REQUIREMENTS FOR UTC AND CIVIL TIMEKEEPING ON EARTH

Edited by
John H. Seago
Robert L. Seaman
P. Kenneth Seidelmann
Steven L. Allen

American Astronautical Society

Volume 115
SCIENCE AND TECHNOLOGY SERIES

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Front Cover Illustration:

Pendulum motion demonstrates the rotation of the Earth (à la Foucault) and the metering of time independent of Earth's rotation. UTC and Civil Timekeeping provide both, but will that continue?

Image Credit: Artwork by Pete Marenfeld, courtesy of NOAO.

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FOREWORD

On May 29 and May 30, 2013, a colloquium on *Requirements for UTC and Civil Timekeeping on Earth* was held at the Jefferson Scholars Foundation in Charlottesville, Virginia, hosted by the University of Virginia (UVa) and the UVa Astronomy Department. This gathering was a successor to the colloquium on *Decoupling Civil Timekeeping from Earth Rotation* held in Exton, Pennsylvania in October, 2011.

The Exton colloquium was conducted in advance of the Radiocommunication Assembly of the International Telecommunication Union (ITU) in January 2012, which considered a proposal to eliminate future leap seconds from Coordinated Universal Time (UTC). Rather than eliminate leap seconds, the ITU-R requested additional studies of broader scope, to ensure that all the technical options have been fully addressed. Because the Assembly's recommendation paralleled guidance from specialists attending the 2011 colloquium in Exton, another colloquium seemed fitting. The enclosed proceedings, together with those of the 2011 Exton colloquium, greatly expand on the documentation available from specialized meetings devoted to the definition of UTC. Furthermore, these proceedings provide more diverse insights into civil-timekeeping practice than any previous meeting concerning UTC definition, including philosophical, societal, and non-scientific viewpoints toward the use of time-of-day.

The Charlottesville colloquium was concurrent with the 10th anniversary of *The Future of UTC* colloquium in Torino (Turin), Italy, the first specialist colloquium dedicated to UTC redefinition and the only public meeting to date sanctioned by an ITU-R study group. In contrast to the 2003 Torino colloquium, which garnered fourteen talks but only three written papers, the enclosed proceedings include twenty-two contributed manuscripts, with each concluded by a chronicled discussion. These manuscripts were presented in seven sessions over two days to an attending audience involving twenty international discussants, expressing viewpoints both favoring and opposing a redefinition of UTC.

The level of national and international contribution to this colloquium was most remarkable considering the economic climate at the time. Within the U.S.A., automatic government spending cuts, coupled with the widely reported misuse of travel funds by at least one government agency, resulted in the "sequestration" of almost all travel subsidies from U.S. government agencies during the timeframe of the colloquium. One of the colloquium's co-sponsors—the American Institute of Aeronautics and Astronautics (AIAA)—abruptly canceled its annual Missile Defense Conference and Exhibition scheduled for March, 2013. About the same time, the Institute of Navigation (ION) Military Division announced the cancellation of its Joint Navigation Conference, originally scheduled for June 10-13, 2013.

Owing to the unusual fiscal environment surrounding the colloquium, many potential attendees, and some co-authors, expressed regret for their absence. Ten contributing authors could not attend: Henno Boomkamp of the European Space Operations Centre (ESOC), Stephen Colebourne of OpenGamma, David Finkleman of the Center for Space Standards and Innovation (CSSI), Thomas Johnson and Barbara Wiley of the National Geospatial-Intelligence Agency (NGA), Yuko Hanado,

Mizuhiko Hosokawa, Hiroyuki Ito, and Tsukasa Iwama of the National Institute of Information and Communications Technology (NICT), Japan, and Kara Warburton of Termologic. In a few cases, contributed manuscripts were presented by an attending guest speaker on behalf of the author(s) before being deliberated by the audience. Technology was leveraged to include valued presentations and discussions with Fr. Paul Gabor in Europe using a remote Skype™ video-conferencing connection. Dava Sobel of Aeon Magazine,* George Kaplan of the U.S. Naval Observatory, and Alison Peck of the National Radio Astronomy Observatory (NRAO), also participated as interested observers and discussants. Special gratitude is reserved for audio-visual technologist David Rigby, who was instrumental in the success of the meeting's remote presentations, and Jefferson-Scholar Rachael Lynn Beaton, whose sponsorship facilitated access to Jefferson Scholars Foundation.

