THERMAL TESTING ON THE LENOVO THINKPAD T420, DELL LATITUDE E6420, AND HP ELITEBOOK 8460P

Using laptops in the workplace offers workers benefits, including greater mobility and flexibility, but also presents a major drawback: the heat that many laptops give off can frustrate workers, especially when they are on the go. Picking up a hot laptop numerous times a day becomes uncomfortable and annoying. Additionally, hotter operating temperatures are more likely to cause various hardware failures, increasing the expense and inconvenience of laptop repair or replacement and of lost work.

To combat these problems, Lenovo designed the Lenovo ThinkPad T420 with lower operating temperatures in mind.

Principled Technologies used a thermal imaging camera and a data logger to record the surface temperature of the Lenovo ThinkPad T420 and two other laptops in spots that affect user comfort: the palm rest, the touchpad, the fan outlet, and the underside of the laptop at its hottest spot. We measured the temperatures in these areas while various workloads ran, and found that the Lenovo ThinkPad T420 provided a more comfortable user experience than the Dell™ Latitude™ E6420 and HP EliteBook 8460p, by remaining as much as 10.8 degrees Celsius cooler. Because many workers use their laptops constantly throughout the day, and in different locations, the consistently lower temperatures of the Lenovo ThinkPad T420 improve its ability to be a comfortable and reliable laptop for users.

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Commissioned by Lenovo

THE IMPORTANCE OF KEEPING COOL

Many employees have their laptops with them for the majority of their workday—at their workstation, in meetings, at other remote locations, and at home when necessary. For this reason, the match of employee to laptop must be a successful one. When making the purchase decision for your department, remember to factor in basic comfort as a purchase point. The surface temperature of an active laptop plays a significant factor in user comfort—users definitely notice when their laptop is running uncomfortably hot.

The productivity of the entire organization suffers when an employee laptop malfunctions. A user might lose his or her work, have to wait for a replacement system, or waste time attempting to troubleshoot the problem. Furthermore, no company wishes to spend additional money replacing broken laptops. It is common knowledge within the IT industry that operating temperatures degrade hardware reliability. Excess heat can cause hard drives, CPUs, memory, and other components to fail. For example, overheating can expand hard drive platters, causing a hard drive to fail. At the very least, excess heat will likely reduce the drive's effective operating life. According to a recent Fujitsu whitepaper, hard disk manufacturers now suggest cooler operating temperatures for the drive enclosures.[1] Because many users fail to back up their data on a regular basis, adequate ventilation and cooling in a laptop plays a large part in avoiding problems, such as catastrophic data loss due to hard drive failure.

With user comfort and system reliability in mind, we measured the temperature of key spots on the three identically configured laptops, all of which feature the same 2nd generation Intel® Core™ processor, while they ran different workloads. For more information about how we tested, see Appendix D.

We measured the temperature of the laptops at key spots that affect user comfort, and found that the Lenovo ThinkPad T420 generally ran cooler. Figure 1 shows the range of temperatures (above ambient temperature) we recorded at the laptops' key spots, while running each of the six workloads. Because the ambient temperature varied throughout our testing, the temperature difference between the ambient temperature and the surface temperature we recorded for each system makes the fairest comparison.

[1] http://www.fujitsu.com/downloads/COMP/fcpa/hdd/sata-mobile-ext-duty_wp.pdf

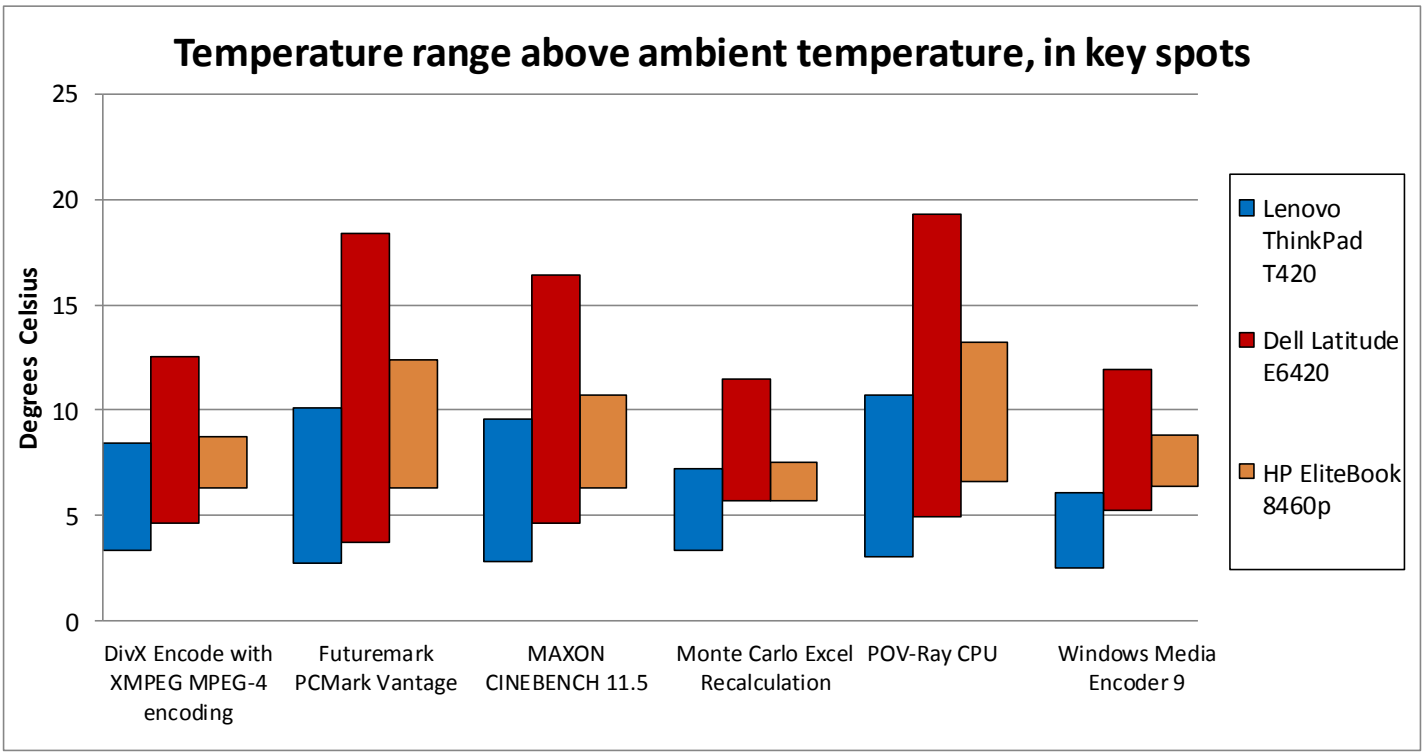


Figure 1: Range in temperatures above ambient temperature, in degrees Celsius, at key spots on the laptops for the six workloads. Lower numbers are better.

WHAT WE FOUND

In our tests, we found that the Lenovo ThinkPad T420 was generally cooler in the key spots we measured while running different workloads. Figure 2 on the next page shows the temperature difference, in degrees Celsius, between the ambient temperature and the surface temperature we recorded for each system, and presents the coolest temperatures in light blue. This measurement provides the best comparison for the user experience the laptops provided. See Appendix C for the absolute temperature readings we recorded.

