What's New in Linux on System z

Martin Schwidefsky
IBM Lab Böblingen, Germany
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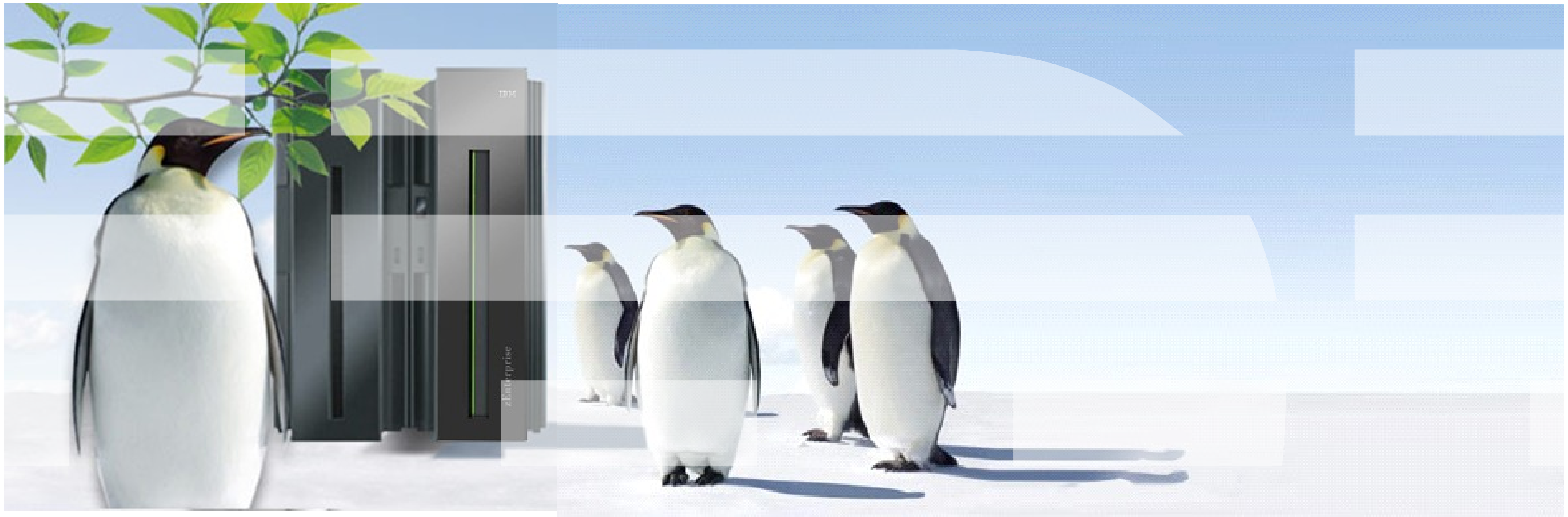

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Linux on System z introduction

Interesting facts and numbers

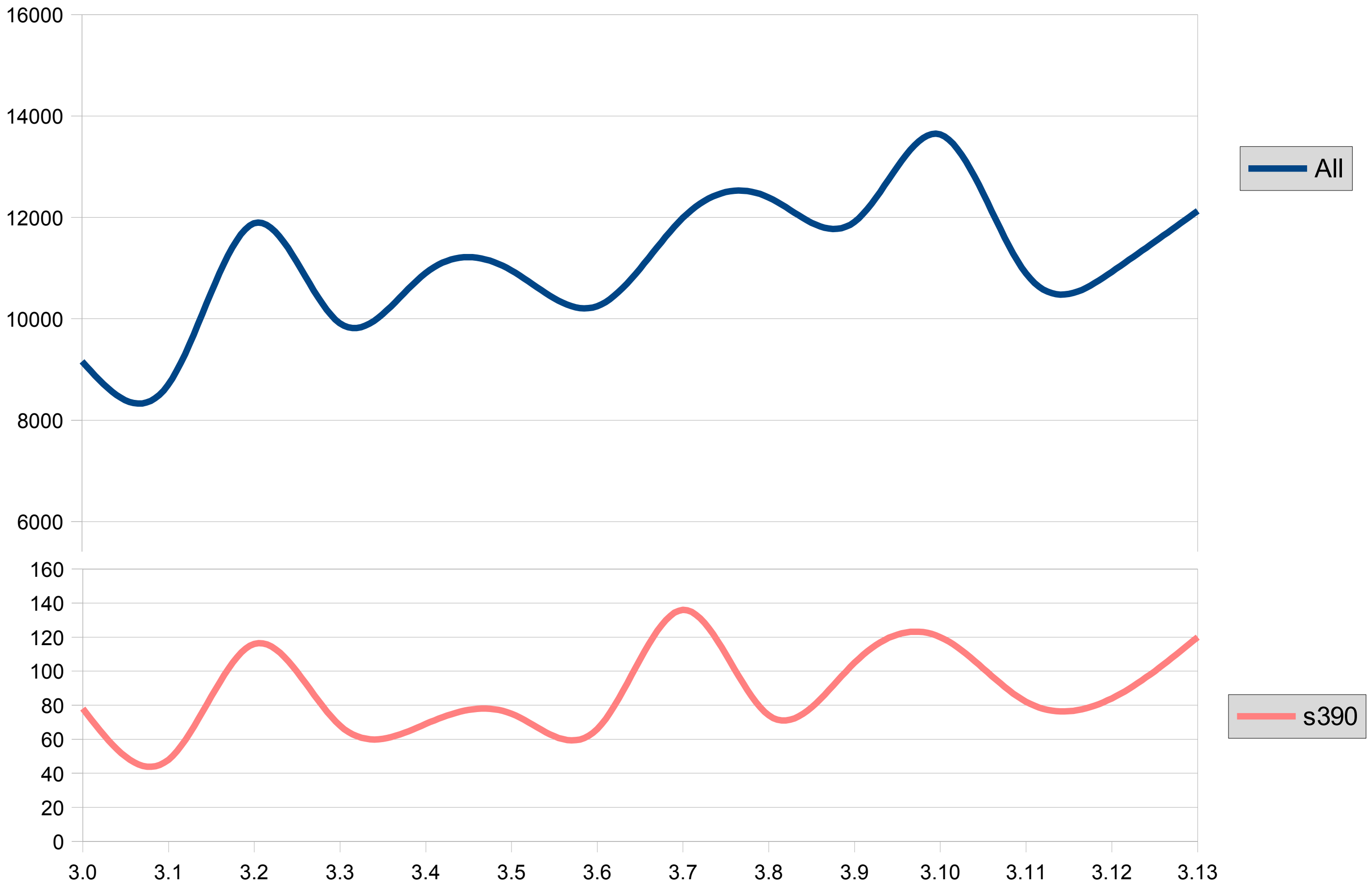
Facts on Linux

- Linux kernel 1.0.0 was released with 176,250 lines of code
  How many lines of code has the kernel version 3.13 ?
  - 17,931,010 lines of code (+3,283,977 since v3.0)
- How many of the world's top 500 supercomputers run Linux (Nov 2013)?
  482 / 96.4%
- What percentage of web servers run Linux (Feb 2014) ?
  67.1% run Unix, of those 53.3% run Linux (45.1% unknown) = 35.7%
- What percentage of desktop clients run Linux (Jan 2014) ?
  1.93% via Linux, 6.75% via Android
- What is the architecture with the larges amount of core changes?
  ARM, with ~115 KLOC per release for v3.x, followed by mips and powerpc with ~26 KLOC and x86 with ~23 KLOC. System z (alias s390) had an average of ~7 KLOCS
- Linux is Linux, but …features, properties and quality differ dependent on your platform and your use case

Source: http://kernel.org
http://top500.org/statistics
http://w3techs.com
http://www.w3counter.com

