Advanced Programming in the UNIX Environment

Week 04, Segment 8:
time(3) is an illusion

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time(3)

```
#include <time.h>

time_t time(time_t *tloc);
```

Returns: time_t if OK, -1 on error

The time() function returns the value of time in seconds since 0 hours, 0 minutes, 0 seconds, January 1, 1970, Coordinated Universal Time.

(We already talked about the Y2K38 problem - see Week 01, Segment 3.)

Terminal — 80×24

```
apue$ cat time1.c
#include <err.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

int
main() {
        time_t t;

        if ((t = time(NULL)) < 0) {
                err(EXIT_FAILURE, "unable to call time()");
                /* NOTREACHED */
        }
        printf("time(3) says: %ld\n", t);

        return EXIT_SUCCESS;
}
apue$ cc time1.c
apue$ ./a.out
time(3) says: 1601225930
apue$
```

```
static char sccsid[] = "@(#)time.c      8.1 (Berkeley) 6/4/93";
#else
__RCSID("$NetBSD: time.c,v 1.12 2012/03/13 21:13:37 christos Exp $");
#endif
#endif /* LIBC_SCCS and not lint */

#include "namespace.h"
#include <sys/types.h>
#include <sys/time.h>

#include <time.h>

time_t
time(time_t *t)
{
        struct timeval tt;

        if (gettimeofday(&tt, NULL) == -1)
                return (time_t)-1;
        if (t != NULL)
                *t = (time_t)tt.tv_sec;
        return (time_t)tt.tv_sec;
}
                                                    57,1    2170    100%
```

gettimeofday(2)

```
#include <sys/time.h>

int gettimeofday(struct timeval * restrict tp, void * restrict tzp);
```

Returns: 0 if OK, -1 on error

The system's notion of the current UTC time is obtained with the gettimeofday() call. The time is expressed in seconds and *microseconds* since midnight (0 hour), January 1, 1970.

```
struct timeval {
        time_t      tv_sec;         /* seconds */
        suseconds_t tv_usec;        /* and microseconds */
};
struct timezone {
        int         tz_minuteswest; /* of Greenwich */
        int         tz_dsttime;     /* type of dst correction to apply */
};
```

Terminal — 80×28

```
apue$ diff -bu time1.c time2.c
--- time1.c     2020-09-27 16:57:07.374599358 +0000
+++ time2.c     2020-09-27 17:10:59.846633567 +0000
@@ -6,6 +6,7 @@
 int
 main() {
         time_t t;
+        struct timeval tv;

         if ((t = time(NULL)) < 0) {
                 err(EXIT_FAILURE, "unable to call time()");
@@ -13,5 +14,11 @@
         }
         printf("time(3) says: %ld\n", t);

+        if (gettimeofday(&tv, NULL) < 0) {
+                err(EXIT_FAILURE, "unable to gettimeofday()");
+                /* NOTREACHED */
+        }
+        printf("gettimeofday(2) says: %ld.%d\n", tv.tv_sec, tv.tv_usec);
+
         return EXIT_SUCCESS;
 }
apue$ cc time2.c
apue$ ./a.out
time(3) says:          1601230573
gettimeofday(2) says: 1601230573.40550
apue$
```

clock_gettime(2)

```
#include <sys/time.h>

int clock_gettime(clockid_t clock_id, struct timespec *tp);
```

Returns: 0 if OK, -1 on error

The `clock_gettime()` function stores the time of the clock identified by `clock_id` into the location specified by `tp`; `clock_id` `CLOCK_REALTIME` represents the amount of time (in seconds and *nanoseconds*) since 00:00 Universal Coordinated Time, January 1, 1970.

Terminal — 80×29

```
apue$ diff -bu time[23].c
--- time2.c     2020-09-27 17:10:59.846633567 +0000
+++ time3.c     2020-09-27 17:11:48.040663199 +0000
@@ -7,6 +7,7 @@
 main() {
         time_t t;
         struct timeval tv;
+        struct timespec ts;

         if ((t = time(NULL)) < 0) {
                 err(EXIT_FAILURE, "unable to call time()");
@@ -20,5 +21,11 @@
         }
         printf("gettimeofday(2) says: %ld.%d\n", tv.tv_sec, tv.tv_usec);

+        if (clock_gettime(CLOCK_REALTIME, &ts) < 0) {
+                err(EXIT_FAILURE, "unable to call clock_gettime()");
+                /* NOTREACHED */
+        }
+        printf("clock_gettime(2) says: %ld.%ld\n", ts.tv_sec, ts.tv_nsec);
+
         return EXIT_SUCCESS;
 }
apue$ cc time3.c
apue$ ./a.out
time(3) says:           1601230621
gettimeofday(2) says:  1601230621.192601
clock_gettime(2) says: 1601230621.192604618
apue$
```

Breaking time using gmtime(3)

```
$ date +%s
1601230776
$ date
Sun Sep 27 18:19:37 UTC 2020
```

```
#include <time.h>

struct tm *gmtime(const time_t *clock);
```

Returns: pointer to struct_tm if OK, NULL on error

The gmtime() function converts to Coordinated Universal Time (UTC) and returns a pointer to the tm structure described in tm(3).