Laptop	Lenovo ThinkPad T420	Dell Latitude E6420	HP EliteBook 8460p
DivX® Encode with XMPEG MPEG-4 encoding			
Ambient temperature	22.8°C	23.2°C	22.2°C
Right palm rest	ΔT=3.3	ΔT=4.6	ΔT=6.3
Touch pad	ΔT=6.8	ΔT=7.0	ΔT=6.8
Fan outlet	ΔT=5.1	ΔT=12.5	ΔT=8.7
Underside hottest spot	ΔT=8.4	ΔT=10.2	ΔT=8.6
Futuremark® PCMark ®Vantage			
Ambient temperature	23.6°C	23.5°C	21.9°C
Right palm rest	ΔT=2.7	ΔT=3.7	ΔT=6.3
Touch pad	ΔT=6.4	ΔT=7.1	ΔT=6.9
Fan outlet	ΔT=8.1	ΔT=18.4	ΔT=12.4
Underside hottest spot	ΔT=10.1	ΔT=10.9	ΔT=10.0
MAXON CINEBENCH 11.5			
Ambient temperature	23.1°C	23.1°C	22.8°C
Right palm rest	ΔT=2.8	ΔT=4.6	ΔT=6.3
Touch pad	ΔT=6.3	ΔT=7.3	ΔT=6.8
Fan outlet	ΔT=6.7	ΔT=16.4	ΔT=10.7
Underside hottest spot	ΔT=9.6	ΔT=11.9	ΔT=9.3
Monte Carlo Excel® recalculation			
Ambient temperature	23.7°	23.6°	21.5°
Right palm rest	ΔT=3.3	ΔT=5.7	ΔT=5.7
Touch pad	ΔT=6.7	ΔT=8.2	ΔT=6.8
Fan outlet	ΔT=3.8	ΔT=11.0	ΔT=6.6
Underside hottest spot	ΔT=7.2	ΔT=11.5	ΔT=7.5
POV-Ray CPU			
Ambient temperature	24.5°	24.3°	23.6°
Right palm rest	ΔT=3.0	ΔT=4.9	ΔT=6.6
Touch pad	ΔT=6.5	ΔT=7.8	ΔT=7.0
Fan outlet	ΔT=8.5	ΔT=19.3	ΔT=13.2
Underside hottest spot	ΔT=10.7	ΔT=11.7	ΔT=10.4
Windows Media® Encoder 9			
Ambient temperature	23.7°	23.7°	22.3°
Right palm rest	ΔT=2.5	ΔT=5.2	ΔT=6.5
Touch pad	ΔT=6.1	ΔT=8.1	ΔT=7.1
Fan outlet	ΔT=3.5	ΔT=10.0	ΔT=6.4
Underside hottest spot	ΔT=6.1	ΔT=11.9	ΔT=8.8

Figure 2: Degrees Celsius above ambient temperature of key spots for the laptops while running each workload.

Figures 3 through 8 show the thermal images of the laptops, while running the six workloads, with temperatures in degrees Celsius above ambient temperature at key spots on the laptops.

As Figure 3 shows, during the DivX Encode with XMPEG MPEG-4 encoding workload, the key spots on the Lenovo ThinkPad T420 ranged from 3.3°C to 8.4°C above ambient temperature, the Dell Latitude E6420 ranged from 4.6°C to 12.5°C above ambient temperature, and the HP EliteBook 8460p ranged from 6.3°C to 8.7°C above ambient temperature.

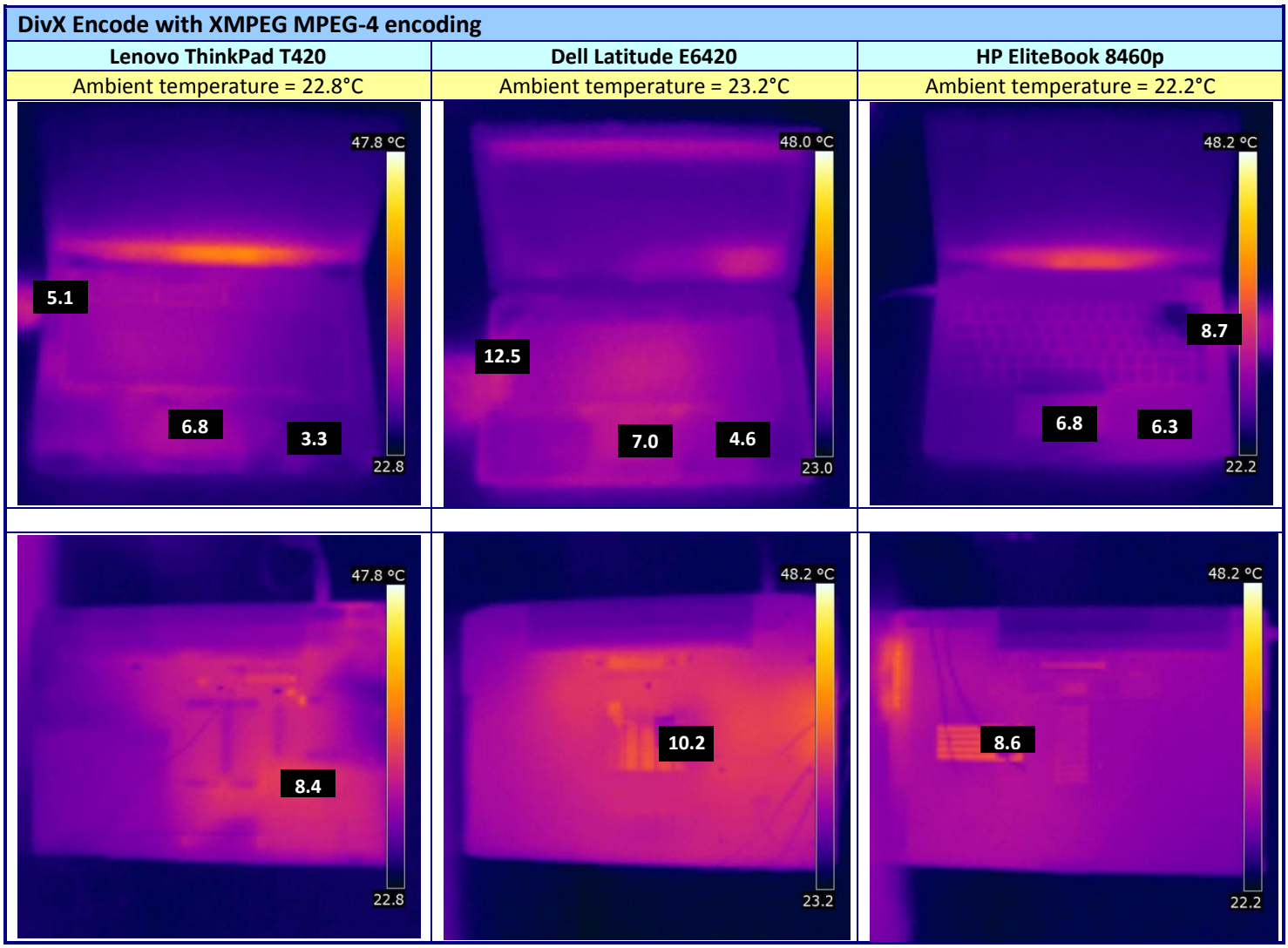


Figure 3: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the DivX Encode with XMPEG MPEG-4 encoding workload.

As Figure 4 shows, during the Futuremark PCMark Vantage workload, the key spots on the Lenovo ThinkPad T420 ranged from 2.7°C to 10.1°C above ambient temperature, the Dell Latitude E6420 ranged from 3.7°C to 18.4°C above ambient temperature, and the HP EliteBook 8460p ranged from 6.3°C to 12.4°C above ambient temperature.