On Tuesday, May 28, twenty-five attendees and their guests attended a twilight reception at the historic McCormick Observatory atop nearby Mount Jefferson. The reception featured an orientation regarding the history of McCormick Observatory by Ed Murphy, UVa Associate Professor, Education and Public Outreach, ISM, UV and Radio Astronomy. Attendees enjoyed views of Saturn and the globular cluster M13 through McCormick Observatory's celebrated 26" refractor by Alvan Clark & Sons, and a tour which included the observatory's plate vault.

On Friday, May 31, twenty-one colloquium attendees and their guests participated in a morning tour of nearby Monticello, the famous plantation homestead of gentleman farmer, inventor, and 3rd U.S. President, Thomas Jefferson. This event featured Jefferson's interest in timekeeping through two devices of his own design: the Great Clock with its dual indoor/outdoor faces, hourly gong, and 7-day movement, and a reproduction of Jefferson's captivating spherical sundial. The Monticello tour was followed by a luncheon buffet of authentic Southern fare at historic Michie Tavern.

In keeping with the previous volume of proceedings, the co-chairs have included an extended introduction and summary of the meeting's topics and technical points as a separate paper. This summary, which is an expression of the co-chairs, is no substitute for exploring the actual manuscripts and discussions, and readers are encouraged to consider the proceedings volume in its entirety.

John H. Seago
Robert L. Seaman
P. Kenneth Seidelmann
Steven L. Allen

Volume Editors

* http://www.aeonmagazine.com/world-views/what-if-clock-time-no-longer-tracked-the-sun/

Figure 1. Colloquium Attendees.

Table 1. Colloquium Participants (as ordered from left to right in Figure 1.)

Name	Organization	Nationality
Martin Burnicki	Meinberg Funkuhren	Germany
Dava Sobel	Aeon Magazine	USA
Kevin K. Birth	Dept. of Anthropology, Queens College, CUNY	USA
Stephen (Steve) Malys	National Geospatial–Intelligence Agency (NGA)	USA
P. Kenneth (Ken) Seidelmann	University of Virginia (UVa)	USA
Dennis D. McCarthy	United States Naval Observatory (USNO, retired)	USA
Steven (Steve) L. Allen	UCO/Lick Observatory	USA
Andrew Main (Zefram)	Photobox Ltd.	United Kingdom
Servando A. Diaz	University of Arkansas	USA
Chris Tuason	University of Texas	USA
Yasuhiro Koyama	National Institute of Information and Communications Technology (NICT), Japan	Japan
Alison Peck	National Radio Astronomy Observatory (NRAO)	USA
Harlan Stenn	Network Time Foundation (NTF)	USA
James (Jim) Kiessling	U.S. Civil Service	USA
Arnold H. Rots	Smithsonian Astrophysical Observatory (SAO)	The Netherlands
Russell O. Redman	National Research Council (NRC)	Canada
Daniel Gambis	IERS Earth Orientation Center, Observatoire de Paris	France
Robert (Rob) L. Seaman	National Optical Astronomy Observatory (NOAO)	USA
George H. Kaplan	United States Naval Observatory (USNO, contractor)	USA
John H. Seago	Analytical Graphics, Inc. (AGI)	USA
Paul Gabor[*]	Vatican Observatory	Czech Republic

[*] *remote participant, not pictured*

CONTENTS

INTRODUCTION

AAS 13-501

THE COLLOQUIUM ON REQUIREMENTS FOR UTC AND CIVIL TIMEKEEPING ON EARTH

John H. Seago,* Robert L. Seaman,†
P. Kenneth Seidelmann‡ and Steven L. Allen§

On May 29 and May 30, 2013, the Colloquium on *Requirements for UTC and Civil Timekeeping on Earth* was hosted in Charlottesville, Virginia by the University of Virginia (UVa), the UVa Astronomy Department, and the Jefferson Scholars Foundation. This paper highlights various technical perspectives supporting requirements and various recommendations discussed by colloquium participants. [View Full Paper]

* Astrodynamics Engineer, Analytical Graphics, Inc., 220 Valley Creek Blvd., Exton, Pennsylvania 19341-2380, U.S.A.

