Technical white paper

Mainframe Alternative Sizing

Reference application based system sizing and cost comparison

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Executive summary

The purpose of this paper is to show the relative throughput between various HP Mission-Critical Converged Infrastructure based systems and an IBM System z mainframe running the same IBM z/OS batch and CICS mainframe application. The data presented in this paper enables one to answer the question “How much HP x86 processor based system capacity, e.g., how many servers/CPUs, will I need to take on a given sized mainframe workload (size stated here in MIPS or MSUs)” or to take on the workload of an LPAR (Logical Partition) of a given size.

This paper summarizes the finding of a sizing study which HP and Microsoft completed in 2012. These findings show that single Mainframe Alternative (MFA) systems can deliver the equivalent of many 1,000s of MIPS of service. These findings also show the relative throughput achieved on several HP system alternatives.

In order to accomplish this study, a representative z/OS batch and CICS mainframe application was written in COBOL, and this z/OS Reference Application (zRef) was run both in an IBM mainframe LPAR with over a thousand MIPS of processor capacity and on various HP MFA systems. The alternative hardware infrastructure was comprised of Intel® Xeon® based HP ProLiant Servers and HP Storage and Networking. The MFA software stack consisted of the Microsoft® Windows® Server Operating System, Microsoft SQL Server, and Micro Focus Enterprise Server. Together, these components from HP, Intel®, Microsoft, and Micro Focus represent MFA systems able to run many applications written for z/OS with a very strong customer value proposition.

Runs of the z/OS Reference Application (zRef) on the mainframe were overseen by z/OS, DB2 and CICS systems programming and performance experts with significant and deep relevant experience. The objective set for that team was to maximize throughput in the mainframe LPAR, and considerable effort was expended to achieve this goal. This was done in order to provide a fair baseline for comparison of capacity between the mainframe and MFA systems. The findings of this project, discussed in this paper, support the following conclusions:

• A single HP MFA system can provide the equivalent of several thousands of MIPS of capacity.
• MFA systems can deliver the levels of services (CICS response time, batch elapsed time) that mainframe shops require and are accustomed to.
• HP MFA-based solutions can concurrently run Batch and CICS COBOL workloads while achieving Service Level Agreement (SLA) commitments.
• The equivalent MIPS capacity of HP MFA systems ranges from several hundreds (100s) to many thousands (1,000s) of MIPS in a single system.

Mainframe alternative business case

At the business level, re-hosting mainframe applications to HP MFA systems has compelling cost savings amongst other clear advantages:

• **Increase enterprise agility:** Re-hosting all of your mainframe applications to an MFA platform removes a proprietary platform from the datacenter and the overall environment is simplified by elimination of the associated unique tools, processes, methods, and means. A simpler environment can be managed and run at a lower cost.

• **Reduce infrastructure costs:** While keeping the application essentially unchanged, application re-host onto HP MFA systems changes the operating system, database, TP monitor, and system management of the production environment, and also the application development environment and tools. This paper shows examples of mainframe alternative systems which delivered throughput comparable to a given capacity mainframe, with a cost of ownership substantially less than half and therefore, the long-term return on platform migration investment can be significant. Many organizations have made this move and accrued these very positive financial benefits. Re-writing the applications, in contrast to re-host as was done in this study, also changes the application code which typically would increase cost and risk.

• **Preserve skills dilemma:** Applications re-hosted to an HP MFA system are, by definition, not changed or in the case of re-write new code is written to reproduce existing functionality and data design. What does change is the platform on which the applications are run and the development environment in which they are maintained. Therefore, it is possible to continue to leverage existing technology skills in the new environment. Because of the now unified application development environment for both mainframe and distributed applications, both sets of developers can work together with common tools and, over time, become one.

This white paper helps support the case for HP MFA systems, running the Microsoft Application Platform and Micro Focus Enterprise Server for z/OS compatibility, as a replacement for current mainframe infrastructure, while preserving the value in the mainframe applications—and in the case of re-host, by continuing to run the current application programs. In this study only incidental change was made to the data design or the code.
Reference application based sizing

It is common practice for the mainframe community to express the size of its mainframe systems in MIPS, a simple metric historically defined as millions of instructions per second. The use of MIPS as a metric persists, even though workload characteristics can cause MIPS of service delivered to vary due to factors such as the number of Central Processors (CPs) in a single mainframe system. The use of MIPS continues, even though IBM itself long ago moved to Service Units (MSUs for millions of Service Units) as the sizing metric for capacity-based mainframe software pricing. As discussed in the executive summary and in an appendix to this document, IBM also uses PVUs, Processor Value Units, as the pricing basis for distributed systems software, even when run on System z.

Many myths persist about the “speed” of Intel processors relative to mainframe CPs, and the workload throughput capacity of Intel Xeon based servers. One still hears exclamatory statements such as “You’re crazy if you think I’m going to replace my mainframe with hundreds (or thousands) of distributed servers”. We agree with the sentiments behind such statements because to do that would not be logical. But fact is that it takes only one or a few HP servers to replace most mainframes. HP created a z/OS reference application in order to provide a real basis for measurement based comparison in place of this myth.

IBM published information related to sizing

We are not aware of any information published by IBM which compares z/OS application throughput delivered by System z, to any other type or class of system. However for software license cost calculation, including when Java, Linux, and other distributed systems software is run on System z, IBM publishes Processor Value Unit (PVU) tables. As of this writing, IBM gives the same PVU rating, 120 or 100, to both current System z CPs and some Intel Xeon processors used in HP ProLiant servers. As discussed in an appendix to this document, this equal rating suggests a 1:1 ratio in processing capacity. This seems inconsistent with the IBM claim made in some of its sales programs that as many as 48 Intel Xeon based server instances can be consolidated onto one IFL which suggest a 48:1 capacity ratio between an IFL and an x86 CPU core. To resolve this large discrepancy was another justification for the 2012 sizing study which found a throughput ratio between these two limits.