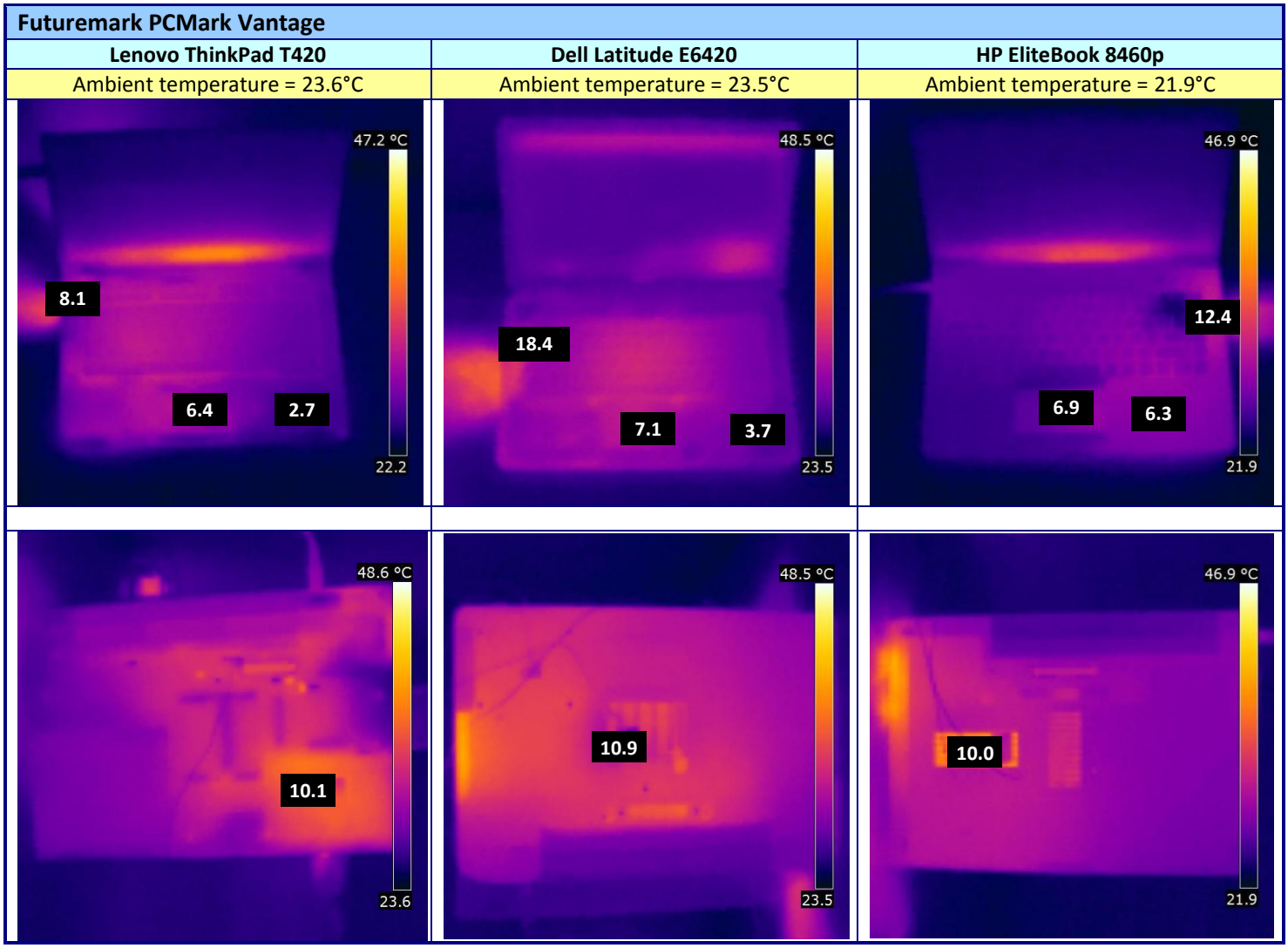


Figure 4: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the Futuremark PCMark Vantage workload.

As Figure 5 shows, during the MAXON CINEBENCH 11.5 workload, the key spots on the Lenovo ThinkPad T420 ranged from 2.8°C to 9.6°C above ambient temperature, the Dell Latitude E6420 ranged from 4.6°C to 16.4°C above ambient temperature, and the HP EliteBook 8460p ranged from 6.3°C to 10.7°C above ambient temperature.

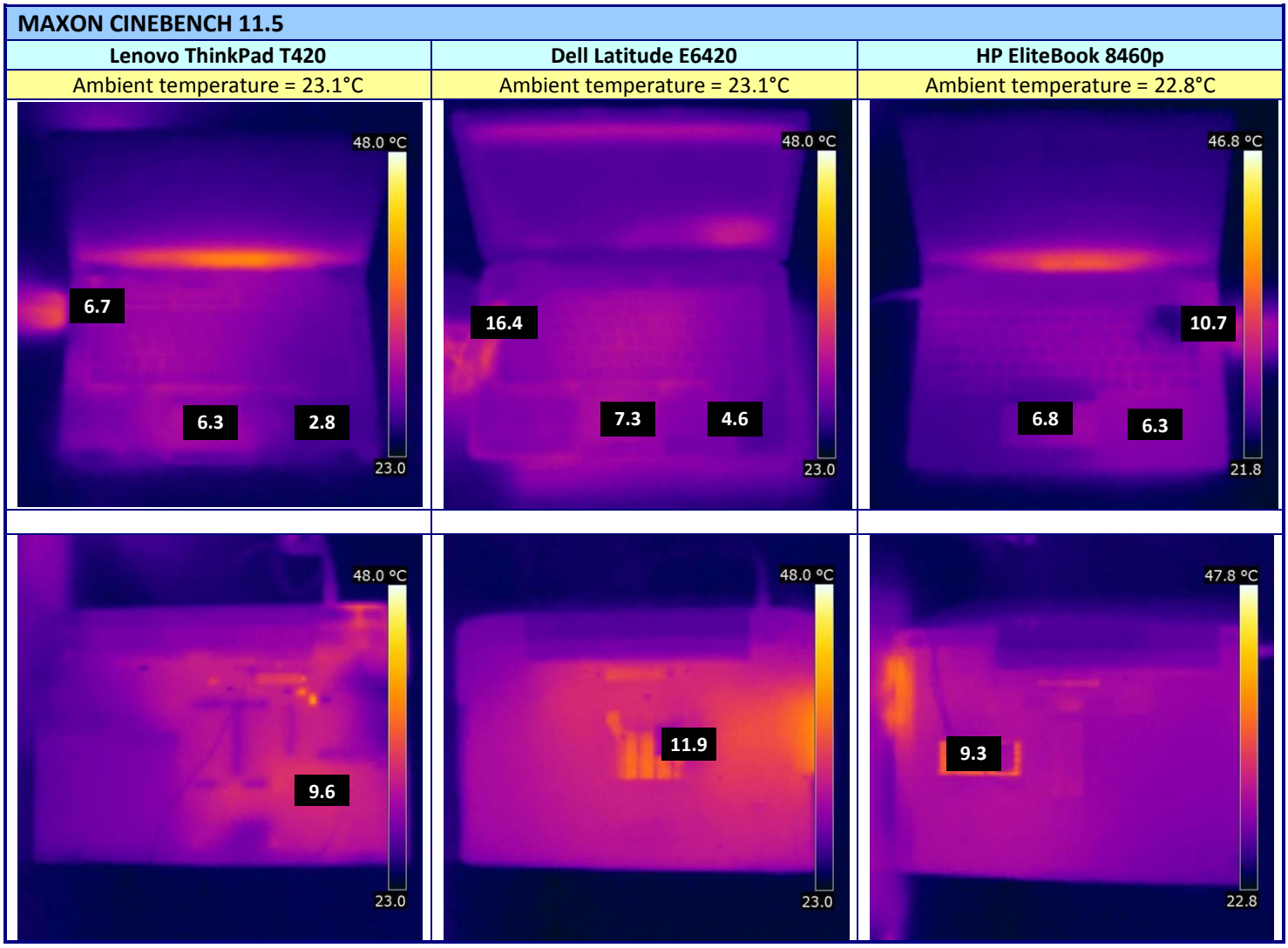


Figure 5: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the MAXON CINEBENCH 11.5 workload.

As Figure 6 shows, during the Monte Carlo Excel recalculation workload, the key spots on the Lenovo ThinkPad T420 ranged from 3.3°C to 7.2°C above ambient temperature, the Dell Latitude E6420 ranged from 5.7°C to 11.5°C above ambient temperature, and the HP EliteBook 8460p ranged from 5.7°C to 7.5°C above ambient temperature.

