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## Revision History

<table>
<thead>
<tr>
<th>Rev</th>
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<th>Date</th>
</tr>
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<tbody>
<tr>
<td>Edition 1</td>
<td>Initial version of this report.</td>
<td>10 November 2017</td>
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## References

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<tr>
<th>Ref #</th>
<th>Document</th>
<th>Author</th>
<th>Date</th>
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Executive Summary

PassMark Software® conducted objective performance testing on fifteen (15) security products. This report presents our results and findings as a result of performance benchmark testing conducted on these products.

For more details on which versions were tested, please see the section “Products and Versions”.

Testing included twenty-three (23) performance metrics. These performance metrics are as follows:

- Boot Time;
- Scan Time;
- User Interface Launch Time;
- Memory Usage during System Idle;
- Memory Usage during Initial Scan;
- Browse Time;
- Edge Launch Time;
- Installation Time;
- Installation Size;
- File Copy, Move and Delete;
- Installation of Third Party Applications;
- Network Throughput (previously named “Binary Download Test”)
- File Format Conversion;
- File Compression and Decompression;
- PE Scan Time;
- File Copy Disk to Disk;
- File Copy Over Network;
- File Download;
- PCMark 8 Home Score;
- Word Document Launch and Open Time;
- Run Excel Macro;
- Save Word Document as PDF; and
- USB 3.0 File Copy.
Overall Score

PassMark Software assigned every product a score depending on its ranking in each metric compared to other products in the same category.

Security Software

In the following table the highest possible score attainable is 345; in a hypothetical situation where a product has attained first place in all 23 metrics. Internet Security products have been ranked by their overall scores:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norton Security</td>
<td>264</td>
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<tr>
<td>ESET Smart Security</td>
<td>218</td>
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<td>F-Secure SAFE</td>
<td>215</td>
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<td>McAfee Internet Security</td>
<td>203</td>
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<tr>
<td>Panda Internet Security</td>
<td>189</td>
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<tr>
<td>Bitdefender Internet Security</td>
<td>182</td>
</tr>
<tr>
<td>Avira Internet Security</td>
<td>175</td>
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<tr>
<td>Windows Defender</td>
<td>174</td>
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<tr>
<td>Kaspersky Internet Security</td>
<td>166</td>
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<tr>
<td>Trend Micro Internet Security</td>
<td>166</td>
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<tr>
<td>G Data Internet Security</td>
<td>163</td>
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<td>Trend Micro Virus Buster</td>
<td>162</td>
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<td>SourceNext ZERO</td>
<td>155</td>
</tr>
<tr>
<td>AVG Internet Security</td>
<td>148</td>
</tr>
<tr>
<td>Avast Internet Security</td>
<td>142</td>
</tr>
</tbody>
</table>
# Products and Versions

The names and versions of the two security products tested are as follows:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product Name</th>
<th>Release Year</th>
<th>Product Version</th>
<th>Date Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symantec Corporation</td>
<td>Norton Security</td>
<td>2017</td>
<td>22.11.0.41</td>
<td>Oct 2017</td>
</tr>
<tr>
<td>Panda Security SL</td>
<td>Panda Internet Security</td>
<td>2016</td>
<td>17.0.1</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>AVG Technologies</td>
<td>AVG Internet Security</td>
<td>2017</td>
<td>17.7.3032</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>Intel Security Group</td>
<td>McAfee Internet Security</td>
<td>2017</td>
<td>16.0.3</td>
<td>Sep 2017</td>
</tr>
<tr>
<td>F-Secure Corporation</td>
<td>F-Secure Internet Security</td>
<td>2017</td>
<td>17.192 build 128</td>
<td>Oct 2017</td>
</tr>
<tr>
<td>Avira Operations GmbH</td>
<td>Avira Internet Security</td>
<td>2017</td>
<td>15.0.32.12</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>ESET, spol. s r.o.</td>
<td>ESET Internet Security</td>
<td>2017</td>
<td>10.1.219.0</td>
<td>Oct 2017</td>
</tr>
<tr>
<td>Trend Micro Inc.</td>
<td>Trend Micro Virus Buster</td>
<td>2017</td>
<td>12.0.1153</td>
<td>Oct 2017</td>
</tr>
<tr>
<td>G Data Software AG</td>
<td>G Data Internet Security</td>
<td>2017</td>
<td>25.4.0.2</td>
<td>Nov 2017</td>
</tr>
<tr>
<td>Kaspersky Lab</td>
<td>Kaspersky Internet Security</td>
<td>2017</td>
<td>22.9.0.68</td>
<td>Sep 2017</td>
</tr>
<tr>
<td>SourceNext Corporation</td>
<td>SourceNext ZERO</td>
<td>2017</td>
<td>21.2.25.23</td>
<td>Oct 2017</td>
</tr>
<tr>
<td>Avast Software</td>
<td>Avast Internet Security</td>
<td>2017</td>
<td>17.7.2314</td>
<td>Sep 2017</td>
</tr>
<tr>
<td>Microsoft Corporation</td>
<td>Windows Defender</td>
<td>2017</td>
<td>Windows 10 Home 1703 OS Build 15063.540</td>
<td>Aug 2017</td>
</tr>
<tr>
<td>Bitdefender</td>
<td>Bitdefender Internet Security</td>
<td>2017</td>
<td>22.0.10.141</td>
<td>Sep 2017</td>
</tr>
</tbody>
</table>
Performance Metrics Summary

We have selected a set of objective metrics which provide a comprehensive and realistic indication of the areas in which a security product may impact system performance for end users. Our metrics test the impact of the security software on common tasks that end-users would perform on a daily basis.

All of PassMark Software’s test methods can be replicated by third parties using the same environment to obtain similar benchmark results. Detailed descriptions of the methodologies used in our tests are available as "Appendix 2 – Methodology Description" of this report.

Benchmark 1 – Boot Time

This metric measures the amount of time taken for the machine to boot into the operating system. Security software is generally launched at Windows startup, adding an additional amount of time and delaying the startup of the operating system. Shorter boot times indicate that the application has had less impact on the normal operation of the machine.

Benchmark 2 – Scan Time

All security solutions have functionality designed to detect viruses and various other forms of malware by scanning files on the system. This metric measured the amount of time required to scan a set of clean files. Our sample file set comprised a total file size of 982 MB and was made up of files that would typically be found on end-user machines, such as media files, system files and Microsoft Office documents.