gmtime(3) and the struct tm

```
struct tm {
        int     tm_sec;         /* seconds after the minute [0-61] */
        int     tm_min;         /* minutes after the hour [0-59] */
        int     tm_hour;        /* hours since midnight [0-23] */
        int     tm_mday;        /* day of the month [1-31] */
        int     tm_mon;         /* months since January [0-11] */
        int     tm_year;        /* years since 1900 */
        int     tm_wday;        /* days since Sunday [0-6] */
        int     tm_yday;        /* days since January 1 [0-365] */
        int     tm_isdst;       /* Daylight Savings Time flag */
};
```

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Paris, 6 July 2016

Bulletin C 52

To authorities responsible for the measurement and distribution of time

UTC TIME STEP
on the 1st of January 2017

A positive leap second will be introduced at the end of December 2016.
The sequence of dates of the UTC second markers will be:

2016 December 31, 23h 59m 59s
2016 December 31, 23h 59m 60s
2017 January 1, 0h 0m 0s

The difference between UTC and the International Atomic Time TAI is:

from 2015 July 1, 0h UTC, to 2017 January 1 0h UTC : UTC-TAI = - 36s
from 2017 January 1, 0h UTC, until further notice : UTC-TAI = - 37s

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Paris, 07 July 2020

Bulletin C 60

To authorities responsible
for the measurement and
distribution of time

INFORMATION ON UTC - TAI

NO leap second will be introduced at the end of December 2020.
The difference between Coordinated Universal Time UTC and the
International Atomic Time TAI is :

from 2017 January 1, 0h UTC, until further notice : UTC-TAI = -37 s

Leap seconds can be introduced in UTC at the end of the months of December or June, depending on the evolution of UT1-TAI. Bulletin C is mailed every six months, either to announce a time step in UTC, or to confirm that there will be no time step at the next possible date.

Unix Epoch and leap seconds

```
1483228798 should be 'Sat Dec 31 23:59:58 2016'; is: Sat Dec 31 23:59:58 2016
1483228799 should be 'Sat Dec 31 23:59:59 2016'; is: Sat Dec 31 23:59:59 2016
1483228800 should be 'Sat Dec 31 23:59:60 2016'; is: Sun Jan  1 00:00:00 2017

Sat Dec 31 23:59:58 2016 should be 1483228798; is 1483228798
Sat Dec 31 23:59:59 2016 should be 1483228799; is 1483228799
Sat Dec 31 23:59:60 2016 should be 1483228800; is 1483228800
Sun Jan  1 00:00:00 2017 should be 1483228801; is 1483228800
```

```
struct tm {
        int tm_sec; /* seconds after the minute [0-61] */
        ...
}

struct tm {
        int tm_sec; /* Seconds. [0-60] (1 leap second) */
        ...
}
```

gmtime(3) and the struct tm

```
$ date +%s
1601230776
$ date
Sun Sep 27 18:19:37 UTC 2020
```

```
#include <time.h>

struct tm *gmtime(const time_t *clock);
```

Returns: pointer to struct_tm if OK, NULL on error

The gmtime() function converts to Coordinated Universal Time (UTC) and returns a pointer to the tm structure described in tm(3).

gmtime(3) and the struct tm

```
$ date +%s
1601230776
$ date
Sun Sep 27 18:19:37 UTC 2020
```

```
#include <time.h>

struct tm *gmtime(const time_t *clock);
                                        Returns: pointer to struct_tm if OK, NULL on error
char *asctime(const struct tm *tm);
        Returns: string in "Thu Nov 24 18:22:48 1986\n\0" format if OK, NULL on error
```

Terminal — 80×30

```
apue$ diff -bu time[34].c
--- time3.c     2020-09-27 17:11:48.040663199 +0000
+++ time4.c     2020-09-27 20:03:22.934565666 +0000
@@ -8,6 +8,7 @@
        time_t t;
        struct timeval tv;
        struct timespec ts;
+       struct tm *tm;

        if ((t = time(NULL)) < 0) {
                err(EXIT_FAILURE, "unable to call time()");
@@ -27,5 +28,11 @@
        }
        printf("clock_gettime(2) says: %ld.%ld\n", ts.tv_sec, ts.tv_nsec);

+       if ((tm = gmtime(&t)) == NULL) {
+               err(EXIT_FAILURE, "unable to call gmtime()");
+               /* NOTREACHED */
+       }
+       printf("asctime(3) says:       %s", asctime(tm));
+
        return EXIT_SUCCESS;
 }
apue$ cc time4.c
apue$ ./a.out
time(3) says:           1601237010
gettimeofday(2) says:  1601237010.469965
clock_gettime(2) says: 1601237010.469969078
asctime(3) says:       Sun Sep 27 20:03:30 2020
apue$
```

gmtime(3) and the struct tm

```
struct tm {
        int     tm_sec;         /* seconds after the minute [0-61] */
        int     tm_min;         /* minutes after the hour [0-59] */
        int     tm_hour;        /* hours since midnight [0-23] */
        int     tm_mday;        /* day of the month [1-31] */
        int     tm_mon;         /* months since January [0-11] */
        int     tm_year;        /* years since 1900 */
        int     tm_wday;        /* days since Sunday [0-6] */
        int     tm_yday;        /* days since January 1 [0-365] */
        int     tm_isdst;       /* Daylight Savings Time flag */
};
```

