KDUMP AND INTRODUCTION TO VMCORE ANALYSIS

HOW TO GET STARTED WITH INSPECTING KERNEL FAILURES

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SUMMARY

TOPICS TO BE COVERED

- **WHAT IS A VMCORE, AND WHEN IS IS CAPTURED?**
- **CONFIGURATION OF THE KDUMP UTILITY AND TESTING**
- **SETTING UP A VMCORE ANALYSIS SYSTEM**
- **USING THE "CRASH" UTILITY FOR INITIAL ANALYSIS OF VMCORE CONTENTS**

WHAT IS A VMCORE?

It is the contents of system RAM. Ordinarily, captured via:

- makedumpfile
- VMWare suspend files
- QEMU suspend-to-disk images

```
# hexdump -C vmcore -s 0x00011d8 -n 200
000011d8  56 4d 43 4f 52 45 49 4e  46 4f 00 00 4f 53 52 45  |VMCOREINFO..OSRE|
000011e8  4c 45 41 53 45 3d 32 2e  36 2e 33 32 2d 35 37 33  |LEASE=2.6.32-573|
000011f8  2e 32 32 2e 31 2e 65 6c  36 2e 78 38 36 5f 36 34  |.22.1.el6.x86_64|
00001208  0a 50 41 47 45 53 49 5a  45 3d 34 30 39 36 0a 53  |.PAGESIZE=4096.S|
00001218  59 4d 42 4f 4c 28 69 6e  69 74 5f 75 74 73 5f 6e  |YMBOL(init_uts_n|
00001228  73 29 3d 66 66 66 66 66  66 66 66 38 31 61 39 36  |s)=ffffffff81a96|
00001238  39 36 30 0a 53 59 4d 42  4f 4c 28 6e 6f 64 65 5f  |960.SYMBOL(node_|
00001248  6f 6e 6c 69 6e 65 5f 6d  61 70 29 3d 66 66 66 66  |online_map)=ffff|
00001258  66 66 66 66 38 31 63 31  61 36 63 30 0a 53 59 4d  |ffff81c1a6c0.SYM|
00001268  42 4f 4c 28 73 77 61 70  70 65 72 5f 70 67 5f 64  |BOL(swapper_pg_d|
00001278  69 72 29 3d 66 66 66 66  66 66 66 66 38 31 61 38  |ir)=ffffffff81a8|
00001288  64 30 30 30 0a 53 59 4d  42 4f 4c 28 5f 73 74 65  |d000.SYMBOL(_ste|
00001298  78 74 29 3d 66 66 66 66                           |xt)=ffff|
000012a0
```

WHEN IS ONE WRITTEN?

By default, when the kernel encounters a state in which it cannot gracefully continue execution. Automatic captures can be expected on a configured system following:

- Kernel code level issues including
  - Memory corruption
  - Use-after-free conditions
  - Invalid memory accesses
- Machine Check exceptions

The kernel can be configured to also initiate a panic condition under a specific event condition. These can be found in the sysctl tunables on a system with "panic" in the title.

```
# sysctl -A | grep panic
kernel.panic = 0
kernel.panic_on_oops = 1
kernel.softlockup_panic = 0
kernel.unknown_nmi_panic = 0
kernel.panic_on_unrecovered_nmi = 0
kernel.panic_on_io_nmi = 0
kernel.hung_task_panic = 0
kernel.panic_on_warn = 0
vm.panic_on_oom = 0
```

KDUMP CONFIGURATION

The kdump service is the primary mechanism configuration component that allows systems to capture a vmcore during a failure.

- Provided by the "kexec-tools" package
- Configuration located in /etc/kdump.conf and most options are documented within the configuration file.

```
#raw /dev/sda5
#ext4 /dev/sda3
#ext4 LABEL=/boot
#ext4 UUID=03138356-5e61-4ab3-b58e-27507ac41937
#net my.server.com:/export/tmp
#net user@my.server.com
path /var/crash
core_collector makedumpfile -c --message-level 1 -d 31
#core_collector scp
#core_collector cp --sparse=always
#extra_bins /bin/cp
#link_delay 60
#kdump_post /var/crash/scripts/kdump-post.sh
#extra_bins /usr/bin/lftp
#disk_timeout 30
#extra_modules gfs2
#options modulename options
#default shell
#debug_mem_level 0
#force_rebuild 1
#sshkey /root/.ssh/kdump_id_rsa
#fence_kdump_args -p 7410 -f auto -c 0 -i 10
#fence_kdump_nodes node1 node2
```

CONFIGURATION CONT.