Benchmark 3 – User Interface Launch Time

This metric provides an objective indication as to how responsive a security product appears to the user, by measuring the amount of time it takes for the user interface of the security software to launch from Windows. To allow for caching effects by the operating system, both the initial launch time and the subsequent launch times were measured. Our final result is an average of these two measurements.

Benchmark 4 – Memory Usage during System Idle

This metric measures the amount of memory (RAM) used by the product while the machine and security software are in an idle state. The total memory usage was calculated by identifying all security software processes and the amount of memory used by each process.

The amount of memory used while the machine is idle provides a good indication of the amount of system resources being consumed by the security software on a permanent basis. Better performing products occupy less memory while the machine is idle.

Benchmark 5 – Memory Usage during Initial Scan

This metric measures the amount of memory (RAM) used by the product during an initial security scan. The total memory usage was calculated by identifying all security software processes and the amount of memory used by each process during the scan.
Benchmark 6 – Browse Time
It is common behavior for security products to scan data for malware as it is downloaded from the internet or intranet. This behavior may negatively impact browsing speed as products scan web content for malware. This metric measures the time taken to browse a set of popular internet sites to consecutively load from a local server in a user’s browser window.

Benchmark 7 – Edge Launch Time
This metric is one of many methods to objectively measure how much a security product impacts on the responsiveness of the system. This metric measures the amount of time it takes to launch the user interface of Microsoft Edge. To allow for caching effects by the operating system, both the initial launch time and the subsequent launch times were measured. Our final result is an average of these two measurements.

Benchmark 8 – Installation Time
The speed and ease of the installation process will strongly influence the user’s first impression of the security software. This test measures the minimum installation time required by the security software to be fully functional and ready for use by the end user. Lower installation times represent security products which are quicker for a user to install.

Benchmark 9 – Installation Size
In offering new features and functionality to users, security software products tend to increase in size with each new release. Although new technologies push the size limits of hard drives each year, the growing disk space requirements of common applications and the increasing popularity of large media files (such as movies, photos and music) ensure that a product’s installation size will remain of interest to home users.

This metric aims to measure a product’s total installation size. This metric is defined as the total disk space consumed by all new files added during a product’s installation.

Benchmark 10 – File Copy, Move and Delete
This metric measures the amount of time taken to move, copy and delete a sample set of files. The sample file set contains several types of file formats that a Windows user would encounter in daily use. These formats include documents (e.g. Microsoft Office documents, Adobe PDF, Zip files, etc), media formats (e.g. images, movies and music) and system files (e.g. executables, libraries, etc).

Benchmark 11 – Installing Third Party Applications
This metric measures the amount of time taken to install and uninstall third party programs. The installation speed of third party applications may be impacted by security behavior such as heuristics or real time malware scanning.

Benchmark 12 – Network Throughput
The metric measures the amount of time taken to download a variety of files from a local server using the HyperText Transfer Protocol (HTTP), which is the main protocol used on the web for browsing, linking and data transfer. Files used in this test include file formats that users would typically download from the web, such as images, archives, music files and movie files.
Benchmark 13 – File Format Conversion
This test measures the amount of time taken to convert an MP3 file to a WAV and subsequently, convert the same MP3 file to a WMA format.

Benchmark 14 – File Compression and Decompression
This metric measures the amount of time taken to compress and decompress different types of files. Files formats used in this test included documents, movies and images.

Benchmark 15 – File Download
This test measures the amount of time taken to download a set of setup files from a local server using the HyperText Transfer Protocol (HTTP). The data set comprised a total file size of 290MB, and the formats used include executables and Microsoft installation packages.

Benchmark 16 – PE Scan Time
All security solutions have functionality designed to detect viruses and various other forms of malware by scanning files on the system. This metric measured the amount of time required to scan a set of PE (Portable Executable) files. Our sample file set comprised a total file size of 2.03GB and consisted of .exe (329MB), .dll (920MB) and .sys files (827MB).

Benchmark 17 – File Copy Disk To Disk
This test measures the amount of time taken to copy files between two local drives. The data set comprised a total file size of 5.44GB, and the formats used included documents, movies, images and executables.

Benchmark 18 – File Copy Over Network
This test measures the amount of time taken to copy files from a local drive to a local server. The data set comprised a total file size of 5.44GB, and the formats used included documents, movies, images and executables.

Benchmark 19 – PCMark 8 Home Score
This test measures the overall performance as an overall score over a range of areas, including memory, video, gaming, music, communications, productivity and HDD performance.

Benchmark 20– Word Document Launch and Open Time
This metric measures how much security software impacts on the responsiveness and performance of the system. This metric measures the amount of time it takes to open a large, mixed media document with Microsoft Word. To allow for caching effects by the operating system, both the initial launch time and the subsequent launch times were measured. Our final result is an average of these two measurements.

Benchmark 21 – Run Excel Macro
This test measures the amount of time taken to open an Excel document and run a macro to perform a range of operations. The test is run five times with a reboot in between each run. Our final result is taken as an average of these five measurements.
Benchmark 22 – Save Word Document as PDF

This test measures the amount of time taken to open a large Word document and save it in PDF format. The test is run five times with a reboot in between each run. Our final result is taken as an average of these five measurements.

Benchmark 23 – USB 3.0 File Copy

This test measures the amount of time taken to copy files from a USB 3.0 drive to a local disk. The data set comprised a total file size of 6.06GB, and the formats used included documents, movies, system files and executables.
Internet Security Software – Test Results

In the following charts, we have highlighted the results we obtained for Norton Security in yellow. The average has also been highlighted in blue for ease of comparison.

**Benchmark 1 – Boot Time (seconds)**

The following chart compares the average time taken for the system to boot (from a sample of five fast boots) for each Internet Security product tested. Products with lower boot times are considered better performing products in this category.
Benchmark 2 – Scan Time (seconds)

The following chart compares the average time taken to scan a set of 6159 files (totaling 982 MB) for each Internet Security product tested. This time is calculated by averaging the initial (Run 1) and subsequent (Runs 2-5) scan times. Products with lower scan times are considered better performing products in this category.
Benchmark 3 – User Interface Launch Time (milliseconds)

The following chart compares the average time taken to launch a product’s user interface. Products with lower launch times are considered better performing products in this category.
Benchmark 4 – Memory Usage during System Idle (megabytes)

The following chart compares the average amount of RAM in use by an Internet Security product during a period of system idle. This average is taken from a sample of ten memory snapshots taken at roughly 60 seconds apart after reboot. Products with lower idle RAM usage are considered better performing products in this category.¹