gmtime(3) and the struct tm

```
struct tm {
        int     tm_sec;         /* seconds after the minute [0-61] */
        int     tm_min;         /* minutes after the hour [0-59] */
        int     tm_hour;        /* hours since midnight [0-23] */
        int     tm_mday;        /* day of the month [1-31] */
        int     tm_mon;         /* months since January [0-11] */
        int     tm_year;        /* years since 1900 */
        int     tm_wday;        /* days since Sunday [0-6] */
        int     tm_yday;        /* days since January 1 [0-365] */
        int     tm_isdst;       /* Daylight Savings Time flag */
        long    tm_gmtoff;      /* offset from UTC in seconds */
        __aconst char *tm_zone; /* timezone abbreviation */
};
```

gmtime(3) and the struct tm

```
$ date +%s
1601240163
$ TZ=US/Easter date
Sun Sep 27 20:56:10 GMT 2020
```

```
#include <time.h>

struct tm *gmtime(const time_t *clock);
struct tm *localtime(const time_t *clock);
                                    Returns: pointer to struct_tm if OK, NULL on error
char *asctime(const struct tm *tm);
        Returns: string in "Thu Nov 24 18:22:48 1986\n\0" format if OK, NULL on error
```

Terminal — 80×30

```
apue$ diff -bu time[45].c
--- time4.c     2020-09-27 20:03:22.934565666 +0000
+++ time5.c     2020-09-27 20:42:56.421829266 +0000
@@ -34,5 +34,11 @@
         }
         printf("asctime(3) says:       %s", asctime(tm));

+        if ((tm = localtime(&t)) == NULL) {
+                err(EXIT_FAILURE, "unable to call gmtime()");
+                /* NOTREACHED */
+        }
+        printf("localtime is:          %s", asctime(tm));
+
         return EXIT_SUCCESS;
 }
apue$ cc time5.c
apue$ ./a.out
time(3) says:           1601239518
gettimeofday(2) says:   1601239518.556678
clock_gettime(2) says: 1601239518.556681863
asctime(3) says:        Sun Sep 27 20:45:18 2020
localtime is:           Sun Sep 27 20:45:18 2020
apue$
```

Terminal — 80×30

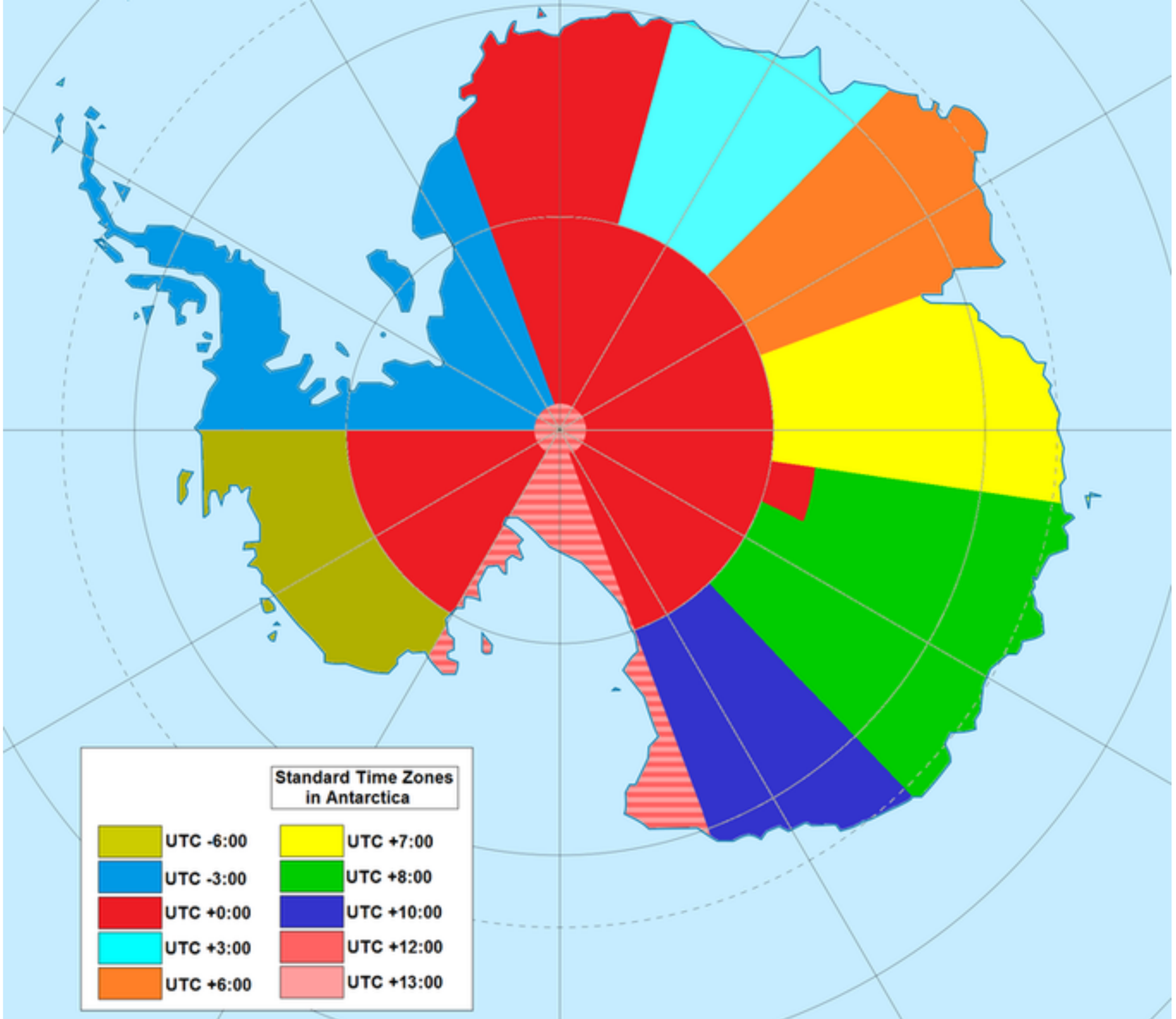
```
apue$ diff -bu time[45].c
--- time4.c     2020-09-27 20:03:22.934565666 +0000
+++ time5.c     2020-09-27 20:42:56.421829266 +0000
@@ -34,5 +34,11 @@
         }
         printf("asctime(3) says:       %s", asctime(tm));

+        if ((tm = localtime(&t)) == NULL) {
+                err(EXIT_FAILURE, "unable to call gmtime()");
+                /* NOTREACHED */
+        }
+        printf("localtime is:          %s", asctime(tm));
+
         return EXIT_SUCCESS;
 }
apue$ cc time5.c
apue$ ./a.out
time(3) says:           1601239518
gettimeofday(2) says:   1601239518.556678
clock_gettime(2) says: 1601239518.556681863
asctime(3) says:        Sun Sep 27 20:45:18 2020
localtime is:           Sun Sep 27 20:45:18 2020
apue$ TZ=US/Eastern ./a.out
time(3) says:           1601239573
gettimeofday(2) says:   1601239573.479822
clock_gettime(2) says: 1601239573.479825410
asctime(3) says:        Sun Sep 27 20:46:13 2020
localtime is:           Sun Sep 27 16:46:13 2020
apue$
```