Linux kernel development: System z contributions

Changesets per 3.x kernel release

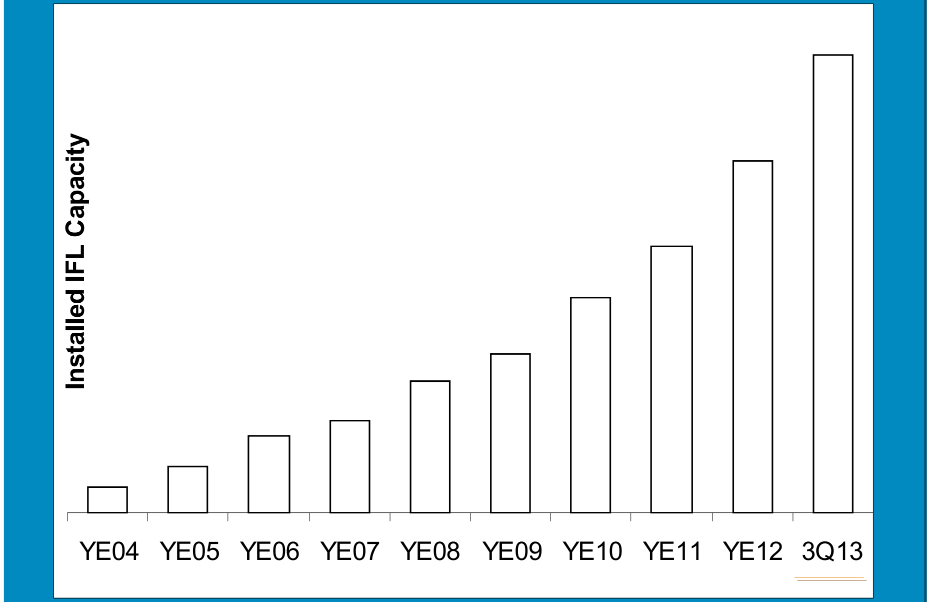


Linux on IBM System z in 3Q2013

*Installed Linux MIPS at 49% CAGR**

- 25.8% of Total installed MIPS run Linux as of 3Q13
- Installed IFL MIPS increased 44% from 3Q12 to 3Q13
- 38% of System z Customers have IFL's installed as of 3Q13
- 81 of the top 100 System z Customers are running Linux on the mainframe as of 3Q13 **
- 58% of new FIE/FIC System z Accounts run Linux (FY10-2Q13)
- 33% of all System z servers have IFLs