¹ ESET, Windows Defender, AVG, and Avast were excluded from this test because not all their processes could be seen by the memory logger
Benchmark 5 – Memory Usage during Initial Scan (megabytes)

The following chart compares the average amount of RAM in use by an Internet Security product during a scan. This average is taken from a sample of ten memory snapshots taken at roughly 12 seconds apart. Products with lower idle RAM usage are considered better performing products in this category.²

² ESET, Windows Defender, AVG, and Avast were excluded from this test because not all their processes could be seen by the memory logger.
**Benchmark 6 – Browse Time (seconds)**

The following chart compares the average time taken for the default browser Microsoft Edge to successively load a set of popular websites through the local area network from a local server machine. Products with lower browse times are considered better performing products in this category.\(^3\)

\(^3\) AVG and Avast were excluded from this test as the test script was blocked by the application’s firewall.
Benchmark 7 – Edge Launch Time (milliseconds)

The following chart compares the average launch times of the Microsoft Edge after rebooting the machine for each Internet Security product we tested. Products with lower launch times are considered better performing products in this category.
Benchmark 8 – Installation Time (seconds)

The following chart compares the minimum time it takes for security products to be fully functional and ready for use by the end user. Products with lower installation times are considered better performing products in this category.
Benchmark 9 – Installation Size (megabytes)

The following chart compares the total size of files added during the installation of security products. Products with lower installation sizes are considered better performing products in this category.
Benchmark 10 – File Copy, Move and Delete (seconds)

The following chart compares the average time taken to copy, move and delete several sets of sample files for each Internet Security product tested. Products with lower times are considered better performing products in this category.
Benchmark 11 – Installation of Third Party Applications (seconds)

The following chart compares the average time taken to install 3 different third-party applications for each Internet Security product tested. Products with lower times are considered better performing products in this category.
Benchmark 12 – Network Throughput (seconds)

The following chart compares the average time to download a sample set of common file types for each Internet Security product tested. Products with lower times are considered better performing products in this category.
Benchmark 13 – File Format Conversion (seconds)

The following chart compares the average time it takes for five sample files to be converted from one file format to another (MP3 → WMA, MP3 → WAV) for each Internet Security product tested. Products with lower times are considered better performing products in this category.
Benchmark 14 – File Compression and Decompression (seconds)

The following chart compares the average time it takes for sample files to be compressed and decompressed for each Internet Security product tested. Products with lower times are considered better performing products in this category.

![Chart comparing file compression and decompression times for various Internet Security products. The chart shows that Norton Security has the fastest average time of 39.6 seconds, followed by McAfee Internet Security at 39.4 seconds. The worst performing product is Windows Defender with an average time of 49.4 seconds.]
**Benchmark 15 – File Download (seconds)**

The following chart compares the average time taken to download a set of setup files from a local server. The test was performed 5 times, and the average of all 5 runs was taken as the result. Products with lower times are considered better performing products in this category.⁴

- Norton Security: 3.5
- McAfee Internet Security: 3.8
- Kaspersky Internet Security: 3.8
- Trend Micro Virus Buster: 3.9
- Trend Micro Internet Security: 4.0
- F-Secure SAFE: 4.1
- Windows Defender: 4.4
- Avira Internet Security: 4.5
- G Data Internet Security: 4.9
- SourceNext ZERO: 5.3
- Bitdefender Internet Security: 5.5
- ESET Internet Security: 5.7
- Average: 7.1
- Avast Internet Security: 24.1
- AVG Internet Security: 25.3

⁴ Panda Internet Security was excluded from this test as the test script was blocked by the application.
Benchmark 16 – PE Scan Time (seconds)

The following chart compares the average time taken to scan a set of 6351 portable executable files (totaling 2076 MB) for each Internet Security product tested. This time is calculated by averaging the initial (Run 1) and subsequent (Runs 2-5) scan times. Products with lower scan times are considered better performing products in this category.
Benchmark 17 – File Copy Disk to Disk (seconds)

The following chart compares the average time taken to copy a total of 8,501 files, with a total file size of 5.44GB files, from one local drive to another local drive for each Internet Security product tested. The test was performed 5 times, and the average of all 5 runs was taken as the result. Products with lower times are considered better performing products in this category.
Benchmark 18 – File Copy Over Network (seconds)

The following chart compares the average time taken to transfer a total of 8,501 files over the local network, with a total file size of 5.44GB files, from a local drive on the test machine to a local server. The test was performed 5 times, and the average of all 5 runs was taken as the result. Products with lower times are considered better performing products in this category. 

<table>
<thead>
<tr>
<th>Product</th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trend Micro Virus Buster</td>
<td>95.1</td>
</tr>
<tr>
<td>ESET Internet Security</td>
<td>152.8</td>
</tr>
<tr>
<td>F-Secure SAFE</td>
<td>153.0</td>
</tr>
<tr>
<td>McAfee Internet Security</td>
<td>153.4</td>
</tr>
<tr>
<td>G Data Internet Security</td>
<td>155.7</td>
</tr>
<tr>
<td>Norton Security</td>
<td>156.0</td>
</tr>
<tr>
<td>Kaspersky Internet Security</td>
<td>160.3</td>
</tr>
<tr>
<td>Average</td>
<td>165.2</td>
</tr>
<tr>
<td>Bitdefender Internet Security</td>
<td>169.5</td>
</tr>
<tr>
<td>Trend Micro Internet Security</td>
<td>172.6</td>
</tr>
<tr>
<td>Panda Internet Security</td>
<td>174.0</td>
</tr>
<tr>
<td>Avira Internet Security</td>
<td>175.3</td>
</tr>
<tr>
<td>Avast Internet Security</td>
<td>185.9</td>
</tr>
<tr>
<td>AVG Internet Security</td>
<td>185.9</td>
</tr>
<tr>
<td>SourceNext ZERO</td>
<td>186.1</td>
</tr>
<tr>
<td>Windows Defender</td>
<td>214.8</td>
</tr>
</tbody>
</table>

5 AVG was excluded from this test as the test script was blocked by the application’s firewall.
Benchmark 19 – PCMark 8 Home Score

The following chart compares the average PCMark 8 Home score for each Internet Security product tested. The test was performed 2 times, and the average of both runs was taken as the result. Products with higher scores are considered better performing products in this category.
Benchmark 20 – Word Document Launch and Open Time (milliseconds)

The following chart compares the average time taken to launch Microsoft Word and open a 10MB document. Products with lower launch times are considered better performing products in this category.

