



Earthquakes and the Moon

Tales from the Ops Side

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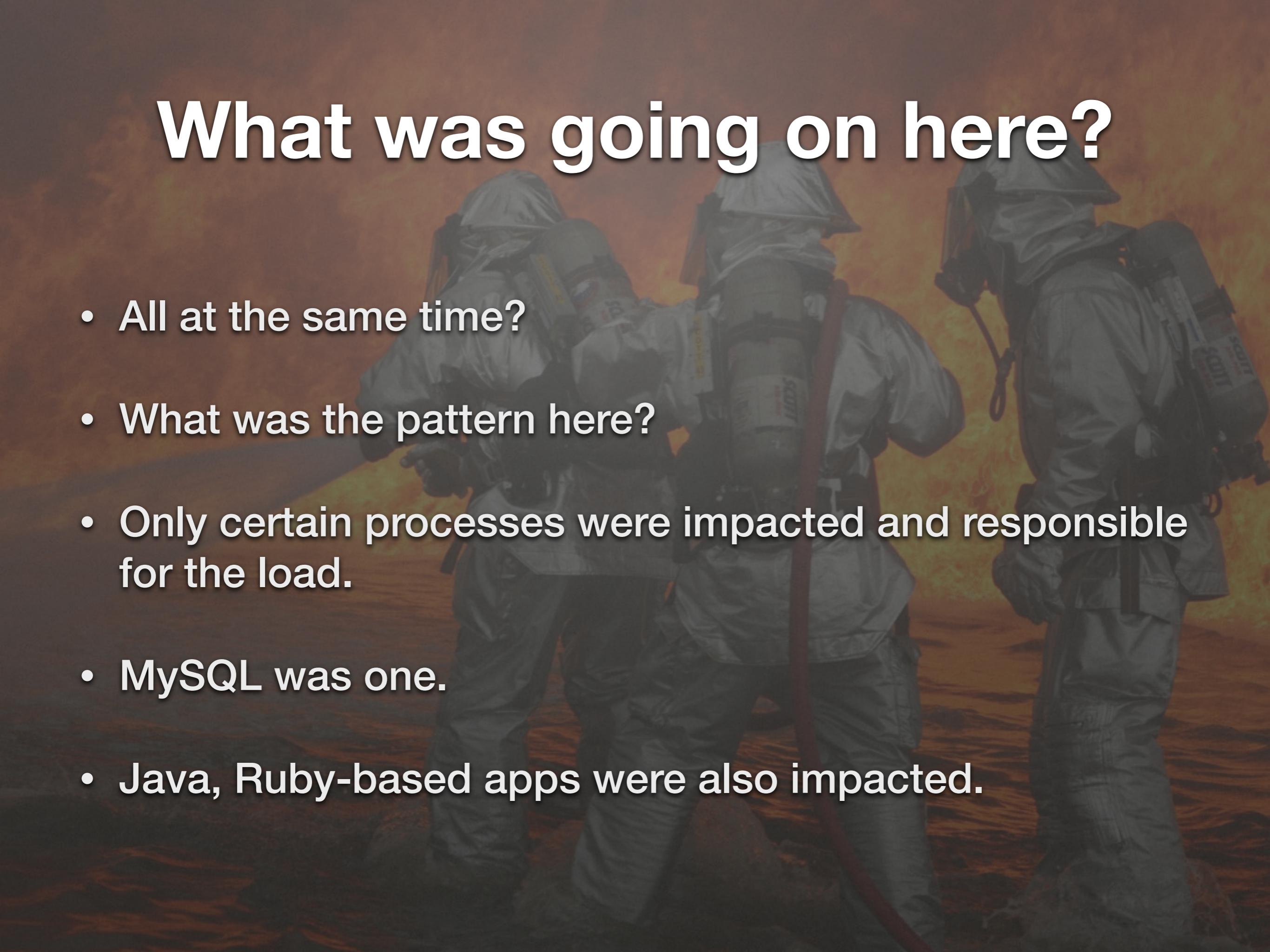


Where were you
June 30, 2012 at 8pm?

