# Linux Crash Dump Analysis

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# Agenda

- Welcome to panic
- Getting started
- Advanced Studies
- Case Studies
- References

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"Computers crash. It's just a fact of life."

from the "panic" book

# Kernel Panic

- An action taken by an operating system upon detecting an internal fatal error from which it cannot safely recover.
  - Kernel printed errors messages via console
  - Freeze the system to dump the memory to dump device
  - Reboot
  - Save vmcore file to filesystem

# Causes

- Bugs in kernel, modules or drivers
  - Panic
    - Exception or trap
    - Assertion or BUG_ON
  - Oops
    - If panic_on_oops gets set
- Triggers for system, process hang
  - Watchdogs
  - Sysrq
- Fatal hardware errors…
  - Intel MCE (Machine Check Exceptions)
  - PCIE Uncorrectable Errors
  - Firmware bugs

# Debug Information

- Console messages
- System's configurations
  - Hardware
  - Software (kernel, apps)
- Full system logs around the panic time
- Kernel core dump
- Other information dump…
  - MCE banks and registers
  - PCIe TLP packets and registers
  - IPMI SEL logs (BIOS and SMI logs)

STB (Service Tool Bundle) is developed for Solaris and Linux OSes vendors

# Kernel Crash Dump

- Memory snapshot while kernel panic
  - Kernel pages only (by default)
  - User pages dump is supported
  - Data on swap device is not included
  - Memory consistence
    - Dump after death
      - Very small partial of memory may not be consistent
      - Depends on dump mechanisms
    - Live dump is always not consistent!
- Kernel dump utilities
  - Kdump (mainline)
  - Disk dump
  - Net dump

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# Panic - Console Messages

```
[3265705.369809] BUG: unable to handle kernel NULL pointer dereference at 0000000000000011
[3265705.377625] IP: [<ffffffff811d17f3>] mem_cgroup_iter+0x163/0x2b0
[3265705.385085] PGD 1c65328067 PUD 2f4818d067 PMD 0
[3265705.391169] Oops: 0000 [#1] SMP
[3265705.395814] Modules linked in: kpatch_s8wspkpx(OE) nbd(OE) tcp_diag inet_diag sch_dsmark act_
[3265705.476305]  dca [last unloaded: nbd]
[3265705.480030] CPU: 28 PID: 51681 Comm: test Tainted: G        W  OE K------------ T 3.10.0-327.
[3265705.492495] Hardware name: Lenovo ThinkServer SD350X/B900G3-10G-N, BIOS A2.16 07/08/2016
[3265705.502088] task: ffff880114fd6480 ti: ffff882f6d8d4000 task.ti: ffff882f6d8d4000
[3265705.511088] RIP: 0010:[<ffffffff811d17f3>]  [<ffffffff811d17f3>] mem_cgroup_iter+0x163/0x2b0
[3265705.521114] RSP: 0018:ffff882f6d8d7dc8  EFLAGS: 00010286
[3265705.527937] RAX: ffff8808756bb600 RBX: ffff882f6f452000 RCX: ffff8808756bb610
[3265705.536586] RDX: ffff882f6ebaca00 RSI: 0000000000000000 RDI: ffff882f6ebaca20
[3265705.545244] RBP: ffff882f6d8d7e10 R08: ffff882f6d8d4000 R09: ffff88014fb50079
[3265705.553885] R10: 000000000000000a R11: 0000000000000000 R12: 000000001f4eb000
[3265705.562525] R13: 0000000000000000 R14: ffff8808756bb600 R15: 0000000000000001
[3265705.571164] FS:  00007fcbdf0e9700(0000) GS:ffff882fbf180000(0000) knlGS:0000000000000000
[3265705.580741] CS:  0010 DS: 0000 ES: 0000 CR0: 0000000080050033
[3265705.587961] CR2: 0000000000000011 CR3: 0000000785a2c000 CR4: 00000000003407e0
[3265705.596561] DR0: 0000000000000000 DR1: 0000000000000000 DR2: 0000000000000000
[3265705.605180] DR3: 0000000000000000 DR6: 00000000fffe0ff0 DR7: 0000000000000400
[3265705.613758] Stack:
[3265705.617189]  01ff882f6d8d7dd8 ffff882f40ad6000 ffff882f6d8d7e10 ffff882f40ad6000
[3265705.626167]  ffff882f6f452000 000000001f4eb000 0000000000000000 ffff882f40ad6000
[3265705.635131]  0000000000000000 ffff882f6d8d7e68 ffffffff811d227f ffff88021c47c380
[3265705.644108] Call Trace:
[3265705.647945]  [<ffffffff811d227f>] memcg_stat_show+0x16f/0x2f0
[3265705.655190]  [<ffffffff810f5853>] cgroup_seqfile_show+0x73/0x80
[3265705.662503]  [<ffffffff81203e47>] ? seq_buf_alloc+0x17/0x40
[3265705.669442]  [<ffffffff8120433a>] seq_read+0xfa/0x3a0
[3265705.675875]  [<ffffffff811e033c>] vfs_read+0x9c/0x170
[3265705.682273]  [<ffffffff811e0e8f>] SyS_read+0x7f/0xe0
[3265705.688593]  [<ffffffff816479c9>] system_call_fastpath+0x16/0x1b
[3265705.695923] Code: 4c 8b 30 eb 0f 0f 1f 00 4c 89 ff e8 28 43 f2 ff 84 c0 75 1e 48 8b 33 4c 89
[3265705.719001] RIP  [<ffffffff811d17f3>] mem_cgroup_iter+0x163/0x2b0
[3265705.726466]  RSP <ffff882f6d8d7dc8>
[3265705.731272] CR2: 0000000000000011
~
```