Installed Capacity Over Time

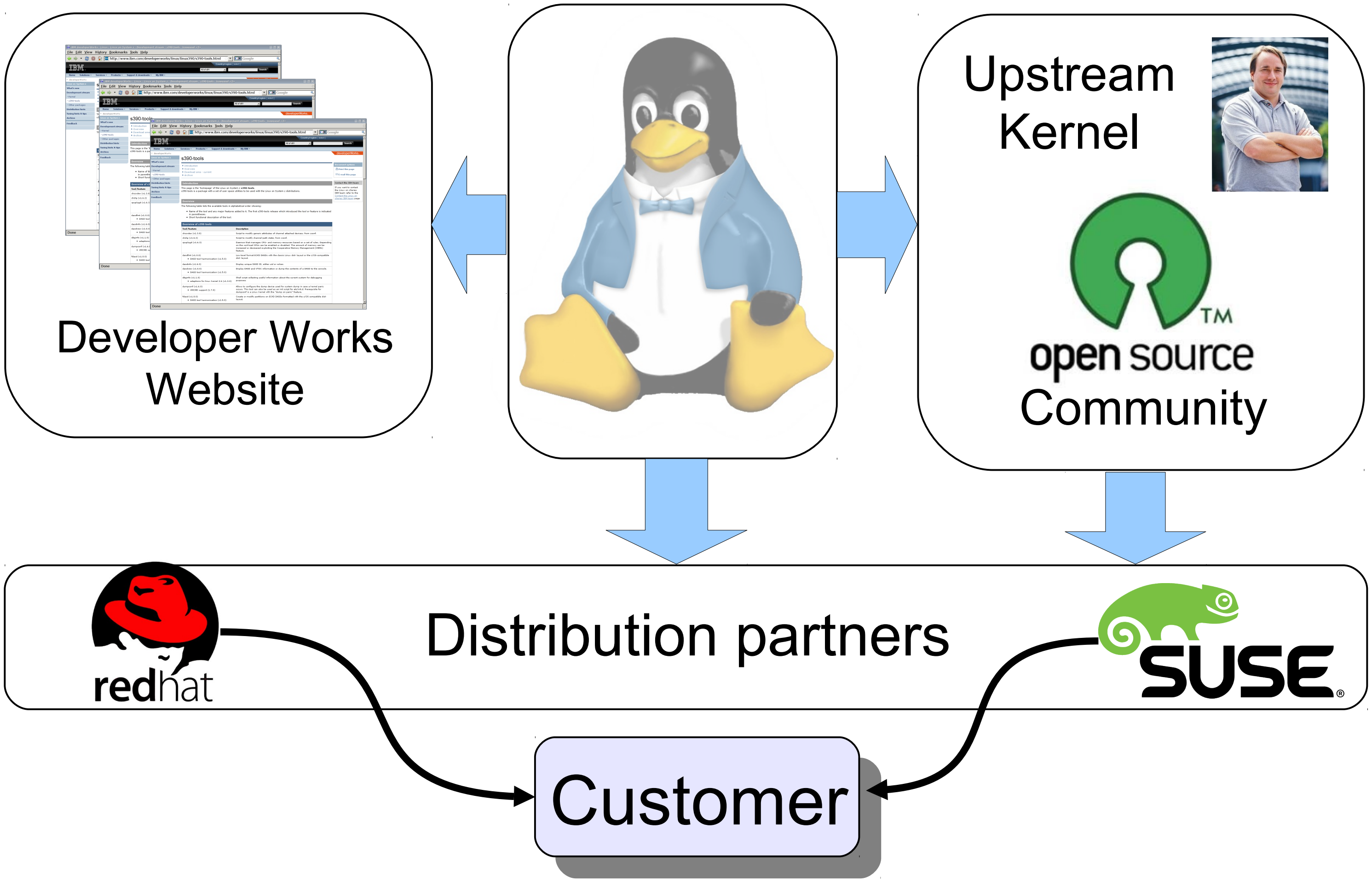


* Based on YE 2003 to 3Q 2013
**Top 100 is based on total installed MIPS

Linux on System z distributions

What is available today

Building a Linux distribution for System z



Developer Works Website

Upstream Kernel

Community

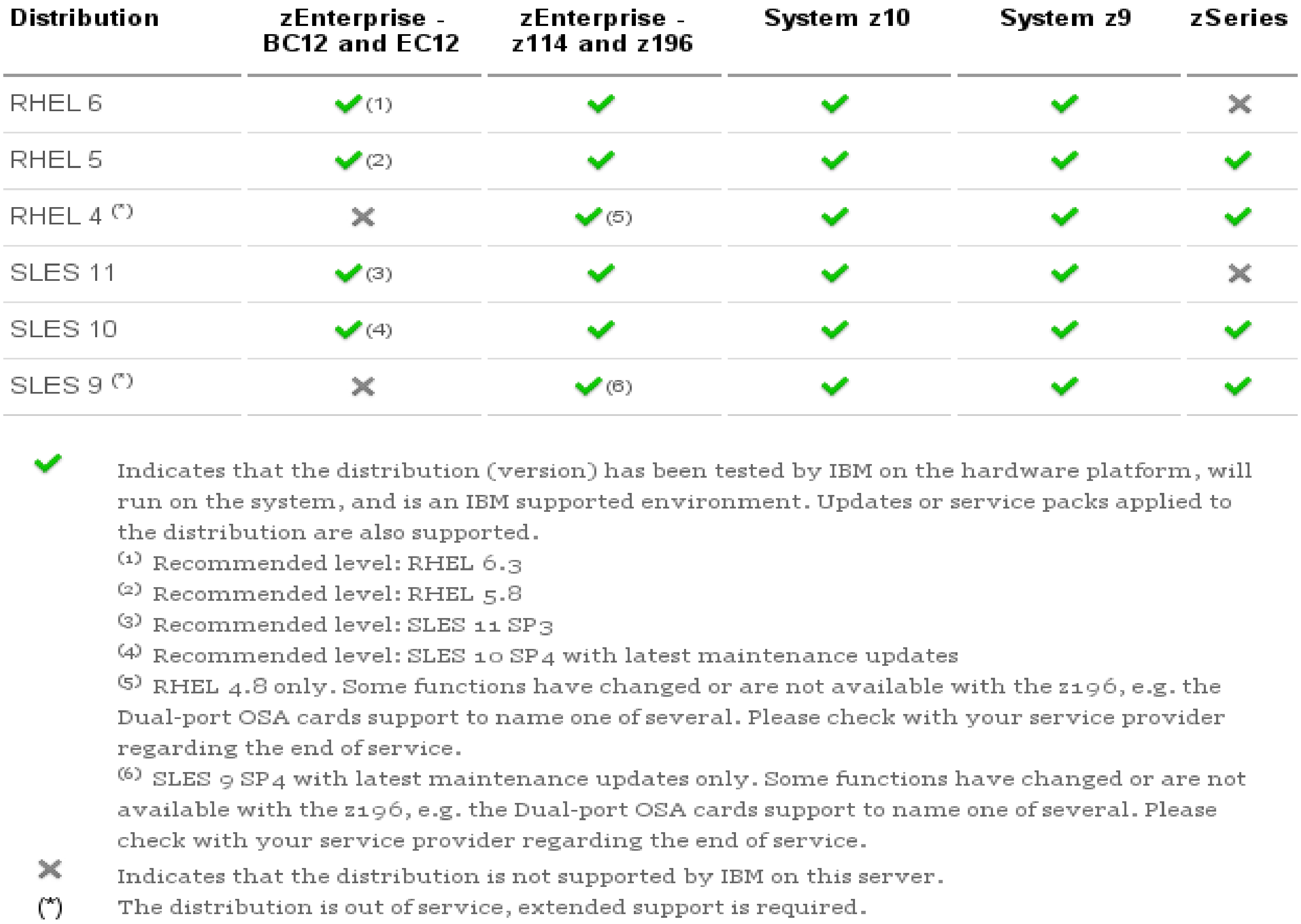
Distribution partners

Customer

Linux on System z distributions in service

- **SUSE Linux Enterprise Server 9 (GA 08/2004)**
  - Kernel 2.6.5, GCC 3.3.3, Service Pack 4 (GA 12/2007), end of regular life cycle
- **SUSE Linux Enterprise Server 10 (GA 07/2006)**
  - Kernel 2.6.16, GCC 4.1.0, Service Pack 4 (GA 04/2011)
- **SUSE Linux Enterprise Server 11 (GA 03/2009)**
  - Kernel 2.6.27, GCC 4.3.3, Service Pack 1 (GA 06/2010), Kernel 2.6.32
  - Kernel 3.0, GCC 4.3.4, Service Pack 3 (GA 07/2013)
- **Red Hat Enterprise Linux AS 4 (GA 02/2005)**
  - Kernel 2.6.9, GCC 3.4.3, Update 9 (GA 02/2011), end of regular life cycle
- **Red Hat Enterprise Linux AS 5 (GA 03/2007)**
  - Kernel 2.6.18, GCC 4.1.0, Update 10 (GA 10/2013)
- **Red Hat Enterprise Linux AS 6 (GA 11/2010)**
  - Kernel 2.6.32, GCC 4.4.0 Update 5 (GA 11/2013)
- **Others**
  - Debian, Slackware,
  - Support may be available by some third party

Supported Linux Distributions



Distribution	zEnterprise - BC12 and EC12	zEnterprise - z114 and z196	System z10	System z9	zSeries
RHEL 6	✓ (1)	✓	✓	✓	✗
RHEL 5	✓ (2)	✓	✓	✓	✓
RHEL 4 (*)	✗	✓ (5)	✓	✓	✓
SLES 11	✓ (3)	✓	✓	✓	✗
SLES 10	✓ (4)	✓	✓	✓	✓
SLES 9 (*)	✗	✓ (6)	✓	✓	✓

✓ Indicates that the distribution (version) has been tested by IBM on the hardware platform, will run on the system, and is an IBM supported environment. Updates or service packs applied to the distribution are also supported.

(1) Recommended level: RHEL 6.3

(2) Recommended level: RHEL 5.8

(3) Recommended level: SLES 11 SP3

(4) Recommended level: SLES 10 SP4 with latest maintenance updates

(5) RHEL 4.8 only. Some functions have changed or are not available with the z196, e.g. the Dual-port OSA cards support to name one of several. Please check with your service provider regarding the end of service.

(6) SLES 9 SP4 with latest maintenance updates only. Some functions have changed or are not available with the z196, e.g. the Dual-port OSA cards support to name one of several. Please check with your service provider regarding the end of service.

✗ Indicates that the distribution is not supported by IBM on this server.

(*) The distribution is out of service, extended support is required.

source: http://www.ibm.com/systems/z/os/linux/resources/testedplatforms.html

Current Linux on System z Technology

Features & Functionality developed in the **past 2 years**
contained in the SUSE & Red Hat Distributions

IBM zEnterprise EC12 and BC12 support

- **Transactional execution (kernel 3.7)**

  6.4 11.3

  – Also known as hardware transactional memory

  – CPU features that allows to execute a group of instructions atomically

  – Optimistic execution, if a transaction conflicts a rollback to a saved state is done

- **Storage class memory – Flash Express (kernel 3.7)**

  6.4 11.3

  – Internal Flash Solid State Disk (SSD)

  – Accessed via Extended Asynchronous Data Mover (EADM) sub-channels

  – Support for concurrent MCL updates with kernel version 3.8

- **Support for Crypto Express 4S cards (kernel 3.7)**

  6.4 11.3

  – New generation of crypto adapters plug-able into the I/O drawer

  – New type 10 which uses a bit field to indicate capabilities of the crypto card

- **Native PCI feature cards (base in kernel 3.8, ongoing)**

  – Support for native PCIe adapters visible to the operating system

- **Oprofile zEC12 hardware sampling support (kernel 3.10)**

  – Extend the hardware sampling to support zEC12

System zEC12 features – Transactional Execution

11.3

6.4

- **Transactional execution is a concurrency mechanism of the CPU comparable to database transactions**
  - Several reads and stores from/to memory logically occur at the same time
  - Improves performance for fine-grained serialization
  - Useful for lock-less data structures and speculative compiler optimizations
- **Two types of transactions: constraint and non-constraint**
- **Conflicting memory accesses will cause the transaction to abort**
  - Transaction abort is rather expensive
  - Constraint transaction will automatically restart
  - Ratio of successful vs. aborted transaction is important for performance
- **Kernel support is required to enable user programs to use transactional execution**
  - Control registers setup
  - Debugging support for additional PER controls via ptrace

System zEC12 features – Transactional Execution

11.3

6.4

- **Example of a list_add operation**

```
struct spinlock_t list_lock;
struct list_head list_head;
void list_add(struct list_head *new)
{
    spin_lock(&list_lock, 0, 1);
    list_add(new, &list_head);
    spin_unlock(&list_lock, 1, 0);
}
```