What is zRef?

zRef is a z/OS batch and CICS application written in COBOL and using DB2, which simulates the activities of a financial trading firm or broker. The business transactions accomplish client–broker financial market interaction. The operations also include client reporting and a comprehensive account updating process. Most transactions in zRef are not “trivial”, i.e., they make many SQL calls and CICS command calls such as EXEC CICS LINK calls to other CICS programs.

Characteristics of zRef include:

- zRef was not built to run as a benchmark with the intent to achieve the highest throughput possible. zRef was programmed to be similar to batch and CICS COBOL applications that are commonly in production today, i.e., in the programming style of mainframe applications written in the 1980s. For example, SQL calls to DB2 are simple and many, often using a position cursor and retrieving a single table row at a time.
- zRef was not programmed for high transaction throughput, but rather for relative throughput comparison on various alternative platforms
- zRef is intended to reflect real-world operations as much as possible.
- HP makes zRef available for study or reference, and for others to run in their own environments.

zRef batch

The zRef application used in this study includes two batch jobs, as well as transactional (CICS) programs:

- The Batch Reporting JOB (zRefBR) does a read-only extract from the zRef database, followed by classic sort/merge sequential file processing. The zRef Batch Reporting job contains four extract steps, ten sort steps, three merge steps, and five report steps, for a total of 22 process steps. zRefBR is read-only on the zRef Database and represents typical periodic point in time status reporting (e.g., sales report, accounts status)—the type of report seen in weekly, monthly, and quarterly summaries.

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1 As of 01 July 2013, the page at [01.ibm.com/software/lotus/passportadvantage/pvu_licensing_for_customers.html](http://01.ibm.com/software/lotus/passportadvantage/pvu_licensing_for_customers.html), noted as last updated 05 April 2013, gives a capacity (PVU) rating of either 120 or 100 to both Xeon Nehalem and Sandy Bridge x86 CPU cores and System zEC12/z196/z10/z1 IFLs, depending on server specifics.

2 For example as of this writing in June 2013, at [03.ibm.com/systems/z/os/linux/about/](http://03.ibm.com/systems/z/os/linux/about/) IBM says “with a zEnterprise EC12 (zEC12) you can consolidate up to 48 virtualized x86 cores (Sandy Bridge) or more on a single IFL core.”

3 Assuming that each of the 48 servers has one single CPU core Xeon processor.
• The **Transactional batch update** (zRefBU) job runs the same business transactions as in the CICS transactional workload, but in this case, driven from an input file. The zRef Batch Update job simulates, for example, the processing of business transactions that arrive via file transfer, such as FTP.

The zRef batch jobs could be submitted and run alone or in parallel, and also while zRef CICS was running.

**zRefCICS**

The CICS portion of zRef (zRefCICS) consists of ten CICS transactions processed by 30+ executable CICS programs, which read, update, and insert data into a DB2 database and optionally log audit information (write) to a VSAM ESDS file.

Figure 1 shows a picture of the configuration in which zRef was run:

- **zRefCICS** was deployed in two CICS regions, with workload into the first region generated by simulated TN3270 users. zRef also interacts with an external system simulating a market exchange which accepts trade orders and returns trade confirmations.
- End user submitted transaction, e.g., trade requests, cause a message to be sent to the External System, which in turn submits additional transactions (trade confirmations) back into zRef as additional CICS transactions processed by the 2nd CICS region.
- A VSAM ESDS file to which zRef CICS can write an “audit record” for each completed business transaction.
- The relatively complex schema of the zRef Relational Database.

**Figure 1. zRefCICS runtime configuration, and representation of the zRef database schema**

For each sizing run, the number of simulated TN3270 users is increased incrementally (ramped up), thereby increasing the submitted transaction rate, and then held for a period at the maximum throughput that the system could sustain while still giving good response time, and then ramped back down.
**System(s) under test (SUT)**

The IBM system used for all batch and CICS runs was a “2-engines even” LPAR in a 4-engine IBM z10 EC 2097-604. As is common practice, DB2 was run in the same LPAR. A series of HP MFA System configurations were run, one a single system with both the application server and DBMS for direct comparison to the mainframe setup and the others with the DBMS on a separate server as is common practice with distributed system. All systems used are shown in table 1.

The DASD storage array used on the mainframe system was an HP XP 24000 storage array which is generally considered a high end system. However this XP 24000 was concurrently supporting other systems. The XP 24000 presented virtual 3390 volumes to the mainframe system. The “DASD” used with the HP MFA Systems for all measured and reported runs was an HP P6500 storage array, formerly named EVA, and generally considered a mid-range system.