STANDARD TIME ZONES OF THE WORLD

Add time zone number to local time to obtain UTC. Subtract time zone number from UTC to obtain local time. WEST

EAST Subtract time zone number from local time to obtain UTC. Add time zone number to UTC to obtain local time.


Standard Time Zones in Antarctica
UTC -6:00
UTC -3:00
UTC +0:00
UTC +3:00
UTC +6:00
UTC +7:00
UTC +8:00
UTC +10:00
UTC +12:00
UTC +13:00

DAYLIGHT SAVING TIME

Areas in the world that use Daylight Saving Time in all country or some of its regions.

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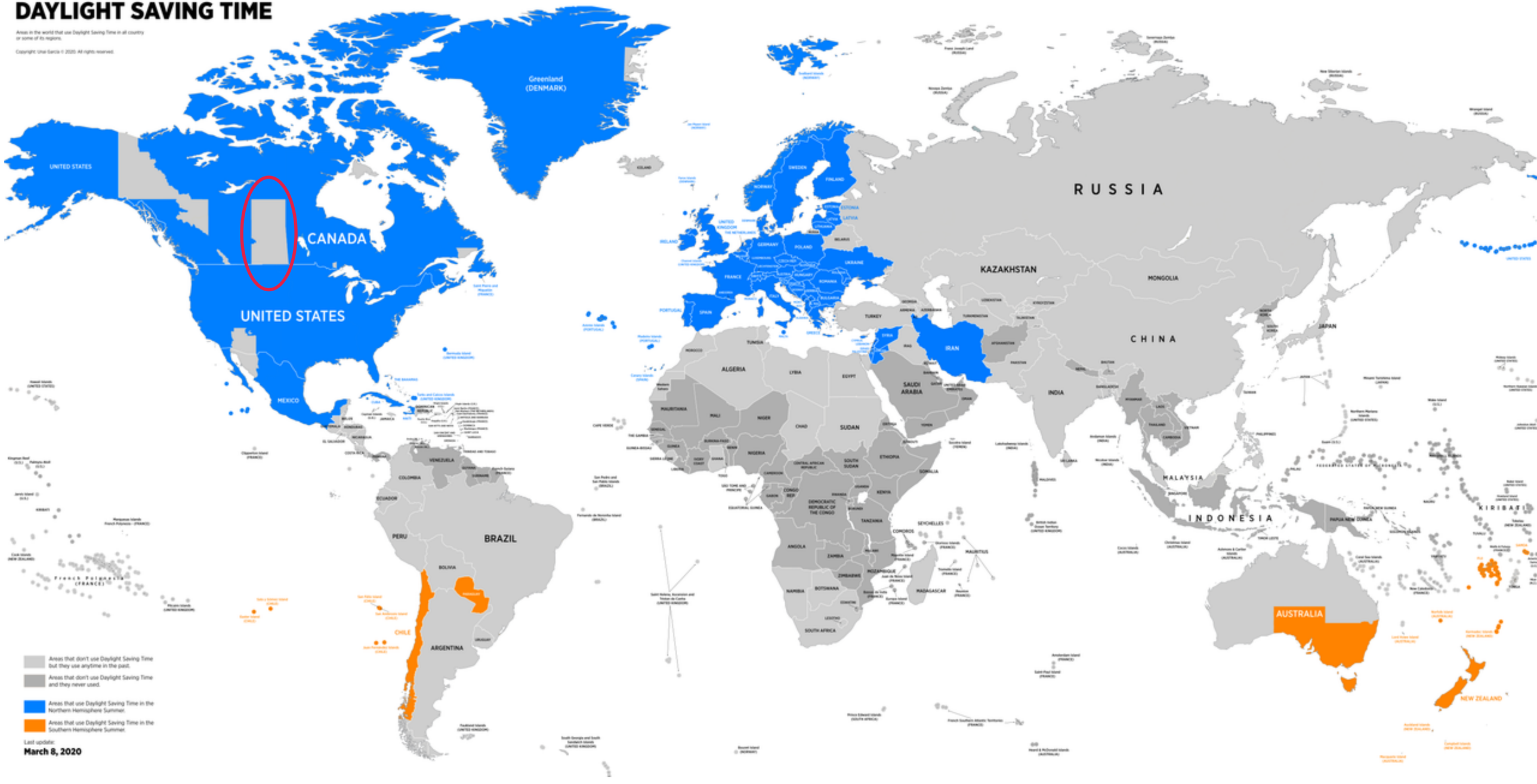
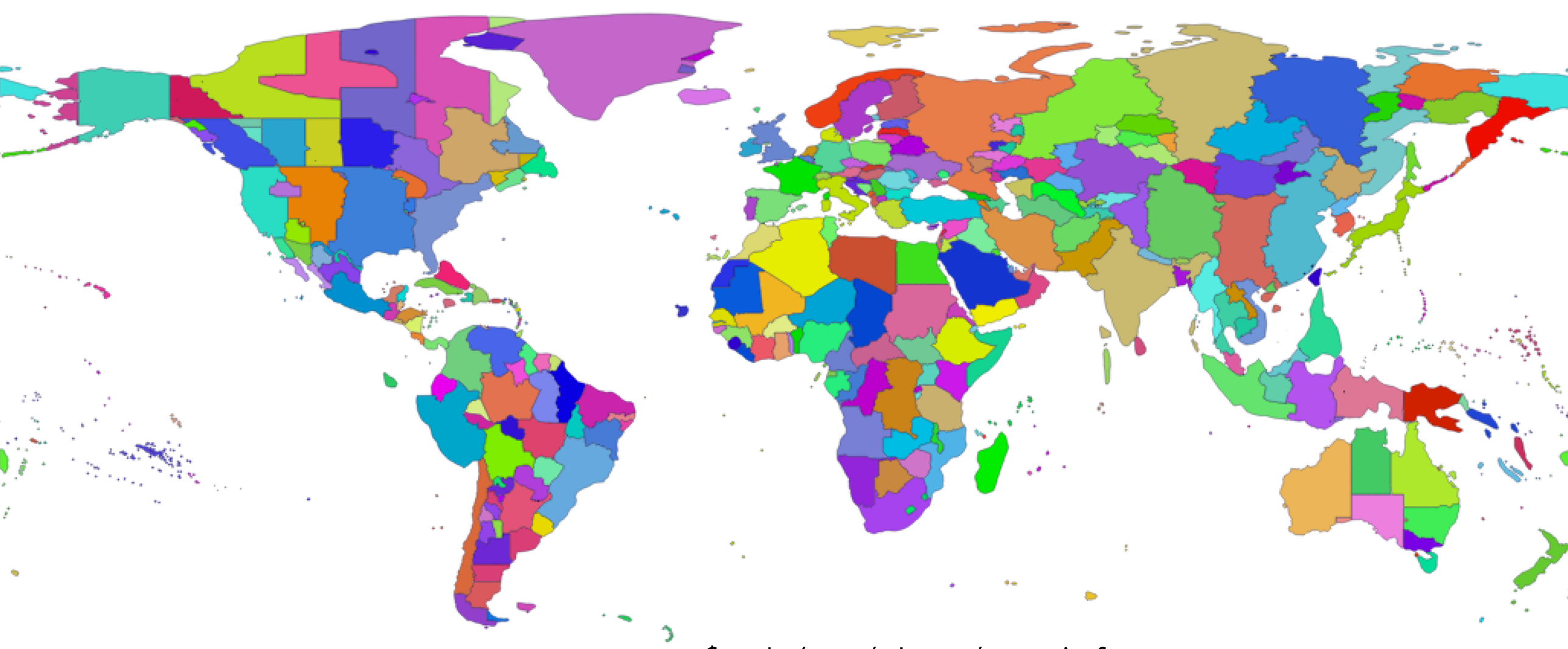