Multiple Site Outages

- First thought - networking outage?
- Servers seemed to be accessible, so it was not the network.
- Were we under attack? Maybe.
- Server *load* alerts started piling in from all over the cluster.

What was going on here?

A dramatic photograph of several firefighters in full protective suits and helmets standing in a row. They are silhouetted against a bright, intense fire with orange and yellow flames visible behind them. The firefighters appear to be in a formation, possibly preparing for or engaged in a rescue operation.

- All at the same time?
- What was the pattern here?
- Only certain processes were impacted and responsible for the load.
- MySQL was one.
- Java, Ruby-based apps were also impacted.

Trusty strace to the rescue

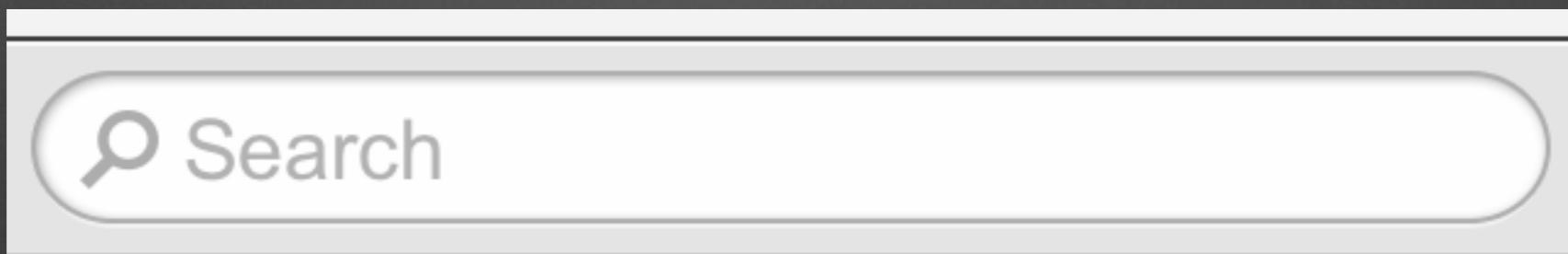
Attaching to one of the misbehaving processes
with strace showed a strange pattern...

```
[pid 1635] gettimeofday({{1437609799, 134032}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134125}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134209}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134297}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134382}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134472}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134554}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134640}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134729}, NULL) = 0
[pid 1635] gettimeofday({{1437609799, 134816}, NULL) = 0
```