<table>
<thead>
<tr>
<th>Table 1. Mainframe and MFA SUT configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
</tr>
</tbody>
</table>
| Baseline 1088 MIPS IBM Mainframe System | “2 engines even” LPAR on an IBM z10 EC 2097-604 | • 8 GB RAM  
• Two OSA ports  
• Four 4 Gb FICON connections; however, FICON throughput was limited by an intervening 2 Gb switch.  
We believe this is a typical configuration that is running in many production environments. | • IBM z/OS 1.13  
– IBM COBOL  
– IBM JES  
• IBM CICS TS 3.2  
• IBM DB2 9.1  
• IBM DFSORT  
• CA ACF2  
• IBM RMF  
• CA SYSVIEW | 1 LPAR of 1088 MIPS was SUT. Both database and applications run together in this LPAR. |
| HP DL980 application and database server single system configuration | HP DL980 with eight Xeon E7-4870 2.4 GHz 10 core Processors (80 CPU cores total) | • 1 TB RAM  
• 4x10 Gb Ethernet connection  
• 4x8 Gb/s Fibre Channel HBAs (host bus adapters) | Microsoft  
• Windows Server 2008 R2  
• SQL Server 2008 R2  
• System Center  
• MS Active Directory  
**Micro Focus**  
Enterprise Server  
• COBOL Run Time  
• JES Engine  
• CICS TP support  
• SORT  
• HSF (Stats)  
• ESM (Security API) | Application and Database Server |
| HP DL980 application server with HP DL580 database server | HP DL580 with four Xeon E7-8867L processors (2.13 GHz), 10 cores each (40 CPU cores total) | • Same DL980 as used above  
• 256 GB RAM  
• 4x10 Gb Ethernet  
• 4x Fibre Channel | Microsoft  
• Windows Server 2008 R2  
• SQL Server 2008 R2 | DBMS Server |
<table>
<thead>
<tr>
<th>Platform</th>
<th>Hardware system</th>
<th>Configuration detail</th>
<th>System software</th>
<th>Notes/role</th>
</tr>
</thead>
</table>
| 12 Core HP BL460 application server with HP DL580 database server (configuration 1) | HP BL460 with two Xeon x5675 processors (3.06 GHz), 6 CPU cores each (12 CPU cores total) | • 64 GB RAM  
• 4x10 Gb Ethernet  
• 4x Fibre Channel | Same software configuration as Application Server above | Application Server |
| Same as DL580 DB server above | DBMS Server |
| 2 Core HP BL460 application server with HP DL580 database server—(configuration 2) | Same BL460 as above but with only 2 CPU cores activated | Same BL460 as above | Same as Application Servers above | Application Server |
| Same as DL580 DB Server above | DBMS Server |
| Hyper-V Virtual machine with HP DL580 database server | Four Virtual CPUs allocated to the VM | Hyper-V host machine same as BL460 above | Same as Application Servers above | DBMS Server |

**Baseline throughput on z/OS**

This section presents the baseline results against which the MFA systems were compared.

**Batch throughput on z/OS**

In many mainframe shops, batch elapsed time is the critical throughput requirement. In many shops the peak overnight batch MIPS used is more than peak daytime transactional MIPS used.

**zRefBR: 68 minutes**

zRefBR extracted 8 million records from the zRefDB to a sequential dataset and then processed those records in a series of sorts and merges finally printing to SYSOUT. Again, multiple runs were made to find the average run time of 68.1 minutes when run standalone with no other work running in the LPAR. When three zRefBR JOBs were run concurrently, the elapsed time was extended by only about 12% and ranged from 71.9 to 80.6 minutes.

**zRefBU: 2 hours 42 minutes**

This was the simpler of the two batch JOBs—a single step that processed 30,000 business transactions from a file of records. Multiple runs were made to obtain the average run time of 161.9 minutes. The elapsed time ranged from 155.0 to 167.3 minutes.
CICS Throughput on z/OS

zRefCICS: 124 TPS at 93% CPU busy

Multiple runs were made, first to find the peak number of users for the workload, which was reached at 1400 users. Response times then began to grow beyond normal operating bounds (>1.5 seconds). Several test runs were then made at or near that level, with the resulting transactions per second (TPS) ranging from 120 to 129, at an average of 124 TPS. For these runs, CPU busy time ranged from 92% to 95%, averaging 93%.

Figure 2 shows one baseline zRefCICS run on a 1,088 MIPS LPAR of the IBM z10-604 mainframe system. For the run shown in figure 2, the number of users (and TPS, proportionally) was increased to the point where response time began to significantly exceed 1 second per transaction. At this maximum, CPU busy was near 100% and system response times begin to increase without a corresponding improvement in throughput (see figure 3 for further explanation).

Mainframe CPU busy was taken from RMF data logged in the SMF type 70 record.

Figure 2. zRefCICS run on “two engines” 1,088 MIPS LPAR in IBM z10-604

Figure 3 plots number of active TN-3270 users versus response time (in seconds). The figure shows that response time began to exceed 1 second at 1250 users and continued to increase from there. A maximum of 1400 simulated users for the mainframe LPAR was achieved.

Figure 3. Number of simulated TN-3170 users vs. end-user response time on 1,088 MIPS IBM z10 LPAR
Throughput on MFA systems

Batch comparative results

As described previously, zRefBR is a batch reporting workload and zRefBU makes the same set of complex updates to the zRefDB as are done by zRefCICS transactional programs, but in a batch process driven by an input file. In both cases, a large number of records are processed. For the sizing runs conducted, the size of the zRefBR workload was 8 million records, and the zRefBU workload was 30,000 business transactions. The chart below compares the measured results.

Figure 4. Comparative zRef batch JOB elapsed time

The above chart shows MFA system averages for the two classes of systems on which timed runs were made compared to measured results on the mainframe as reported by SMF. Table 2 below shows the same data for the mainframe and the specific measured times for 3 of the MFA systems included in the averages above. This was for one batch job running stand-alone, i.e., no other batch or CICS workload was running.

Batch throughput is especially dependent on IO performance. The amount of main storage RAM memory available on the MFA systems probably allowed the Windows Server File System cache more file data and thereby provide better IO performance.