Last update:
March 8, 2020



```
$ find /usr/share/zoneinfo -type f \
        -name '[A-Z]*' -print | wc -l
     595
```

```
$ cd /usr/share/zoneinfo
$ for tz in $(find * -type f -name '[A-Z]*'); do
> echo $tz
> TZ=$tz date
> echo
> done
```

mktime(3) and the struct tm

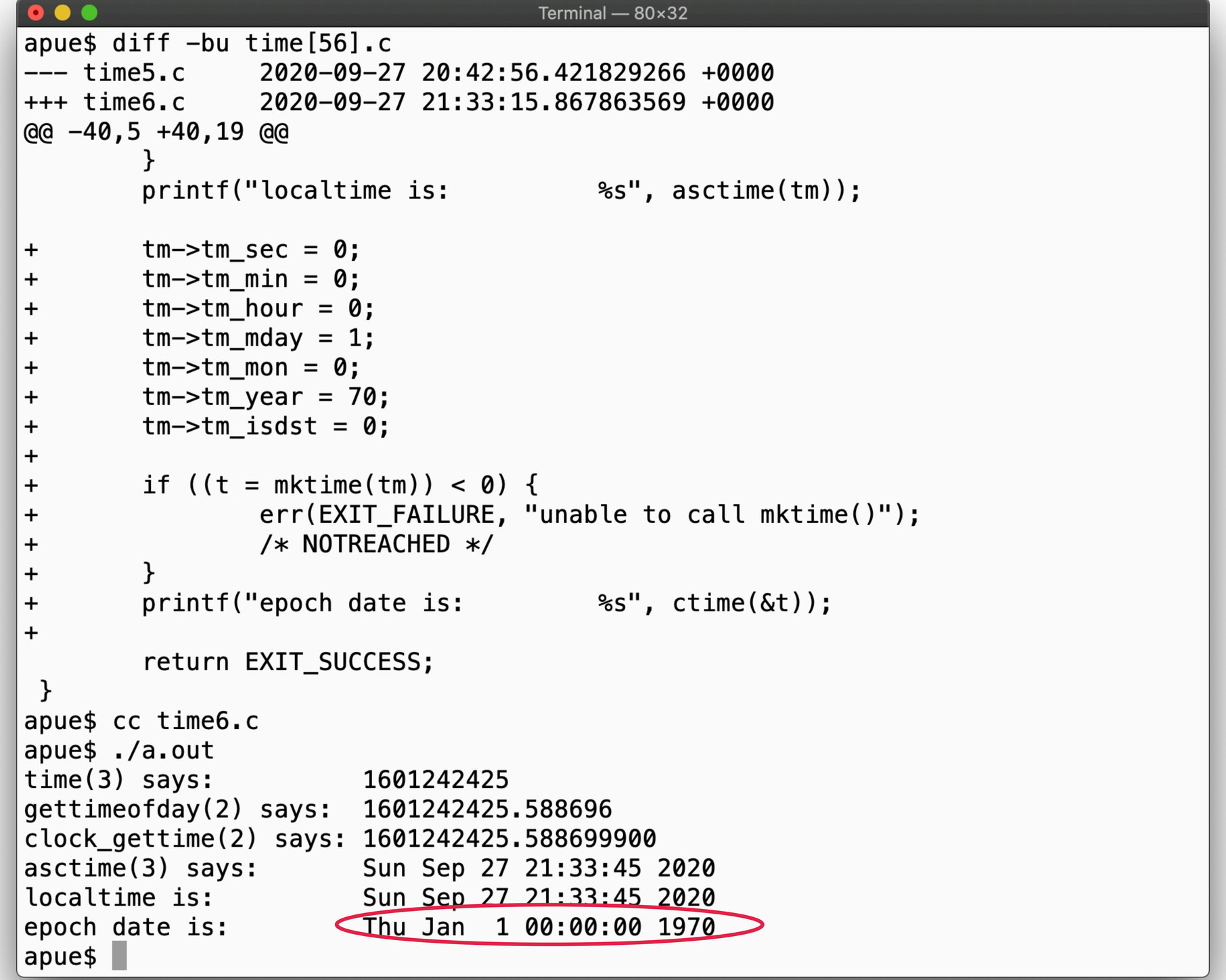
```
#include <time.h>

time_t mktime(struct tm *tm);
                                                    Returns: time_t if OK, -1 on error

char *ctime(const time_t *clock);
                                        Returns: string like asctime(3) if OK, NULL on error
```

mktime(3) operates in the reverse direction from gmtime(3)/localtime(3).

ctime(3) is like asctime(3), but takes a time_t * instead of a struct tm *.