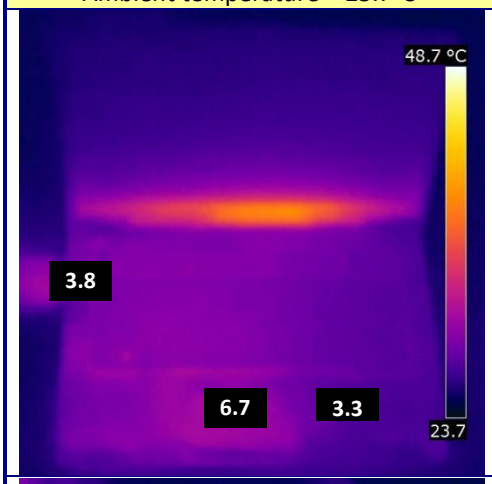
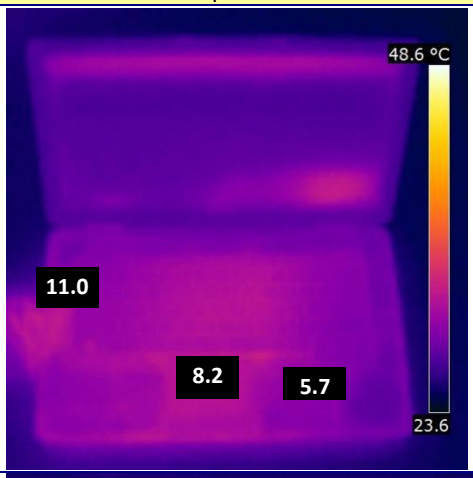
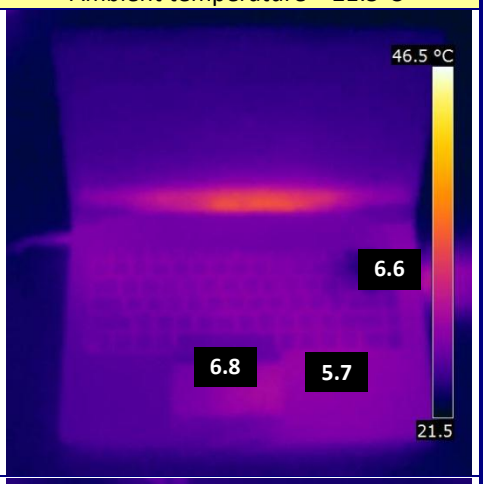
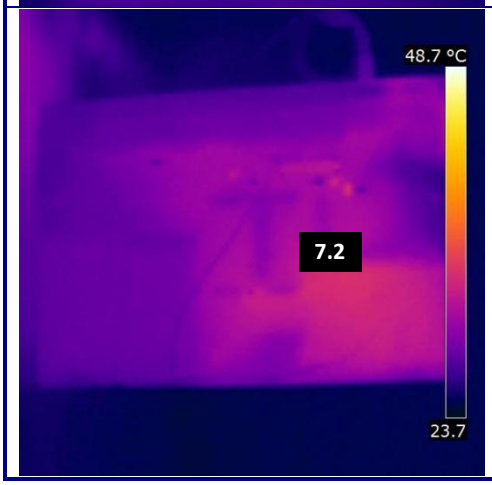
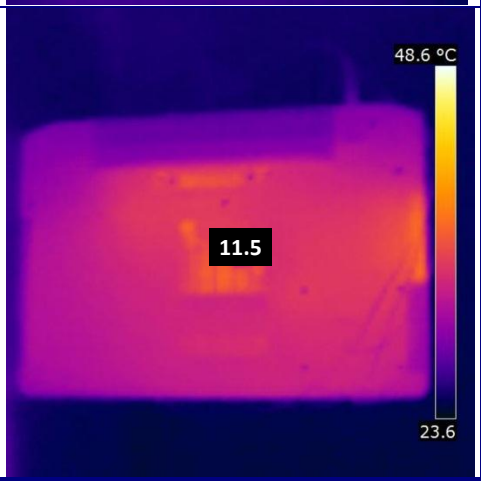
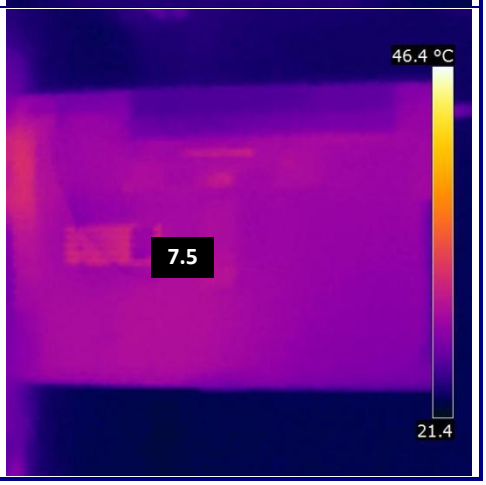
Monte Carlo Excel recalculation		
Lenovo ThinkPad T420	**Dell Latitude E6420**	**HP EliteBook 8460p**
Ambient temperature = 23.7°C	Ambient temperature = 23.6°C	Ambient temperature = 21.5°C
		
		

Figure 6: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the Monte Carlo Excel recalculation workload.

As Figure 7 shows, during the POV-Ray CPU workload, the key spots on the Lenovo ThinkPad T420 ranged from 3.0°C to 10.7°C above ambient temperature, the Dell Latitude E6420 ranged from 4.9°C to 19.3°C above ambient temperature, and the HP EliteBook 8460p ranged from 6.6°C to 13.2°C above ambient temperature.

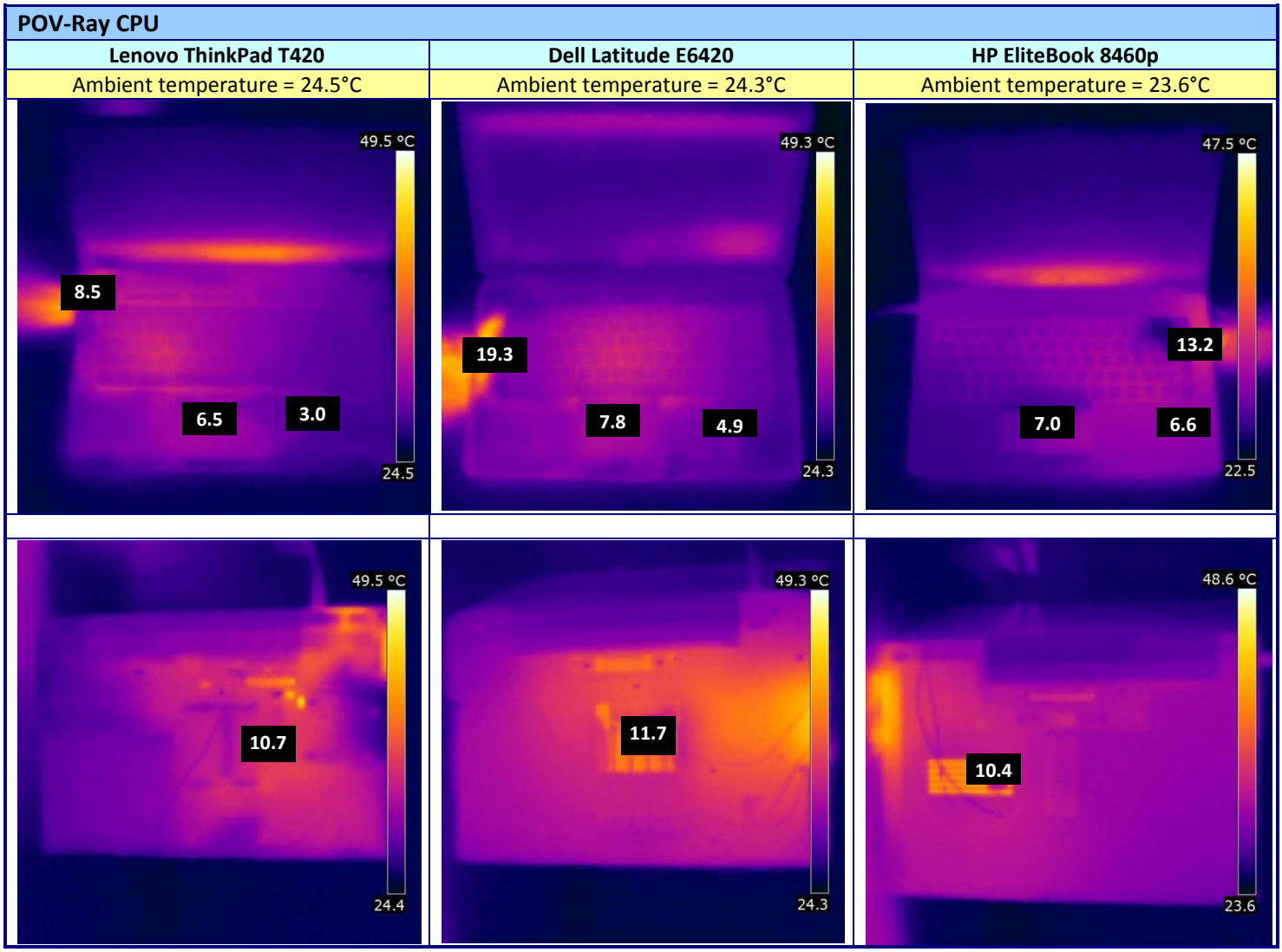


Figure 7: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the POV-Ray CPU workload.