† Data Engineer, National Optical Astronomy Observatory, 950 N. Cherry Ave., Tucson, Arizona 85719, U.S.A.

‡ Research Professor, Astronomy Department, University of Virginia, P.O. Box 400325, Charlottesville, Virginia 22904, U.S.A.

§ Programmer/Analyst, UCO/Lick Observatory, ISB 1156 High Street, Santa Cruz, California 95064, U.S.A.

Session 1:
RETROSPECTIVES ON TIME

AAS 13-502

PLANES WILL CRASH!
THINGS THAT LEAP SECONDS DIDN'T, AND DID, CAUSE

Steven L. Allen*

In 1970, just as the CCIR decreed that radio broadcast time signals would have leap seconds, IAU Commission 31 (Time) made its report to the 14th General Assembly in Brighton. Along with other objections the section on "Coordinated Time" indicated that "the world-wide collision avoidance systemfor aircraft (CAS) ... cannot admit stepping time adjustments". Four decades and 25 leap seconds later no planes have crashed, but computer operating systems have crashed. This presentation gives some looks into the recent news about the effects of leap seconds. [View Full Paper]

* Programmer/Analyst, UCO/Lick Observatory, ISB 1156 High Street, Santa Cruz, California 95064, U.S.A.

AAS 13-503

EXPERIENCES OF LEAP SECOND ADJUSTMENT OPERATIONS AND QUESTIONNAIRES IN JAPAN

Yasuhiro Koyama,[*] Tsukasa Iwama,[*] Hiroyuki Ito,[*] Yuko Hanado[*] and Mizuhiko Hosokawa[*]

The National Institute of Information and Communications Technology (NICT) in Japan has responsibilities for Japan Standard Time (JST) and is trying to generate and maintain a stable and reliable time scale. NICT has been trying to perform smooth operations of the past leap second adjustments to JST and there has been no major confusion in Japan as the result of careful preparations. Along with these efforts, questionnaires were conducted to gather information concerning the influences from leap second adjustments and opinions towards possible future changes to UTC in 2001 and 2007. The results of these questionnaires are summarized along with the experiences of the operations of leap second adjustments. [View Full Paper]

* National Institute of Information and Communications Technology (NICT), Nukuikitamachi 4-2-1, Koganei, Tokyo 184-8795, Japan.

AAS 13-504

TECHNICAL ASPECTS OF LEAP SECOND PROPAGATION AND EVALUATION

Martin Burnicki*

Leap seconds are scheduled by the International Earth Rotation Service (IERS) whenever the difference between true Earth rotation and the UTC time scale reaches a certain limit. Whenever a leap second has been scheduled by the IERS, a warning must be disseminated to time keeping devices so that clocks become aware of the scheduled leap second early enough to be able to handle the leap second properly. There are different ways to propagate leap second warnings, and different ways to handle leap seconds, and thus there are a number of pitfalls causing unexpected results and potential malfunctioning. [View Full Paper]

* Senior Software Engineer, Meinberg Funkuhren GmbH & Co. KG, Lange Wand 9, D-31812 Bad Pyrmont, Germany.

Session 2:
THE TERMINOLOGY OF TIME

AAS 13-505

DIPLOMACY OF LEGAL TRANSLATIONS: GMT V. UT

Paul Gabor*

This paper aims to communicate the results of my investigation into a question that arose at the 2011 colloquium on civil timekeeping in Exton, Pennsylvania. We have looked into the background, the procedures and practices, the politics and diplomacy of translations of legally binding documents on timekeeping within the structures of the European Union. All linguistic versions being equally binding, the corps of official translators, and of the equivalence tables of specialist terms they use, is the hub where many influences meet. What place is there for expert opinions and definitions agreed upon by the international scientific community? [View Full Paper]

* Vatican Observatory, Department of Astronomy, University of Arizona, Tucson, Arizona 85721-0065, U.S.A.