Typical pattern:
1) lock, 2) a short operation, 3) unlock

```
    Traditional code:

          # spin_lock
          larl    %r3,list_lock
          lhi     %r1,1
    lock: lhi     %r0,0
          cs      %r0,%r1,0(%r3)
          ltr     %r0,%r0
          jne     lock
          # list_add
          larl    %r4,list_head
          lg      %r5,0(%r4)
          stg     %r4,0(%r2)
          stg     %r5,8(%r2)
          stg     %r2,0(%r5)
          stg     %r2,8(%r4)
          # spin_unlock
          cs      %r1,%r0,0(%r3)
          br      %r14
```

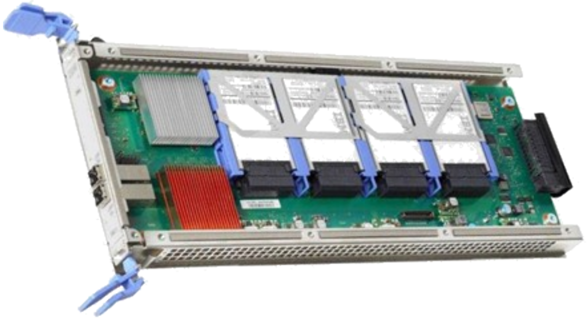
```
Transactional code

# begin transaction
tbeginc 0,0
# list_add
larl    %r4,list_head
lg      %r5,0(%r4)
stg     %r4,0(%r2)
stg     %r5,8(%r2)
stg     %r2,0(%r5)
stg     %r2,8(%r4)
# end transaction
tend
br      %r14
```

zEC12/zBC12 features – Flash Express

11.3

6.4

- **PCIe I/O adapter with NAND Flash SSDs**
  - Flash Express cards are plugged as pairs to build a RAID10
    - Pair is connected with interconnect cables
    - Card replacement is concurrent if one card fails
  - Up to 4 pairs of cards are supported (4 * 1.4TB = 5.6TB)
- **New tier of memory: Storage Class Memory**
  - Accessed via Extended Asynchronous Data Mover (EADM) subchannels via the new Storage Class Memory (SCM) block driver
- **Flash Express is split into memory increments**
  - Memory increments are assigned to LPARs via the SE or HMC
  - Memory increment size is 16 GB
- **Flash Express is not persistent over IML**



Linux on System z features – Core kernel

6.3 11.3

- **Two stage dumper / kdump support (kernel 3.2, s390-tools-1.17.0)**
  - Use a Linux kernel to create a system dump
    - Use a preloaded crash-kernel to run in case of a system failure
    - Can be triggered either as panic action or by the stand-alone dumper, integrated into the shutdown actions framework
  - Pro
    - Enhanced dump support that is able to reduce dump size, shared disk space, dump to network, dump to a file-system etc.
    - The makedumpfile tool can be used to filter the memory of the crashed system
    - Dump disk space sharing is possible for server farms using network dump
  - Con
    - kdump is not as reliable as the stand-alone dump tools
    - kdump cannot dump a z/VM named saved system (NSS)
    - For systems running in LPAR kdump consumes memory

Linux on System z features – two stage dumper / kdump support

6.3

11.3

- Add a crashkernel= to the kernel command line

```
crashkernel=<size>@<offset>
```

- Boot your system and check the reservation

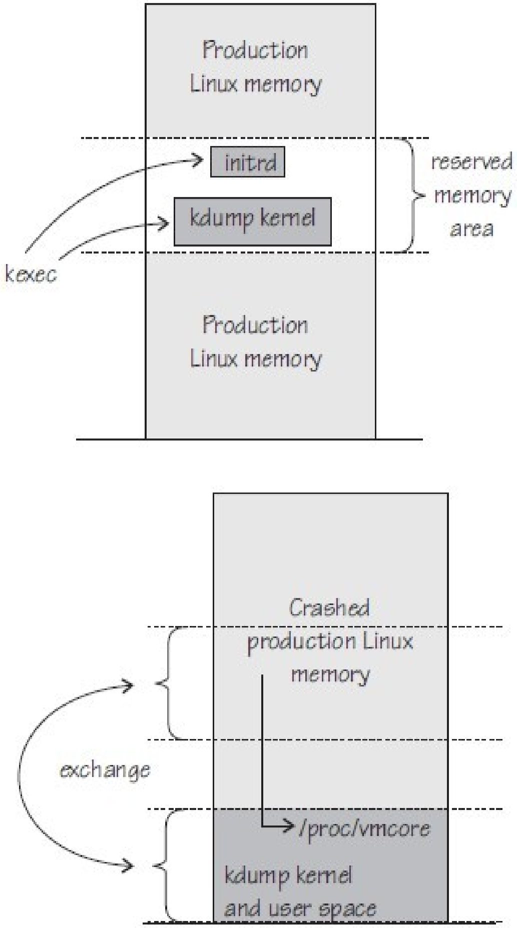
```
#cat /proc/iomem
00000000-3fffffff : System RAM
00000000-005f1143 : Kernel code
005f1144-00966497 : Kernel data
00b66000-014c4e9f : Kernel bss
40000000-47ffffff : Crash kernel
48000000-7fffffff : System RAM
```

- Load the kdump kernel with kexec

```
# kexec -p kdump.image –initrd kdump.initrd
--command-line=”dasd=1234 root=/dev/ram0”
```

- Manually trigger for kdump under z/VM

```
#cp system restart
```



Linux on System z features – Core kernel

- **Allow to compare dump system with boot system** 11.3
  - With z/VM 6.2 Single-System-Image it is possible to move active Linux instances between different z/VM instances
  - To aid debugging a log of past live-guest-relocations is made available in both the live system and in the dump of a system
- **Fuzzy Live Dump (kernel 3.5)** 11.3
  - Add the capability to generate a dump of a live system.
  - Not all data structures will be consistent but the dump may still be useful.
- **AP adapter resiliency (kernel 3.7)** 11.3
  - Improve RAS capabilities of the AP bus and the zcrypt devices.
  - External AP bus configuration changes are now handled correctly.

Linux on System z features – FICON

- **Extended DASD statistics (kernel 3.1)**

  6.3

  – Add detailed per-device debugging of DASD I/Os via debugfs

  – Useful to analyze problems in particular for PAV and HPF

- **DASD sanity check to detect path connection errors (kernel 3.3)**

  11.3

  – An incorrect physical connection between host and storage server which is not detected by hardware or microcode can lead to data corruption

  – Add a check in the DASD driver to make sure that each available channel path leads to the same storage server

- **FICON Express8S hardware data router support for FCP (kernel 3.2)**

  11.3

  – Hardware data router support requires an adapted qdio request format.

  – Improves performance by reducing the path length for data.

Linux on System z features – Networking

- **Support VEPA Mode (kernel 3.8, s390-tools 1.22)**

  11.3

  - Virtual Ethernet Port Aggregator (VEPA) mode support
  - All packages are sent to the networking switch to enable external routing
  - Reduces CPU overhead in the virtual machine
  - Uses the security, filtering, and management features of the physical switch

- **Extend lscpu tool and add new chcpu tool (util-linux 2.21)**

  11.3

  - Improve the lscpu tool to display CPU topology and CPU state
  - Add the new chcpu tool to change CPU state, rescan CPUs and change the CPU dispatching mode (horizontal vs. vertical polarization)

Linux on System z features - lscpu & chcpu

11.3

- Query CPU information

```
# lscpu -a
Architecture:           s390x
CPU op-mode(s):         32-bit, 64-bit
Byte Order:             Big Endian
CPU(s):                 3
On-line CPU(s) list:    0-2
Thread(s) per core:     1
Core(s) per socket:     1
Socket(s) per book:     1
Book(s):                3
Vendor ID:              IBM/S390
BogoMIPS:               18115.00
Hypervisor:             z/VM 6.2.0
Hypervisor vendor:      IBM
Virtualization type:    full
Dispatching mode:       horizontal
L1d cache:              96K
L1i cache:              64K
L2d cache:              1024K
L2i cache:              1024K
```

