GPS Solutions (2021) 25:75
https://doi.org/10.1007/s10291-021-01117-y

EDITORIAL

Topical collection on timekeeping in space: technology, practice, promise, and benefits

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Published online: 22 March 2021
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Since the early days of space exploration, timekeeping has served as both an enabler and a benefactor of our highest achievements. A steady sequence of technological advances led to today's multicultural GNSS, which in turn has revolutionized location, navigation, and timekeeping infrastructures. Originally, GPS and GLONASS (the first GNSS) were satellite navigation missions focused solely on military applications. Even the worldwide PNT community looked at these systems as such at the time. In this regard, it is interesting to note that in the 1980s, as the cost of GPS was increasing beyond initial estimates, representatives from the U.S. Department of Defense presented talks at conferences (the editors of this special issue remember one in particular), looking to foster some type of cost-sharing with the commercial sector. Needless to say, the commercial sector at the time saw no commercial advantage to GNSS, and so the cost-sharing scheme came to naught… how wrong could those commercial sector individuals have been? Today, GNSS represents a multi-billion dollar activity, with applications extending well beyond defense. Looking into the future, we see the limits of GNSS applications being only set by the imagination of GNSS engineers and scientists.

In this topical collection, we consider all aspects of space timing, which for GNSS is arguably the heart. More specifically, the various papers in this collection look at GNSS timekeeping from a very broad perspective. Some of the papers examine how atomic timekeeping might appear in space and on the ground for GNSS in the coming decades: papers that examine the question of how far is far enough for the improvement of onboard atomic clocks, how those improvements in onboard atomic clocks might manifest, how satellite crosslink time-transfer might improve constellation timekeeping, how integrating clocks into clock systems (e.g., ensembling) might improve onboard and user-segment capabilities. Still, other papers provide ideas on new space platforms and systems that have applications beyond PNT or that are designed to provide only time.

One issue of growing importance is how GNSS receivers can be designed to provide improved robustness, precision, traceability, and yet with less sensitivity to jamming and spoofing. Other papers in this collection examine how GNSS data can be better processed analytically, not solely for greater precision but for ease of operation and real-time applications. The interoperability of GNSS, which often requires proper treatment of biases, whether instrumental or related to system timescale differences, is another theme represented by the papers in this special issue and one we expect to be rapidly developed throughout this decade.

Finally, we cannot forget the role GNSS has (and will continue to play) in fundamental science. In this initial collection of papers, these range from tests of relativity to synchronization of networks of astronomical observatories. In all, we believe that the papers comprising this collection show where GNSS timekeeping is today and where it is likely to head in the coming decades in order that GNSS technologists' imaginations remain unconstrained.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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James Camparo joined The Aerospace Corporation's Atomic Physics section in January 1981 immediately after obtaining his doctorate from Columbia University. His dissertation dealt with "laser snow" (i.e., photochemically produced cesium hydride) and the spin-exchange detection of free hydrogen/deuterium atoms created in the laser snow process. He is currently a Fellow in Aerospace's Physical Sciences Laboratories, where his interests include research and development of laser-pumped atomic clocks, the study of atomic timekeeping onboard spacecraft, and experiments investigating the field/atom interaction. Dr. Camparo is the author or co-author of over 100 scientific papers and holds six patents in the area of atomic clocks. Dr. Camparo has been a part-time faculty member at California State University Dominguez Hills, lecturing in both the Physics and Chemistry departments, and since 2005 an adjunct professor of physics at Whittier College. Dr. Camparo was captain of the Columbia Fencing Team (1977) and holds a second-degree black belt in Tae-Kwon-Do. In his spare time, Dr. Camparo enjoys the theater, history, and spending time with his family and grandchildren.