As Figure 8 shows, during the Windows Media Encoder 9 workload, the key spots on the Lenovo ThinkPad T420 ranged from 2.5°C to 6.1°C above ambient temperature, the Dell Latitude E6420 ranged from 5.2°C to 11.9°C above ambient temperature, and the HP EliteBook 8460p ranged from 6.4°C to 8.8°C above ambient temperature.

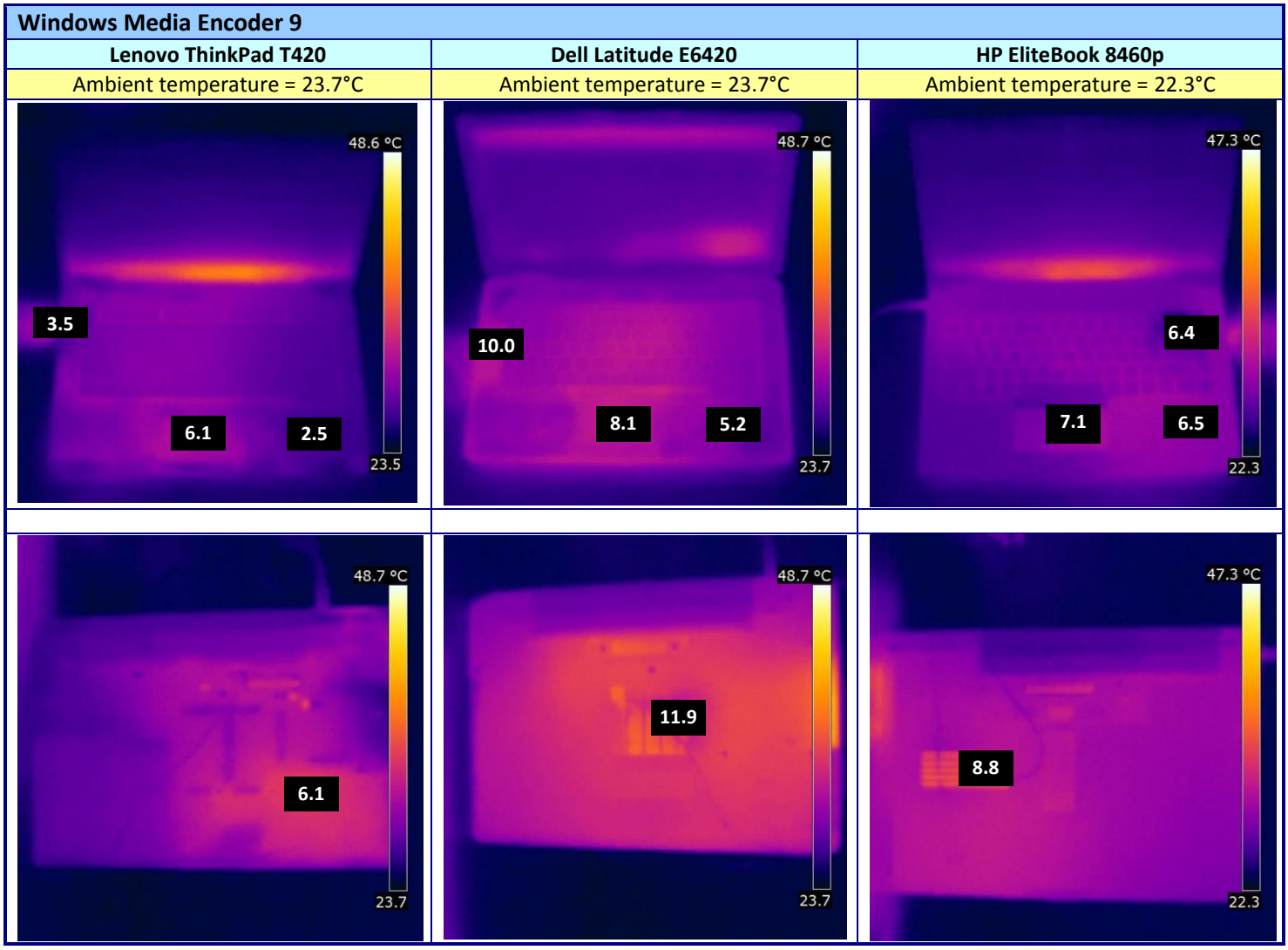


Figure 8: Thermal images, with temperatures, in degrees Celsius above ambient temperature, at key spots for the laptops running the Windows Media Encoder 9 workload.

SUMMARY

As they bring their work from the office to the boardroom to their homes, workers need no longer suffer from the discomfort and reliability problems from laptops that run consistently hot. As we demonstrated in our tests, the Lenovo ThinkPad T420 stays cooler overall than the Dell Latitude E6420 and HP EliteBook 8460p in spots that are key for a pleasant user experience. This makes the Lenovo ThinkPad T420 a great choice for users looking for a laptop with the power of 2nd generation Intel Core processors and the ability to stay cool while handling their most difficult work.

APPENDIX A – SYSTEM CONFIGURATION INFORMATION

Figure 9 provides detailed configuration information about the test systems. Note that PT purchased these systems directly from their respective vendor, and that all systems remained in their factory default setting for our tests.

System	Lenovo ThinkPad T420	Dell Latitude E6420	HP EliteBook 8460p
General			
Number of processor packages	1	1	1
Number of cores per processor	2	2	2
Number of hardware threads per core	2	2	2
System power management policy	Max performance	Ultra performance	High performance
Processor power-saving option	Enhanced Intel SpeedStep® Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology
System dimensions (length x width x height)	13-3/8” x 9-1/4” x 1-3/8”	13-7/8” x 9-1/2” x 1-1/4”	13-3/8” x 9-1/4” x 1-3/8”
System weight	4 lbs. 13 oz.	5 lbs. 5 oz.	5 lbs. 6 oz.
CPU			
Vendor	Intel	Intel	Intel
Name	Core i7	Core i7	Core i7
Model number	2620M	2620M	2620M
Stepping	D2	D2	D2
Socket type and number of pins	Socket 988B rPGA	Socket 988B rPGA	Socket 988B rPGA
Core frequency (GHz)	2.70	2.70	2.70
Bus frequency	5.0 GT/s DMI Link Speed	5.0 GT/s DMI Link Speed	5.0 GT/s DMI Link Speed
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	512 KB (256 KB per core)	512 KB (256 KB per core)	512 KB (256 KB per core)
L3 cache	4 MB (shared)	4 MB (shared)	4 MB (shared)
Platform			
Vendor	Lenovo	Dell	HP
Motherboard model number	4177CTO	0K0DNP	161C
Motherboard chipset	Intel QM67	Intel QM67	Intel QM67
BIOS name and version	Lenovo 83ET46WW (1.16) (03/07/2011)	Dell A01 (03/02/2011)	HP 68SCF Ver. F.01 (03/11/2011)
Memory module(s)			
Vendor and model number	Samsung M471B5273CH0-CH9	Hyundai HMT351S6BFR8C-H9	Samsung M471B5273DH0-CH9
Type	PC3-10600	PC3-10600	PC3-10600
Speed (MHz)	1,333	1,333	1,333
Speed running in the system (MHz)	1,333	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24	9-9-9-24	6-6-6-20
Size (MB)	4,096	4,096	4,096