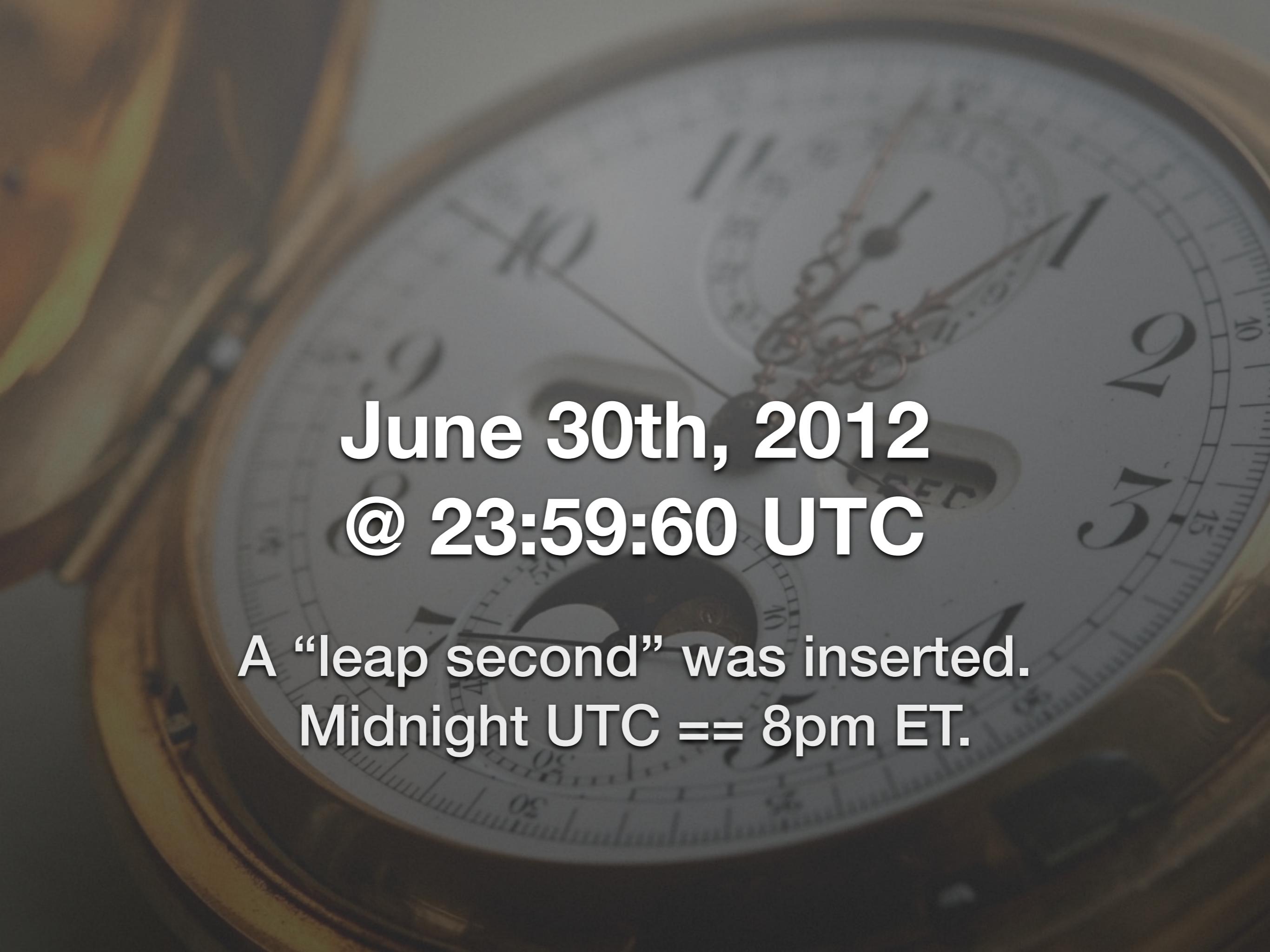
gettimeofday()?

More Questions...

- Why were all these processes asking for the time of day over and over again?
- Was there some crazy time event?



- Doing a quick search online for “time event” revealed the answer.

