Hot Patching

Advanced Operating Systems and Virtualization
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Why hot patching?

- Huge costs of downtime → reduce cost of planned downtime
- Common tiers of change management:
  - incident response
    - "we are down and/or exploited"
  - emergency change
    - "we could go down: we are vulnerable"
  - scheduled change
    - "time is not critical, we keep safe"

Hot Patching is handy here!

Why is Rebooting a Problem?

- Disruption to users/applications
- Sysadmins don't always have control of users or applications
- Many applications aren't distributed
- Re-architecting can be expensive or impractical
- Distributed systems need to reboot too
- (Up)time is money
- Hardware reboot failures

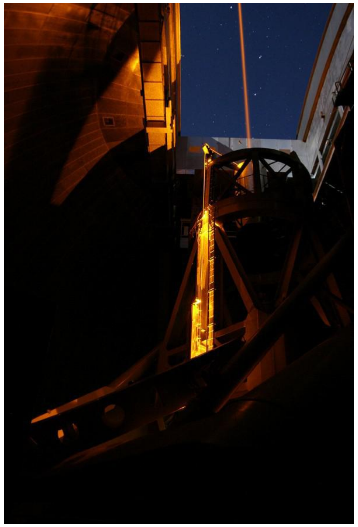
Barcelona Supercomputing Center

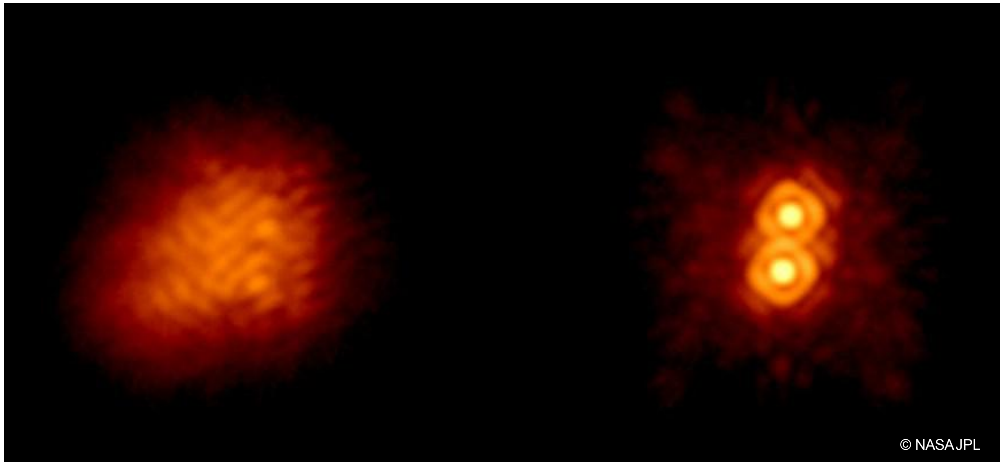
Mare Nostrum Supercomputer

- **50k Sandy Bridge cores**
- **The most beautiful supercomputer in the world**
- **Terabytes of data**
- **Reboot?**

NASA JPL

Hale telescope PALM-3000 Adaptive optics





© NASA JPL

- **5m telescope with adaptive optics on Mount Palomar**
- **Avoid atmospheric blurring in Real Time**
- **Control 3888 segments of a deformable mirror with a latency <250 µs**
- **Reboot?**

SAP HANA

In-memory database and analytics engine

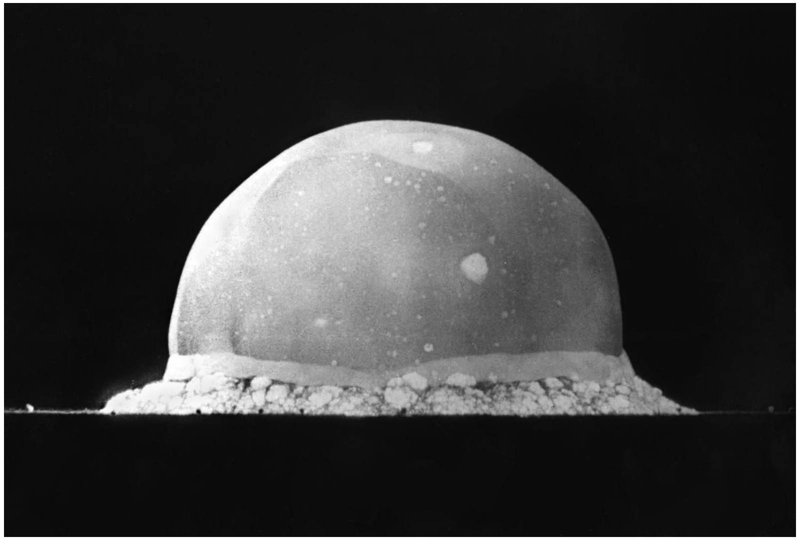
© HP

HP DL980 w/ 12 TB RAM

- **4-16 TB of RAM**
- **All operations done in memory**
- **Disk used for journalling**
- **Active-Passive HA**
- **Failover measured in seconds**
- **Reboot?**