Table 2. Stand-alone Batch (zRefBR and zRefBU) results, shown in minutes to complete

<table>
<thead>
<tr>
<th>Platform</th>
<th>Hardware</th>
<th>zRefBR elapsed time (minutes)</th>
<th>zRefBU elapsed time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline system: Mainframe</td>
<td>“2 engines even” LPAR on an IBM z10 EC 2097-604</td>
<td>68.1</td>
<td>161.9</td>
</tr>
<tr>
<td>HP DL980 application and database server</td>
<td>HP DL980 (80 core) with 8x Xeon E7-4870 2.4 GHz processors, 10 cores each</td>
<td>9.1</td>
<td>15.6</td>
</tr>
<tr>
<td>HP DL980 application server with HP DL580 database server</td>
<td>HP DL980 (80 core) with 8x Xeon E7-4870 2.4 GHz processors, 10 cores each</td>
<td>8.5</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>HP DL580 (40 core) with 4x Xeon E7-8867L processors (2.13 GHz), 10 cores each</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP BL460 application server with HP DL580 database server</td>
<td>HP BL460 (12 core) with 2x Xeon x5675 processors (3.06 GHz), 6 cores each</td>
<td>7.3</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>Same DBMS Server as above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Batch concurrency**

Mainframe systems regularly run many batch jobs concurrently. Doubt about distributed systems still exists in the minds of many who ask if distributed systems, including Windows Server OS based systems, are also able to do "two things at once". The chart in figure 5 shows Application Server CPU busy on the 2 CPU (core) BL460 server, for the period of time when and after 13 batch jobs were submitted.

*Figure 5. CPU Busy (heavy black line) running multiple batch jobs concurrently on a single HP MFA system*

Some observations on the data:

- For the first about 9 minutes, 3 zRefBR and 10 zRefBU jobs are running concurrently (heavy black line in early portion of chart).
  - System ran at 99% CPU busy on application server with all 13 jobs running.
  - The DBMS server running SQL server ran at only ~3% (not shown).
- For the next about 16 minutes, 10 zRefBU jobs continue to run.
  - System ran at ~48% CPU busy time on application server with 10 zRefBU jobs running.
  - The DBMS server running SQL server ran at ~4% (not shown).
- For the last about 4 minutes, no batch or other application workload was running.

**Key observation:** The elapsed time of these jobs was not significantly longer than when each job was run standalone!
CICS comparative results

Figure 6 shows a summary of CICS throughput found in the study. The maximum number of CICS users supported by the mainframe was 1400 at a throughput rate of 124 TPS. Even with only 2 CPU cores, the BL460 server exceeded this CICS throughput. The average for all BL460 configurations is shown in the 2nd entry. The average TPS achieved by the two DL980 based configurations is shown in the 3rd entry. All rates are the maximum rate that could be achieved while keeping end-user response time under ~1 second.

Figure 6. Relative CICS throughput in transactions per second

The figure above shows averages for the types of HP servers on which runs were made. Table 3 shows zRefCICS OLTP throughput achieved on the mainframe and individual alternative systems from which the averages are computed, and the percentage of CPU consumed to achieve that throughput. Unused CPU time represents additional capacity available to do other work. For example, 7% of the mainframe LPAR capacity was available, e.g., to run concurrent batch, and 60% of the DL980 capacity was available, e.g., to perform BI work against the zRef DB.

Runs were also made in a Microsoft Hyper-V Virtual Machine to demonstrate throughput in a virtual server. The virtual machine results are not included in any of the averages shown in the figure above.

Table 3. System level TPS results, zRefCICS

<table>
<thead>
<tr>
<th>Platform</th>
<th>Hardware</th>
<th>CPU % busy</th>
<th>Transactions per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 1088 MIPS mainframe system</td>
<td>“2 engines even” LPAR on an IBM z10 EC 2097-604</td>
<td>93%</td>
<td>124</td>
</tr>
<tr>
<td>HP DL980 application and database server</td>
<td>HP DL980 (80 core) with 8x Xeon E7-4870 2.4 GHz processors, 10 cores each</td>
<td>40%</td>
<td>816</td>
</tr>
<tr>
<td>HP DL980 application server with HP DL580 database server</td>
<td>HP DL980 (80 core) with 8x Xeon E7-4870 2.4 GHz processors, 10 cores each</td>
<td>29%</td>
<td>936</td>
</tr>
<tr>
<td>12 Core HP BL460 application server with HP DL580 database server</td>
<td>HP BL460 (12 core) with 2x Xeon x5675 processors (3.06 GHz), 6 cores each</td>
<td>76%</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>Same DBMS Servers as above</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>2 Core HP BL460 application server with HP DL580 database server</td>
<td>HP BL460 (2 core) with 2x Xeon x5675 processors (3.06 GHz), 1 core each</td>
<td>100%</td>
<td>182</td>
</tr>
<tr>
<td></td>
<td>Same DBMS Servers as above</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Hyper-V Virtual Machine</td>
<td>4 Virtual CPUs in a single VM running on a 12 CPU core BL460 VM host as used above</td>
<td>99%</td>
<td>282</td>
</tr>
<tr>
<td></td>
<td>Same DBMS Servers as above</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Three Hyper-V VMs running in Parallel</td>
<td>12 Virtual CPUs, 4 in each of 3 VMs running on a 12 CPU core BL460 VM host as used above</td>
<td>98%</td>
<td>819</td>
</tr>
<tr>
<td></td>
<td>Same DBMS Servers as above</td>
<td>15%</td>
<td></td>
</tr>
</tbody>
</table>
In figure 7, response time versus users is plotted for the z10 mainframe and two MFA systems, the single server HP DL980 like the z10 is a single system running both the application and the DBMS, and the 12 CPU core HP BL460 application server using a DL580 as the database server. The mainframe measurement data is shown as the blue line to the left; all three systems ran the exact same CICS workloads. The HP DL980 and HP BL460 based systems had a lower starting response time, and continued to have a lower response time than the mainframe’s best up to about 8,000 users. The HP DL980 system did not exceed a 1-second response time until the ~11,000-user mark.