# Header & Register Dumps

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[3265705.391169] Oops: 0000 [#1] SMP
[3265705.395814] Modules linked in tcp_diag inet_diag sch_dsmark sch_ingress binfmt_misc..[snipped]..
[3265705.480030] CPU: 28 PID: 51681 Comm: test Tainted: G W OE K---------- T 3.10.0.x86_64 #1
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[3265705.536586] RDX: ffff882f6ebaca00 RSI: 0000000000000000 RDI: ffff882f6ebaca20
[3265705.545244] RBP: ffff882f6d8d7e10 R08: ffff882f6d8d4000 R09: ffff88014fb50079
[3265705.553885] R10: 000000000000000a R11: 0000000000000000 R12: 000000001f4eb000
[3265705.562525] R13: 0000000000000000 R14: ffff8808756bb600 R15: 0000000000000001
[3265705.571164] FS: 00007fcbdf0e9700(0000) GS:ffff882fbf180000(0000) knlGS:0000000000000000
[3265705.580741] CS: 0010 DS: 0000 ES: 0000 CR0: 0000000080050033
[3265705.587961] CR2: 0000000000000011 CR3: 0000000785a2c000 CR4: 00000000003407e0
[3265705.596561] DR0: 0000000000000000 DR1: 0000000000000000 DR2: 0000000000000000
[3265705.605180] DR3: 0000000000000000 DR6: 00000000fffe0ff0 DR7: 0000000000000400
[..... Snipped.....]

# Stack & Call Trace

[3265705.613758] Stack:
[3265705.617189]  01ff882f6d8d7dd8 ffff882f40ad6000 ffff882f6d8d7e10 ffff882f40ad6000
[3265705.626167]  ffff882f6f452000 000000001f4eb000 0000000000000000 ffff882f40ad6000
[3265705.635131]  0000000000000000 ffff882f6d8d7e68 ffffffff811d227f ffff88021c47c380
[3265705.644108] Call Trace:
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[3265705.662503]  [<ffffffff81203e47>] ? seq_buf_alloc+0x17/0x40
[3265705.669442]  [<ffffffff8120433a>] seq_read+0xfa/0x3a0
[3265705.675875]  [<ffffffff811e033c>] vfs_read+0x9c/0x170
[3265705.682273]  [<ffffffff811e0e8f>] SyS_read+0x7f/0xe0
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[3265705.695923] Code: 4c 8b 30 eb 0f 0f 1f 00 4c 89 ff e8 28 43 f2 ff 84 c0 75 1e 48 8b 33 4c 89 f7 e8 69 43 f2 ff 48 85 c0 49 89 c6 74 69 4c 8b 78 70 <41> f6 47 10 01 74 d6 4d 85 ff 0f 94 c0 4d 85 e>
[3265705.719001] RIP  [<ffffffff811d17f3>] mem_cgroup_iter+0x163/0x2b0
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[3265705.731272] CR2: 0000000000000011

# Type

TSC based timestamp and instruction which caused the panic

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[3265705.395814] Modu linked in tcp_diag inet_diag sch_dsmark sch_ingre _misc..[snipped]..
[3265705.480030] CP D: 51681 Comm: test Tainte
[3265705.492495] Har name: Lenovo ThinkServer S
[3265705.553885] R10: 000000000000000a R11: 0000000000000000 R12: 00000001f4eb000

x86 exception-specific exception error code for this page fault. See x86 implementation:
int __die(const char *str, struct pt_regs *regs, long err);

Panic messages printed by show_fault_oops which is handled by CPU exception handler. The page fault address is included.