- ESET Internet Security: 1970 ms
- Avira Internet Security: 2024 ms
- SourceNext ZERO: 2049 ms
- F-Secure SAFE: 2049 ms
- Trend Micro Internet Security: 2125 ms
- Panda Internet Security: 2162 ms
- Avast Internet Security: 2205 ms
- Bitdefender Internet Security: 2355 ms
- Average: 2515 ms
- AVG Internet Security: 2545 ms
- Kaspersky Internet Security: 2642 ms
- Windows Defender: 2666 ms
- Trend Micro Virus Buster: 2805 ms
- G Data Internet Security: 2823 ms
- Norton Security: 3067 ms
- McAfee Internet Security: 4674 ms
**Benchmark 21 – Run Excel Macro (seconds)**

The following chart compares the average time taken to launch Microsoft Excel and run a macro. Products with lower times are considered better performing products in this category.
Benchmark 22 – Save Word Document to PDF (seconds)

The following chart compares the average time taken to launch Microsoft Word and open a 10MB document and save it as a PDF. Products with lower times are considered better performing products in this category.
**Benchmark 23 – USB 3.0 File Copy (seconds)**

The following chart compares the average time taken to copy a set of files from an external USB 3.0 drive to a local disk. Products with lower times are considered better performing products in this category. 6

<table>
<thead>
<tr>
<th>Product</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McAfee Internet Security</td>
<td>44.5</td>
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<tr>
<td>Avast Internet Security</td>
<td>45.7</td>
</tr>
<tr>
<td>AVG Internet Security</td>
<td>45.9</td>
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<tr>
<td>Norton Security</td>
<td>46.2</td>
</tr>
<tr>
<td>Panda Internet Security</td>
<td>47.6</td>
</tr>
<tr>
<td>Trend Micro Internet Security</td>
<td>49.2</td>
</tr>
<tr>
<td>Trend Micro Virus Buster</td>
<td>50.8</td>
</tr>
<tr>
<td>ESET Internet Security</td>
<td>58.0</td>
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<tr>
<td>SourceNext ZERO</td>
<td>74.8</td>
</tr>
<tr>
<td>Bitdefender Internet Security</td>
<td>90.1</td>
</tr>
<tr>
<td>Average</td>
<td>91.7</td>
</tr>
<tr>
<td>F-Secure SAFE</td>
<td>168.1</td>
</tr>
<tr>
<td>Windows Defender</td>
<td>210.5</td>
</tr>
<tr>
<td>Kaspersky Internet Security</td>
<td>309.0</td>
</tr>
</tbody>
</table>

6 Avira and G Data were excluded from this benchmark because the security software blocked the test script from running to completion.
Disclaimer and Disclosure

This report only covers the versions that are listed in the “Products and Versions” section of this report.

Disclaimer of Liability

While every effort has been made to ensure that the information presented in this report is accurate, PassMark Software Pty Ltd assumes no responsibility for errors, omissions, or out-of-date information and shall not be liable in any manner whatsoever for direct, indirect, incidental, consequential, or punitive damages resulting from the availability of, use of, access of, or inability to use this information.

Disclosure

Symantec Corporation funded the production of this report, selected the test metrics and list of products to include in this report, and supplied some of the test scripts used for the tests.

Trademarks

All trademarks are the property of their respective owners.

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Appendix 1 – Test Environment

For our testing, PassMark Software used a test environment running Windows 10 Home (64-bit) with the following hardware specifications:

**Windows 10 Home (64-bit) System**

<table>
<thead>
<tr>
<th>Model</th>
<th>Lenovo H50W-50 i5</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Intel Core i5-4460 CPU @ 3.20GHz 3.20 GHz</td>
</tr>
<tr>
<td>Video Card</td>
<td>NVIDIA GeForce GT 705</td>
</tr>
<tr>
<td>RAM</td>
<td>8GB DDR3 RAM</td>
</tr>
<tr>
<td>SSD (Main Boot Drive)</td>
<td>Intel SSD 730 Series 240GB</td>
</tr>
<tr>
<td>2nd Drive</td>
<td>Samsung 1000GB 7200RPM HD103UJ</td>
</tr>
<tr>
<td>Network</td>
<td>Gigabit (1GB/s) switch</td>
</tr>
<tr>
<td>O/S</td>
<td>Windows 10 Home 10.0 (Build 10240)</td>
</tr>
</tbody>
</table>

For network tests (wget, http), PassMark Software used a server with the following specifications:

**Test Server – Windows Server 2012**

<table>
<thead>
<tr>
<th>CPU</th>
<th>Intel Xeon E3-1220v2 CPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Card</td>
<td>Kingston 8GB (2 x 4GB) ECC</td>
</tr>
<tr>
<td>Motherboard</td>
<td>Intel S1200BTL Server Motherboard</td>
</tr>
<tr>
<td>RAM</td>
<td>4GB DDR3 RAM, 1333 Mhz</td>
</tr>
<tr>
<td>HDD</td>
<td>Samsung 1.5TB 7200RPM</td>
</tr>
<tr>
<td>Network</td>
<td>Gigabit (1GB/s) switch</td>
</tr>
</tbody>
</table>
Appendix 2 – Methodology Description

Windows 10 Image Creation
A bootable version of OSForensics was used to create a “clean” baseline image prior to testing. Our aim was to create a baseline image with the smallest possible footprint and reduce the possibility of variation caused by external operating system factors.

The baseline image was restored prior to testing of each different product. This process ensures that we install and test all products on the same, “clean” machine.

The steps taken to create the base Windows 10 image are as follows:

1. Installation and activation of Windows 10 Home Edition.
2. Disabled Automatic Updates.
3. Changed User Account Control settings to “Never Notify”.
4. Disable Windows Defender automatic scans to avoid unexpected background activity.
5. Disable the Windows firewall to avoid interference with security software.
6. Disabled Superfetch to ensure consistent results.
7. Installed HTTP Watch for Browse Time testing.
8. Installed Windows Performance Toolkit x64 for Boot Time testing.
9. Installed Active Perl for interpretation of some test scripts.
10. Install OSForensics for testing (Installation Size) purposes.
11. Update Windows.
13. Created a baseline image of the boot drive using OSForensics.

Benchmark 1 – Boot Time
PassMark Software uses tools available from the Windows Performance Toolkit (as part of the Microsoft Windows 10 ADK obtainable from the Microsoft Website).

The Boot Performance (fast startup) test is ran as an individual assessment via the Windows Assessment Console. The network connection is disabled and the login password is removed to avoid interruption to the test. The final result is taken as the total boot duration excluding BIOS load time.

