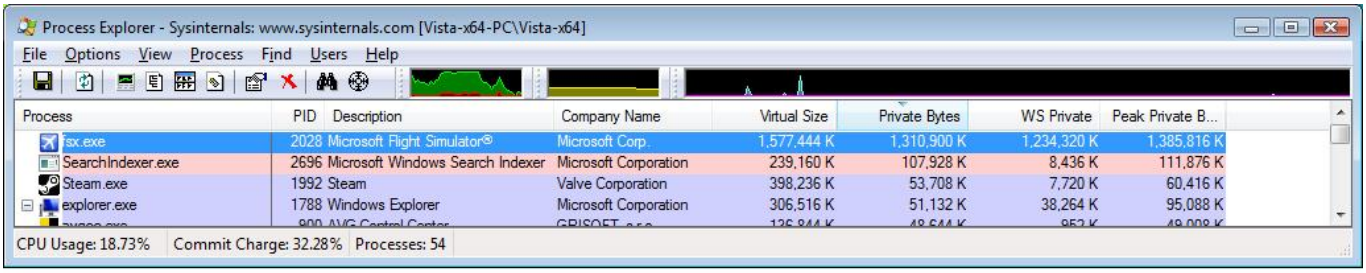
Flight Simulator X memory usage

2GB system memory installed



The above screenshot was taken during the 'Swiss Outing' mission at the test settings listed above. Nearly 1.5GB of memory is in use (Private Bytes), although only 1.1GB was comprised of physical memory. The exclusive memory usage for the Flight Simulator X process (fsx.exe) peaked at just over 1.5GB.

4GB system memory installed



With 4GB of system memory installed the Flight Simulator X process was using over 1.3GB of memory (Private Bytes), which was mostly comprised of physical memory. In contrast, with 2GB installed, nearly 400MB of data was stored in the paging file. The peak memory usage (including data held in the paging file) was just under 1.4GB.

Flight Simulator X Analysis

Flight Simulator X generally performs well with 2GB of system memory. However, for enthusiasts looking to achieve the highest possible details settings, installing 4GB provides the extra headroom needed to get the most out of the CPU and graphic hardware so that the game continues to run at peak performance.

Crysis

(64-bit, Patch 1.1)

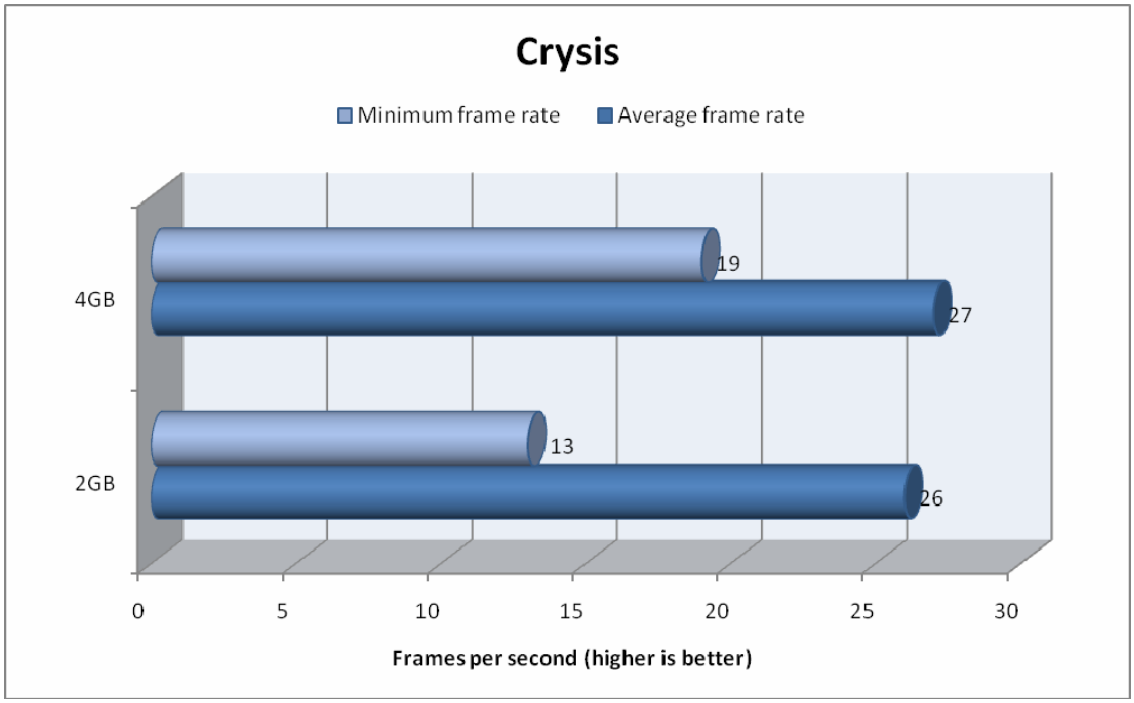
Crysis is probably the most technically advanced first-person shooter on the market today, offering support for DirectX 9 and DirectX 10 graphics cards and multi-core processors. As was the case with its predecessor, Far Cry, Crysis is illustrative of how games evolve to take advantage of ever more powerful hardware. Crysis also provides an early indication of the level of hardware resources that many other games in the future will require.