| | Length | Name | Description |
|---|---|---|---|
| P | 1 bit | Present | When set, the page fault was caused by a page-protection violation. When not set, it was caused by a non-present page. |
| W | 1 bit | Write | When set, the page fault was caused by a page write. When not set, it was caused by a page read. |
| U | 1 bit | User | When set, the page fault was caused while CPL = 3. This does not necessarily mean that the page fault was a privilege violation. |
| R | 1 bit | Reserved write | When set, the page fault was caused by reading a 1 in a reserved field. |
| I | 1 bit | Instruction Fetch | When set, the page fault was caused by an instruction fetch. |

# CPU PID Comm Taint Version

[3265705.369809] BUG: unable to handle kernel NULL pointer dereference at 0000000000000011
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[3265705.395814] Modules linked in tcp_diag inet_diag sch_dsmark sch_ingress binfmt_misc [snipped]
[3265705.480030] CPU: 28 PID: 51681 Comm: test Tainted: G W OE K------------ T 3.10.0.x86_64 #1
[3265705.492495] Hardware name: Lenovo ThinkServer SD350X/B900G3-10G-N, BIOS A2.16 07/08/2016
[3265705.502088] task: ffff880114fd6480 ti: ffff882f6d8d4000 task.ti: ffff882f6

Panic Task

```
/**
 *  print_tainted - return a string to represent the kernel taint state.
 *
 *  'P' - Proprietary module has been loaded.
 *  'F' - Module has been forcibly loaded.
 *  'S' - SMP with CPUs not designed for SMP.
 *  'R' - User forced a module unload.
 *  'M' - System experienced a machine check exception.
 *  'B' - System has hit bad_page.
 *  'U' - Userspace-defined naughtiness.
 *  'D' - Kernel has oopsed before
 *  'A' - ACPI table overridden.
 *  'W' - Taint on warning.
 *  'C' - modules from drivers/staging are loaded.
 *  'I' - Working around severe firmware bug.
 *  'O' - Out-of-tree module has been loaded.
 *  'E' - Unsigned module has been loaded.
 *  'L' - A soft lockup has previously occurred.
 *  'K' - Kernel has been live patched.
 *
 *  The string is overwritten by the next call to print_tainted().
 */
const char *print_tainted(void)
{
```

```
static const struct tnt tnts[] = {
    { TAINT_PROPRIETARY_MODULE,     'P', 'G' },
    { TAINT_FORCED_MODULE,          'F', ' ' },
    { TAINT_UNSAFE_SMP,             'S', ' ' },
    { TAINT_FORCED_RMMOD,           'R', ' ' },
    { TAINT_MACHINE_CHECK,          'M', ' ' },
    { TAINT_BAD_PAGE,               'B', ' ' },
    { TAINT_USER,                   'U', ' ' },
    { TAINT_DIE,                    'D', ' ' },
    { TAINT_OVERRIDDEN_ACPI_TABLE,  'A', ' ' },
    { TAINT_WARN,                   'W', ' ' },
    { TAINT_CRAP,                   'C', ' ' },
    { TAINT_FIRMWARE_WORKAROUND,    'I', ' ' },
    { TAINT_OOT_MODULE,             'O', ' ' },
    { TAINT_UNSIGNED_MODULE,        'E', ' ' },
    { TAINT_SOFTLOCKUP,             'L', ' ' },
    { TAINT_LIVEPATCH,              'K', ' ' },
    { TAINT_16,                     '?', '-' },
    { TAINT_17,                     '?', '-' },
    { TAINT_18,                     '?', '-' },
    { TAINT_19,                     '?', '-' },
    { TAINT_20,                     '?', '-' },
    { TAINT_21,                     '?', '-' },
    { TAINT_22,                     '?', '-' },
    { TAINT_23,                     '?', '-' },
    { TAINT_24,                     '?', '-' },
    { TAINT_25,                     '?', '-' },
    { TAINT_26,                     '?', '-' },
    { TAINT_27,                     '?', '-' },
    { TAINT_HARDWARE_UNSUPPORTED,   'H', ' ' },
    { TAINT_TECH_PREVIEW,           'T', ' ' },
};
```