- Change CPU configuration, e.g. disable a CPU

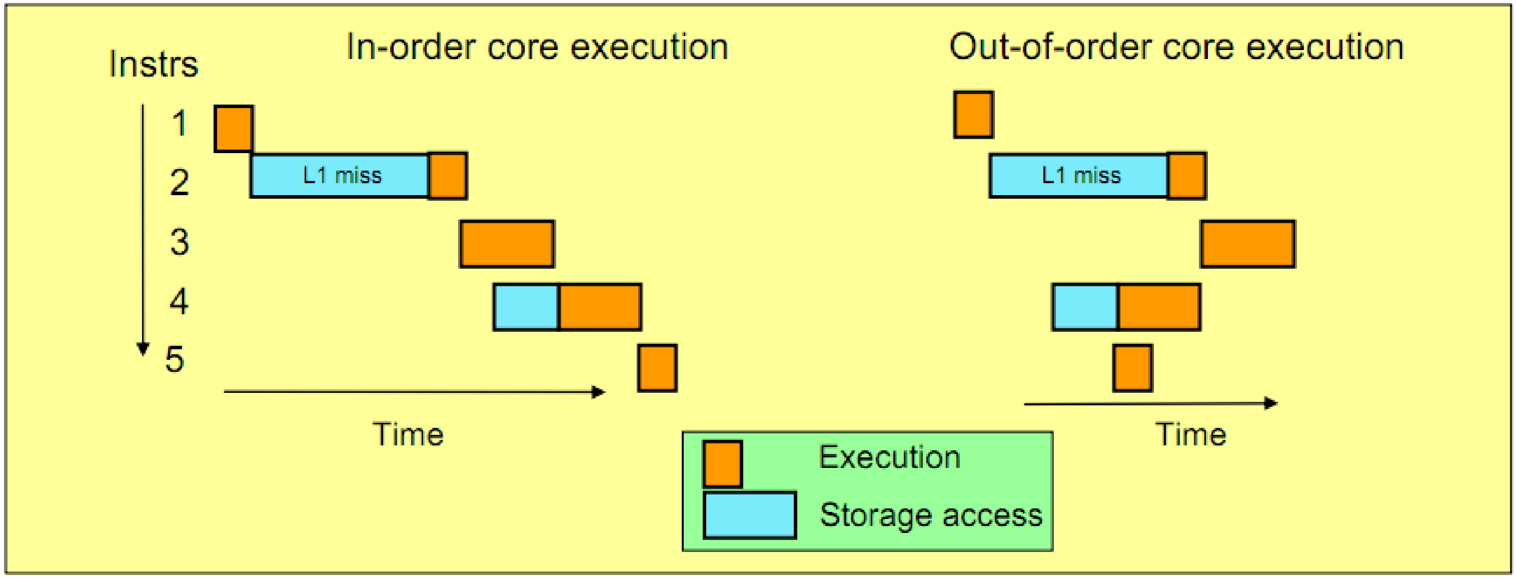
```
# chcpu -d 2
CPU 2 disabled
```

Linux on System z features – Compiler toolchain

- **zEnterprise 196 exploitation (gcc 4.6)**

6.1 11.2

  - Use option -march=z196 to utilize the new instructions added with z196
  - Use -mtune=z196 to schedule the instruction appropriate for the new out-of-order pipeline of z196
  - Re-compiled code/apps get further performance gains through 110+ new instructions



Future Linux on System z Technology

Software which has already been developed
and integrated into the upstream Linux Kernel
- but is **not yet available** in any
Enterprise Linux Distribution

PCI support

- **Native PCIe feature cards introduced on zEC12 and zBC12**
  - 10GbE RoCE Express, network card for SMC-R
  - zEDC Express, data compression/decompression card

- **Native PCIe adapter concept**
  - Plugged into an PCIe I/O drawer
  - Managed by an internal firmware processor (IFP)
  - Device driver for the PCIe function is located in the operating system

- **Uses standard Linux PCI support and drivers with some constraints**
  - Only MSIX, no port I/O, memory mapped I/O by use of PCI load/store instructions
  - Provides ability to assign individual functions of an adapter to an LPAR
  - Converted System z architecture code to use generic hardirqs
  - Only selected PCIe adapters are known to the IFP and surfaced to the OS

10GbE RoCE Express

- **Native PCIe networking card**
  - 10 Gigabit remote direct memory access (RDMA) capable network card
  - Uses Infiniband RDMA over Converged Ethernet (RoCE) specification
  - Up to 16 10GbE RoCE Express adapters per machine
  - Reduced latency and lower CPU overhead
  - Supports point-to-point connections and switch connection with an enterprise-class 10 GbE switch

- **Software support**
  - z/OS V2R1 with PTFs supports SMC-R with RoCE
  - z/VM support planned
  - Linux support in available upstream but not included in any distribution yet

zEDC Express

- **Native PCIe data compression / decompression card**
  - Up to 8 adapters can be installed into a single machine
  - With large blocks, it can compress data at more than 1 GB per second
  - Implements compression as defined by RFC1951 (DEFLATE)
  - Comparable to “gzip -1”

- **Software support**
  - z/OS V2R1, V1R13 and V1R12 with PTFs
  - Linux device driver to gain access to zEDC has been posted on LKML and has been accepted into the upstream kernel
  - The zlib open source library is a C implementation commonly used to provide compression and decompression services.

System z kernel features – memory management

Add support for physical memory > 4TB (kernel 3.3)

- Increase the maximum supported memory size from 4TB to 64TB.
- Memory sizes large than 4TB require a 4-level page table
- Makes memory accesses by the kernel slightly slower, the kernel will automatically use a 3-level page table for memory sizes <= 4TB

Transparent huge page support (kernel 3.7)

- Make the common code transparent huge page support available for Linux on System z.
- With THP 1MB pages will be used to back normal anonymous memory mappings.
- Any application will benefit from using huge pages.
- Not as effective as using the large pages directly, no memory savings for page tables due to huge page splitting.

Add page table dumper (kernel 3.7)

- Add a sysfs interface to read the current layout of the kernel address space.
- Useful information for the kernel developer.

System z kernel features – memory management

- **Implement write protection based dirty page detection (kernel 3.8)**
  - Convert dirty page detection from the change-bit in the storage key to a fault based method. An unmodified page is now always mapped read-only.
  - Due to dirty page accounting for memory mappings no additional faults are necessary
  - Removes the storage key operations to detect page dirty state
- **Implement fault based referenced page detection (kernel 3.12)**
  - Convert referenced page detection from the reference-bit in the storage key to a fault based method. An old page is now always mapped with the invalid bit set (no read, no write access).
  - New mappings are always created with the software referenced bit set
  - Removes the storage key operations to detect page referenced state.
- **Avoiding storage key operations improves performance**
  - The savings in storage key operations outweigh the slightly increase number of faults
  - After IPL a system without KVM will not access the storage keys at all
  - KVM still makes use of storage keys for provide correct guest virtualization

System z kernel features – I/O improvements

- **No automatic port rescan on events (kernel 3.7)**
  - The rescan of a zfcp port following a fabric change event can cause high fabric traffic, especially when many Linux images share an FCP channel over multiple subchannels with NPIV enabled. This can lead to errors due to timeouts.
  - Ports are still scanned when the adapter is set online and on manual user triggered writes to the port_rescan sysfs attribute.
- **Safe offline interface for DASD devices (kernel 3.8, s390-tools 1.21)**
  - Gracefully complete all outstanding I/O requests before a DASD is set offline.
- **Add robustness against missing interrupts to non-path-grouped internal IO requests (kernel 3.8, s390-tools 1.22)**
  - Improve the Linux behavior in case of a missing interrupt during path grouping
- **Improve speed of dasdfmt (kernel 3.10)**
  - Reorganize format I/O requests and enable usage of PAV.
- **Add channel ID sysfs attribute (kernel 3.10)**
  - Add an attribute to each channel-path description with the channel-ID of the path