System	Lenovo ThinkPad T420	Dell Latitude E6420	HP EliteBook 8460p
Number of memory module(s)	1	1	1
Amount of RAM in system (GB)	4	4	4
Chip organization (single-sided/double-sided)	Double-sided	Double-sided	Double-sided
Channel (single/dual)	Single	Single	Single
Hard disk			
Vendor and model number	Hitachi HTS723232A7A364	Western Digital WD3200BEKT-75PVMT0	Hitachi HTS725032A9A364
Number of disks in system	1	1	1
Size (GB)	320	320	320
Buffer size (MB)	16	16	16
RPM	7,200	7,200	7,200
Type	SATA 3.0Gb/s	SATA 3.0 Gb/s	SATA 3.0 Gb/s
Controller	Intel Mobile Express Chipset SATA AHCI Controller	Intel Mobile Express Chipset SATA RAID Controller	Intel Mobile Express Chipset SATA AHCI Controller
Driver	Intel 10.1.0.1008 (11/06/2010)	Intel 10.1.0.1008 (11/06/2010)	Intel 10.1.2.1004 (01/12/2011)
Operating system			
Name	Windows® 7 Professional x64	Windows 7 Professional x64	Windows 7 Professional x64
Build number	7600	7600	7600
Service Pack	NA	NA	NA
File system	NTFS	NTFS	NTFS
Kernel	X64-based PC	X64-based PC	X64-based PC
Language	English	English	English
Microsoft DirectX® version	11	11	11
Graphics			
Vendor and model number	Intel HD Graphics 3000	Intel HD Graphics 3000	Intel HD Graphics 3000
Type	Integrated	Integrated	Integrated
Chipset	Intel HD Graphics Family	Intel HD Graphics Family	Intel HD Graphics Family
BIOS version	2089.0	2089.11	2089.0
Total available graphics memory (MB)	1,696	1,696	1,696
Dedicated video memory (MB)	64	64	64
System video memory (MB)	0	0	0
Shared system memory (MB)	1,632	1,632	1,632
Resolution	1,366 x 768	1,366 x 768	1,366 x 768
Driver	Intel 8.15.10.2321 (03/06/2011)	Intel 8.15.10.2266 (12/16/2010)	Intel 8.15.10.2291 (01/27/2011)
Sound card/subsystem			
Vendor and model number	Conexant 20672 SmartAudio HD	IDT High Definition Audio CODEC	IDT High Definition Audio CODEC

System	Lenovo ThinkPad T420	Dell Latitude E6420	HP EliteBook 8460p
Driver	Conexant 8.32.14.0 (11/22/2010)	IDT 6.10.0.6316 (12/07/2010)	IDT 6.10.6325.0 (01/27/2011)
Ethernet			
Vendor and model number	Intel 82579LM Gigabit	Intel 82579LM Gigabit	Intel 82579LM Gigabit
Driver	Intel 11.8.84.0 (12/21/2010)	Intel 11.8.81.0 (10/28/2010)	Intel 11.8.84.0 (12/21/2010)
Wireless			
Vendor and model number	Intel Centrino Advanced-N 6205	Intel Centrino Advanced-N 6205	Intel Centrino Advanced-N 6205
Driver	Intel 14.0.1.2 (12/21/2010)	Intel 14.0.1.2 (12/21/2010)	Intel 14.0.1.2 (12/21/2010)
Optical drive(s)			
Vendor and model number	Matshita UJ8A0A	TSSTcorp TS-U633J	HP TS-L333F
Type	DVD-RW	DVD-RW	DVD-RW
USB ports			
Number	3	4	4
Type	USB 2.0	USB 2.0	USB 2.0
Other	eSATA & media card reader	eSATA & media card reader	eSATA & media card reader
IEEE 1394 ports			
Number	1	0	1
Monitor			
LCD type	LED	LED	LED
Screen size	14.0”	14.0”	14.0”
Refresh rate (Hz)	60	60	60
Battery			
Type	Lenovo 42T4795 Lithium-ion	Dell T54FJ Lithium-ion	HP CC06 Lithium-ion
Size (length x width x height)	8-3/16” x 2-1/8” x 13/16”	8-1/4” x 2” x 7/8”	8-1/8” x 1-15/16” x 13/16”
Rated capacity	10.8V / 5,200mAh / 57Wh	11.1V / 5,400mAh / 60Wh	11.1V / 5,600mAh / 62Wh
Weight	12 oz.	11 oz.	11 oz.

Figure 9: Configuration information for the test systems.

APPENDIX B – SCHEMATIC OF THE LAPTOP FOR TEMPERATURE READINGS

Figure 10 shows where we measured temperature on the topside of each laptop. Please note that for the HP EliteBook 8460p, the fan outlet area is on the opposite side of the laptop shown here.

Figure 10: Yellow text indicates the areas where we measured temperature.

Figure 11 shows the underside of a laptop, where we measured the hottest spot, as determined by our thermal imager.

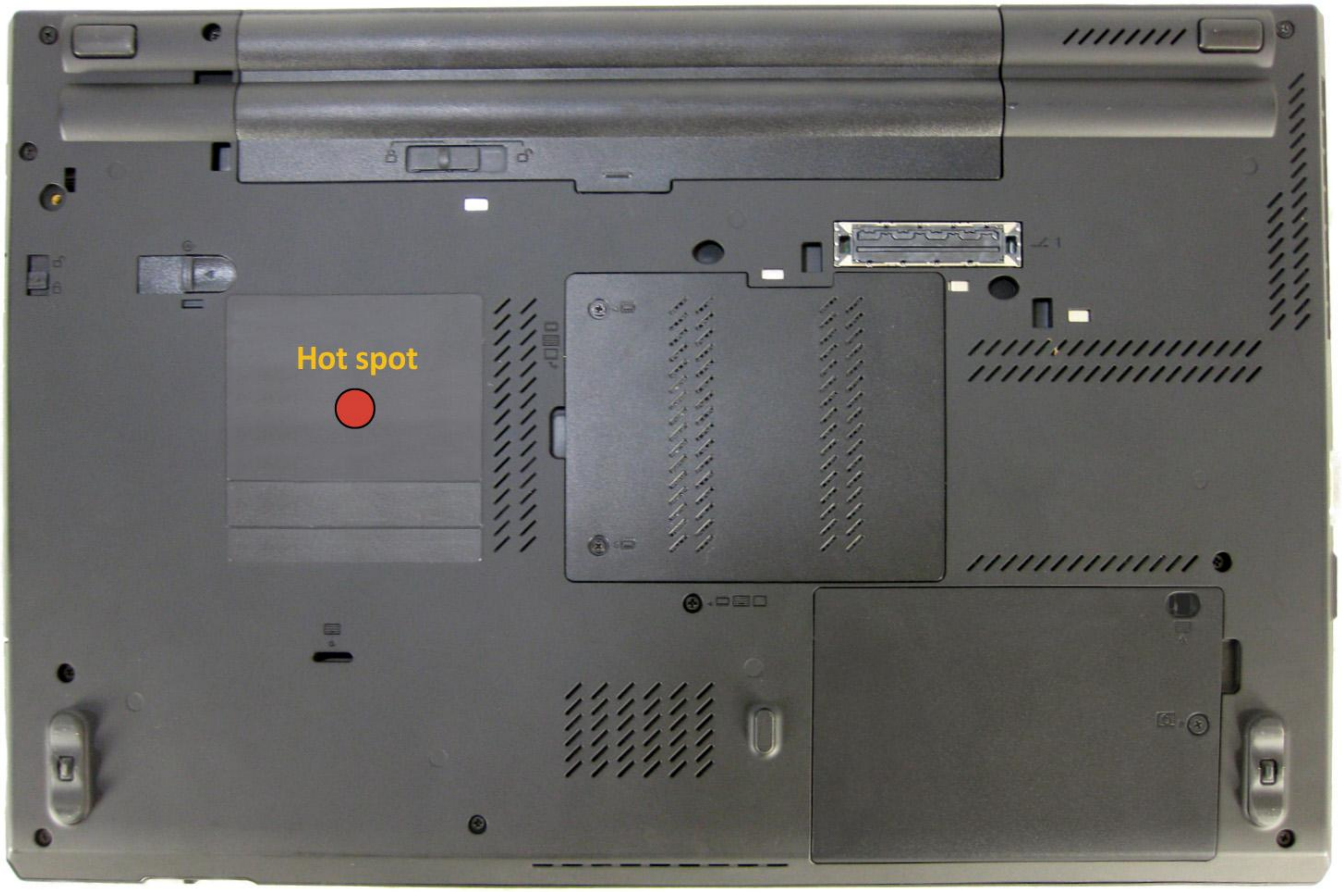


Figure 11: Underside of a laptop. We used a thermal imager to determine the hottest point and measured temperature at that spot.

APPENDIX C – DETAILED TEST RESULTS

Figure 12 shows the laptop temperatures at key spots, in degrees Celsius, while running each workload.