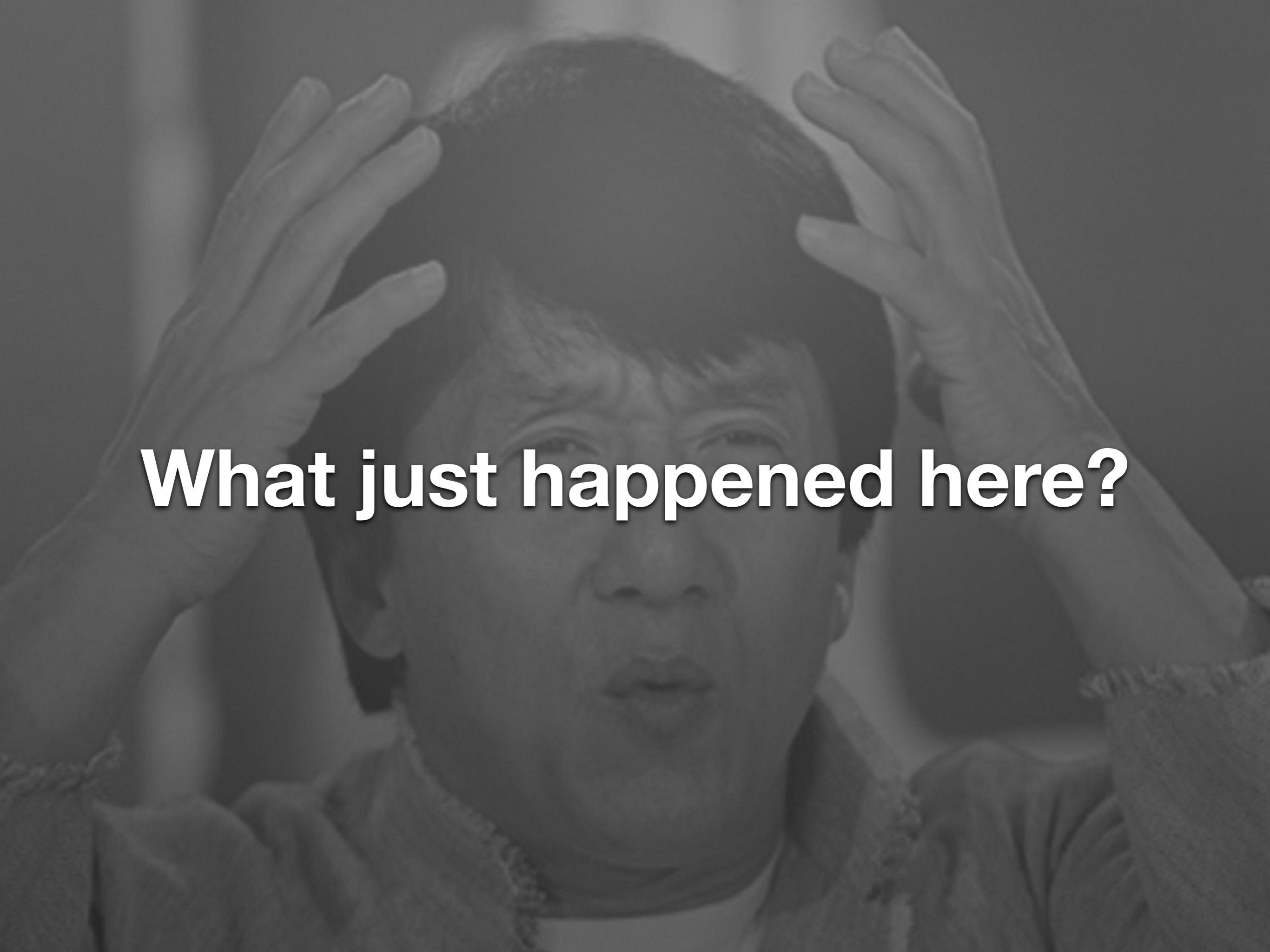


**June 30th, 2012
@ 23:59:60 UTC**

A “leap second” was inserted.
Midnight UTC == 8pm ET.

OK, now what?

- What's a “leap second” and how do we fix it?
- Goal was to stabilize the cluster.
- Restarting the affected processes seemed to resolve the issue, but sometimes a full reboot was required.
- Within an hour, things had calmed down.

A black and white photograph of a man with light-colored hair, wearing a dark t-shirt. He is shown from the chest up, looking directly at the camera with a neutral to slightly thoughtful expression. His hands are clasped behind his head, with fingers interlaced. The background is plain and light-colored.

What just happened here?

What's a “leap second”?

```
$ date
```

```
Sat Jun 30 23:59:59 UTC 2012
```

- Apparently, 25 leap seconds were inserted since 1972.
- Why was this leap second so special?
- The answer, like most things in life, is complicated...

A black and white photograph showing a close-up of a person's hand. The hand is positioned palm-up, fingers slightly spread, holding a small, rectangular object between the thumb and forefinger. The background is dark and out of focus, creating a shallow depth of field that highlights the hand and the object.

Let's hold for a minute here.

Why is timekeeping so important?

Staying on time

- Time is the universal frame of reference.
- It's the only way events can be coordinated and correlated.
- In the modern day, high resolution timekeeping is essential.
- Atomic clocks, satellites, and even celestial bodies are consulted to ensure we're all on the same clock.