Benchmark 2 – Scan Time
Scan Time is the time it took for each product to scan a set of sample files. The sample used was identical in all cases and contained a mixture of system files and Office files. In total there were 6159 files whose combined size was 982 MB. Most of these files come from the Windows system folders. As the file types can influence scanning speed, the breakdown of the main file types, file numbers and total sizes of the files in the sample set is given here:

<table>
<thead>
<tr>
<th>File Extension</th>
<th>Number of Files</th>
<th>File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>.dll</td>
<td>2589</td>
<td>490MB</td>
</tr>
</tbody>
</table>
This scan was run without launching the product’s user interface, by right-clicking the test folder and choosing the “Scan Now” option. To record the scan time, we have used product’s built-in scan timer or reporting system. Where this was not possible, scan times were taken manually with a stopwatch.

In previous years of testing, we noticed many more products showing a substantial difference between the initial scan time (first scan) and subsequent scan times (scans 2 to 5). We believe this behavior is due to products themselves caching recently scanned files.

As a result of this mechanism, we have averaged the four subsequent scan times to obtain an average subsequent scan time. Our final result for this test is an average of the subsequent scan average and the initial scan time.
Benchmark 3 – User Interface Launch Time

The launch time of a product’s user interface was taken using AppTimer (v1.0.1006). For each product tested, we obtained a total of fifteen samples from five sets of three UI launches, with a reboot before each set to clear caching effects by the operating system. When compiling the results the first of each set was separated out so that there was a set of values for the initial launch after reboot and a set for subsequent launches.

We have averaged the subsequent launch times to obtain an average subsequent launch time. Our final result for this test is an average of the subsequent launch average and the initial launch time.

In some cases, AppTimer did not correctly record the time taken for UI launch. For instance, some applications would open their window and look like they were ready, but then continued to be unresponsive. Where the measurement from AppTimer appeared inaccurate, we have taken the time manually with a stop watch.

AppTimer is publically available from the PassMark Website.

Benchmark 4 – Memory Usage during System Idle

The MemLog++ utility was used to record process memory usage on the system at boot, and then every minute for another fifteen minutes after. This was done only once per product and resulted in a total of 15 samples. The first sample taken at boot is discarded.

The MemLog++ utility records memory usage of all processes, not just those of the anti-malware product. As a result of this, an anti-malware product’s processes needed to be isolated from all other running system processes. To isolate relevant process, we used a program called Process Explorer which was run immediately upon the completion of memory usage logging by MemLog++. Process Explorer is a Microsoft Windows Sysinternals software tool which shows a list of all DLL processes currently loaded on the system.

Benchmark 5 – Memory Usage during Initial Scan

The MemLog ++ utility was used to record process memory during an on-demand scan of the boot drive over a 2 minute period. This was done only once per product and resulted in a total of 10 samples each.

The MemLog ++ utility records memory usage of all processes, not just those of the anti-malware product. As a result of this, an anti-malware product’s processes needed to be isolated from all other running system processes. To isolate relevant process, we used a program called Process Explorer which was run immediately upon the completion of memory usage logging by MemLog ++. Process Explorer is a Microsoft Windows Sysinternals software tool which shows a list of all DLL processes currently loaded on the system.

Benchmark 6 – Browse Time

We used Javascript to load a list of 103 ‘popular’ websites consecutively from a local server.

On each page in the sample data, a few lines of javascript are added to the website’s html to execute the javascript script that loads the next website in the chain. To begin with, once the first website has been loaded completely, the script is executed to load the second website in the chain. Once this has finished loading, the script is executed to then load the third website in the chain. This process is repeated until the final website in the chain has loaded.
The start time and end time of this process are recorded and the difference is calculated in seconds to get the final result.

For this test, we have used the default Windows browser *Microsoft Edge* (Version 38.143930.0).

The set of websites used in this test include front pages of high traffic pages. This includes shopping, social, news, finance and reference websites.

The Browse Time test is executed five times and our final result is an average of these five samples. The local server is restarted between different products and one initial 'test' run is conducted.

**Benchmark 7 – Edge Launch Time**

The average launch time of Microsoft Edge interface was taken using *AppTimer*. This test was practically identical to the User Interface launch time test. For each product tested, we obtained a total of fifteen samples from five sets of three Edge launches, with a reboot before each set to clear caching effects by the operating system. When compiling the results, the first of each set was separated out so that there was a set of values for the initial launch after reboot and a set for subsequent launches.

For this test, we have used *Microsoft Edge* *(Version 40.15063.0.0)* as our test browser.

We have averaged the subsequent launch times to obtain an average subsequent launch time. Our final result for this test is an average of the subsequent launch average and the initial launch time.

*AppTimer* is publicly available from the [PassMark Website](https://www.passmark.com).

**Benchmark 8 – Installation Time**

This test measures the minimum Installation Time a product requires to be fully functional and ready for use by the end user. Installation time can usually be divided in three major phases:

- **The Extraction and Setup phase** consists of file extraction, the EULA prompt, product activation and user configurable options for installation.

- **The File Copy phase** occurs when the product is being installed; usually this phase is indicated by a progress bar.

- **The Post-installation phase** is any part of the installation that occurs after the File Copy phase. This phase varies widely between products; the time recorded in this phase may include a required reboot to finalize the installation or include the time the program takes to become idle in the system tray.

To reduce the impact of disk drive variables, each product was copied to the Desktop before initializing installation. Each step of the installation process was manually timed with a stopwatch and recorded in as much detail as possible. Where input was required by the end user, the stopwatch was paused and the input noted in the raw results in parenthesis after the phase description.

Where possible, all requests by products to pre-scan or post-install scan were declined or skipped. Where it was not possible to skip a scan, the time to scan was included as part of the installation time. Where an optional
component of the installation formed a reasonable part of the functionality of the software, it was also installed (e.g. website link checking software as part of an Internet Security Product).

Installation time includes the time taken by the product installer to download components required in the installation. This may include mandatory updates or the delivery of the application itself from a download manager. We have noted in our results where a product has downloaded components for product installation.

We have excluded product activation times due to network variability in contacting vendor servers or time taken in account creation.

**Benchmark 9 – Installation Size**

A product’s Installation Size was previously defined as the difference between the initial snapshot of the Disk Space (C: drive) before installation and the subsequent snapshot taken after the product is installed on the system. Although this is a widely used methodology, we noticed that the results it yielded were not always reproducible in Vista due to random OS operations that may take place between the two snapshots. We improved the Installation Size methodology by removing as many Operating System and disk space variables as possible.