# HW FW Registers

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[3265705.553885] R10: 000000000000000a R11: 0000000000000000 R12: 00000001f4eb000
[3265705.562525] R13: 0000000000000000 R14: ffff8808756bb600 R15: 0000000000000001
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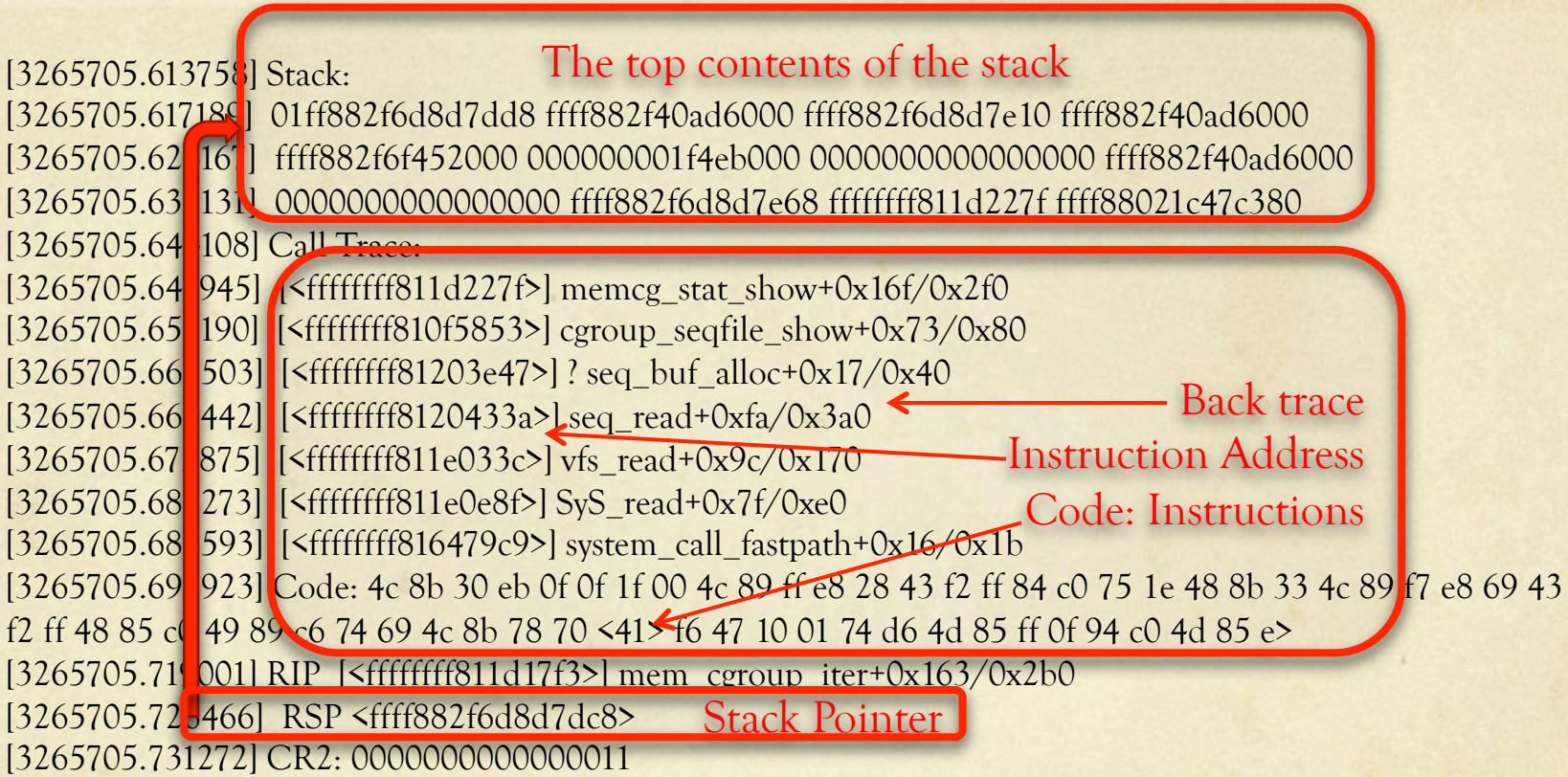
[3265705.605180] DR3: 0000000000000000 DR6: 00000000fffe0ff0 DR7: 0000000000000400
[..... Snipped.....]

**Exception/Trap Frame**

# Stack & Call Trace




**Please refer to Documentation/oops-tracing.txt**

# Crash – Post-mortem Debugging

- A tool for Linux crash dump analysis
  - Maintained by David Anderson from Red Hat
  - Understands all core dump formats
    - Kdump, diskdump, xendump etc.
  - Understands key kernel data structures & meta data
    - Tasks, page table, Slab, files, page cache, devices etc.
  - Also working for live system
- Can be extended via…
  - Patch contributions to core commands
  - Crash extension modules loading by extend command
  - Support gdb scripts
  - Python scripts
  - Eppic scripts
  - See https://people.redhat.com/anderson/extensions.html