A brief history of time, literally

- Greenwich Mean Time (GMT) was the first widely adopted time standard that kept track of the “mean solar time” (a.k.a.: a day). It wasn’t enough.
- TAI - Time based on atomic clocks. Very static.
- UT0 and UT1 - Time based on the precise rotation of the Earth. Always changing.
- Coordinated Universal Time (UTC) - TAI with “leap seconds” to keep in sync with UT0 and UT1.
- GPS - in their own world with their own standard.

A photograph of a sunset or sunrise over a body of water. The sky is filled with warm, orange, and yellow hues from the setting or rising sun, which is partially visible behind a dark silhouette of land or hills. The water in the foreground reflects these colors, creating a shimmering effect.

**Did you know our days
are getting longer?**

A full-disk satellite image of Earth, showing cloud cover and the outlines of continents like North America, South America, Africa, and Australia. The image has a dark blue background where oceans are located and various shades of green and brown for landmasses.

Earth's rotation is slowing down.

A day today is about 1.7 milliseconds longer than it was 100 years ago.

Why?

The Moon

- The Moon is tugging on the Earth (and vise versa).



- Tidal forces cause a drag on the Earth, which pushes the Moon further away from us, and slows down the Earth's rotation.



The Earth can speed up too!

The Earth is a living being.

Major events like *earthquakes*
can also affect the rotation of the Earth.