**Figure 7.** IBM z10 versus HP DL980 response times vs. workload

CICS application throughput with only 2 CPs/CPU cores—running near 100%

Figure 8 shows a zRefCICS run with the application server running on an HP ProLiant BL460 server with only two active CPU cores. This compares the maximum workload capacity between the HP 2 core system and an IBM “2 engines even” (2 CP) LPAR. This 2 core HP System delivered about 1.5x the throughput as was achieved on the z10. As was true for the z10 mainframe, the 2 core HP system ran at near 100% CPU busy to deliver this throughput.

This run demonstrates that an HP ProLiant system can run at or near 100% CPU busy while continuing to deliver good end-user response time. IBM mainframe systems are widely understood to run at these levels while providing good service. This was important to demonstrate because it is not always understood that HP MFA systems can also be run at these high utilization levels for a sustained period.

The foreground graph in figure 5 shows the 2 core BL460 server near and at 100% CPU busy for a sustained period of time while the background graph shows high transaction throughput for this same period.

**Figure 8.** Two-CPU throughput comparison
CICS + Batch—2 things at once

Another secondary objective of the study was to determine how well the MFA systems could do “two things at once”, that is, to show how much CICS throughput and response time would be affected by concurrent batch. To make this observation, multiple zRef batch jobs were run concurrently on top of a heavy CICS workload on the 2 core HP BL460 server. zRefCICS was run at 154 TPS which is about 85% the maximum 182 TPS peak the BL460 delivered at 99.9% CPU busy (while only running zRefCICS). While the system was running at 154 TPS and 85% CPU busy:

- Three (3) copies of zRefBR were run concurrently, which drove CPU busy to 100%. During this time response time degraded but was still acceptable at about 1.2 seconds.
- Ten copies of zRefBU were submitted, and 6 concurrent copies (running on the equivalent of 6 initiators) drove CPU to about 96% while response time remained mostly sub-1 second.

In the figure below, the heavy black line in the foreground graph shows CPU busy during the run described above. The background graph shows CICS user count and transaction response time.

**Figure 9.** Batch workload on top of high volume but less than peak CICS workload.
MIPS of service delivered

Figure 10 charts the relative level of service delivered by the mainframe and four MFA systems. For example, the MFA scale-down server, which was the HP BL460 running two CPU cores (second value from the left), delivered 1.5 times the CICS transaction throughput as did the mainframe system. Below the chart bars is a calculated MIPS of service delivered by each system (explained below the chart).

Figure 10. MIPS of CICS service delivered by IBM z10 2097-604 and several MFA systems

<table>
<thead>
<tr>
<th>Thousands of MIPS</th>
<th>MIPS of CICS service delivered</th>
<th>Percent CP or CPU busy</th>
</tr>
</thead>
<tbody>
<tr>
<td>z/OS on z10 604 (+DB)</td>
<td>1,015</td>
<td>93%</td>
</tr>
<tr>
<td>MFA scale down to 2 CPU BL460</td>
<td>1,489</td>
<td>99%</td>
</tr>
<tr>
<td>MFA scale down BL460</td>
<td>5,738</td>
<td>76%</td>
</tr>
<tr>
<td>MFA single system DL980 (+DB)</td>
<td>6,687</td>
<td>41%</td>
</tr>
<tr>
<td>MFA DL980 w/SQL on DL580</td>
<td>7,671</td>
<td>29%</td>
</tr>
</tbody>
</table>

While delivering its peak throughput of 124 TPS, the CPU utilization of the mainframe system was only 93%. Multiplying 93% by the 1,088 MIPS rating of that LPAR, it can be said that this mainframe system was delivering 1,015 MIPS of service. Using the 1,015 MIPS of service as a baseline:

- The 2 CPU core BL460 based system delivered 1.5 times as much throughput and therefore 1.5 times as many MIPS of service. $1.5 \times 1015 = 1,489$ MIPS of service delivered.
- Using the same logic and formula, the 12 CPU core BL460 based system delivered 5.7 times as much throughput and therefore 5,738 MIPS of service delivered.
- Likewise the two DL980 configurations delivered 6,687 and 7,671 MIPS of service respectively.
What about MIPS per CPU?

For multiprocessor servers in general, as processors are added when running a single workload, the per-processor service delivered decreases for each additional processor added. This is generally true for all hardware systems, mainframe and MFAs alike, and is commonly called “the symmetric multiprocessing (SMP) effect”. This happens because as the CPU/core count increases, threads and CPUs begin to contend with each other, creating inefficiencies and data in RAM (main storage) tends to be further away, in time, from the processor that needs to access it.

The chart in figure 11 below chart shows the declining amount of service (MIPS or TPS, etc.) delivered by each CP or CPU (core) relative to the total number of CPs/CPU in that system. If MIPS-per-CPU were fixed, the curves would be straight horizontal lines.

Figure 11. MIPS per CPU as the CPU count increases, for mainframe and HP ProLiant servers

For the z10 and a z196 the data above comes from the MIPS ratings available at tech-news.com/publib/. For the MFA systems the data are as observed on the MFA systems used in this study. Some key points from figure 11:

- The lowest z196 mainframe system with full capacity engines is the 2817-701 which is rated at ~1,202 MIPS for a single CP or CPU engine.
- An 80 CP z196 (a 2817-780) is rated at only 654 MIPS per CP, which is only 54% of the 1,202 MIPS expected from the single CP in a 2817-701.
- Other examples include the 2817-704 rated at 4,320 MIPS, or 1,080 MIPS per CP, the 708 rated at 8,072 or 1,009 MIPS per CP and the 710 rated at 9,788 or 979 MIPS per CP.