Laptop	Lenovo ThinkPad T420	Dell Latitude E6420	HP EliteBook 8460p
DivX Encode with XMPEG MPEG-4 encoding			
Ambient temperature	22.8°C	23.2°C	22.2°C
Right palm rest	26.1	27.8	28.5
Touch pad	29.6	30.2	29.0
Fan outlet	27.9	35.7	30.9
Underside hottest spot	31.2	33.4	30.8
Futuremark PCMark Vantage			
Ambient temperature	23.6°C	23.5°C	21.9°C
Right palm rest	26.3	27.2	28.2
Touch pad	30.0	30.6	28.8
Fan outlet	31.7	41.9	34.3
Underside hottest spot	33.7	34.4	31.9
MAXON CINEBENCH 11.5			
Ambient temperature	23.1°C	23.1°C	22.8°C
Right palm rest	25.9	27.7	29.1
Touch pad	29.4	30.4	29.6
Fan outlet	29.8	39.5	33.5
Underside hottest spot	32.7	35.0	32.1
Monte Carlo Excel recalculation			
Ambient temperature	23.7°	23.6°	21.5°
Right palm rest	27.0	29.3	27.2
Touch pad	30.4	31.8	28.3
Fan outlet	27.5	34.6	28.1
Underside hottest spot	30.9	35.1	29.0
POV-Ray CPU			
Ambient temperature	24.5°	24.3°	23.6°
Right palm rest	27.5	29.2	30.2
Touch pad	31.0	32.1	30.6
Fan outlet	33.0	43.6	36.8
Underside hottest spot	35.2	36.0	34.0
Windows Media Encoder 9			
Ambient temperature	23.7°	23.7°	22.3°
Right palm rest	26.2	28.9	28.8
Touch pad	29.8	31.8	29.4
Fan outlet	27.2	33.7	28.7
Underside hottest spot	29.8	35.6	31.1

Figure 12: Temperature, in degrees Celsius, of key spots for the laptops while running each workload.

APPENDIX D – HOW WE TESTED

This appendix outlines the series of tests we used to measure surface heat in key spots that affect the user's comfort while working on the system. To measure the thermal profile of the laptop systems as they run various performance benchmarks requires two specialized tools: a FLIR® i7 thermal imaging camera and a Fluke® NetDAQ® 2680A Data Acquisition System with Type T thermocouples, which includes both a hardware device and software that runs on a controller PC.

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. We used Type T thermocouples, which are suited for measurements in the −200° to 350°C range.

Data acquisition (DAQ) is the process of sampling signals that measure real-world physical conditions, in this case, temperature. For our testing, we installed the Fluke DAQ software on a controller PC connected via Ethernet to the NetDAQ device. Five Type T thermocouples connect to the NetDAQ through a 20-channel input module, and attach to five test points on the laptop PC under test. We placed thermocouples in the fan outlet area and underside hot spot by using the Fluke FLIR i7 imaging camera to determine the hottest point in each location. The location of the hard disk test point depends upon the manufacturer's placement of the hard disk. Each of these five channels is configured and controlled using the Fluke DAQ software installed on the controller PC. As each benchmark runs, the NetDAQ logs, in real time, the temperature of each of the five test points. After each run, the NetDAQ log is exported to Excel. We reviewed the output to determine the highest temperature and its associated performance score. In this way, we learned how much the surface temperature rises above ambient temperature when the laptop PC runs performance benchmarks.

In addition to logging the surface temperature in real time with the NetDAQ, we captured a thermal image using a Fluke FLIR i7 thermal imaging camera. These images provide a digital record of the thermal map of both the top and the underside of the laptop for each benchmark test.

The FLIR i7 is fully automatic. Similar to any digital camera, you simply point and click to see the heat variations in heat of the environment or surface of interest. The camera creates a visual representation of heat differences.

All of the tests require a Fluke 2680A Data Acquisition System to measure surface temperature on the laptop and to ensure a consistent ambient temperature between 70°F and 74°F. Appendix B presents a schematic that shows the key spots on each laptop where we measured the temperature.

Setting up the laptop

1. Set the power plan to high performance using the `Power Options` control panel.
2. Set the display brightness to 100 percent:
   a. Click Start.
   b. In the Start menu's quick search field, type `Power Options`.
   c. Move the Screen brightness slider all the way to the right.
3. Set the remaining power plan settings as follows:
   - Dim the display: Never
   - Turn off the display: Never
   - Put the computer to sleep: Never
4. Disable the screen saver.
5. Plug the AC adapter into the laptop, and completely charge the battery.
6. Place the laptop in a windowless, climate-controlled room.
7. Attach a type-t thermocouple to the laptop in the four locations noted in Appendix B.
8. Configure the Fluke NetDAQ 2680A Data Acquisition System to take measurements from the four surface

temperature probes and one ambient temperature probe using the Fluke DAQ software.

a. Connect the five type-t thermocouples to five channels in the Fluke Fast Analog Input module (FAI).
b. In the Fluke DAQ software, click each surface temperature channel, select Thermocouple from the list of Functions, and choose T from the list of ranges.
c. Label each channel with the surface location associated with each thermocouple.
d. In the Fluke DAQ software, click the ambient temperature channel, select Thermocouple from the list of Functions, and choose T from the list of ranges.
e. Label this channel Ambient.

9. While running each test, use a Fluke 2680A Data Acquisition System to monitor ambient and surface temperature.

Measuring surface temperature of the laptop while running the DivX Encode with XMPEG MPEG-4 encoding workload

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera

Setting up the test

1. Reset the system with the appropriate test image.
2. Download XMPEG 5.0.3 from http://www.videohelp.com/tools/XMPEG.
3. Download DivX 8 from http://www.divx.com/en/software/download/start.
4. Install XMPEG 5.03 and DivX 8 with the default options.
5. Copy the hdwatermellon.mpg file to My Videos.
6. Right-click the XMPEG 5.0 window, select Open, select the hdwatermellon.mpg file, and click Open.
7. Right-click the XMPEG 5.0 window again, and select options: Uncheck boxes for auto under the Format and FPS sections; make sure the YV12 format is selected, and click OK.
8. Right-click the XMPEG 5.0 window again, and choose Set Plug-in options.
9. Select the Codec compression radio button.
10. Select the DivX 6.x Codec and click Configure 1st pass.
    - Set the Certification Profile to “1080HD”and click OK.
    - Click Configure 1st pass, again, set the Rate control mode to 1-pass at 8000 kbit/s, and click OK.
    - Click Configure 1st pass, again, slide the Encoding presets slider as far to the right as possible, and click OK. (Ensure this is set the same for all laptops)
11. Click the Audio tab, select No Compression, and click OK.
12. Exit XMPEG.

Running the test

1. Reboot the system.
2. Launch XMPEG, right-click the XMPEG 5.0 window and select Open.
3. Select the hdwatermellon.mpg and click Open.
4. Start the Fluke 2680A data logger using the Fluke DAQ software.
5. Right-click the XMPEG 5.0 window, choose Start Conversion.
6. Stop the Fluke 2680A data logger using the Fluke DAQ software when the conversion completes.
7. Save the thermal measurement data to a CSV file.
8. Repeat steps 2 through 8 two more times, and report the median of the three runs.
9. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
10. Use the time stamp of the highest temperature to determine when to take the thermal image during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

Measuring surface temperature of the laptop while running Futuremark PCMark Vantage

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera

Setting up the test

1. Reset the system with the appropriate test image.
2. Download the PCMark_Vantage_v100_installer.exe Windows package from www.futuremark.com/benchmarks/pcmarkvantage/download/.
3. Install PCMark Vantage 1.0.0 with the default options by double-clicking the PCMark_Vantage_v100_installer.exe file.
4. Launch PCMark Vantage 1.0.0 by clicking on the PCMark Vantage x64 desktop icon. Enter the registration code, click Register, and click OK.
5. Exit PCMark Vantage 1.0.0.
6. Download the PCMark Vantage 1.0.2.0 Patch (PCMark_Vantage_v102_patch_1901.exe Windows package) from www.futuremark.com/benchmarks/pcmarkvantage/download/.
7. Install the patch by double-clicking the PCMark_Vantage_v102_patch_1901.exe file.