Required additional configuration:

- The "crashkernel" option.
  - This is applied within the bootloader configuration file and determines how much RAM is used for the secondary kernel which is responsible for writing the contents of RAM for the primary failing kernel
  - Should be sized appropriately to the amount of RAM installed to the system, with an eye to how many paths and modules are loaded on the system to establish a base level of functionality.

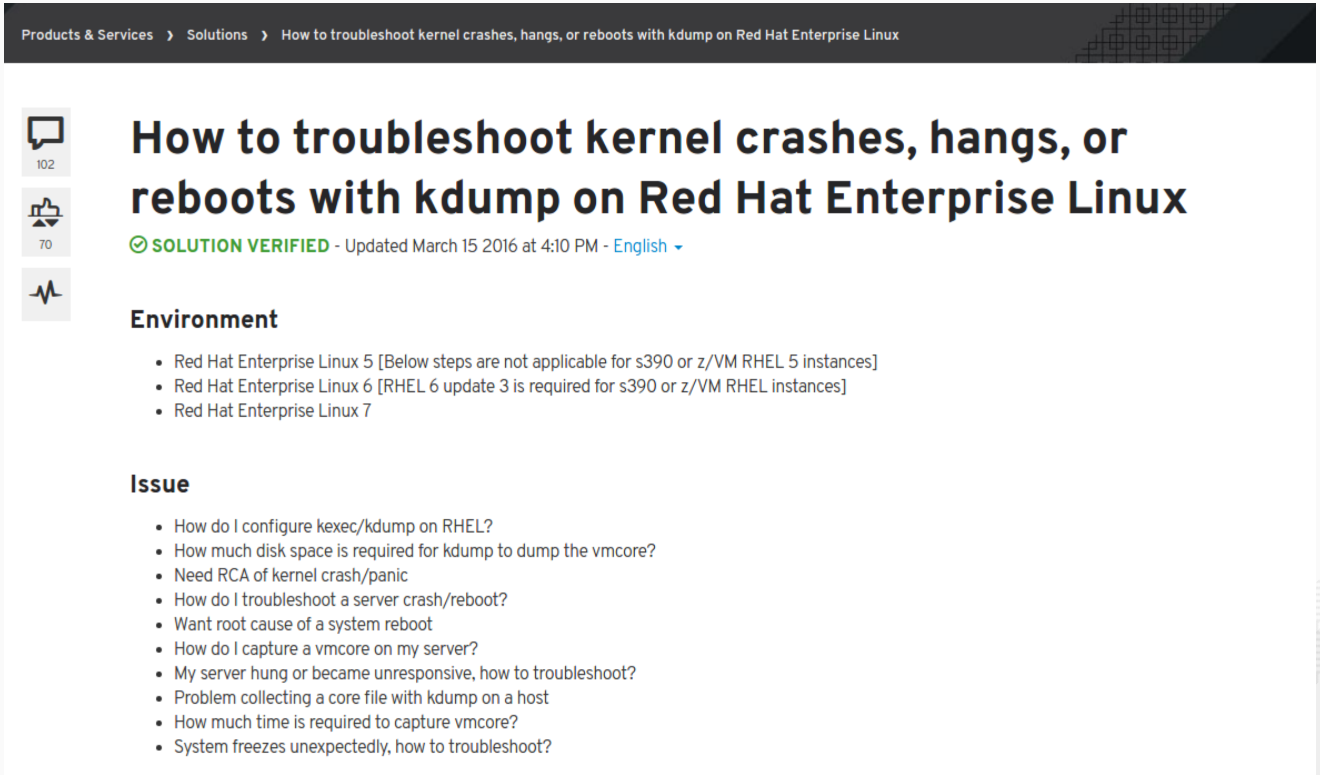
CONFIGURATION CONT.