One reason to run multiple LPARs on higher CP count mainframe systems is to mitigate this declining performance effect.

For the HP MFA systems, this study found equivalent s MIPS-per-CPU ranges from 232 to 474.

- 2 CPU core results were an average of 474 equivalent MIPS of service delivered per CPU core.
- 12 CPU core result decreases 12% to 420, or 88% of the 2-CPU core BL460 baseline
  - vs. the mainframe decrease of 16% from 2 to 12 CPs on the z196.
- 80 CPU core result decreases 51% to 232, or 49% of the 2-CPU core BL460 baseline
  - vs. the mainframe decrease of 42% from 2 to 80 CPs on the z196.
Summary of throughput findings

1. Intel-based HP MFA systems running Micro Focus Enterprise Server and Microsoft SQL Server on the Windows Server OS, provided superior response times and throughput relative to what the study was able to achieve on the 1,088 MIPS LPAR on the IBM mainframe system used in this study.
   A. Other HP ProLiant based systems running this same software stack delivered much higher levels of throughput. Throughput equivalent to over 7,000 MIPS of service was observed in this study.

2. HP MFA systems can run multiple batch jobs concurrently in parallel without significant elongation of job elapsed time.

3. HP MFA Systems are able to run batch and CICS (transactional) workloads at high levels of server utilization, similar to the level of utilization commonly seen on mainframe systems.

4. HP MFA systems can run batch jobs concurrently with heavy CICS workload, without significant degradation of service levels, up to the point of near 100% CPU saturation.

5. MFA systems run well in Hyper-V virtual machines, and achieve levels of throughput similar to what would be expected in a real machine of similar configuration.

6. MIPS of service delivered, or throughput per CP on System z and per CPU core on HP ProLiant servers, both decline at a similar rate as more CPs/CPU are added to a single system.
Cost of MIPS or equivalent

While the comparisons to this point have been performance- and capacity-related, business value can only be seen by also looking at the total cost of ownership of these systems. Three costs comparisons are shown:

1. Stay on existing z10 with 1,088 MIPS
2. Acquire a new zEnterprise z114 with the equal capacity (1,062 MIPS)
3. Cost of a new zEnterprise z196 with a MIPS capacity similar to that of the service delivered by the HP ProLiant DL980 based configurations (6,547 MIPS)

All costs include server HW plus infrastructure software (OS, JES, and CICS or equivalent, and DBMS). All costs include 3 years of HW maintenance and SW licensing or maintenance, depending on the SW pricing model.

The first result, shown in figure 12, is a 3 year cost of ownership comparison to the mainframe system used in this study. The height of the bars represents the cost of each system and NOT its performance/capacity which was shown earlier. For example, based on the CICS throughput delivered, the performance/capacity of the first two systems shown, the z10-604 LPAR and the 2 CPU BL460/DL580 configurations, is about equal, while the systems to the right delivered over 6x that throughput. The z10-604 mainframe cost in this figure does not include the purchase price of the mainframe.

Figure 12. HW & Infrastructure SW cost comparison—keep existing z10 mainframe vs. new HP MFA (bar height represent cost, not throughput)

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4 The IBM mainframe hardware purchase and maintenance cost data come from tech-news.com/publib/ as of the date of this publication.
5 The IBM software prices come from Alinean, Inc, alinean.com/.
6 HP, Microsoft, and Micro Focus license costs come from those companies respectively.
In the next comparison, the mainframe cost shown includes the cost of a new zEnterprise system with a rated capacity approximately the same (1,062 MIPS z114) as the 1,088 capacity of the mainframe LPAR used in this study. As above, **the height of the bars represents the cost of each system and NOT its performance/capacity.** As in figure 12 above, the throughput delivered by the first two systems was about equal, and the systems to the right delivered over 6x more CICS throughput.

**Figure 13.** Total cost of ownership comparison—Purchase of a new zEnterprise z114 mainframe vs. MFA (bar height represent cost, not throughput)

Figures 12 and 13 show that whether the mainframe system has to be purchased or not, the TCO of the HP MFA systems is lower, while the performance of those HP MFA systems is higher.

Figure 14 shows the cost comparison between the HP DL980 systems used in this study and a z196-514, the IBM mainframe with a MIPS rating closest to the MIPS of equivalent service delivered by the DL980 used in this study.

**Figure 14.** Total cost of ownership comparison about 6,600 MIPS equivalent service (throughput).
Disaster recovery cost comparison

For truly mission critical applications, many companies wish to establish a disaster recovery (DR) center able to take over all essential workloads in the case of an outage event at the primary datacenter. The lower cost of HP MFA systems compared to mainframe systems makes this much more economically feasible. The table below shows a comparison cost of “duplicate” mainframe and MFA systems.

Table 4. TCO analysis with MFA high-availability cluster

<table>
<thead>
<tr>
<th>IBM CICS &amp; DB2 on z/OS</th>
<th>HP/Microsoft/Micro Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>One half of IBM z10 2097-604 running z/OS, CICS and DB2</td>
<td>Assumed: 20% Batch 80% CICS systems running 75% utilization</td>
</tr>
<tr>
<td>1088 MIPS</td>
<td>Two failover clusters of two servers7 each</td>
</tr>
<tr>
<td>138 MSUs</td>
<td>• Application Server: 2—BL460/2 cores</td>
</tr>
<tr>
<td></td>
<td>- Microsoft Windows Server 2008 R2</td>
</tr>
<tr>
<td></td>
<td>- Micro Focus Enterprise Server</td>
</tr>
<tr>
<td></td>
<td>• Database Server: 2—BL460/2 cores</td>
</tr>
<tr>
<td></td>
<td>- Microsoft Windows Server 2008 R2</td>
</tr>
<tr>
<td></td>
<td>- Microsoft SQL Server 2008 R2</td>
</tr>
</tbody>
</table>

$4,907,340—3 yr TCO $134,500—3 yr TCO

Other conclusions

The 2012 sizing study compared the throughput achieved running the same batch and CICS workload on both an IBM mainframe and several HP MFA systems. The reference application, zRef, was run on an IBM mainframe and on a variety of HP MFA systems with CICS only, batch only stand-alone and multiple jobs concurrently, and batch and CICS run concurrently.