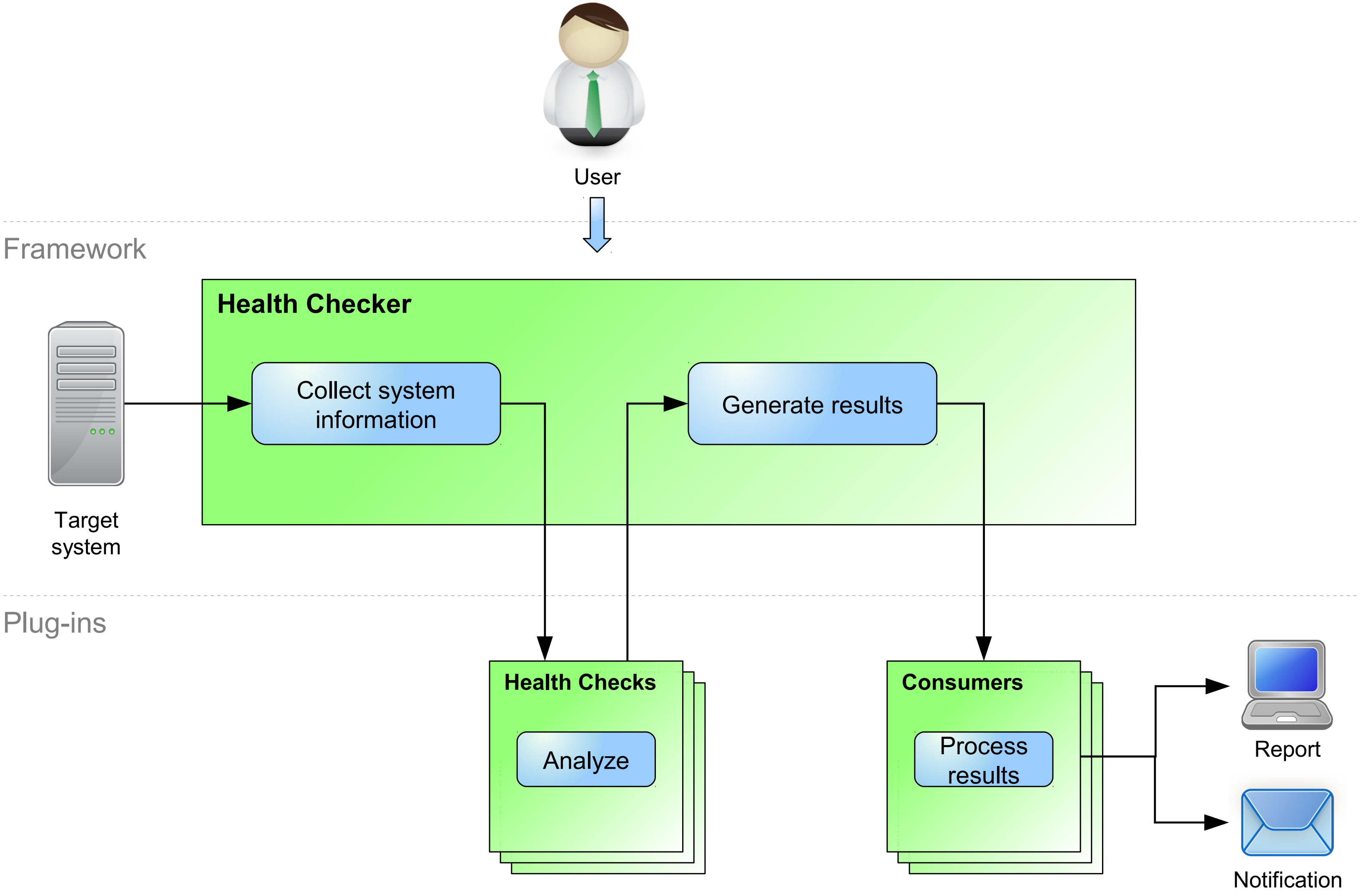
System z kernel features – improvements

- **BPF JIT compiler for System z (kernel 3.7)**
  - The Berkeley Packet Filter is an interface and a language definition that allows to pass a filter to the kernel to select network packets to send on a socket
  - The BPF JIT compiler in the kernel translates the interpreted BPF code to System z code.
  - A secondary use of the BFP language is system call filtering.
- **Expose CPU cache topology in sysfs (kernel 3.7)**
  - Add an interface to expose the CPU cache topology to user space.
  - System z only provides information about CPU caches which are private to a CPU, information about shared caches is not exposed.

LNXHC – Linux Health Checker

- The Linux Health Checker is a command line tool for Linux.
- Its purpose is to identify potential problems before they impact your system's availability or cause outages.
- It collects and compares the active Linux settings and system status for a system with the values provided by health-check authors or defined by you. It produces output in the form of detailed messages, which provide information about potential problems and the suggested actions to take.
- The Linux Health Checker will run on any Linux platform which meets the software requirements. It can be easily extended by writing new health check plug-ins.
- The Linux Health Checker is an open source project sponsored by IBM. It is released under the Eclipse Public License v1.0
- http://lnxhc.sourceforge.net/

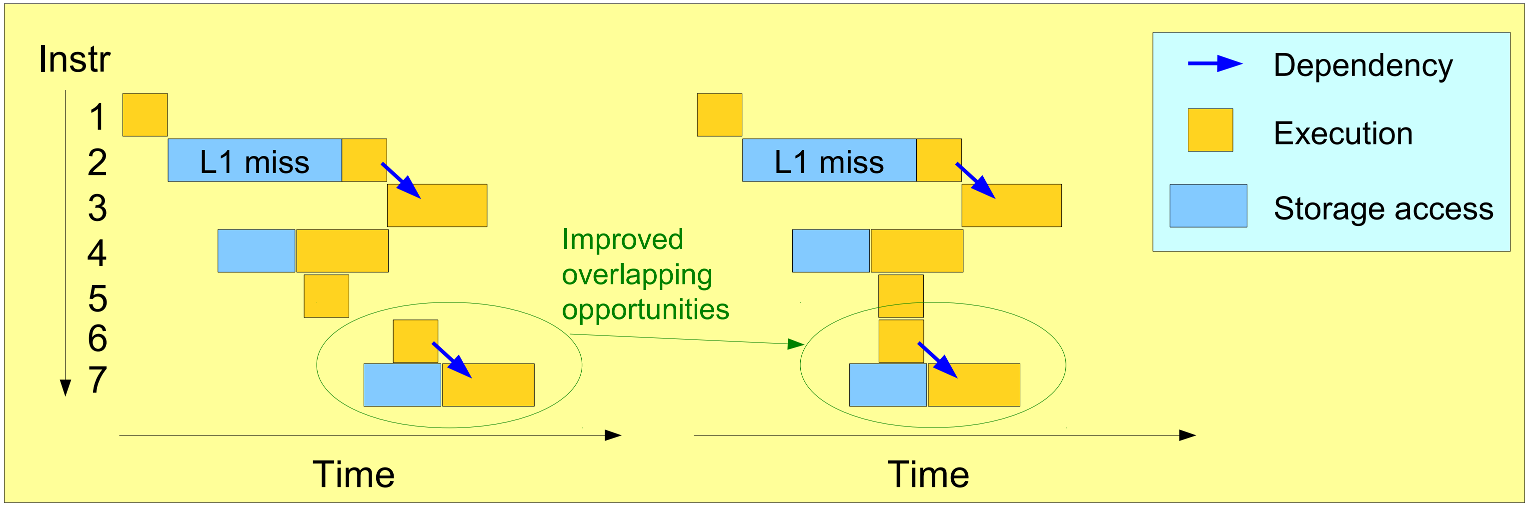
LNXHC – Linux Health Checker system overview