Not a New Idea:1943 Manhattan Project

- IBM punchcard automatic calculators were used to crunch the numbers
- A month before the Trinity nuclear device test, the question was: “What will the yield be, how much energy will be released?”
- The calculation would normally take three months to complete – recalculating any batches with errors
- Multiple colored punch cards introduced to fix errors in calculations while the calculator was running



Trinity test site, 16ms after initiation

Windows Hot Patching (2003)

- Windows Server 2003 SP1
- Stops Kernel execution for activeness check
  - Schedule deferred procedure calls on all but current CPUs and keep them busy
- Uses short jumps patched into functions for redirection
  - The second redirection jumps to a new function
- Removed in Windows 8 and later versions
  - only ~10 patches used it in 12 years of support

Linux kpatch (2014)

- Tries to overcome the costs and problems of rebooting systems to apply patches
- Based on two "simple" steps:
  1. Build the patch module (`kpatch-build foo.patch`)
  2. Apply the patch (`kpatch load kpatch-foo.ko`)

Building the Patch Module

- Much harder than patching the kernel
- Compile kernel with/without patch
- Compare binaries
- Detect which functions have changed
- Extract object code of changed functions into patch module

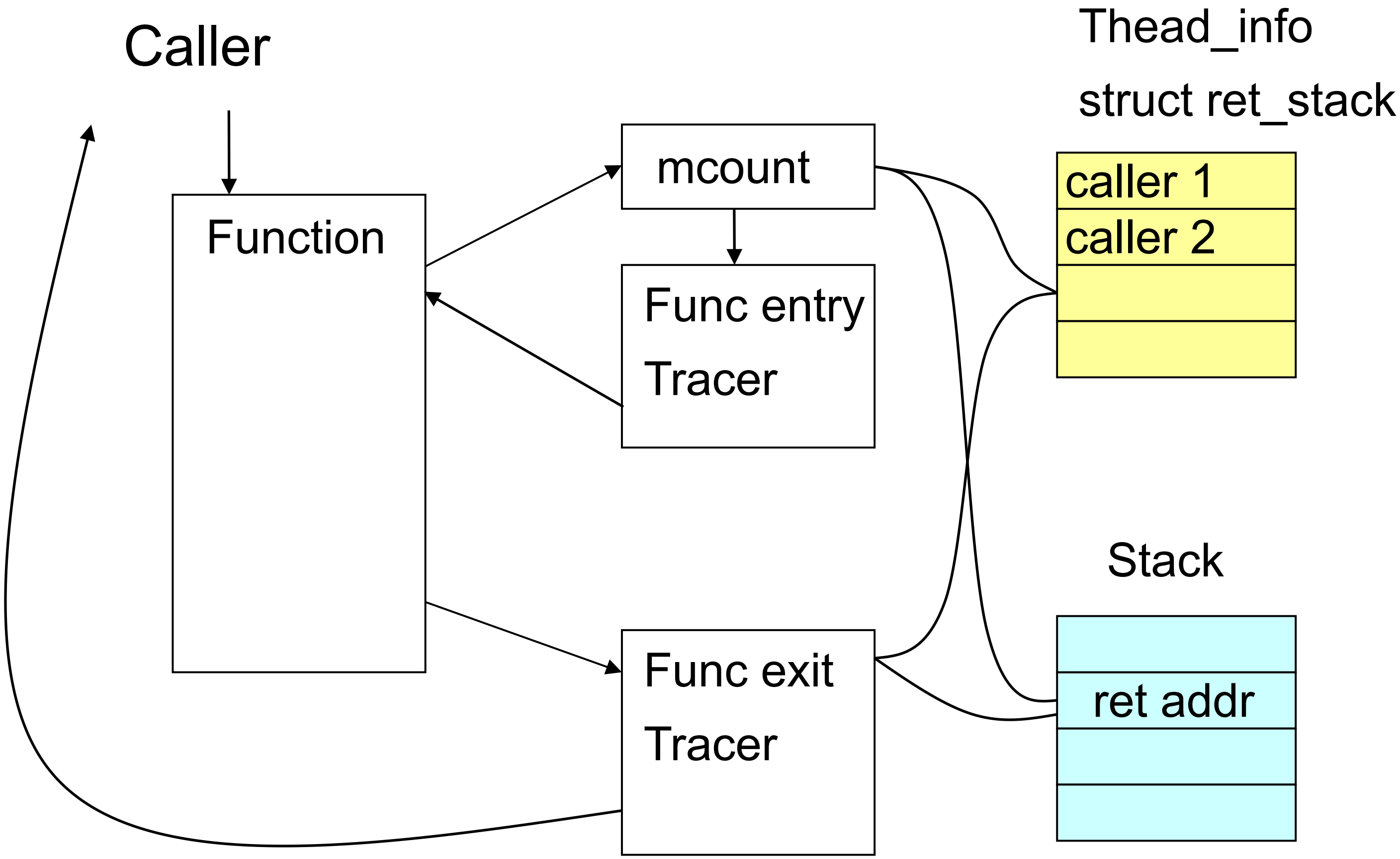
Patching the Kernel

- Load new functions into memory
- Link new functions into kernel
  - Allows access to unexported kernel symbols
- Activeness safety check
  - Prevent old & new functions from running at same time
  - `stop_machine()` + stack backtrace checks
- Patch it!
  - Uses ftrace