For example:

```
# awk '/^title/,/EOF/' /boot/grub/grub.conf
title Red Hat Enterprise Linux Server (2.6.32-573.22.1.el6.x86_64)
        root (hd0,0)
        kernel /vmlinuz-2.6.32-573.22.1.el6.x86_64 crashkernel=128M ro
          root=/dev/mapper/vg_unused-lv_root
          initrd /initramfs-2.6.32-573.22.1.el6.x86_64.img
```

FURTHER ASSISTANCE:

- How to troubleshoot kernel crashes, hangs, or reboots with kdump on Red Hat Enterprise Linux
- https://access.redhat.com/solutions/6038



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How to troubleshoot kernel crashes, hangs, or reboots with kdump on Red Hat Enterprise Linux

SOLUTION VERIFIED - Updated March 15 2016 at 4:10 PM - English

Environment

- Red Hat Enterprise Linux 5 [Below steps are not applicable for s390 or z/VM RHEL 5 instances]
- Red Hat Enterprise Linux 6 [RHEL 6 update 3 is required for s390 or z/VM RHEL instances]
- Red Hat Enterprise Linux 7

Issue

- How do I configure kexec/kdump on RHEL?
- How much disk space is required for kdump to dump the vmcore?
- Need RCA of kernel crash/panic
- How do I troubleshoot a server crash/reboot?
- Want root cause of a system reboot
- How do I capture a vmcore on my server?
- My server hung or became unresponsive, how to troubleshoot?
- Problem collecting a core file with kdump on a host
- How much time is required to capture vmcore?
- System freezes unexpectedly, how to troubleshoot?

FURTHER ASSISTANCE:

- In addition, the following lab app guides administrators through the process of configuration dynamically based on the individual end system.
  - Kdump Helper
  - https://access.redhat.com/labs/kdumphelper/

KDUMP TESTING

Though the kdump service and configuration is fairly straightforward, the possible sources of failure are numerous. It is paramount to test the configuration. By initiating a kernel panic and verifying that a vmcore is present afterwards, confidence is raised that the service will function at a later date.

```
root@example ~]# echo c > /proc/sysrq-trigger
```

KDUMP TESTING

Which is closely followed by a backtrace and what looks like a system boot iteration.

```
Saving vmcore-dmesg.txt
Saved vmcore-dmesg.txt
Copying data : [100.0 %]
Excluding unnecessary pages : [100.0 %]
Copying data : [ 100.0 %]
Saving core complete
Restarting system.
machine restart
```

Failures to write a vmcore can be addressed here as opposed to following an outage event.

ANALYSIS SYSTEM

For any system that will review vmcore contents, the following must be installed:

1. The crash utility, available within the rhel-6-server-rpms base channel
2. Debugging symbols contained within the "vmlinux" file from the debuginfo package associated with the vmcore needing to be analyzed.

```
[root@example ~]# yum install crash --disablerepo=\* --enablerepo=rhel-6-server-rpms
Loaded plugins: product-id, security, subscription-manager
Setting up Install Process
Resolving Dependencies
<snip>
Dependencies Resolved

=====================================================================================
 Package        Arch            Version                 Repository               Size
=====================================================================================
Installing:
 crash          x86_64          7.1.0-3.el6_7.1         rhel-6-server-rpms       2.5 M

Transaction Summary
=====================================================================================
Install       1 Package(s)

Total download size: 2.5 M
Installed size: 7.0 M
Is this ok [y/N]: y
```

```
[root@example ~]# yum install kernel-debuginfo-`uname -r` --disablerepo=* \
--enablerepo=rhel-6-server-debug-rpms
Loaded plugins: product-id, security, subscription-manager
Setting up Install Process
rhel-6-server-debug-rpms                                   | 2.9 kB     00:00
rhel-6-server-debug-rpms/primary_db                        | 1.8 MB     00:00
Resolving Dependencies
<snip>
Dependencies Resolved

=====================================================================================
 Package                     Arch   Version                Repository              Size
=====================================================================================
Installing:
 kernel-debuginfo            x86_64 2.6.32-573.8.1.el6 rhel-6-server-debug-rpms 266 M
Installing for dependencies:
 kernel-debuginfo-common-x86_64
                             x86_64 2.6.32-573.8.1.el6 rhel-6-server-debug-rpms  43 M

Transaction Summary
=====================================================================================
Install       2 Package(s)

Total size: 309 M
Total download size: 43 M
Installed size: 1.7 G
Is this ok [y/N]: y
```

ANALYSIS SYSTEM

Though the above example shows the simplest method for achieving a working vmcore analysis system, the full kernel-debuginfo is not necessary. The core symbols are contained within the "vmlinux" file within the package.

```
# rpm -qlp kernel-debuginfo-2.6.32-573.8.1.el6.x86_64.rpm | grep 'vmlinux' -C 5
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vdso
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vdso/vdso.so.debug
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vdso/vdso32-int80.so.debug
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vdso/vdso32-syscall.so.debug
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vdso/vdso32-sysenter.so.debug
/usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vmlinux
/usr/lib/debug/usr
```