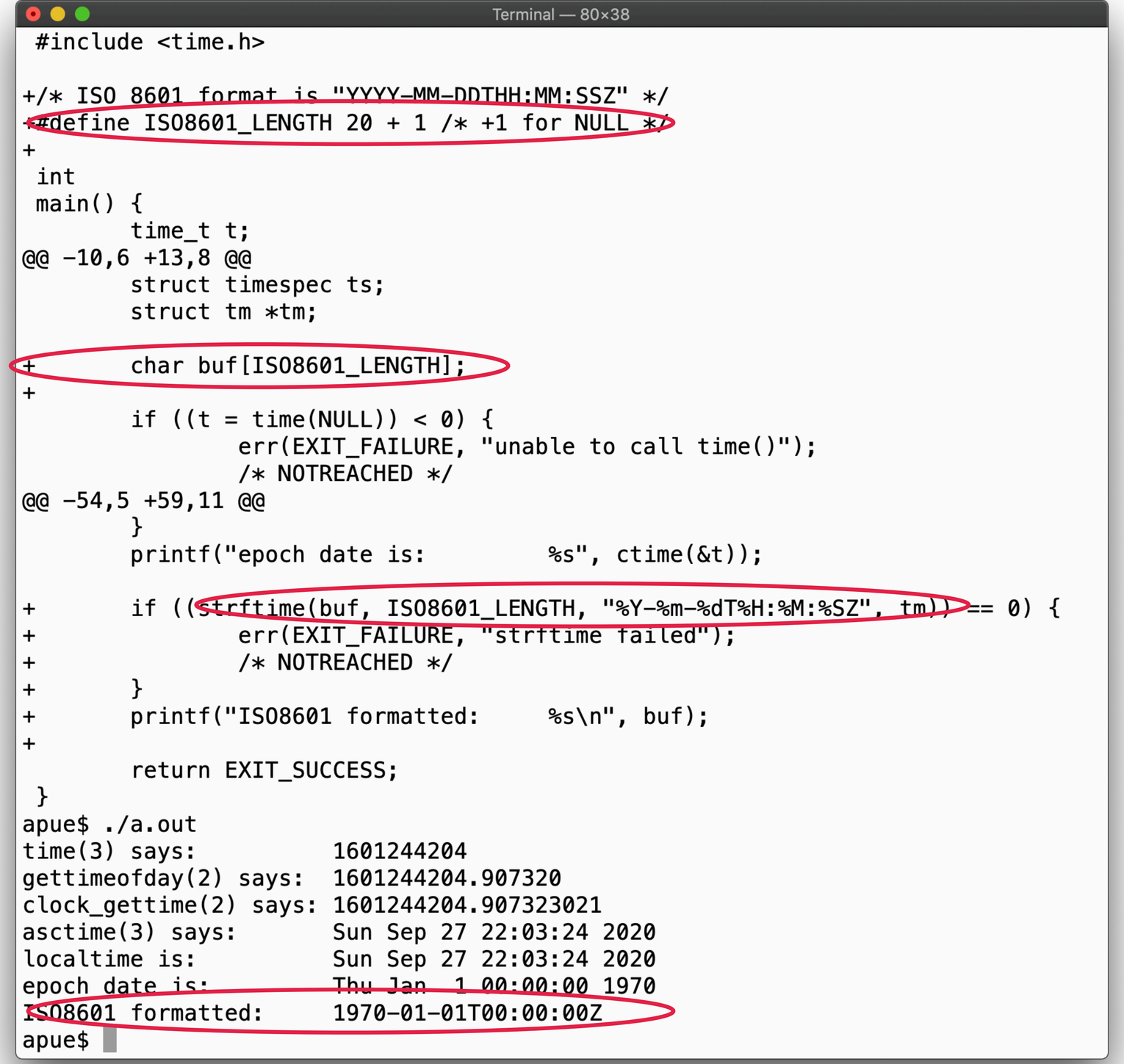

Terminal — 80×32
apue$ diff -bu time[56].c
--- time5.c 2020-09-27 20:42:56.421829266 +0000
+++ time6.c 2020-09-27 21:33:15.867863569 +0000
@@ -40,5 +40,19 @@
 }
 printf("localtime is: %s", asctime(tm));
+ tm->tm_sec = 0;
+ tm->tm_min = 0;
+ tm->tm_hour = 0;
+ tm->tm_mday = 1;
+ tm->tm_mon = 0;
+ tm->tm_year = 70;
+ tm->tm_isdst = 0;
+
+ if ((t = mktime(tm)) < 0) {
+ err(EXIT_FAILURE, "unable to call mktime()");
+ /* NOTREACHED */
+ }
+ printf("epoch date is: %s", ctime(&t));
+
 return EXIT_SUCCESS;
}
apue$ cc time6.c
apue$ ./a.out
time(3) says: 1601242425
gettimeofday(2) says: 1601242425.588696
clock_gettime(2) says: 1601242425.588699900
asctime(3) says: Sun Sep 27 21:33:45 2020
localtime is: Sun Sep 27 21:33:45 2020
epoch date is: Thu Jan 1 00:00:00 1970
apue$