AAS 13-506

ON THE TERM COORDINATED UNIVERSAL TIME

David Finkleman* **and Kara Warburton†**

The definition and use of the term *Coordinated Universal Time* is more than a technical matter. Practical considerations are as important as technical requirements because using and applying accurate and precise time measurements are critical to many fundamental applications—not just knowing "what time it is." Clarity of the meaning of the term is one of the most important practical requirements. We maintain that if the definition of Coordinated Universal Time is changed to remove the essential connection between that time scale and synodic benchmarks, the term Coordinated Universal Time, abbreviated UTC, cannot be used to refer to the revised time scale that is disconnected from Earth rotation. [View Full Paper]

* Senior Scientist, Center for Space Standards and Innovation, 7150 Campus Drive, Suite 260, Colorado Springs, Colorado 80920, U.S.A.

† Ph.D. Candidate, City University of Hong Kong, Kowloon Tong, Hong Kong.

AAS 13-507

VOCABULARY FOR TIME-SCALES

Russell O. Redman*

Much of the discussion regarding the future of Coordinated Universal Time (UTC) has focused on a "Yes / No" question on whether we should continue to insert leap seconds into UTC to keep it synchronized with the rotation of the Earth. Closer analysis of the problem reveals several other options, which can be explained using some proposed new vocabulary to dissect the concept of a timescale into its component parts.
[View Full Paper]

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Session 3:
THE APPLICATION OF TIME

AAS 13-508

ROBUST NAVIGATION ISSUES IN THE EVENT OF GNSS FAILURES*

James Kiessling†

Civil society currently has ubiquitous availability of both timing and navigation data from various Global Navigation Satellite Systems (GNSS). This availability is not assured in future times and places due to both extremes in natural environments and adverse human efforts to create extreme unnatural environments. The potential span of variability of the natural environment can include repetition of the 1859 super flare with attendant effects on the ionosphere and sustained degradation of the satellite assets due to enhanced radiation environments. Application of unnatural environments can include drastic and destructive effects such as High Altitude Nuclear Detonations (HAND) and the more mundane GPS jamming as done by North Korea. Given that future GNSS availability cannot be assured, suitable and robust navigation backup means beyond GNSS are necessary for aviation and other users. One aspect of assured navigation in the absence of other sources requires quality ephemeris information to the celestial reference that has no particular *a priori* information as to when GNSS will be lost.
[View Full Paper]

* This material does not present an official view or position of the U.S. Government.

† An employee of the U.S. Government acting in his private capacity.

AAS 13-509

THE GPS SVN59 SATELLITE ANOMALY OF 17 JUNE 2012*

Thomas Johnson,† Stephen Malys‡ and Barbara Wiley§

The National Geospatial-Intelligence Agency (NGA) has a supportive role in the daily operations of the U.S. Global Positioning System (GPS). The Earth-Centered, Earth-Fixed World Geodetic System 1984 (WGS 84) reference frame is realized by the adoption of a self-consistent set of highly-accurate coordinates for the Department of Defense (DoD) GPS Monitor Stations. Over the past decades, numerous procedures and operational controls have been instituted to ensure the continuous uninterrupted GPS operations. It was a failure of these procedures that caused an erroneous broadcast message from GPS Space Vehicle Number 59 (SVN59) on June 17, 2012. This occurred due to an improper application of the leap second in the NGA Earth Orientation Parameter Predictions (EOPP) which NGA delivers to the USAF for their use in generating GPS satellite broadcast messages. The duration of the error was limited to 27 minutes due to quick discovery and resolution of the problem. An internal NGA 'after action review' of the events leading up to this failure resulted in the development and implementation of additional safe guards to prevent future incidents. [View Full Paper]

* Approved for Public Release Case 13-350.

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‡ Senior Scientist for Geodesy and Geophysics, National Geospatial-Intelligence Agency, InnoVision Basic and Applied Research Office, 7500 GEOINT Drive, Springfield, Virginia 22150, U.S.A.

§ National Geospatial-Intelligence Agency, Source Geomatics Office, 3838 Vogel Road, Arnold, Missouri 63010, U.S.A.

