

## Precise time scales and navigation systems: what time is it and where are we?

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### Extended Abstract

Today the precision of atomic clocks enables us to accurately answer the question “when?”, but also “where?”. In fact, through the use of ultra-precise atomic frequency standards, we can form time scales, such as the international time standard Coordinated Universal Time (UTC), capable of dating events with nanosecond accuracy. Similarly, Global Navigation Satellite Systems (GNSS), using atomic clocks, can provide location estimation all over the world with sub-meter accuracy.

In timekeeping, as well as in navigation systems, the questions may be similar, but the answers are frequently dissimilar, due to different goals, requirements, technology availability, and constraints. In both cases precision clocks, measuring systems, and a reference time scale are required (Fig 1); in both cases we need to estimate how often the clocks are to be resynchronized and what is the acceptable time error that a clock may accumulate without compromising system performance. We require a mathematical model to predict clock behavior in order to maintain agreement with another reference clock or to ensure updated navigation messages. We need to understand the “normal” behavior of a clock to be able to quickly identify anomalies which can lead to incorrect estimates.

The general lecture presents the needs of precise Timing and Navigation, explaining the current international timekeeping architecture and the timing systems of the current GNSS, with a general view for all publics, and also giving insight to the most demanding topics that still challenge Time Metrology.

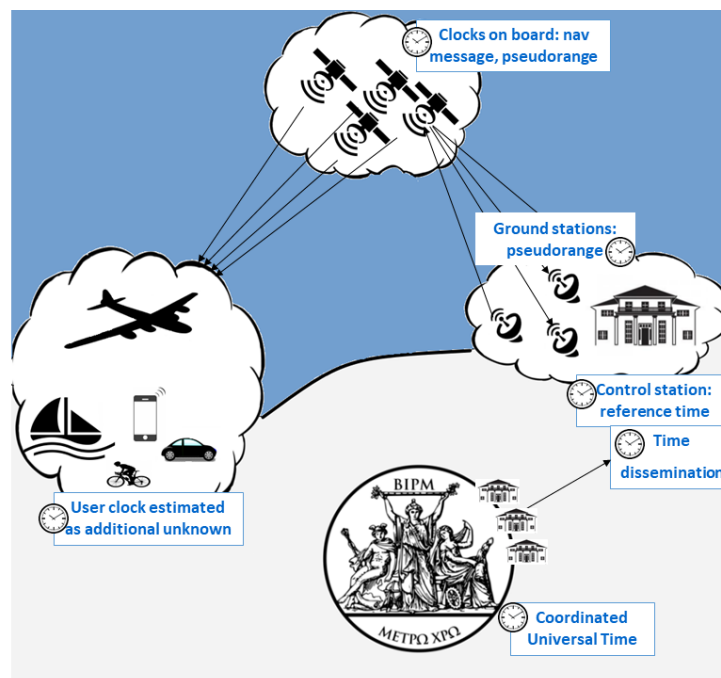


Figure 1. Clocks and time scales in a Global Navigation Satellite System [1]

### References

- [1] P.Tavella, G.Petit, “Precise time scales and navigation systems: mutual benefits of timekeeping and positioning” *Satell Navig* 1:10, 2020, [doi.org/10.1186/s43020-020-00012-0](https://doi.org/10.1186/s43020-020-00012-0)