Using PassMark’s OSForensics we created initial and post-installation disk signatures for each product. These disk signatures recorded the amount of files and directories, and complete details of all files on that drive (including file name, file size, checksum, etc) at the time the signature was taken.

The initial disk signature was taken immediately prior to installation of the product. A subsequent disk signature was taken immediately following a manual update and system reboot after product installation. Using OSForensics, we compared the two signatures and calculated the total disk space consumed by files that were new, modified, and deleted during product installation. Our result for this metric reflects the total size of all newly added files during installation.

**Benchmarks 10-15 – Real-Time Performance**

We used a single script in testing Benchmarks 9-14. The script consecutively executes tests for Benchmarks 9-14. The script times each phase in these benchmarks using CommandTimer.exe and appends results to a log file.

**Benchmarks 10 – File Copy, Move and Delete**

This test measures the amount of time required for the system to copy, move and delete samples of files in various file formats. This sample was made up of 812 files over 760,867,636 bytes and can be categorized as documents [26% of total], media files [54% of total] and PE files (i.e. System Files) [20% of total].

The breakdown of the main file types, file numbers and total sizes of the files in the sample set is shown in the following table:

<table>
<thead>
<tr>
<th>File format</th>
<th>Number</th>
<th>Size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC</td>
<td>8</td>
<td>30,450,176</td>
</tr>
<tr>
<td>DOCX</td>
<td>4</td>
<td>13,522,409</td>
</tr>
<tr>
<td>PPT</td>
<td>3</td>
<td>5,769,216</td>
</tr>
<tr>
<td>PPTX</td>
<td>3</td>
<td>4,146,421</td>
</tr>
<tr>
<td>File Type</td>
<td>Count</td>
<td>Size</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>---------------</td>
</tr>
<tr>
<td>XLS</td>
<td>4</td>
<td>2,660,352</td>
</tr>
<tr>
<td>XLSX</td>
<td>4</td>
<td>1,426,054</td>
</tr>
<tr>
<td>PDF</td>
<td>73</td>
<td>136,298,049</td>
</tr>
<tr>
<td>ZIP</td>
<td>4</td>
<td>6,295,987</td>
</tr>
<tr>
<td>7Z</td>
<td>1</td>
<td>92,238</td>
</tr>
<tr>
<td>JPG</td>
<td>351</td>
<td>31,375,259</td>
</tr>
<tr>
<td>GIF</td>
<td>6</td>
<td>148,182</td>
</tr>
<tr>
<td>MOV</td>
<td>7</td>
<td>57,360,371</td>
</tr>
<tr>
<td>RM</td>
<td>1</td>
<td>5,658,646</td>
</tr>
<tr>
<td>AVI</td>
<td>8</td>
<td>78,703,408</td>
</tr>
<tr>
<td>WMV</td>
<td>5</td>
<td>46,126,167</td>
</tr>
<tr>
<td>MP3</td>
<td>28</td>
<td>191,580,387</td>
</tr>
<tr>
<td>EXE</td>
<td>19</td>
<td>2,952,914</td>
</tr>
<tr>
<td>DLL</td>
<td>104</td>
<td>29,261,568</td>
</tr>
<tr>
<td>AX</td>
<td>1</td>
<td>18,432</td>
</tr>
<tr>
<td>CPL</td>
<td>2</td>
<td>2,109,440</td>
</tr>
<tr>
<td>CPX</td>
<td>2</td>
<td>4,384</td>
</tr>
<tr>
<td>DRV</td>
<td>10</td>
<td>154,864</td>
</tr>
<tr>
<td>ICO</td>
<td>1</td>
<td>107,620</td>
</tr>
<tr>
<td>MSC</td>
<td>1</td>
<td>41,587</td>
</tr>
<tr>
<td>NT</td>
<td>1</td>
<td>1,688</td>
</tr>
<tr>
<td>ROM</td>
<td>2</td>
<td>36,611</td>
</tr>
<tr>
<td>SCR</td>
<td>2</td>
<td>2,250,240</td>
</tr>
<tr>
<td>SYS</td>
<td>1</td>
<td>37,528,093</td>
</tr>
<tr>
<td>TLB</td>
<td>3</td>
<td>135,580</td>
</tr>
<tr>
<td>TSK</td>
<td>1</td>
<td>1,152</td>
</tr>
<tr>
<td>UCE</td>
<td>1</td>
<td>22,984</td>
</tr>
<tr>
<td>EXE</td>
<td>19</td>
<td>2,952,914</td>
</tr>
<tr>
<td>DLL</td>
<td>104</td>
<td>29,261,568</td>
</tr>
<tr>
<td>AX</td>
<td>1</td>
<td>18,432</td>
</tr>
<tr>
<td>CPL</td>
<td>2</td>
<td>2,109,440</td>
</tr>
<tr>
<td>CPX</td>
<td>2</td>
<td>4,384</td>
</tr>
<tr>
<td>DRV</td>
<td>10</td>
<td>154,864</td>
</tr>
<tr>
<td>ICO</td>
<td>1</td>
<td>107,620</td>
</tr>
<tr>
<td>MSC</td>
<td>1</td>
<td>41,587</td>
</tr>
<tr>
<td>NT</td>
<td>1</td>
<td>1,688</td>
</tr>
<tr>
<td>ROM</td>
<td>2</td>
<td>36,611</td>
</tr>
<tr>
<td>SCR</td>
<td>2</td>
<td>2,250,240</td>
</tr>
<tr>
<td>-----</td>
<td>----</td>
<td>----------</td>
</tr>
<tr>
<td>SYS</td>
<td>1</td>
<td>37,528,093</td>
</tr>
<tr>
<td>TLB</td>
<td>3</td>
<td>135,580</td>
</tr>
<tr>
<td>TSK</td>
<td>1</td>
<td>1,152</td>
</tr>
<tr>
<td>UCE</td>
<td>1</td>
<td>22,984</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>812</strong></td>
<td><strong>760,867,636</strong></td>
</tr>
</tbody>
</table>

This test was conducted five times to obtain the average time to copy, move and delete the sample files, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 11 – Third Party Program Installation**

This test measured how much time was required to install and uninstall a third party application. For this test, *CommandTimer.exe* timed how long it took to install and uninstall the following applications on the test machine:

- Firefox 3.6.3 (11,909 KB) (MSI File)
- Microsoft .NET 3.5 (34,121 KB) (MSI File)
- Steam (1,551 KB) (MSI File)

This test was conducted five times to obtain the average time to install/uninstall the above third party programs, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 12 – Network Throughput**

This benchmark measured how much time was required to download a sample set of binary files of various sizes and types over a 100MB/s network connection. The files were hosted on a server machine running Windows Server 2008 and IIS 7. *CommandTimer.exe* was used in conjunction with *GNU Wget* (version 1.10.1) to time and conduct the download test.