AAS 13-510

THE LEAP MINUTE—PREDICTING THE UNPREDICTABLE

John H. Seago*

Amidst the controversial effort to eliminate leap seconds from Coordinated Universal Time (UTC), the so-called *leap minute* has been recurrently tendered as an alternative approach to reconcile atomic time with astronomical time-of-day. This paper discourses some civil-timekeeping requirements addressed by intercalary minutes, factors that could affect leap-minute scheduling, and the supposed advantages and disadvantages of such a compromise proposal. Particularly, the leap minute does not appear to have obvious and overwhelming advantages over the convention it proposes to replace; furthermore, the inaugural leap minute is expected to happen beyond the professional lifetimes of current advocates, and there is no evidence that its official adoption now would ensure its operational acceptance later. [View Full Paper]

* Astrodynamics Engineer, Analytical Graphics, Inc., 220 Valley Creek Blvd., Exton, Pennsylvania 19341-2380, U.S.A.

AAS 13-511

ADAPTED UNIVERSAL TIME—STRETCHING THE DAY BY MILLISECONDS USING LETTER TIME FORMAT

Servando A. Diaz* **and Chris Tuason†**

Adapted Universal Time (UTA) is proposed as a new uniform timescale system designed to work in conjunction with Coordinated Universal Time (UTC). Leap seconds create a discontinuity that certain computer systems have had difficulties in handling. UTA eliminates this problem by adding to each day miniscule time durations called a Mean Stretch Adjustment (MSA), which are daily increments. This daily MSA value, calculated to a precision of nanoseconds, completes an assessed Length of Day (LOD). This UTA improvement to UTC was initially inspired by Google's "Leap Smear" adjustment. UTA uses Letter TimeFormat where hours are indicated with letters instead of numbers which is based on Sanford Fleming's Cosmopolitan Time, UTA's timescale runs uninterrupted in the background for POSIX-like computer systems for NTP (Network Time Protocol) interoperability synchronization. UTA keeps UTC as the official civil time standard with its current 24-hour time format and occasional leap seconds, while computer internet servers follow UT1 running on UTA's stretched time.
[View Full Paper]

* Mechanical Engineering Department, University of Arkansas – Fayetteville, Arkansas 72701, U.S.A.

† Aerospace Engineering Department, The University of Texas at Austin, Texas 78705, U.S.A.

AAS 13-512

RECOMMENDATIONS ON UTC DEFINITION FROM IAG WORKING GROUP 1.1.1

Henno Boomkamp*

This paper presents the points of view on UTC from the Working Group on precise orbit estimation of the International Association of Geodesy (IAG) that existed over the period 2004-2011. The IAG organization of commissions, subcommissions and working groups is regularly restructured, and in the most recent reorganization this Working Group has been superseded by various new entities. However, the reply from the Working Group 1.1.1 to the questionnaire on the possible discontinuation of leap seconds will be of interest to the current study, and is presented here. [View Full Paper]

* Chair IAG WG 1.1.1 (2004-2011), European Space Operations Centre, Robert-Bosch-Strasse 5, D-64293 Darmstadt, Germany.

ROUND-TABLE DISCUSSION OF MAY 29, 2013

ROUND-TABLE DISCUSSION OF MAY 29, 2013

In the discussion concluding the first day of the Colloquium on *Requirements for UTC and Civil Timekeeping*, attendees revisited issues and asked questions related to topics presented earlier in the day. The issues discussed included research studies based on time of day, historical terminology, leap-second representation, applications of proposed *Adapted Universal Time* (UTA), Earth's timekeeping in the distant future, the lack of available rationale for national positions, and issues surrounding more than one available timescale. [View Full Discussion]

Session 4:
THE PERCEPTION OF TIME

AAS 13-514

IMPRACTICAL PRECISION OF CALENDARS

Paul Gabor*

What are calendars for? The question has at least two strata: practical an symbolic. What are the relative merits of these two lines of reflection on the nature of these cultural artifacts? The positivist bias present in the historiography of astronomy of late 19th c. and early 20th c. meant that attention focused exclusively on utilitarian purposes. This paper proposes to examine one of the claims which used to be often repeated in this context, viz., that the original motivation for the development of calendars was agricultural scheduling. We will submit a quantitative analysis of the precision of calendars, and of the requirements of scheduling in agriculture, arguing that the latter do not readily explain the former, offering an argument for a less utilitarian purpose of calendars. [View Full Paper]

* Vatican Observatory, Department of Astronomy, University of Arizona, Tucson, Arizona 85721-0065, U.S.A.