# Invoking Crash

- Running crash with…
  - vmcore or living system
  - Build out vmlinux and modules debug binaries
    - Or kernel-debuginfo & kernel-debuginfo-common-x86_64
  - The help <command> shows the manual and examples

```
crash> help

*               files           mach            repeat          timer
alias           foreach         mod             runq            tree
ascii           fuser           mount           search          union
bt              gdb             net             set             vm
btop            help            p               sig             vtop
dev             ipcs            ps              struct          waitq
dis             irq             pte             swap            whatis
eval            kmem            ptob            sym             wr
exit            list            ptov            sys             q
extend          log             rd              task
```

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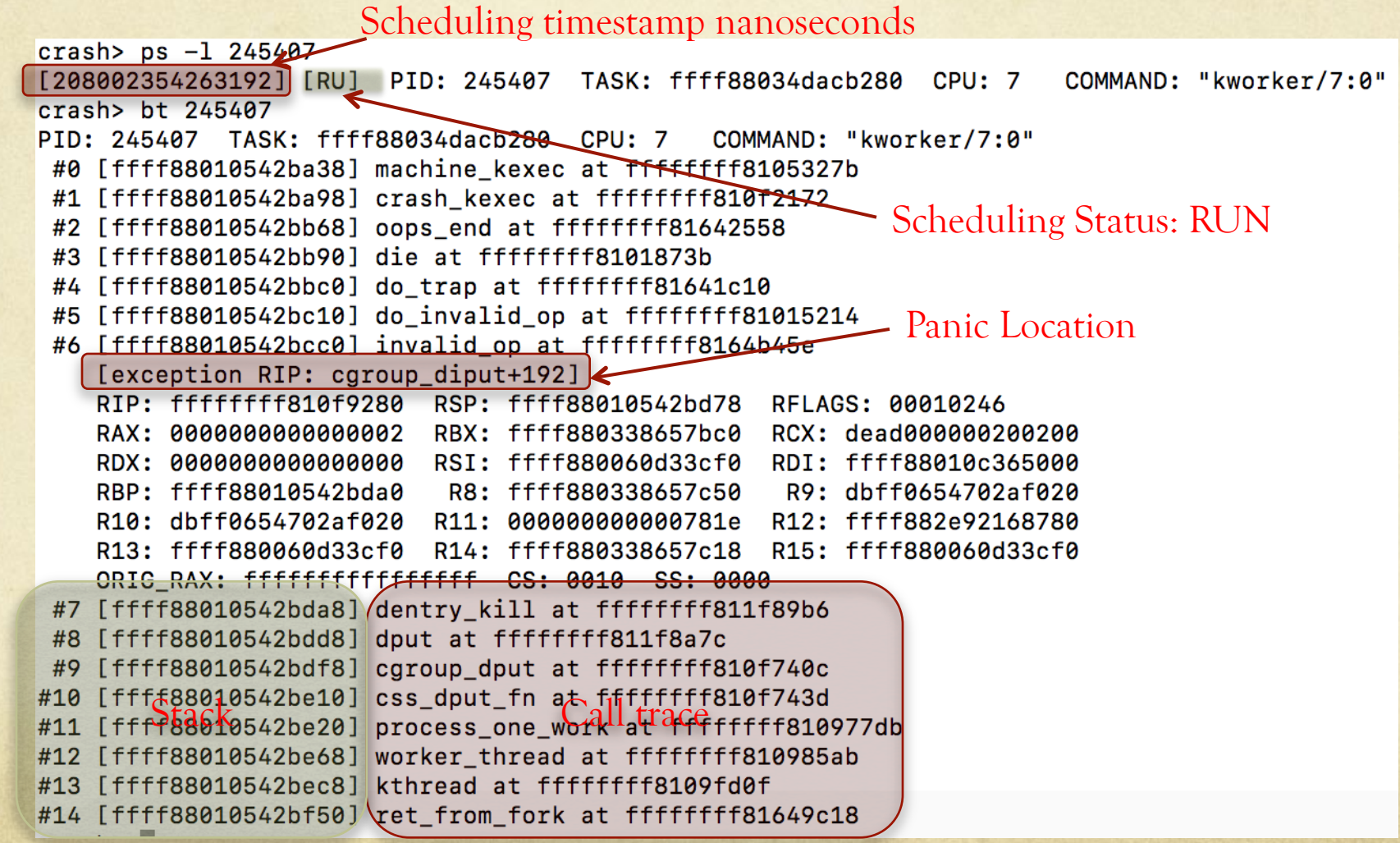
# Panic Process Status



# Panic Location

- RIP could give panic location
- Find source code location by dis –l

```
crash> dis -l cgroup_diput+192
/usr/src/debug/kernel-3.10.0/kernel/cgroup.c: 889
0xffffffff810f9280 <cgroup_diput+192>:  ud2

crash> l *cgroup_diput+192
0xffffffff810f9280 is in cgroup_diput (kernel/cgroup.c:889).
884    {
885            /* is dentry a directory ? if so, kfree() associated cgroup */
886            if (S_ISDIR(inode->i_mode)) {
887                    struct cgroup *cgrp = dentry->d_fsdata;
888
889                    BUG_ON(!(cgroup_is_removed(cgrp)));
```