ANALYSIS SYSTEM

Extracting this file for direct use can be achieved via the "rpm2cpio" and "cpio" command combination below:

```
# TEMPDIR=$(mktemp -d)
# cd $TEMPDIR
# rpm2cpio /tmp/kernel-debuginfo-2.6.32-573.8.1.el6.x86_64.rpm | \
cpio -idmv ./usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vmlinux
./usr/lib/debug/lib/modules/2.6.32-573.8.1.el6.x86_64/vmlinux
3252733 blocks
```

ANALYSIS SYSTEM

OTHER RESOURCES AVAILABLE:

Both of the projects below allow the process of downloading separate debuginfo packages and maintaining separate directory structures for each individual vmcore to be entirely automated. Both provide a web interface that can be used to queue vmcores for analysis on local infrastructure.

- **Retrace Server**
  - https://fedoraproject.org/wiki/Features/RetraceServer
    - Well maintained with updates on regular interval
- **Core Analysis System**
  - https://fedorahosted.org/cas/
    - Not maintained at this time, the last commits to the upstream project were in 2010
- **redhat-support-tool**
  - https://access.redhat.com/articles/445443#btextract
  - This simple tool is available for retrieving necessary debuginfo packages.
  - It requires a similar release system such as Red Hat Enterprise Linux 6 for vmcores captured on a Red Hat Enterprise Linux 6 system.

INITIAL ANALYSIS

NOW THAT A VMCORE HAS BEEN CAPTURED, WHAT NEXT?

The initial steps within a vmcore can be distilled down to the following few commands:

1. log
2. bt
3. kmem -i

Each of these commands help narrow the focus of what could have caused a particular outage and will be discussed in the following slides.

INITIAL ANALYSIS

Crash itself is a debugger utility that acts as an interactive shell, accessing the contents of a given vmcore in a human readable format using the debugging symbols provided.

```
[root@example 127.0.0.1-2016-04-25-13:21:13]# crash -v

crash 7.1.0-3.el6_7.1
Copyright (C) 2002-2014  Red Hat, Inc.
Copyright (C) 2004, 2005, 2006, 2010  IBM Corporation
Copyright (C) 1999-2006  Hewlett-Packard Co
Copyright (C) 2005, 2006, 2011, 2012  Fujitsu Limited
Copyright (C) 2006, 2007  VA Linux Systems Japan K.K.
Copyright (C) 2005, 2011  NEC Corporation
Copyright (C) 1999, 2002, 2007  Silicon Graphics, Inc.
Copyright (C) 1999, 2000, 2001, 2002  Mission Critical Linux, Inc.
This program is free software, covered by the GNU General Public License,
and you are welcome to change it and/or distribute copies of it under
certain conditions.  Enter "help copying" to see the conditions.
This program has absolutely no warranty.  Enter "help warranty" for details.

GNU gdb (GDB) 7.6
Copyright (C) 2013 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-unknown-linux-gnu".
```

Opening the utility simply requires the vmcore and vmlinux file

INITIAL ANALYSIS - LOG

The log command returns the contents of the failed kernels log_buf array. When a message is emitted within the kernel via the printk() function call, the string is put into the this array in the correct entry.

For any kernel panic event, the cause of the condition will generally be noted at the end of the output.

```
BUG: unable to handle kernel NULL pointer dereference at (null)
IP: [<ffffffff81350f46>] sysrq_handle_crash+0x16/0x20
PGD 21d711067 PUD 21d520067 PMD 0
Oops: 0002 [#1] SMP
last sysfs file: /sys/devices/pci0000:00/0000:00:05.7/usb1/1-1/speed
CPU 0
Modules linked in: onload(U) sfc_char(U) sfc_resource(U) sfc_affinity(U) <snip>

Pid: 2932, comm: bash Not tainted 2.6.32-573.8.1.el6.x86_64 #1 Bochs Bochs
RIP: 0010:[<ffffffff81350f46>]  [<ffffffff81350f46>] sysrq_handle_crash+0x16/0x20
RSP: 0018:ffff88021da87e18  EFLAGS: 00010096
RAX: 0000000000000010 RBX: 0000000000000063 RCX: 0000000000000000
RDX: 0000000000000000 RSI: 0000000000000000 RDI: 0000000000000063
RBP: ffff88021da87e18 R08: 0000000000000000 R09: 00007fed7d8f5700
R10: 00000000ffffffff R11: 0000000000000246 R12: 0000000000000000
R13: ffffffff81b109a0 R14: 0000000000000286 R15: 0000000000000004
FS:  00007fed7d8f5700(0000) GS:ffff880028200000(0000) knlGS:0000000000000000
CS:  0010 DS: 0000 ES: 0000 CR0: 0000000080050033
CR2: 0000000000000000 CR3: 000000021db04000 CR4: 00000000000406f0
DR0: 0000000000000000 DR1: 0000000000000000 DR2: 0000000000000000
DR3: 0000000000000000 DR6: 00000000ffff0ff0 DR7: 0000000000000400
<snip>
```