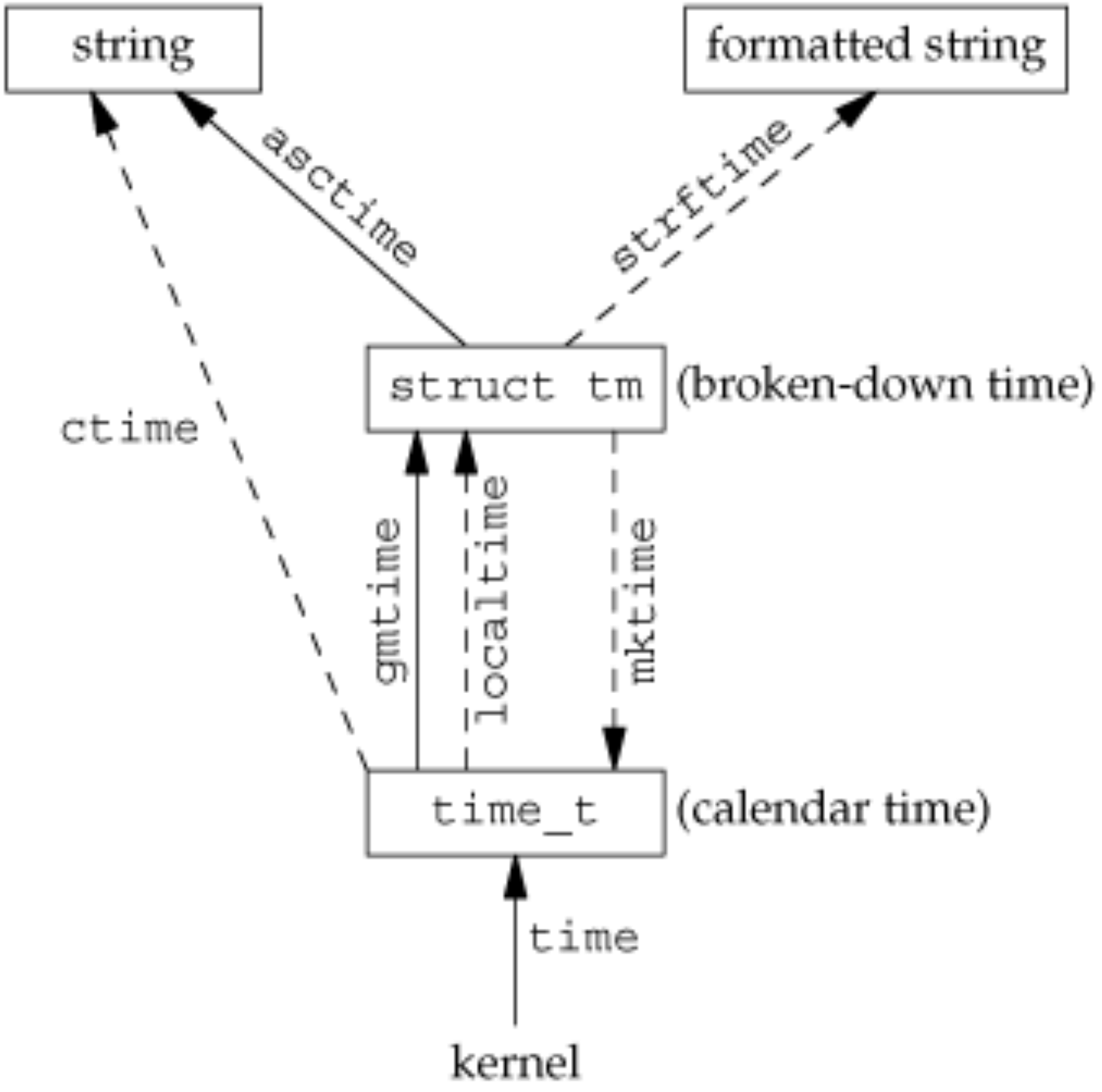
gmtime(3) and the struct tm

```
$ date
Sun Sep 27 21:47:30 UTC 2020
$ date +%D
09/27/20
$ date +%Y-%m-%dT%H:%M:%SZ
2020-09-27T21:47:47Z
```

```
#include <time.h>

ssize_t strftime(char * restrict buf, size_t maxsize,
        const char * restrict format, const struct tm * restrict timeptr);
                                                Returns: number of characters placed into buffer
```


Terminal — 80×38
#include <time.h>
+/* ISO 8601 format is "YYYY-MM-DDTHH:MM:SSZ" */
+#define ISO8601_LENGTH 20 + 1 /* +1 for NULL */
+
int
main() {
time_t t;
@@ -10,6 +13,8 @@
struct timespec ts;
struct tm *tm;
+char buf[ISO8601_LENGTH];
+
if ((t = time(NULL)) < 0) {
err(EXIT_FAILURE, "unable to call time()");
/* NOTREACHED */
@@ -54,5 +59,11 @@
}
printf("epoch date is: %s", ctime(&t));
+if ((strftime(buf, ISO8601_LENGTH, "%Y-%m-%dT%H:%M:%SZ", tm)) == 0) {
+err(EXIT_FAILURE, "strftime failed");
+/* NOTREACHED */
+}
+printf("ISO8601 formatted: %s\n", buf);
+
return EXIT_SUCCESS;
}
apue$ ./a.out
time(3) says: 1601244204
gettimeofday(2) says: 1601244204.907320
clock_gettime(2) says: 1601244204.907323021
asctime(3) says: Sun Sep 27 22:03:24 2020
localtime is: Sun Sep 27 22:03:24 2020
epoch date is: Thu Jan 1 00:00:00 1970
ISO8601 formatted: 1970-01-01T00:00:00Z
apue$


string
formatted string
asctime
strftime
struct tm
(broken-down time)
ctime
gmtime
localtime
mktime
time_t
(calendar time)
time
kernel

Links and Discussions

- https://www.iana.org/time-zones
- https://en.wikipedia.org/wiki/ISO_8601
- https://infiniteundo.com/post/25326999628/falsehoods-programmers-believe-about-time
- https://en.wikipedia.org/wiki/Coordinated_Universal_Time
- https://en.wikipedia.org/wiki/Leap_second
- http://hpiers.obspm.fr/eop-pc/products/bulletins/subscription.html
- https://pubs.opengroup.org/onlinepubs/9699919799/xrat/V4_xbd_chap04.html#tag_21_04_16
- http://www.madore.org/~david/computers/unix-leap-seconds.html