# x64 SystemV ABI

| Register | Usage | Preserved across function calls |
|---|---|---|
| `%rax` | temporary register; with variable arguments passes information about the number of vector registers used; 1st return register | No |
| `%rbx` | callee-saved register; optionally used as base pointer | Yes |
| `%rcx` | used to pass 4th integer argument to functions | No |
| `%rdx` | used to pass 3rd argument to functions; 2nd return register | No |
| `%rsp` | stack pointer | Yes |
| `%rbp` | callee-saved register; optionally used as frame pointer | Yes |
| `%rsi` | used to pass 2nd argument to functions | No |
| `%rdi` | used to pass 1st argument to functions | No |
| `%r8` | used to pass 5th argument to functions | No |
| `%r9` | used to pass 6th argument to functions | No |
| `%r10` | temporary register, used for passing a function's static chain pointer | No |
| `%r11` | temporary register | No |
| `%r12-r15` | callee-saved registers | Yes |

# x64 Stack Frame

| Position | Contents | Frame |
|---|---|---|
| `8n+16(%rbp)` | memory argument eightbyte $n$ | Previous |
| | ... | |
| `16(%rbp)` | memory argument eightbyte 0 | |
| `8(%rbp)` | return address | |
| `0(%rbp)` | previous `%rbp` value | |
| `-8(%rbp)` | unspecified | Current |
| | ... Local Variable | |
| `0(%rsp)` | variable size | |
| `-128(%rsp)` | red zone | |

# Function Prologue

```
crash> dis cgroup_diput 10
0xffffffff810f91c0 <cgroup_diput>:      nopl   0x0(%rax,%rax,1) [FTRACE NOP]
0xffffffff810f91c5 <cgroup_diput+5>:    push   %rbp
0xffffffff810f91c6 <cgroup_diput+6>:    mov    %rsp,%rbp
0xffffffff810f91c9 <cgroup_diput+9>:    push   %r15
0xffffffff810f91cb <cgroup_diput+11>:   mov    %rsi,%r15
0xffffffff810f91ce <cgroup_diput+14>:   push   %r14
0xffffffff810f91d0 <cgroup_diput+16>:   push   %r13
0xffffffff810f91d2 <cgroup_diput+18>:   push   %r12
0xffffffff810f91d4 <cgroup_diput+20>:   push   %rbx
```

# Function Epilogue

```
crash> dis cgroup_diput+144 8
0xffffffff810f9250 <cgroup_diput+144>:  pop    %rbx
0xffffffff810f9251 <cgroup_diput+145>:  pop    %r12
0xffffffff810f9253 <cgroup_diput+147>:  pop    %r13
0xffffffff810f9255 <cgroup_diput+149>:  pop    %r14
0xffffffff810f9257 <cgroup_diput+151>:  pop    %r15
0xffffffff810f9259 <cgroup_diput+153>:  pop    %rbp
0xffffffff810f925a <cgroup_diput+154>:  retq
0xffffffff810f925b <cgroup_diput+155>:  nopl   0x0(%rax,%rax,1)
```

# Arguments and return values

- Find arguments and return values from registers
- Exception Frame saves the context of…
  - System call
  - Panic exceptions
- bt -e

```
crash>  bt -e
PID: 245407  TASK: ffff88034dacb280  CPU: 7   COMMAND: "kworker/7:0"

 KERNEL-MODE EXCEPTION FRAME AT: ffff88010542bcc8
    [exception RIP: cgroup_diput+192]
    RIP: ffffffff810f9280  RSP: ffff88010542bd78  RFLAGS: 00010246
    RAX: 0000000000000002  RBX: ffff880338657bc0  RCX: dead000000200200
    RDX: 0000000000000000  RSI: ffff880060d33cf0  RDI: ffff88010c365000
    RBP: ffff88010542bda0   R8: ffff880338657c50   R9: dbff0654702af020
    R10: dbff0654702af020  R11: 000000000000781e  R12: ffff882e92168780
    R13: ffff880060d33cf0  R14: ffff880338657c18  R15: ffff880060d33cf0
    ORIG_RAX: ffffffffffffffff  CS: 0010  SS: 0000
```