Bug noted

Registers

INITIAL ANALYSIS - LOG

Continued.

```
Process bash (pid: 2932, threadinfo ffff88021da84000, task ffff88021d450ab0)
Stack:
 ffff88021da87e68 ffffffff81351202 ffff88021ad58728 0000000000000000
<d> 0000000000000022 0000000000000002 ffff88011afd99c0 00007fed7d8fc000
<d> 0000000000000002 fffffffffffffffb ffff88021da87e98 ffffffff813512be
Call Trace:
 [<ffffffff81351202>] __handle_sysrq+0x132/0x1a0
 [<ffffffff813512be>] write_sysrq_trigger+0x4e/0x50
 [<ffffffff811fd29e>] proc_reg_write+0x7e/0xc0
 [<ffffffff81191ab8>] vfs_write+0xb8/0x1a0
 [<ffffffff81192fa6>] ? fget_light_pos+0x16/0x50
 [<ffffffff811925f1>] sys_write+0x51/0xb0
 [<ffffffff8100b0d2>] system_call_fastpath+0x16/0x1b
Code: d0 88 81 a3 6e ff 81 c9 c3 66 66 66 2e 0f 1f 84 00 00 00 00 00 55 48 <snip>
RIP  [<ffffffff81350f46>] sysrq_handle_crash+0x16/0x20
 RSP <ffff88021da87e18>
CR2: 0000000000000000
```

Backtrace

In the event that a vmcore was captured not as a result of a kernel panic, careful inspection of the full ring buffer contents will be necessary. A system may enter a degraded state, but continue operation for some time without encountering a panic state. This, if continued long enough can result in the ring buffer wrapping and thereby masking the original initiating failure condition.

INITIAL ANALYSIS - LOG

In the above example, the following message is reported:

Followed by a register dump, and backtrace. Register contents have been omitted from the following for legibility:

```
BUG: unable to handle kernel NULL pointer dereference at (null)


Pid: 2932, comm: bash Not tainted 2.6.32-573.8.1.el6.x86_64 #1 Bochs Bochs
RIP: 0010:[<ffffffff81350f46>]  [<ffffffff81350f46>] sysrq_handle_crash+0x16/0x20
<snip>
Call Trace:
 [<ffffffff81351202>] __handle_sysrq+0x132/0x1a0
 [<ffffffff813512be>] write_sysrq_trigger+0x4e/0x50
 [<ffffffff811fd29e>] proc_reg_write+0x7e/0xc0
 [<ffffffff81191ab8>] vfs_write+0xb8/0x1a0
 [<ffffffff81192fa6>] ? fget_light_pos+0x16/0x50
 [<ffffffff811925f1>] sys_write+0x51/0xb0
 [<ffffffff8100b0d2>] system_call_fastpath+0x16/0x1b
Code: d0 88 81 a3 6e ff 81 c9 c3 66 66 66 2e 0f 1f 84 00 00 00 00 00 55 48 89 e5 0f 1f 44 00
RIP  [<ffffffff81350f46>] sysrq_handle_crash+0x16/0x20
 RSP <ffff88021da87e18>
CR2: 0000000000000000
```

RIP: Is the instruction that was underway at the time of the failure.

Call Trace: Is the breadcrumb trail of functions that led to this end RIP. Functions with a "?" next to them are a guess by the stack unwinder and should not be assumed to be correct without further verification.

INITIAL ANALYSIS - LOG

Using the above backtrace, the RIP yields the exact operation that was underway at the time of the failure.