In addition to showing relative throughput, the results disproved several common myths:

• Myth #1—Distributed systems can’t do mixed workload, e.g., CICS and batch.
  - Reality—The HP MFA systems delivered good service even while running CICS and batch at very high levels of CPU utilization.

• Myth #2—Mainframe is superior at running batch.
  - Reality—The zRef batch jobs ran in a much shorter elapsed time on the HP MFA platforms than on the mainframe.

• Myth #3—Only a mainframe can run at or near 100% sustained system utilization and deliver good service.
  - Reality—HP MFA systems running near 100% utilization delivered consistent sub-1 second CICS response time.

The study results also enabled a three-year TCO comparison, for both 1,088 MIPS equivalent capacity and also for a z196 with a comparable capacity rating to the equivalent MIPS of services delivered by the HP ProLiant DL980 based system used in the study. As shown above, the cost of the HP MFA system is a much lower than the cost of an equivalent mainframe.

7 2nd server used for HA failover only. Not required to achieve desired performance.
Appendix A: IBM PVU based sizing

IBM Processor Value Unit (PVU) per CPU core ratings suggest 1080 MIPS equivalent per Intel CPU core!

IBM PVU tables for the different processors used in the variety of system types on which IBM distributed system software might be licensed, including System z. As of this writing, in June 2013, the PVU tables are at: 01.ibm.com/software/lotus/passportadvantage/pvu_licensing_for_customers.html. IBM bases its distributed system license fees on these PVU ratings. One might consider using relative PVU ratings as a metric for processor comparison. However, as described below, IBM's PVU rating ratios are not consistent with the findings of this study. This study found the mainframe processors used in the study to be relatively more powerful than the PVU ratings suggest.

Below are data from the table at the above referenced page, shown in the PVUs/CP or Processor core column.

<table>
<thead>
<tr>
<th>Processor</th>
<th>PVUs/IFL CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>zEC12, z196, z10</td>
<td>120</td>
</tr>
<tr>
<td>z114 and z9</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Processor</th>
<th>PVUs/Processor core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Xeon Nehalem EX</td>
<td>120, 100 or 70</td>
</tr>
<tr>
<td>Intel® Itanium®</td>
<td>100</td>
</tr>
<tr>
<td>Intel Xeon Sandy Bridge and Nehalem EP</td>
<td>100 or 70</td>
</tr>
<tr>
<td>AMD Opteron</td>
<td>50</td>
</tr>
</tbody>
</table>

The key point is that IBM gives the same processor value ratings to both System z CPs (IFLs) and Intel Xeon Processor CPU cores. Giving them the same PVU ratings (100 and 120 depending on the specific processor model) indicates that they provide the same processing capacity. For example:

- The 4320 MIPS z196 2817-704 has four CPU cores (CPs) and a PVU rating of 120 per CP.
  - Dividing by CP count calculates a rating of 1080 MIPS per CP.
- A quad core Intel Nehalem EX is also rated at 120 PVUs per CPU core (or 100 or 70 depending on the count of processors in the system in which it is installed).
  - Taking the PVU rating as a measure of power would suggests that the Nehalem EX also has 4320 MIPS of processing capacity at 1080 MIPS per CPU core.
  - And at the lower PVU ratings of 100 and 70, the calculated MIPS per CPU would be 900 and 630 respectively.

These above ratings of Xeon processor cores relative to IFL CPs are much higher than were found in this 2012 study.

It is also very interesting to note that the IBM's PVU table rating per processor core increase with the count of Xeon Nehalem processors in a single system. For example IBM rates a Nehalem EX at 70 PVUs per core when there are two Nehalem processors in a server, 100 PVUs when there are four Nehalems and 120 when there are eight. This is the opposite of the "SMP effect" demonstrated by the declining curves shown in Figure 11 in the body of this document and contrary to the well-known and generally accepted fact that systems generally deliver less throughput per processor as the count of processors (and CPU cores) is increased, of which IBM's System z MSU ratings are an example.
Appendix B: Sizing study systems setup

Sizing run setup, including server, storage, and networking

The test setup consisted of a set of test servers, with input from 3270 emulated users. The data storage consists of an HP XP 24000 storage device (for the mainframe sizing runs) and an HP 6500 for the ProLiant sizing runs. The data connection is as shown below. The infrastructure remained fixed, as shown in figure 15, throughout all of the series of tests, with the changes only occurring in the server or servers under test (within the large rectangle).