# Stack Dump

- bt -f

```
ffff88010542bd78: ffff880338657bc0 ffff882e92168780
ffff88010542bd88: ffff880060d33cf0 ffff880338657c18
ffff88010542bd98: 0000000000001c0 ffff88010542bdd0
ffff88010542bda8: ffffffff811f89b6
[ffff88010542bda8] dentry_kill at ffffffff811f89b6
ffff88010542bdb0: ffff880338657bc0 ffff880338657c18
ffff88010542bdc0: ffff882fbf2f44c0 ffff882fbf2f9a00
ffff88010542bdd0: ffff88010542bdf0 ffffffff811f8a7c
[ffff88010542bdd8] dput at ffffffff811f8a7c
ffff88010542bde0: ffff882f5743a000 ffff882f01437280
ffff88010542bdf0: ffff88010542be08 ffffffff810f740c
[ffff88010542bdf8] cgroup_dput at ffffffff810f740c
ffff88010542be00: ffffc90030aaf020 ffff88010542be18
ffff88010542be10: ffffffff810f743d
[ffff88010542be10] css_dput_fn at ffffffff810f743d
```

# Find Arguments From Stack

- bt -FF

```
    RDX: 0000000000000000  RSI: ffff880060d33cf0  RDI: ffff88010c365000
    RBP: ffff88010542bda0   R8: ffff880338657c50   R9: dbff0654702af020
    R10: dbff0654702af020  R11: 000000000000781e  R12: ffff882e92168780
    R13: ffff880060d33cf0  R14: ffff880338657c18  R15: ffff880060d33cf0
    ORIG_RAX: ffffffffffffffff  CS: 0010  SS: 0000
    ffff88010542bcc8: [ffff880060d33cf0:inode_cache] [ffff880338657c18:dentry]
    ffff88010542bcd8: [ffff880060d33cf0:inode_cache] [ffff882e92168780:dentry]
    ffff88010542bce8: ffff88010542bda0 [ffff880338657bc0:dentry]
    ffff88010542bcf8: 000000000000781e dbff0654702af020
    ffff88010542bd08: dbff0654702af020 [ffff880338657c50:dentry]
    ffff88010542bd18: 0000000000000002 dead000000200200
    ffff88010542bd28: 0000000000000000 [ffff880060d33cf0:inode_cache]
    ffff88010542bd38: [ffff88010c365000:kmalloc-512] ffffffffffffffff
    ffff88010542bd48: cgroup_diput+192 0000000000000010
    ffff88010542bd58: 0000000000010246 ffff88010542bd78
    ffff88010542bd68: 0000000000000000 ffff882fbf2f4cc0
    ffff88010542bd78: [ffff880338657bc0:dentry] [ffff882e92168780:dentry]
    ffff88010542bd88: [ffff880060d33cf0:inode_cache] [ffff880338657c18:dentry]
    ffff88010542bd98: 00000000000001c0 ffff88010542bdd0
    ffff88010542bda8: dentry_kill+326
#7 [ffff88010542bda8] dentry_kill at ffffffff811f89b6
    ffff88010542bdb0: [ffff880338657bc0:dentry] [ffff880338657c18:dentry]
    ffff88010542bdb0: [ffff880338657bc0:dentry] [ffff880338657c18:dentry]
```

# Heap/Kmem Dump

```
crash> kmem -s ffff88010c365000
CACHE            NAME                 OBJSIZE  ALLOCATED     TOTAL  SLABS  SSIZE
ffff882fbec03600 kmalloc-512              512      28413     29440    920    16k
  SLAB              MEMORY             NODE  TOTAL  ALLOCATED  FREE
  ffffea000430d900  ffff88010c364000      0     32          1    31
  FREE / [ALLOCATED]
  [ffff88010c365000]
crash> cgroup ffff88010c365000
struct cgroup {
  flags = 2,
  count = {
    counter = 1
  },
  tasks = {
    counter = 173
  },
  id = 27,
  sibling = {
    next = 0xffff882f4de60c28,
    prev = 0xffff88018b993218
  },
  children = {
    next = 0xffff88010c365028,
    prev = 0xffff88010c365028
  },
  files = {
    next = 0xffff88195c441340,
    prev = 0xffff88195b2dc800
  },
  parent = 0xffff882f4de60c00,
  dentry = 0xffff880338657bc0,
  name = 0xffff882f01437c80,
  subsys = {0x0, 0x0, 0x0, 0xffffc90030aaf000, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0},
```