Running the test

1. Reboot the system.
2. Double-click the PCMark Vantage desktop icon to launch the benchmark.
3. Verify all test suites are selected, and that the HDD Suite target is set to C:.
4. Start the Fluke 2680A data logger using the Fluke DAQ software.
5. Accept the default settings in PCMark Vantage, and click Run Benchmark.
6. When the benchmark run completes, click Submit results.
7. Stop the Fluke 2680A data logger using the Fluke DAQ software.
8. Save the thermal measurement data to a CSV file from the NetDAQ software.
9. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
10. Use the time stamp of the highest temperature during the first run to determine when to take the thermal image of the laptop during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

Measuring surface temperature of the laptop while running MAXON CINEBENCH 11.5

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera

Setting up the test

1. Reset the system with the appropriate test image.
2. Download CINEBENCH 11.5 from http://www.maxon.net/downloads/cinebench/cinebench-115/disclaimer.html.
3. Double-click CINEBENCH ZIP file to extract CINEBENCH R11.5.

Running the test

1. Reboot the system.
2. Launch CINEBENCH R11.5 by double-clicking the CINEBENCH file in the CINEBENCH_11.529 folder.
3. From the menu, select File→Advanced benchmark.
4. From the list of tests in the left panel, select CPU and CPU (Single Core).

5. Start the Fluke 2680A data logger using the Fluke DAQ software.
6. From the menu, select File→Run all selected tests.
7. Stop the Fluke 2680A data logger using the Fluke DAQ software.
8. Save the thermal measurement data to a CSV file from the NetDAQ software.
9. Close CINEBENCH.
10. When asked if you would like to save your benchmark score, click No.
11. Repeat steps 2 through 10 two more times.
12. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
13. Use the time stamp of the highest temperature during the first run to determine when to take the thermal image of the laptop during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

Measuring surface temperature of the laptop while running the Monte Carlo Excel recalculation workload

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera
- Microsoft Excel 2010
- Monte Carlo Black Sholes test file

Setting up the test

1. Reset the system with the appropriate test image.
2. Copy the MonteCarloBlackScholesOptionPricing.xlsm test file to the Documents directory.
3. Locate the MonteCarloBlackScholesOptionPricing.xlsm workload file, and double-click the file to open it.
4. Click Excel Options.
5. In the left column, click Trust Center.
6. Click Trust Center Settings.
7. In the left column, click Macro Settings, and select Enable all macros.
8. Click OK.
9. Close Excel.

Running the test

1. Reboot the laptop.
2. Start the Fluke 2680A data logger using the Fluke DAQ software.
3. Locate the MonteCarloBlackScholesOptionPricing.xlsm workload file, and double-click the file to open it.
4. Press Ctrl+R to begin the Excel recalculation.
5. When the Excel recalculation completes, a dialog reports the execution time of the scenario.
6. Stop the Fluke 2680A data logger using the Fluke DAQ software.
7. Save the thermal measurement data to a CSV file from the NetDAQ software.
8. Repeat steps 2 through 7 two more times without rebooting between runs.
9. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
10. Use the time stamp of the highest temperature during the first run to determine when to take the thermal image of the laptop during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

Measuring surface temperature of the laptop while running POV-Ray CPU

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera

Setting up the test

1. Reset the system with the appropriate test image.
2. Download the latest version of POV-Ray for Windows (currently version 3.7 RC3) from http://www.povray.org/download/.
3. Install POV-Ray with the default options by double-clicking the.msi you just downloaded.

Running the test

1. Reboot the system.
2. From the Start menu, launch POV-Ray.
3. Start the Fluke 2680A data logger using the Fluke DAQ software.
4. Select the Messages tab, and select Run Benchmark (All CPU's) from the Render menu option.
5. When the benchmark run completes, stop the Fluke 2680A data logger using the Fluke DAQ software.
6. Save the thermal measurement data to a CSV file from the NetDAQ software.
7. Repeat steps 2 through 6 two more times.
8. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
9. Use the time stamp of the highest temperature during the first run to determine when to take the thermal image of the laptop during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

Measuring surface temperature of the laptop while running the Windows Media Encoder 9 workload

Test requirements

- Fluke 2680A Data Acquisition System
- FLIR i7 thermal camera

Setting up the test

1. Reset the system to the base test image.
2. Download and install Microsoft Windows Media Player 10 with default settings from http://www.microsoft.com/windows/windowsmedia/mp10/default.aspx.
3. Download and install Windows Media Encoder 9 with default settings from http://www.microsoft.com/windows/windowsmedia/9series/encoder/default.aspx.
4. Copy the kitesurfing.avi to the My Videos directory.

Running the test

1. Reboot the system.
2. Launch Windows Media Encoder 9 by clicking Start→Programs→Windows Media→Windows Media Encoder.
3. Highlight Custom Session, and click OK.
4. Under the Sources tab, click the File radio button from the choices for Source from.
5. Click the Browse button, and navigate to the kitesurfing.avi file in the My Videos directory.
6. Click Open.
7. Click the Output tab.
8. Uncheck Pull from encoder in the center of the screen.

9. Check Encode to file towards the bottom of the screen.
10. Type `Output` in the File name box.
11. Click the Compression tab.
12. Click Edit…
13. In the Media Types section, select Windows Media Video 9 Advanced Profile next to Video.
14. Click OK.
15. Click Apply. A dialog will appear stating that the output file has been renamed with a new extension.
16. Click OK.
17. Start the Fluke 2680A data logger using the Fluke DAQ software.
18. Click the small green Start Encoding button at the top of the screen. The green progress bar at the bottom-right of the screen shows the status of the encoding process.
19. When an Encoding Results window appears, stop the Fluke 2680A data logger using the Fluke DAQ software.
20. Save the thermal measurement data to a CSV file from the NetDAQ software.
21. Click Close.
22. Close Windows Media Encoder. A window appears asking to save the session.
23. Click No.
24. Using Windows Explorer, find and delete the output.wmv file.
25. Repeat steps 2 through 24 two more times.
26. Use the thermal measurement CSV file to find and report the highest temperature measured at each location during the test.
27. Use the time stamp of the highest temperature during the first run to determine when to take the thermal image of the laptop during the third run of the benchmark. Take images of both the top and bottom of the laptop using a FLIR i7 thermal imaging camera.

APPENDIX E – OUR TEST BENCHMARKS

This section provides a brief explanation of each of the benchmark applications we used to test each laptop.

DivX Encode with XMPEG MPEG-4 encoding

XMPEG open-source conversion software allows users to encode video files to DivX format. We used it to convert an AVI file to DivX format. XMPEG can be downloaded from numerous sites, including http://download.cnet.com/XMPEG/3000-2194_4-10698769.html.

Futuremark PCMark Vantage

Futuremark's PCMark Vantage v1.0.2.0 benchmark suite tests system CPU and GPU performance, RAM speeds, and hard drive read/write speeds. The benchmark runs common tasks such as video playback, audio and video transcoding, data encryption, Windows mail, game testing, and Web page rendering. For more information on this benchmark, see http://www.futuremark.com/benchmarks/pcmarkvantage/introduction/.

MAXON CINEBENCH 11.5

CINEBENCH is a free, real-world cross platform test suite designed to evaluate and compare the CPU and graphics performance across various systems and platforms. Based on MAXON CINEMA 4D software, which creates 3D content, the benchmark consists of two main components: the graphics-card performance test, and the CPU performance test. CINEBENCH uses the processing power of a system to render 3D scenes that stress all available processor cores, and reports performance in points (pts). Higher scores are better, as they indicate a faster processor. To learn more, visit http://www.maxon.net.

Monte Carlo Excel recalculation

The Monte Carlo spreadsheet is a mathematical simulation that runs in Microsoft Office Excel. 300,000 instances of the Monte Carlo-Black Sholes mathematical simulation ran in Excel, where they calculated hypothetical call and put prices, and used Excel's lookup functions to compare these prices against historical market prices.

POV-Ray CPU

The Persistence of Vision Raytracer (POV-Ray) is a 3D-graphics creation tool that provides a good benchmark for CPU usage. We used the 3.7 RC3 release. For more information about POV-Ray, visit http://www.povray.org/.

Windows Media Encoder 9

Microsoft Windows Media Encoder 9 is a tool that allows you to convert or capture both live and prerecorded audio, video, and computer screen images to Windows Media formats. For more information about Windows Media Encoder 9, visit http://windows.microsoft.com/en-US/windows/products/windows-media.

ABOUT PRINCIPLED TECHNOLOGIES

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Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.