IBM zEnterprise EC12 and BC12 compiler support

- **New compiler options in support of the zEC12/zBC12 CPU (gcc 4.8)**
  - Option -march=zEC12 to utilize the instructions added with zEC12
  - Option -mtune=zEC12 to schedule the instructions appropriate for the pipeline of zEC12

- **zEC12/zBC12 comes with new instructions**
  - Transactional Memory support
  - Improved branch instructions



System z toolchain

- **Oprofile z196 hardware customer mode sampling (kernel 3.3)**
  - Extend the hardware sampling to support z196.
- **Oprofile zEC12 hardware sample support (kernel 3.10)**
  - Extend the hardware sampling to support zEC12
- **Valgrind System z support**
  - Valgrind is a generic framework for creating dynamic analysis tools and can be used for memory debugging, memory leak detection and profiling (e.g. cachegrind)
  - Valgrind is in essence a virtual machine using just-in-time (JIT) compilation techniques
  - Memory debugging is available with Valgrind version 3.7.0

s390-tools package: what is it?

- s390-tools is a package with a set of user space utilities to be used with the Linux on System z distributions.
  - It is **the** essential tool chain for Linux on System z
  - It contains everything from the boot loader to dump related tools for a system crash analysis .
- This software package is contained in all major (and IBM supported) enterprise Linux distributions which support s390
  - RedHat Enterprise Linux version 4, 5, and 6
  - SuSE Linux Enterprise Server version 9, 10, and 11
- Website: http://www.ibm.com/developerworks/linux/linux390/s390-tools.html
- Feedback: linux390@de.ibm.com

s390-tools package: the content

chccwdev
chchp
chreipl
chshut
chcrypt
chmem

CHANGE

lscss
lschp
lsdasd
lsluns
lsqeth
lsreipl
lsshut
lstape
lszcrypt
lszfcp
lsmem

DISPLAY

dasdfmt
dasdinfo
dasdstat
dasdview
fdasd
tunedasd

DASD

mon_fsstatd
mon_procd
ziomon
hyptop

MONITOR

ip_watcher
osasnmpd
qetharp
qethconf
qethqoat

NETWORK

tape390_display
tape390_crypt

TAPE

dbginfo
dumpconf
zfcpdump
zfcpdbf
zgetdump
scsi_logging_level

DUMP
&
DEBUG

vmconvert
vmcp
vmur
cms-fuse

z/VM

cpuplugd
iucvconn
iucvtty
ts-shell
ttyrun

MISC

zipl

BOOT

Kernel news – Common code

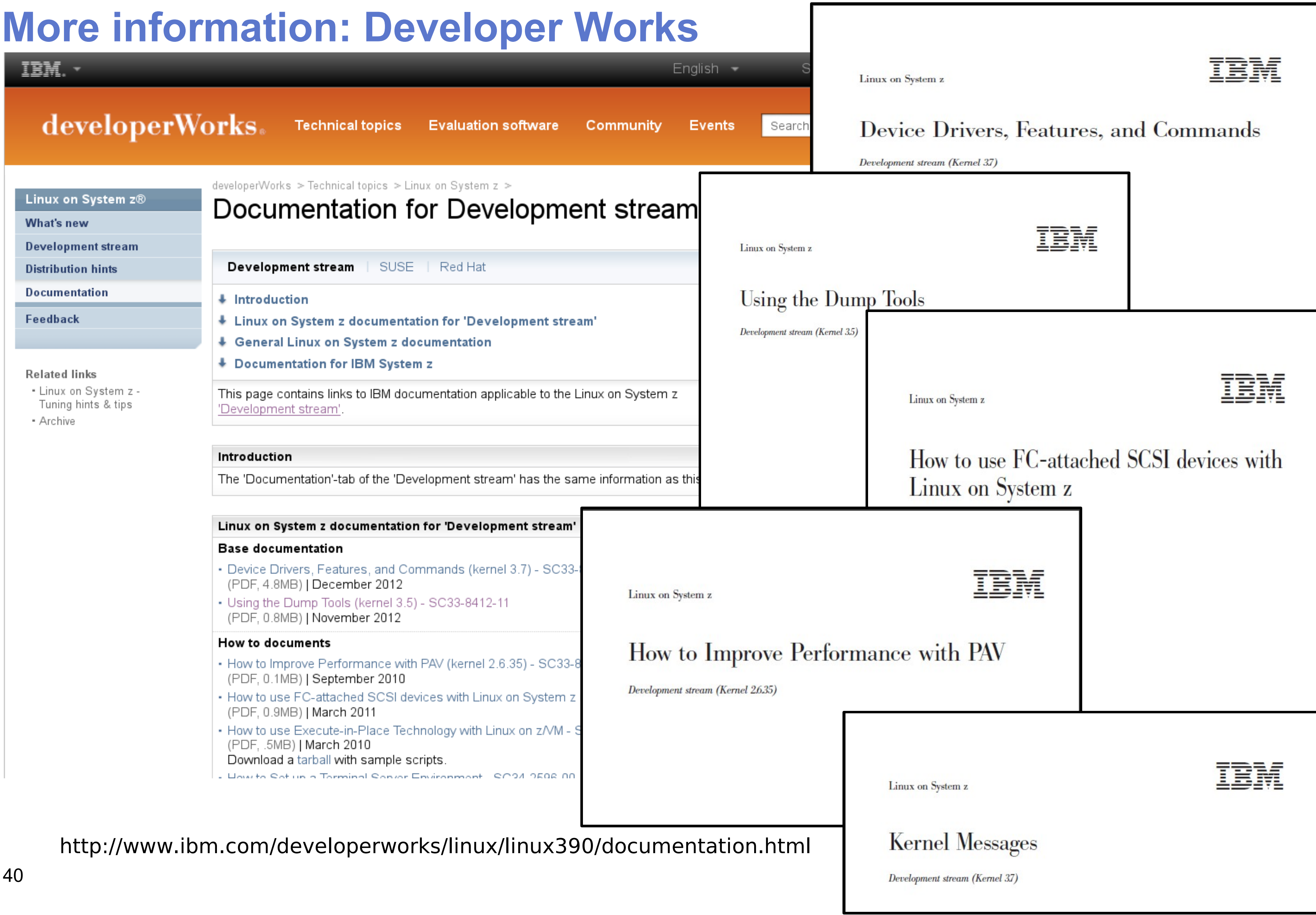
- **Linux version 3.10 (2013-06-30)**
  - (Nearly) full tickless operation
  - Bcache, a block layer cache for SSD caching
  - SysV IPC scalability improvements
  - rwsem & mutex locking scalability improvements
  - ARM big.LITTLE support
  - MIPS KVM support
- **Linux version 3.11 (2013-09-02)**
  - O_TMPFILE open flag to reduce temporary file vulnerabilities
  - Preliminary support for NFS 4.2
  - SYSV IPC message queue scalability improvements
  - Low latency network polling
  - Zswap: A compressed swap cache

Kernel news – Common code

- **Linux version 3.12 (2013-11-03)**
  - RAID5 multithreading
  - VFS locking improvements (lockref)
  - Better Out-Of-Memory handling
  - Improved tty layer locking
  - IPC locking improvements

- **Linux version 3.13 (2014-01-19)**
  - A scalable block layer for high performance SSD storage
  - nftables, the successor of iptables
  - Improved page table access scalability in hugepage workloads
  - TCP Fast Open enabled by default

More information: Developer Works



Related links

- Linux on System z - Tuning hints & tips
- Archive

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Documentation for Development stream

Development stream | SUSE | Red Hat

- Introduction
- Linux on System z documentation for 'Development stream'
- General Linux on System z documentation
- Documentation for IBM System z

This page contains links to IBM documentation applicable to the Linux on System z 'Development stream'.