# Raw Memory Dump

```
crash> rd -s ffff88010c365000 48
ffff88010c365000:  0000000000000002 000000ad00000001
ffff88010c365010:  000000000000001b ffff882f4de60c28
ffff88010c365020:  ffff88018b993218 ffff88010c365028
ffff88010c365030:  ffff88010c365028 ffff88195c441340
ffff88010c365040:  ffff88195b2dc800 ffff882f4de60c00
ffff88010c365050:  ffff880338657bc0 ffff882f01437c80
ffff88010c365060:  0000000000000000 0000000000000000
ffff88010c365070:  0000000000000000 ffffc90030aaf000
ffff88010c365080:  0000000000000000 0000000000000000
ffff88010c365090:  0000000000000000 0000000000000000
ffff88010c3650a0:  0000000000000000 0000000000000000
ffff88010c3650b0:  0000000000000000 0000000000000000
ffff88010c3650c0:  ffff882f5d50c000 ffff881824a4bcc0
ffff88010c3650d0:  ffff881824a4bcc0 ffff88002a8ea4d8
ffff88010c3650e0:  ffff880147cd44d8 0000000000000000
ffff88010c3650f0:  0000000000000000 ffff88010c3650f8
ffff88010c365100:  ffff88010c3650f8 ffff88010c365108
ffff88010c365110:  ffff88010c365108 0000000000000001
ffff88010c365120:  ffff88010c365120 ffff88010c365120
ffff88010c365130:  0000000000000000 0000000000000000
ffff88010c365140:  0000000000000000 0000000000000000
ffff88010c365150:  0000000ffffffe0 ffff88010c365158
ffff88010c365160:  ffff88010c365158 cgroup_free_fn
ffff88010c365170:  ffff88010c365170 ffff88010c365170
```

# Global Variables Dump

```
crash> p irq_stat | head -10
PER-CPU DATA TYPE:
  irq_cpustat_t irq_stat;
PER-CPU ADDRESSES:
  [0]: ffff882fbf212000
  [1]: ffff882fbf232000
  [2]: ffff882fbf252000
  [3]: ffff882fbf272000
  [4]: ffff882fbf292000
  [5]: ffff882fbf2b2000
  [6]: ffff882fbf2d2000
```

The p command could be used directly

```
crash> px irq_stat:1
per_cpu(irq_stat, 1) = $3 = {
  __softirq_pending = 0x0,
  __nmi_count = 0x8549,
  apic_timer_irqs = 0x550574f,
  irq_spurious_count = 0x0,
  icr_read_retry_count = 0x0,
  kvm_posted_intr_ipis = 0x0,
  kvm_posted_intr_wakeup_ipis = 0x0,
  x86_platform_ipis = 0x0,
  apic_perf_irqs = 0x8548,
  apic_irq_work_irqs = 0x30b64,
  irq_resched_count = 0x43572f9,
  irq_call_count = 0x7c2693,
  irq_tlb_count = 0x762c84,
  irq_thermal_count = 0x0,
  irq_threshold_count = 0x0
}
```

The px means hex dump

The :1 indicate the data instance on CPU 1.

# Global Tasks Status

- Check per-CPU runq and on CPU tasks
  - Runq
  - bt -a
- All running/uninterruptable/interruptable tasks
  - foreach RU bt
  - foreach UN bt
  - foreach IN bt
- List kernel/user tasks
  - ps –k
  - ps –u

# Files and IO

- Filesystem information
  - mount
- Who open the files
  - foreach files -R system.journal
  - fuser /usr/lib/libkfm.so.2.0.0
- Process files and page cache
  - files 1954
  - files -c 1954
- Block devices and its request queues
  - dev -d

# Networking

- All NIC interfaces and its net devices
  - net
  - net -n 2618
- Dump arp cache
  - net -a
- All sockets
  - foreach net –s

# Walkers

- Walk a link list

  Using list command, here is an example,

  crash> dentry.d_name 0xffff882f5a1a8180

  crash> dentry -o 0xffff882f5a1a8180 | grep d_sub

  [ffff882f5a1a8220] struct list_head d_subdirs;

  crash > list -H ffff882f5a1a8220 -o 144 -s dentry.d_name

- Walk a tree
  - tree -t radix -r address_space.page_tree ffff880bd08412a8
- Create customized walkers by writing scripts

# Agenda

- Welcome to panic
- Getting started
- Advanced Studies
- Case Studies
- References

# Sysrq Crash

- Make sure crash dump (kdump) works
- Trigger a kernel panic by sysrq
  - echo c > /proc/sysrq-trigger
- Waiting for reboot and saving the core file
- Using crash to check the core file
- Explain how sysrq crashes the kernel

# Read Files From Page Cache

- Using vi to open a text file in system
- Invoking crash against living system
- Walking the file pages from page cache
- Dump the file contents from memory

See my page cache debug blog.

# Agenda

- Welcome to panic
- Getting started
- Advanced Studies
- Case Studies
- References

# References


- Documentation/admin-guide/bug-hunting.rst
- Documentation/admin-guide/tainted-kernels.rst
- Crash White Paper
- x64 System V ABI
- Page cache debug support for crash