The complete sample set of files was made up of 553,638,694 bytes over 484 files and two file type categories: media files [74% of total] and documents [26% of total]. The breakdown of the file types, file numbers and total sizes of the files in the sample set is shown in the following table:

<table>
<thead>
<tr>
<th>File format</th>
<th>Number</th>
<th>Size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPEG</td>
<td>343</td>
<td>30,668,312</td>
</tr>
<tr>
<td>GIF</td>
<td>9</td>
<td>360,349</td>
</tr>
<tr>
<td>PNG</td>
<td>5</td>
<td>494,780</td>
</tr>
<tr>
<td>MOV</td>
<td>7</td>
<td>57,360,371</td>
</tr>
<tr>
<td>RM</td>
<td>1</td>
<td>5,658,646</td>
</tr>
<tr>
<td>AVI</td>
<td>8</td>
<td>78,703,408</td>
</tr>
<tr>
<td>WMV</td>
<td>5</td>
<td>46,126,167</td>
</tr>
<tr>
<td>MP3</td>
<td>28</td>
<td>191,580,387</td>
</tr>
<tr>
<td>PDF</td>
<td>73</td>
<td>136,298,049</td>
</tr>
<tr>
<td>ZIP</td>
<td>4</td>
<td>6,295,987</td>
</tr>
</tbody>
</table>
This test was conducted five times to obtain the average time to download this sample of files, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 13 – File Format Conversion (MP3 → WAV, MP3 → WMA)**

This test measured how much time was required to convert five (5) different MP3 files into WAV files and subsequently, convert the same MP3 samples into a WMA files. The total size of the five (5) MP3s used was 25,870,899 bytes.

To encode the MP3 into another format, we used an application called `ffmpeg.exe`. The format conversion process was timed using `CommandTimer.exe`.

This test was conducted five times to obtain the average conversion speed between these formats, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 14 – File Compression and Decompression**

This test measured the amount of time required to compress and decompress a sample set of files. For this test, we used a subset of the media and documents files used in the File Copy, Move and Delete benchmark. `CommandTimer.exe` recorded the amount of time required for `7zip.exe` to compress the files into a *.zip and subsequently decompress the created *.zip file.

This subset comprised 1,218 files over 783 MB. The breakdown of the file types, file numbers and total sizes of the files in the sample set is shown in the following table:

<table>
<thead>
<tr>
<th>File Type</th>
<th>File Number</th>
<th>Total Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>.xls</td>
<td>13</td>
<td>9.23 MB</td>
</tr>
<tr>
<td>.xlsx</td>
<td>9</td>
<td>3.51 MB</td>
</tr>
<tr>
<td>.ppt</td>
<td>9</td>
<td>7.37 MB</td>
</tr>
<tr>
<td>.pptx</td>
<td>11</td>
<td>17.4 MB</td>
</tr>
<tr>
<td>.doc</td>
<td>17</td>
<td>35.9 MB</td>
</tr>
<tr>
<td>.docx</td>
<td>19</td>
<td>24.5 MB</td>
</tr>
<tr>
<td>.gif</td>
<td>177</td>
<td>1.10 MB</td>
</tr>
<tr>
<td>.jpg</td>
<td>737</td>
<td>66.2 MB</td>
</tr>
<tr>
<td>.png</td>
<td>159</td>
<td>48.9 MB</td>
</tr>
<tr>
<td>.mov</td>
<td>7</td>
<td>54.7 MB</td>
</tr>
<tr>
<td>.rm</td>
<td>1</td>
<td>5.39 MB</td>
</tr>
<tr>
<td>.avi</td>
<td>46</td>
<td>459 MB</td>
</tr>
<tr>
<td>.wma</td>
<td>11</td>
<td>48.6 MB</td>
</tr>
<tr>
<td>.avi</td>
<td>46</td>
<td>459 MB</td>
</tr>
</tbody>
</table>
This test was conducted five times to obtain the average file compression and decompression speed, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 15 – File Download**

This test measures the time it takes to complete an http download of a sample set of installation files over a 100MB/s network connection. The files are hosted on a local server machine running Windows Server 2013 and IIS 7. *CommandTimer.exe* was used in conjunction with the native .NET *DownloadFile()* method to time and conduct the download test. The file set includes the following:

- Firefox Setup 31.0 (30.7 MB) (EXE file)
- GIMP Setup 2.8.10 (86.2 MB) (EXE file)
- LibreOffice Installer Package 4.2.5 (209 MB) (MSI file)
- Adobe Reader Installer 3.5.4.25 (1.00 MB) (EXE file)

This test was conducted five times to obtain the average time to download this sample of files, with the test machine rebooted between each sample to remove potential caching effects.

**Benchmark 16 – PE Scan Time**

This test measures the on demand scan times of a file set comprised only of executable files (.exe, .dll and .sys files). We performed five scans of the sample file set, with a machine restart between each scan to remove possible caching effects. The time taken to scan the files is taken from a security product’s scan logs, or where logs are not available, manually with a stopwatch. Scans were launched by right clicking on the folder to be scanned.

A breakdown of the sample file set is as follows:

<table>
<thead>
<tr>
<th>File Type</th>
<th>Number of Files</th>
<th>File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sys Files</td>
<td>2174</td>
<td>329MB</td>
</tr>
<tr>
<td>Dll Files</td>
<td>2037</td>
<td>920MB</td>
</tr>
<tr>
<td>Exe Files</td>
<td>2140</td>
<td>827MB</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6351</strong></td>
<td><strong>2076MB</strong></td>
</tr>
</tbody>
</table>

We have averaged the four subsequent scan times to obtain an average subsequent scan time. Our final result for this test is an average of the subsequent scan average and the initial scan time.
Benchmark 17 – File Copy Disk to Disk

This test measures the amount of time taken to copy files between two local drives. The data set comprised of 8,501 files with a total file size of 5.44GB, and the formats used included documents, movies, images and executables. A breakdown of the sample file set is given below:

<table>
<thead>
<tr>
<th>File Extension</th>
<th>Number of Files</th>
<th>File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>.jpg</td>
<td>2903</td>
<td>588MB</td>
</tr>
<tr>
<td>.dll</td>
<td>773</td>
<td>25MB</td>
</tr>
<tr>
<td>.exe</td>
<td>730</td>
<td>197MB</td>
</tr>
<tr>
<td>.gif</td>
<td>681</td>
<td>63MB</td>
</tr>
<tr>
<td>.wav</td>
<td>430</td>
<td>260MB</td>
</tr>
<tr>
<td>.sys</td>
<td>501</td>
<td>79MB</td>
</tr>
<tr>
<td>.png</td>
<td>451</td>
<td>27MB</td>
</tr>
<tr>
<td>.mp3</td>
<td>333</td>
<td>2157MB</td>
</tr>
<tr>
<td>.wma</td>
<td>585</td>
<td>925MB</td>
</tr>
<tr>
<td>.docx</td>
<td>267</td>
<td>81MB</td>
</tr>
<tr>
<td>.avi</td>
<td>247</td>
<td>1079MB</td>
</tr>
<tr>
<td>.doc</td>
<td>160</td>
<td>57MB</td>
</tr>
<tr>
<td>.xls</td>
<td>329</td>
<td>132MB</td>
</tr>
<tr>
<td>.ppt</td>
<td>97</td>
<td>148MB</td>
</tr>
<tr>
<td>.zip</td>
<td>14</td>
<td>177MB</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8501</strong></td>
<td><strong>5995MB</strong></td>
</tr>
</tbody>
</table>

A total of five runs of this test were performed, with a machine restart between each run. The time taken to copy files was measured and recorded by CommandTimer.exe. All the files were copied between a folder on the local drive and a 2nd folder on a different drive. Files were deleted from the 2nd drive once the copy was complete. The final result is calculated as an average of the five samples.

Benchmark 18 – File Copy Over Network

This test measures the amount of time taken to transfer files from a local drive on the test machine to a shared folder on the local server. The data set comprised of 8,501 files with a total file size of 5.44GB, and the formats used included documents, movies, images and executables. A breakdown of the sample file set is given below:

<table>
<thead>
<tr>
<th>File Extension</th>
<th>Number of Files</th>
<th>File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>.jpg</td>
<td>2903</td>
<td>588MB</td>
</tr>
<tr>
<td>.dll</td>
<td>773</td>
<td>25MB</td>
</tr>
<tr>
<td>.exe</td>
<td>730</td>
<td>197MB</td>
</tr>
<tr>
<td>.gif</td>
<td>681</td>
<td>63MB</td>
</tr>
<tr>
<td>.wav</td>
<td>430</td>
<td>260MB</td>
</tr>
</tbody>
</table>
A total of five runs of this test were performed, with a machine restart between each run. The time taken to transfer files was measured and recorded by CommandTimer.exe. Files were deleted from the server once the copy was complete. The final result is calculated as an average of the five samples.

**Benchmark 19 – PCMark 8 Home Score**

This test aims to benchmark the test machine’s performance over a series of common home computing tasks. This includes web browsing, writing, photo editing, video chat, and casual gaming. For this benchmark we have installed PCMark 8 Professional Edition (Version 2.7.613). From the interface, the PCMark 8 Home test is launched in conventional mode. This Home test is run twice, with a reboot in between. The final result is an average of the overall scores of the two iterations.

**Benchmark 20 – Word Document Launch and Open Time**

The average launch time of Word interface was taken using AppTimer. This includes the time to launch the Word 2013 application and open a 10MB document. This test was practically identical to the User Interface launch time test. For each product tested, we obtained a total of fifteen samples from five sets of three Word launches, with a reboot before each set to clear caching effects by the operating system. When compiling the results, the first of each set was separated out so that there was a set of values for the initial launch after reboot and a set for subsequent launches.

We have averaged the subsequent launch times to obtain an average subsequent launch time. Our final result for this test is an average of the subsequent launch average and the initial launch time.

AppTimer is publicly available from the PassMark Website.

**Benchmark 21 – Run Excel Macro**

This test measures the time it takes to open an excel document and run an excel macro. The macro performs a range of operations, including reading data from the file system, mathematical calculations, and writing data to the spreadsheet. This test is run using a Windows PowerShell script. We obtained a total of five samples with a reboot in between each to clear caching effects by the operating system. The final result is calculated as an average of the five samples.
**Benchmark 22 – Save Word Document to PDF**

This test measures the time it takes to open a large Word Document (~10 MB) and save it as a PDF document. This test is run using a Windows PowerShell script. We obtained a total of five samples with a reboot in between each to clear caching effects by the operating system. The final result is calculated as an average of the five samples.

**Benchmark 23 – USB 3.0 File Copy**

This test measures the amount of time taken to transfer files from an external drive to a local disk via a USB 3.0 connection. The data set comprised of 6,834 files with a total file size of 6.06GB, and the formats used included documents, movies, images, executables and system files. A breakdown of the sample file set is given below:

<table>
<thead>
<tr>
<th>File Extension</th>
<th>Number of Files</th>
<th>File Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>.dll</td>
<td>1429</td>
<td>627MB</td>
</tr>
<tr>
<td>.doc</td>
<td>496</td>
<td>164MB</td>
</tr>
<tr>
<td>.docx</td>
<td>324</td>
<td>76MB</td>
</tr>
<tr>
<td>.exe</td>
<td>280</td>
<td>1.2GB</td>
</tr>
<tr>
<td>.jog</td>
<td>1564</td>
<td>469MB</td>
</tr>
<tr>
<td>.mp3</td>
<td>394</td>
<td>1.06GB</td>
</tr>
<tr>
<td>.pdf</td>
<td>567</td>
<td>246MB</td>
</tr>
<tr>
<td>.pptx</td>
<td>556</td>
<td>1.06GB</td>
</tr>
<tr>
<td>.pst</td>
<td>2</td>
<td>59.1MB</td>
</tr>
<tr>
<td>.sys</td>
<td>568</td>
<td>145MB</td>
</tr>
<tr>
<td>.xlsx</td>
<td>584</td>
<td>81.0MB</td>
</tr>
<tr>
<td>.zip</td>
<td>70</td>
<td>911MB</td>
</tr>
</tbody>
</table>

A total of five runs of this test were performed, with a machine restart between each run. The time taken to transfer files was measured and recorded by CommandTimer.exe. Files were deleted from the local disk once the copy was complete. The final result is calculated as an average of the five samples.