AAS 13-515

THE MEANING OF A DAY

Rob Seaman*

Springing from the day-and-night cadence of our calendars, civil timekeeping is time kept for a multitude of technical and cultural purposes. Just as the unit of Atomic Time is the SI-second, the natural unit of Universal Time is the *synodic day*. Atomic clocks can now keep time to better than a second in many millions of years. High precision does not imply an accurate clock, however. The day, the month, and the year are all tied to the quirky cadences of astronomical phenomena. It is the very precision of our clocks that creates challenges in synchronizing them to the varying and aperiodic rhythms of nature. However, time signals reach wherever computer networks take them and this now includes spacecraft to other worlds. Perhaps it is simply time to retire the 18th-century notion of Greenwich Mean Time? Rather, it is only Mean Solar Time based on the synodic day that can bring 21st-century coherence to timekeeping spanning our solar system. Whether on Earth, Mars or the Moons of Jupiter, the word *day* means the same thing. [View Full Paper]

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AAS 13-516

THE PRINCESS AND THE PEA: RESEARCH STRATEGIES FOR THE STUDY OF THE MEDIATION OF TIMESCALES BY ARTIFACTS

Kevin K. Birth*

The study of how UTC affects most of its users involves exploring how time services and clocks mediate expert knowledge for non-expert users. This includes addressing how issues that time experts understand can still have consequences felt by non-expert users of UTC, whether these consequences are computer system crashes or the mistiming of important religious practices. This paper develops strategies for studying the assumptions and expectations non-expert clock users have of timescales and explores some of the epistemological and methodological challenges in conducting such studies. Basic interviewing and data analysis techniques are also discussed using examples from the research on religious communities that has been conducted so far. [View Full Paper]

* Professor, Department of Anthropology, Queens College, CUNY, Flushing, New York 11367, U.S.A.

AAS 13-517

ZMANIM, SALĀT, JYOTISH AND UTC: THE ARTICULATION OF RELIGIOUS TIMES AND THE GLOBAL TIMESCALE

Kevin K. Birth*

Throughout the debate over the proposed elimination of the leap second, the issue of the reaction of religious communities to the decoupling of the Earth's rotation from UTC has been raised many times. Through a discussion of scriptural traditions and preliminary analysis of ethnographic data, this paper describes the current practices and standards of the timekeeping systems of Judaism, Islam, and Hinduism and explores how these systems articulate with UTC. This includes a preliminary study of sophisticated religious time services that indicate the proper timing of activity, and a preliminary analysis of data from interviews with people from the Orthodox Jewish, Muslim, and Hindu communities. [View Full Paper]

* Professor, Department of Anthropology, Queens College, CUNY, Flushing, New York 11367, U.S.A.

Session 5:
THE PROGRAMMING OF TIME I

AAS 13-518

PROGRAMMING PERSPECTIVE ON TIME SCALES

Andrew Main*

Present software and wetware suffer from a failure to grasp the philosophical and practical implications of the existence and availability of multiple time scales. Rethinking from a thoroughly modern point of view, this paper outlines the kind of API by which software of the future can better handle present and future horological needs, addressing both specialized and mundane requirements. Concerning the future of UTC, the new analysis challenges the notion that there is a meaningful decision to be made on whether to abolish leap seconds. Some practical issues in programming around leap seconds are discussed. Some technical requirements are identified, and some ideas that have been mistaken for requirements are unmasked. [View Full Paper]

* Scientist at Large, The Perl Foundation, 340 S. Lemon Ave., #6055, Walnut, California 91789-2706, U.S.A.

AAS 13-519

TIME, TIMESTAMPS, AND TIMESCALES

Harlan Stenn*

This paper focuses on the distribution and dissemination of Time and the various aspects of what that really means. We look at what information needs to be in a timestamp to make it much more generally useful, and also the various choices for timescales. Finally, we discuss what is needed to compare and convert timestamps that may be from completely different timescales. To date, there hasn't been a complete or portable way to deal with timestamps and timescales. Network Time Foundation is ready and plans to address these problems. [View Full Paper]

* NTP Project Manager, Founder/President of Network Time Foundation, P.O. Box 918, Talent, Oregon 97540, U.S.A.