We tested a section of the Exodus level, which involves manning a machine gun and fighting off alien 'Scouts' while you are driven along a pre-set route in a jeep. As such, it is a highly repeatable test. We recorded the frame rate using FRAPs from the beginning of the section until you exit the jeep at the foot of the road. Each test was repeated three times, rebooting after each run.

Results

512MB GeForce 8800 GT
1,280 x 1,024, DX10, High detail

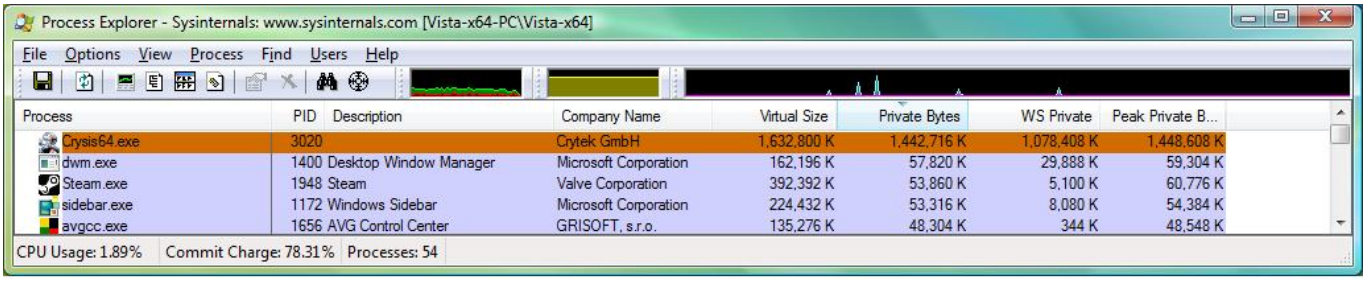
Crysis	2GB	4GB
Average frame rate	26 fps	27 fps
Minimum frame rate	13 fps	19 fps



The minimum frame rate in Crysis is 6fps higher with 4GB of memory compared to 2GB, which is a performance gain of 46%. The poor performance with 2GB is due to stutters and slowdowns. This is most obvious towards the end of the game where memory usage is very high (see below).

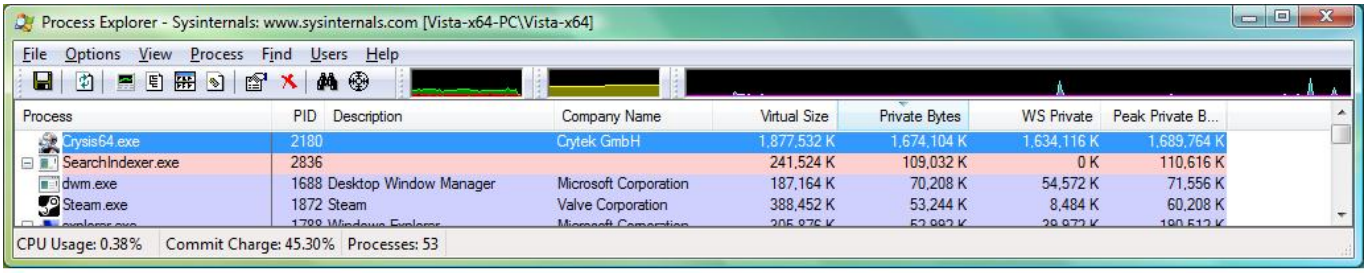
Crysis memory usage

2GB system memory installed



The above screenshot was taken while playing through the final section of the game, including the end battle. The Crysis process (Crysis64.exe) was using nearly 1.1GB of physical memory and over 1.4GB of memory in total. Memory usage was so high that the game frequently stuttered and paused.