Introduction

The 'Documentation'-tab of the 'Development stream' has the same information as this

Linux on System z documentation for 'Development stream'

Base documentation

- Device Drivers, Features, and Commands (kernel 3.7) - SC33-
  (PDF, 4.8MB) | December 2012
- Using the Dump Tools (kernel 3.5) - SC33-8412-11
  (PDF, 0.8MB) | November 2012

How to documents

- How to Improve Performance with PAV (kernel 2.6.35) - SC33-8
  (PDF, 0.1MB) | September 2010
- How to use FC-attached SCSI devices with Linux on System z
  (PDF, 0.9MB) | March 2011
- How to use Execute-in-Place Technology with Linux on z/VM - S
  (PDF, .5MB) | March 2010
  Download a tarball with sample scripts.
- How to Set up a Terminal Server Environment - SC34-2596-00

Linux on System z — IBM — Device Drivers, Features, and Commands — *Development stream (Kernel 3.7)*

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Linux on System z — IBM — How to use FC-attached SCSI devices with Linux on System z

Linux on System z — IBM — How to Improve Performance with PAV — *Development stream (Kernel 2.6.35)*

Linux on System z — IBM — Kernel Messages — *Development stream (Kernel 3.7)*

http://www.ibm.com/developerworks/linux/linux390/documentation.html

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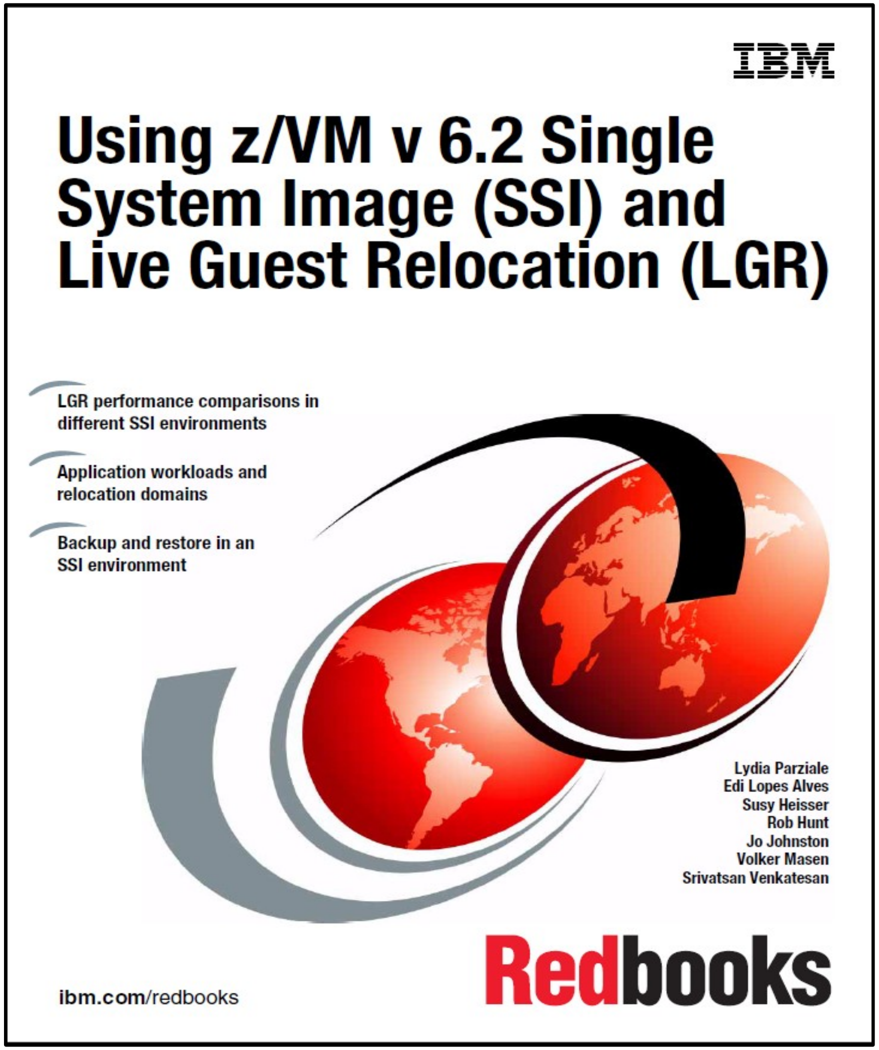

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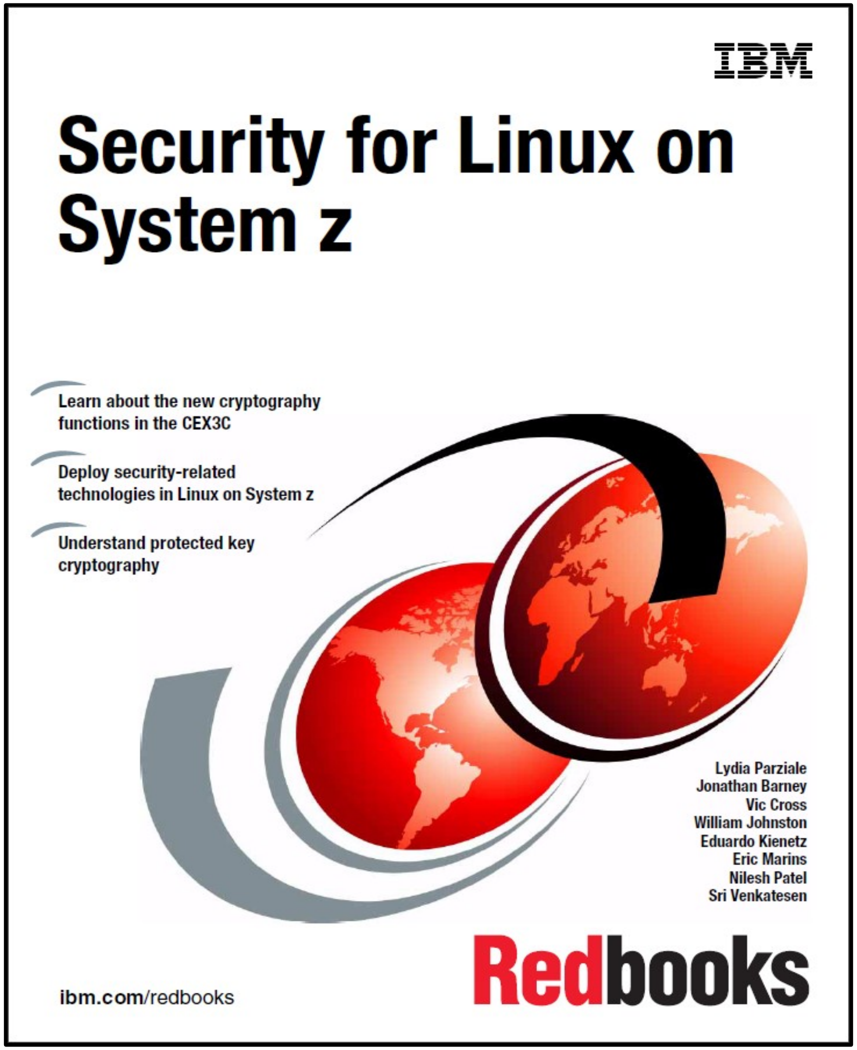

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Questions?

Martin Schwidefsky

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Schönaicher Strasse 220
71032 Böblingen, Germany

Phone +49 (0)7031-16-2247
schwidefsky@de.ibm.com