Kernel crash in sysrq_handle_crash

Resolution

- Determine what issued the sysrq+c and if desired, work to stop the source of the sysrq+c command.

Root Cause

- The box has been panicked with a sysrq+c instruction. This would have to be manually initiated.
- Please see this documentation for more information on the SysRq facility.

Duplicate(s) Info

- What is the source of these Call Traces in /var/log/messages

INITIAL ANALYSIS - BT

Similar to the log command, the bt returns (by default) the backtrace of the task that is currently under inspection. As the active task on opening is the process that is the panicking process, this yields the following on the same vmcore.

```
crash> bt
<snip>
    [exception RIP: sysrq_handle_crash+22]
    RIP: ffffffff81350f46  RSP: ffff88021da87e18  RFLAGS: 00010096
    RAX: 0000000000000010  RBX: 0000000000000063  RCX: 0000000000000000
    RDX: 0000000000000000  RSI: 0000000000000000  RDI: 0000000000000063
    RBP: ffff88021da87e18   R8: 0000000000000000   R9: 00007fed7d8f5700
    R10: 00000000ffffffff  R11: 0000000000000246  R12: 0000000000000000
    R13: ffffffff81b109a0  R14: 0000000000000286  R15: 0000000000000004
    ORIG_RAX: ffffffffffffffff  CS: 0010  SS: 0018
 #9 [ffff88021da87e20] __handle_sysrq at ffffffff81351202
#10 [ffff88021da87e70] write_sysrq_trigger at ffffffff813512be
#11 [ffff88021da87ea0] proc_reg_write at ffffffff811fd29e
#12 [ffff88021da87ef0] vfs_write at ffffffff81191ab8
#13 [ffff88021da87f30] sys_write at ffffffff811925f1
#14 [ffff88021da87f80] system_call_fastpath at ffffffff8100b0d2
    RIP: 000000374aedb520  RSP: 00007ffc06b2c410  RFLAGS: 00010206
    RAX: 0000000000000001  RBX: ffffffff8100b0d2  RCX: 0000000000000400
    RDX: 0000000000000002  RSI: 00007fed7d8fc000  RDI: 0000000000000001
    RBP: 00007fed7d8fc000   R8: 000000000000000a   R9: 00007fed7d8f5700
    R10: 00000000ffffffff  R11: 0000000000000246  R12: 0000000000000002
    R13: 000000374b18e7a0  R14: 0000000000000002  R15: 000000374b18e7a0
    ORIG_RAX: 0000000000000001  CS: 0033  SS: 002b
```

INITIAL ANALYSIS - BT

For initial analysis purposes, the bt command also allows backtraces to be returned for all active tasks in the vmcore via the "-a" flag:

```
crash> bt -a | grep PID -A 1
PID: 2932   TASK: ffff88021d450ab0  CPU: 0   COMMAND: "bash"
 #0 [ffff88021da879e0] machine_kexec at ffffffff8103d1ab
--
PID: 0      TASK: ffff88011e679520  CPU: 1   COMMAND: "swapper"
 #0 [ffff880028246e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e688040  CPU: 2   COMMAND: "swapper"
 #0 [ffff880028286e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e6d0ab0  CPU: 3   COMMAND: "swapper"
 #0 [ffff8800282c6e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e6f5520  CPU: 4   COMMAND: "swapper"
 #0 [ffff880028306e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e704040  CPU: 5   COMMAND: "swapper"
 #0 [ffff880028346e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e74aab0  CPU: 6   COMMAND: "swapper"
 #0 [ffff880123c06e90] crash_nmi_callback at ffffffff81033cf6
--
PID: 0      TASK: ffff88011e767520  CPU: 7   COMMAND: "swapper"
 #0 [ffff880123c46e90] crash_nmi_callback at ffffffff81033cf6
```

INITIAL ANALYSIS - BT

Based on the RIP of the process at the time of the failure, mapping the failure to code is possible.

```
crash> bt | awk '/#8/,/#9/'
 #8 [ffff88021da87d60] page_fault at ffffffff8153bf05
    [exception RIP: sysrq_handle_crash+22]
    RIP: ffffffff81350f46  RSP: ffff88021da87e18  RFLAGS: 00010096
    RAX: 0000000000000010  RBX: 0000000000000063  RCX: 00000000000000
    RDX: 0000000000000000  RSI: 0000000000000000  RDI: 00000000000000
    RBP: ffff88021da87e18   R8: 0000000000000000   R9: 00007fed7d8f57
    R10: 00000000ffffffff  R11: 0000000000000246  R12: 00000000000000
    R13: ffffffff81b109a0  R14: 0000000000000286  R15: 00000000000000
```

RIP

The "dis" function can be used to inspect the RIP using either the hexadecimal representation, or symbol+offset value.

```
crash> dis -l sysrq_handle_crash+22
<snip>/drivers/char/sysrq.c: 130
0xffffffff81350f46 <sysrq_handle_crash+22>:     movb   $0x1,0x0
```

Though the above path is truncated, the above dis operation yields the source in which the system was executing at the time of the failure.