4GB system memory installed



With 4GB of system memory installed the Crysis process (Crysis64.exe) has a Virtual Size of nearly 1.9GB and is using over 1.6GB of physical memory (WS Private). Almost no data is held in the paging file on the hard disk, which means the game remained smooth with no obvious stutters.

Crysis analysis

While Crysis is certainly playable with 2GB of RAM the extra headroom that 4GB of memory provides means that there are far fewer (and less severe) stutters and the game runs much more smoothly. 4GB is also of huge benefit during the more intense sections of the game where memory usage peaks, and this includes the crucial final level, where the need for smooth gameplay is all the more important!

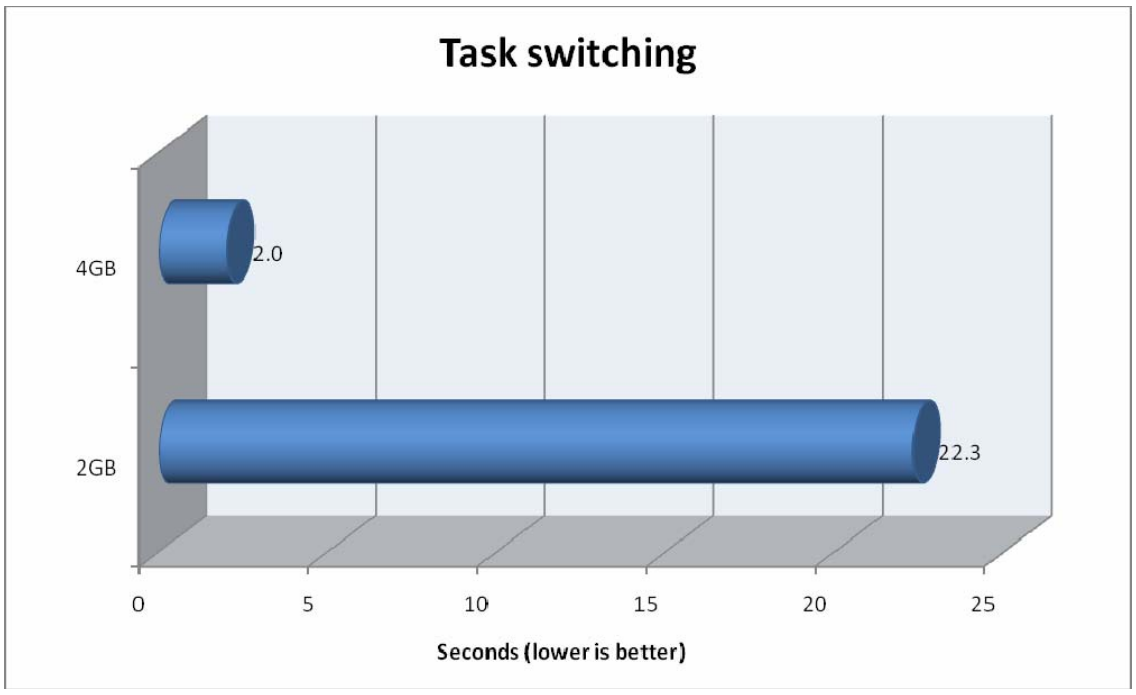
Multi-tasking / Task switching

In this test we recorded the time taken to 'Alt-Tab' out of a Skirmish game of Company of Heroes: Opposing Fronts to an IE7 web browser window with a forum page loaded. The clock is stopped as soon as the browser window becomes responsive (the web page can be scrolled and links can be selected).

The test uses the same 8-player Skirmish map used for the Company of Heroes: Opposing Fronts frame rate test at a resolution of 1,920 x 1,200. We played the game for 5 minutes before pausing and switching to the IE7 window. We also repeated the test three times for each configuration (2GB and 4GB) rebooting between each test.