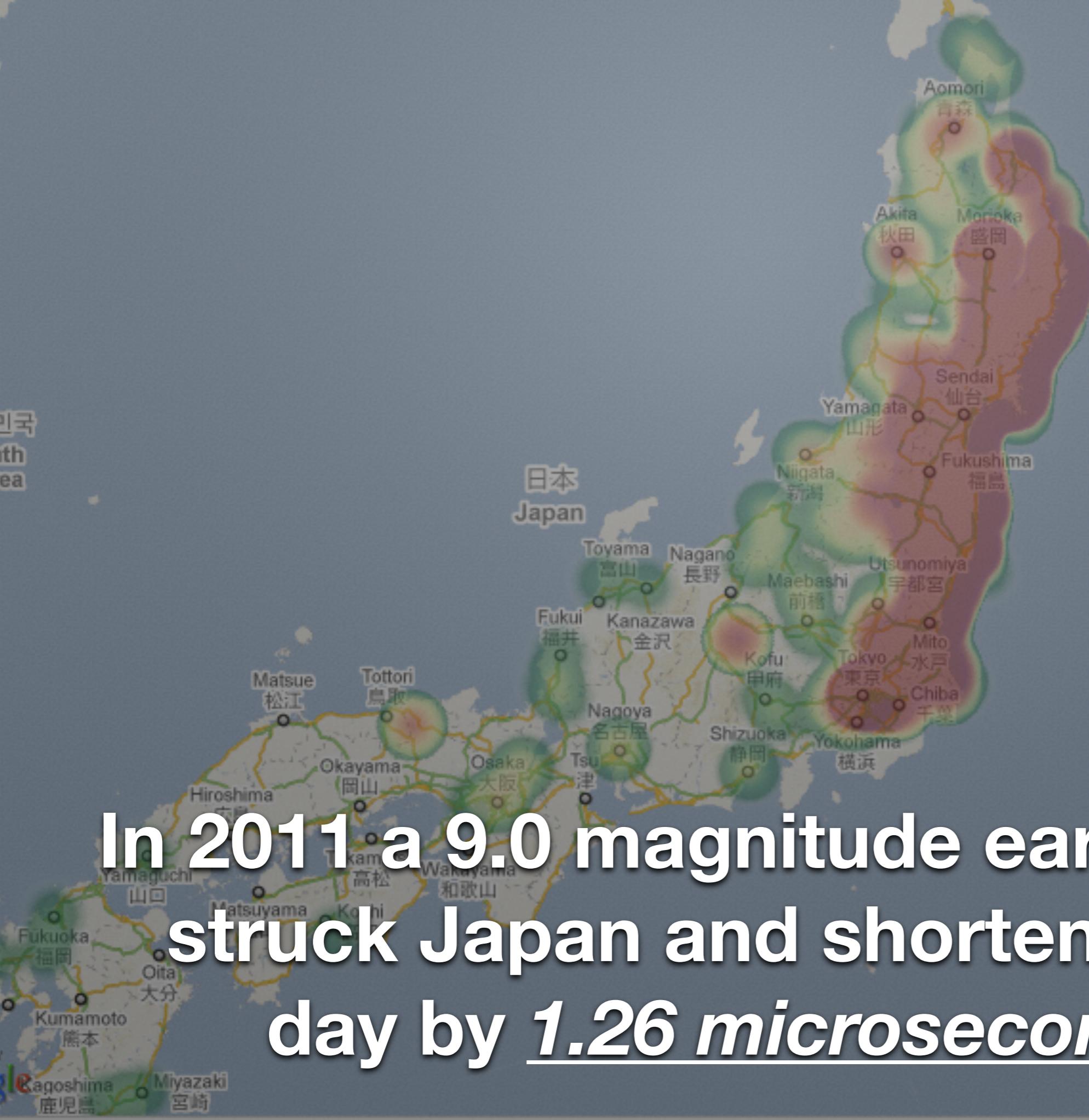


December 26, 2004

A massive 9.1 magnitude earthquake struck in the Indian Ocean off the coast of Indonesia.

A photograph of Earth from space, showing a vast expanse of clouds and landmasses from an orbital perspective. The horizon line is visible in the upper portion of the frame.

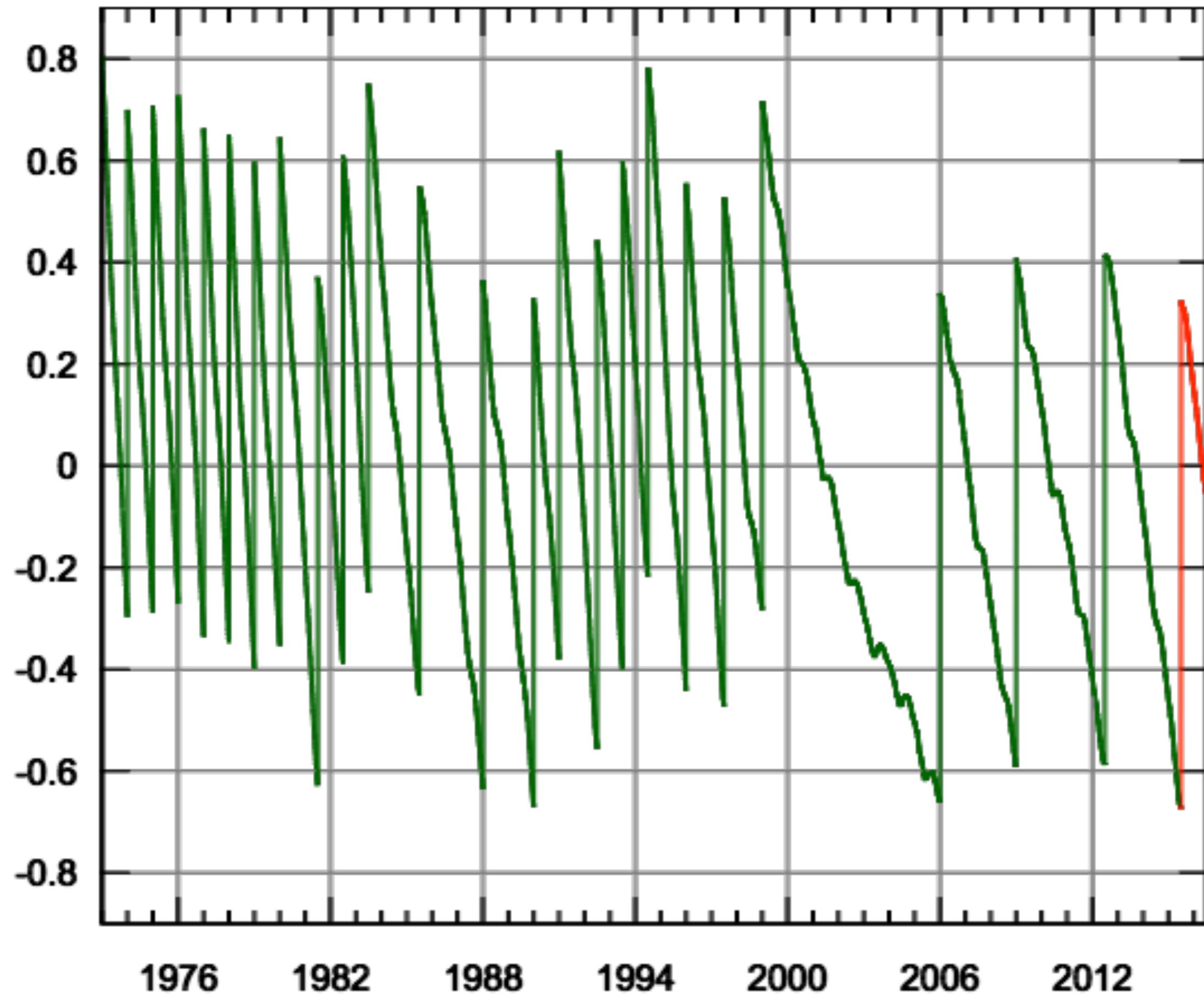
The force was so great that it changed
the moment of inertia of the Earth and
a day was now 3 microseconds shorter.