Figure 15. Sizing test setup

Mainframe system

IBM z10 EC 2097-604\(^8\) and zRef LPAR description

Table 6. Facts about the 2097 model 604 from Tech-news.com

<table>
<thead>
<tr>
<th></th>
<th>LSPR relative perf.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Si re. z/OS 1.8</td>
</tr>
<tr>
<td>1Q '08</td>
<td>4.02</td>
</tr>
<tr>
<td></td>
<td>$2,650,152</td>
</tr>
<tr>
<td></td>
<td>2444</td>
</tr>
<tr>
<td></td>
<td>371</td>
</tr>
<tr>
<td></td>
<td>277</td>
</tr>
</tbody>
</table>

For the IBM z10 EC 2097-604, the “604” naming convention defines the system sub-capacity (the “6”), and the later digits indicate the number of mainframe central processors (CPs)—in this case, the “4”. The zRef LPAR used in the testing had 1088 MIPS of CPU power, specified as follows:

- The zRef LPAR does not get more than the defined two CPs of capacity.
- Given a MIPS rating of 2197, this two-engine LPAR had a nominal rating of 1088 MIPS.
- The zRef LPAR was given 8 GB of main storage (RAM), which is identified as typical for an LPAR of this size running a workload such as zRef, our z/OS Reference Application.

The following devices were allocated to the zRef LPAR:

- Tape was on the system and used for backup storage, but was not used in any performance runs.
- I/O channels—DASD I/O went through four 4 GB FICON connections into the XP 24000 storage array. FICON throughput was limited to 2 GB by an intervening 2 GB switch. This configuration was believed to be typical for many production environments.
- Two OSA ports were used for the TN-3270n client network connections.

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\(^8\) tech-news.com/publib/pl2097.html on 24 March 2012.
**z/OS software**

The following software was run in the zRef LPAR:

- z/OS 1.13
- CICS TS 3.2
- DB2 9.1
- DFSORT
- ACF2
- RMF
- CA SYSVIEW
- Various other IBM and third-party performance monitoring tools

**HP DL980**

**MFA system: HP DL980 system sizing runs**

The primary HP system in Scenarios 1 and 2 was an HP DL980 server. In Scenario 1, the sizing run was performed with the DL980 in a single system configuration. The single system configuration was chosen to mirror those commonly found in single system mainframe production LPARs, where both the database and application would reside together.

**HP MFA DL980 System processors and memory**

The DL980 server tested had 80 CPU cores provided by eight Intel E7-4870 processors, each containing 10 CPU cores. This DL980 for the sizing runs had 1 TB of main memory (RAM) installed. Abundant RAM contributes to higher throughput and this amount of RAM is not unusual on systems of the DL980’s scale. The relatively low cost of this RAM is a contributing factor to the high price/performance delivered by these MFA systems. This cost is included in the TCO numbers presented in this paper. In the 2012 study, no runs were made with less RAM.

The maximum configurable memory for the DL980 server is 4 TB in this configuration.

The DL980 runs with a NUMA architecture server, meaning that certain processors have faster access to some memory and IO channels than other memory and IO. In the 2012 study, no effort was made to place the data or programs in memory or close to any specific CPU. Such an effort might reduce memory access overhead and ultimately increase overall system throughput.

**Input/output considerations**

- **I/O to disk (DASD paths):** Connection to the external storage array (commonly called a SAN, or Storage Area Network) was provided by eight 8 Gb/s Fibre Channel connections provided by four HP AJ764A dual port adapters.
- **I/O Capacity:** The DL980 can currently support up to either 11 or 16 I/O channel adapter cards, depending on the type of card.
- **DASD (disk) I/O:** Two different DASD (disk) configurations were tested. Both configurations had approximately 20 TB of DASD configured in three classes.

**Storage**

The configuration used had an HP Storage P9550 and then later an HP P6500 storage array presented in six disk 1.6 TB logical units (LUNs) or volumes. All reported timed runs were made using the P6500 storage array.

**Network connection**

Separate networks were provided for production use, management, and administration.

For production data communications, two 10GbE ports, on two separate adapters, were “teamed” into a single logical connection (using HP Networking Teaming for Windows Server).

For systems management and administration, a separate Gigabit Ethernet port was used.
**Figure 16.** DL980-based single system tested, showing P6500 storage

While figure 16 shows a single server sizing run configuration, where both the database and the application are on a single server, the rest of the sizing scenarios (scenario 2) are similar to what is shown in figure 17, with a database server separate from the application server.

**Figure 17.** Multi-System configuration showing P6500 storage and SQL Server on separate HP ProLiant DL580 Server
**HP MFA system software**

The MFA systems on which these test results are based were comprised of the following Microsoft system software and z/OS compatibility middleware software from Micro Focus.

**Table 7. Software installed on HP MFA system**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• File server for file sharing services and management.</td>
<td>• SQL Server 2008 R2 Enterprise Edition for relational database management (SQL) services. The zRef database was stored in SQL server.</td>
<td>• Micro Focus Enterprise Server for Windows provides z/OS application infrastructure compatibility. Micro Focus Enterprise Server provided the following functionality:</td>
<td>• Micro Focus Studio Enterprise Edition to provide mainframe application development environment on Windows with Visual Studio IDE</td>
</tr>
<tr>
<td>• Active Directory Lightweight Directory Services as an LDAP server for storage of mainframe user identity and privileged information. These data are used by the Micro Focus server z/OS compatibility middleware for user authentication and authorization.</td>
<td></td>
<td>– CICS-compatible transaction monitor.</td>
<td>• COBOL compiler to compile zRef's COBOL programs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– z/OS JES2-compatible batch processing, including JCL interpretation and support for generation data groups.</td>
<td>– EXEC CICS preprocessor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Sequential and indexed files services, including VSAM compatibility.</td>
<td>– BMS Map Compiler</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– SORT engine</td>
<td>– EXEC SQL preprocessor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Application user authentication and access authorization.</td>
<td>– JCL syntax check and execution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– A systems programming interface.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>– A systems management interface.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Activity logs and journals.</td>
<td></td>
</tr>
</tbody>
</table>

**Resources**

microsoft.com/mainframe
microfocus.com/transform
platformmodernization.org

**Learn more at**

hp.com/go/offmainframes