Results

Task switching	2GB	4GB
1	24 seconds	2 seconds
2	20 seconds	2 seconds
3	23 seconds	2 seconds
Average	**22.3 seconds**	**2 seconds**



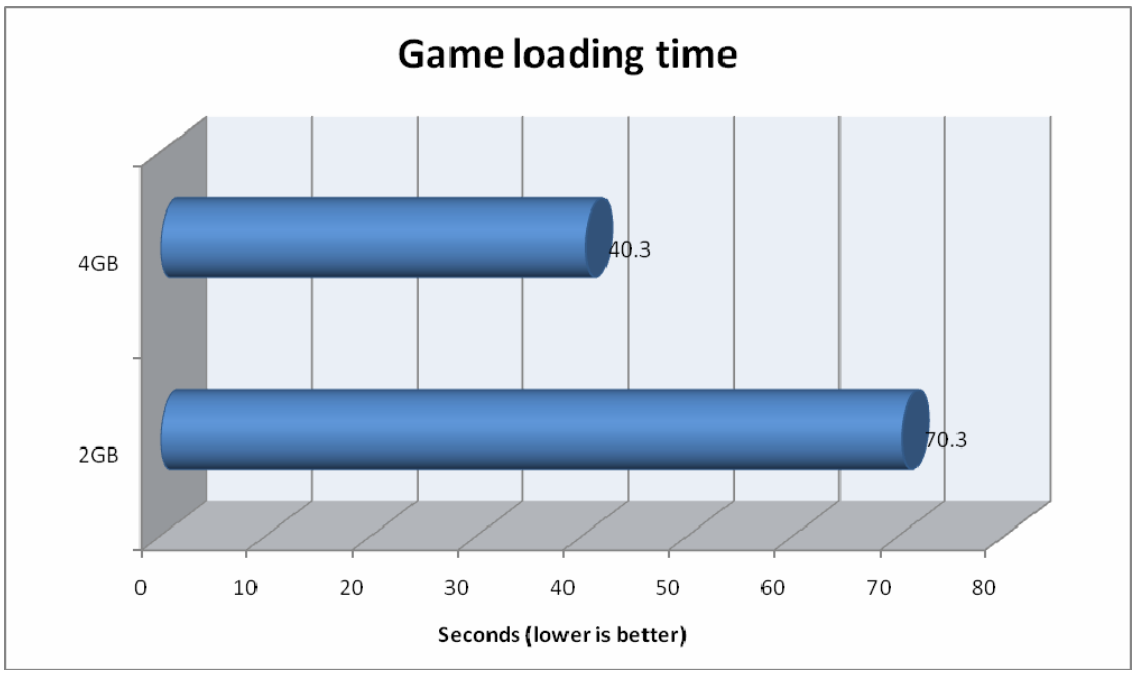
The difference between 2GB and 4GB in this test could not be clearer. With 2GB of memory installed the system has to move the game data to the hard disk before it can free up space to return to the desktop. With 4GB of memory installed the Windows desktop and web browser window are still held in memory meaning that switching between tasks is almost instantaneous.

Game loading times

To test whether 4GB of memory makes a difference to level loading times we measured the time taken to load a saved Skirmish game from Company of Heroes: Opposing Fronts. We recorded the time taken to load an 8-player game from the Montargis Region level. We timed from the moment the saved game was selected to the point at which the game was ready to play. We ran each test three times, rebooting after each test.

Company of Heroes – Opposing Fronts

Game loading time	2GB	4GB
1	78 seconds	41 seconds
2	65 seconds	40 seconds
3	68 seconds	40 seconds
Average	**70.3 seconds**	**40.3 seconds**



With 4GB of memory installed the game consistently took around 40 seconds to load. However, with only 2GB of memory installed the game took significantly longer to load – an extra 30 seconds on average. Game loading times were also far less consistent with only 2GB of memory installed compared to 4GB.

Conclusion

These results show that using 4GB of system memory provides significant performance benefits in modern, resource-hungry PC games. Using 4GB of system memory allows your PC's other components to function at peak performance by drastically reducing the need to access data from the pagefile stored on the hard disk drive, which is typically the slowest component in a PC.

The effects of using 4GB of RAM can be clearly seen in our results. With 4GB installed the average frame rate in Company of Heroes: Opposing Fronts increased by 21% and the minimum frame rate rose by an incredible 460%. Similarly, with 4GB installed the minimum frame rate in Crysis rose by 46%, making the game run much more smoothly and enjoyably.

Game loading times were also significantly enhanced by installing 4GB of RAM; a game of Company of Heroes: Opposing Fronts loaded 75% faster with 4GB installed compared to 2GB.

In addition, using 4GB of memory also provides secondary benefits such as increased multi-tasking flexibility. Switching between a game and a forum window in order to make a post is more than 11 times faster with 4GB than with 2GB.

As games become more and more complex the need for 4GB of system memory will only increase, and this means that 4GB of memory is now an essential upgrade for gamers.

Summary of results