In 2011 a 9.0 magnitude earthquake struck Japan and shortened the day by 1.26 microseconds.

Time does not sit still

- To compensate for these irregularities, the powers that be introduced the “leap second” in 1972.
- International Earth Rotation and Reference Systems Service (IERS) is in charge of scheduling leap seconds.
- They are not predictable.
- Leap seconds are usually announced 6 months in advanced.



Linux and the leap second

- Linux does not have a concept of a “leap second”.
- There are 86,400 seconds in a day. Period.
- To compensate, Linux systems must “repeat” the last second of a day.
- This requires all Linux systems to keep up to date with the latest announcements.

Why did things break in 2012?

- Linux has a high-resolution timer (`hrtimer`) that is used for timing events.
- Many applications like MySQL, or even Java and Ruby-based processes, rely on the `hrtimer`.
- During 2012's leap second, the `hrtimer` kept moving forward while the system clock repeated the last second of the day.
- Any timers set for < 1 second would expire immediately, and would get stuck in a loop.

Again, why did this break?

At the time, there were 24 leap seconds since 1972.

A bug fix in 2007...

```
diff --git a/kernel/time/ntp.c b/kernel/time/ntp.c
index 87aa5ff..cf53bb5 100644
--- a/kernel/time/ntp.c
+++ b/kernel/time/ntp.c
@@ -122,7 +122,6 @@ void second_overflow(void)
 */
time_interpolator_update(-NSEC_PER_SEC);
time_state = TIME_OOP;
-
clock_was_set();
printk(KERN_NOTICE "Clock: inserting leap second "
           "23:59:60 UTC\n");
}
@@ -137,7 +136,6 @@ void second_overflow(void)
 */
time_interpolator_update(NSEC_PER_SEC);
time_state = TIME_WAIT;
-
clock_was_set();
printk(KERN_NOTICE "Clock: deleting leap second "
           "23:59:59 UTC\n");
}
```

Lessons learned?

- Many apps have fixed this bug internally.
- This year's leap second (June 30, 2015) was mostly uneventful.
- Quick fix is to run: `date -s "$ (date)"`
- Some groups want to see leap seconds eliminated due to all these problems.
- Google no longer introduces leap seconds, and instead *smear* an entire second gradually over the course of a year.

Time is complicated

Missing entire centuries with Y2K wasn't a thing.

Inserting entire days with leap years isn't a thing.

Insert a single second, and Ops people get paged.

A high-resolution grayscale photograph of the Moon's surface. The image captures a vast expanse of cratered terrain, with numerous impact craters of varying sizes scattered across the frame. The lighting creates a dramatic contrast between the bright, sunlit areas and the dark, shadowed regions, highlighting the topography of the lunar surface.

Blame the Moon



Questions?

Psst... go check your servers.

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