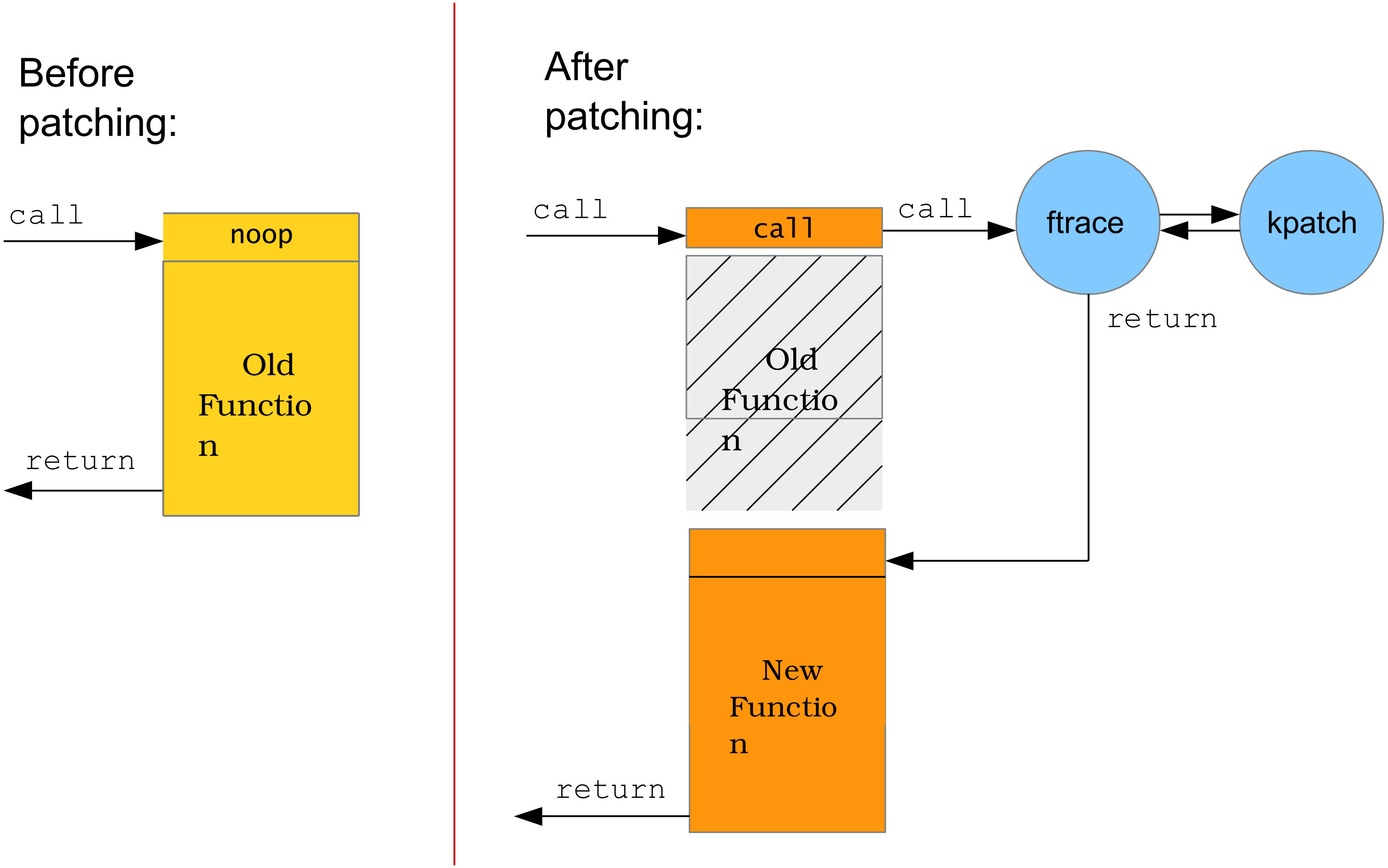
What is ftrace?

- Ftrace is the first generic tracing system to get mainlined
  - Mainlined in 2.6.27
  - Derived from RT-preempt latency tracer
- Provides a generic framework for tracing
  - Infrastructure for defining tracepoints
  - Ability to register different kinds of tracers
  - Specialized data structure (ring buffer) for trace data storage

ftrace Schematization



Patching with ftrace


Before
patching:
call
noop
Old
Functio
n
return
After
patching:
call
call
call
ftrace
kpatch
return
Old
Functio
n
New
Functio
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