INITIAL ANALYSIS - BT

With source file and line number, the Red Hat Code browser can be used to determine what operation was underway at the time.

> Red Hat Code Browser
> https://access.redhat.com/labs/psb/versions/kernel-2.6.32-573.8.1.el6/

Within the code browser, navigating to the drivers/char/sysrq.c source file at line number 130 yields:

```
122 #endif /* CONFIG_VT */
123
124 static void sysrq_handle_crash(int key, struct tty_struct *tty)
125 {
126         char *killer = NULL;
127
128         panic_on_oops = 1;        /* force panic */
129         wmb();
130         *killer = 1;
131 }
132 static struct sysrq_key_op sysrq_crash_op = {
133         .handler        = sysrq_handle_crash,
134         .help_msg        = "Crash",
```

INITIAL ANALYSIS - BT

In the event that the log output shows that there is a failure present in a task that is not in the end default bt command, using the bt command with the specific PID will allow a review of the current state of that task.

For hung_task_panic events, a careful review of the current state of the task is necessary as the panic task will be the "khungtaskd" process and not the actual task that has been within Uninterruptible sleep state for greater than 120 seconds.

INITIAL ANALYSIS - KMEM

The kmem command can be used to determine a wealth of information regarding the VMM subsystem. However, an overview of memory use can be reviewed via the "-i" flag:

```
crash> kmem -i
                 PAGES        TOTAL      PERCENTAGE
    TOTAL MEM  2012387       7.7 GB         ----
         FREE  1911140       7.3 GB   94% of TOTAL MEM
         USED   101247     395.5 MB    5% of TOTAL MEM
       SHARED    12196      47.6 MB    0% of TOTAL MEM
      BUFFERS     4964      19.4 MB    0% of TOTAL MEM
       CACHED    38010     148.5 MB    1% of TOTAL MEM
         SLAB    20287      79.2 MB    1% of TOTAL MEM

   TOTAL SWAP  2047999       7.8 GB         ----
    SWAP USED        0            0    0% of TOTAL SWAP
    SWAP FREE  2047999       7.8 GB  100% of TOTAL SWAP

 COMMIT LIMIT  3054192      11.7 GB         ----
```

Specific types of memory starvation can be evaluated further using the kmem utility in full.

INITIAL ANALYSIS - KMEM

"kmem -s" - Slab usage

```
crash> kmem -s | head
CACHE            NAME                 OBJSIZE  ALLOCATED     TOTAL  SLABS  SSIZE
ffff88011c1d1fc0 onloadfs_inode_cache     616          1         6      1     4k
ffff88011c3e1f80 nfs_direct_cache         200          0         0      0     4k
ffff88011c3d1f40 nfs_commit_data          704          0         0      0     8k
ffff88011c3c1f00 nfs_write_data           960         36        36      9     4k
ffff88011c3b1ec0 nfs_read_data            896          0         0      0     4k
ffff88011c3a1e80 nfs_inode_cache         1048          1         3      1     4k
ffff88011c391e40 nfs_page                 128          0         0      0     4k
ffff88011cc51e00 fscache cookie jar        80          3        48      1     4k
```

"kmem -z" - Per zone statistics

```
crash> kmem -z | head
NODE: 0  ZONE: 0  ADDR: ffff880000015440  NAME: "DMA"
  SIZE: 4095  PRESENT: 3830  MIN/LOW/HIGH: 41/51/61
  VM_STAT:
              NR_FREE_PAGES: 3926
           NR_INACTIVE_ANON: 0
             NR_ACTIVE_ANON: 0
           NR_INACTIVE_FILE: 0
             NR_ACTIVE_FILE: 0
             NR_UNEVICTABLE: 0
                   NR_MLOCK: 0
```

QUESTIONS?

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