Session 6:
THE PROGRAMMING OF TIME II

AAS 13-520

UTC IN ASTRONOMICAL METADATA STANDARDS

Arnold H. Rots*

There are a number of data and data-format standards in use in the astronomical community that include a high level of specificity regarding the metadata information that they require to describe the astronomical coordinates of the data, including time. For FITS the metadata standards are defined in a series of World Coordinate System (WCS) papers, the latest of which is on Time. Within the Virtual Observatory community there is a Space-Time Coordinate metadata standard which is very similar. This paper presents how UTC is dealt with in these standards. In actual coding implementations the leap second file published by USNO is an essential resource.
[View Full Paper]

* Archive Astrophysicist, Chandra X-ray Center, Smithsonian Astrophysical Observatory, 60 Garden Street – MS 67, Cambridge, Massachusetts 02138, U.S.A.

AAS 13-521

DATE AND TIME FOR NINE MILLION JAVA DEVELOPERS

Stephen Colebourne*

The Java programming platform is used by nine million developers worldwide. The next release, v1.8 due early next year, will include a new date and time API developed as the JSR-310 specification. As part of defining this specification, the handling of leap seconds was discussed, resulting in a number of options. The final choice was to define a "Java time-scale" that avoids exposing the concept of leap seconds to developers. The motivations behind the choice made will be discussed. [View Full Paper]

* OpenGamma Ltd., 185 Park Street, London SE1 9BL, United Kingdom.

Session 7:
THE FUTURE OF TIME

AAS 13-522

THE IERS BULLETIN C AND THE PREDICTION OF LEAP SECONDS

Daniel Gambis*

The Earth Orientation Product Center of the IERS is responsible for the prediction and announcement of the leap second (Bulletin C) and the value of DUT1 truncated at 0.1s for transmission with time signals (Bulletin D). Bulletin C is issued twice a year and announces six months in advance the event or non-event of a leap second to be introduced in UTC. Two surveys, in 2002 and 2011, were conducted by the Earth Orientation Center. Results have shown that a large majority of users of the IERS Bulletin C favor the current definition of UTC, with the occasional introduction of leap seconds to maintain UTC close to UT1. However, a number of users satisfied with the current definition of UTC, stressed the need for a longer prediction interval as compared to the six-month announcement which is currently made. In the present paper we analyze the feasibility to extend the prediction announcement to a longer range, between 2 to 10 years. The limitation of an accurate prediction comes from the difficulty to predict the so-called decadal fluctuation attributed to the core-mantle coupling. Simulations performed using data over the last 40 years show that, at the 95% confidence level, it is possible to extend the prediction interval to 2.5 years. An alternative method, based on an artificial neural network, shows so far similar results. [View Full Paper]

* Earth Orientation Center of the IERS, Observatoire de Paris, 61 av. de l'observatoire, 75014 Paris, France.

AAS 13-523

CONSIDERING TIME-SCALE REQUIREMENTS FOR THE FUTURE

Dennis D. McCarthy*

Requirements for time scales can be specified for a variety of desirable features. Among these considerations are precision, accuracy, stability, accessibility, reproducibility, relation to the spatial reference frame in which they are defined, and utility as an independent variable in equations of motion. Some might be described numerically while others might be more difficult to specify quantitatively. However, user requirements for each of these categories depend on the intended application as well as the level of technology available to the user. Coordinated Universal Time (UTC) as defined currently has served as the standardized basis for civil timekeeping throughout the world since 1972. The continued acceptance of that definition or any alternative will depend on the requirements of the users of the future. Each of the requirement categories is explored with regard to the potential users and potential time scales for the future. [View Full Paper]

* U.S. Naval Observatory (retired).

AAS 13-524

FUTURE OPTIONS FOR CIVIL TIMEKEEPING: UTC AND THE ALTERNATIVES

P. Kenneth Seidelmann* **and John H. Seago†**

The 2012 Radiocommunication Assembly and World Radiocommunication Conference of the International Telecommunication Union recommended further studies concerning the future of UTC. Issues regarding UTC definition are not restricted to telecommunication, but have broad impacts scientifically, publicly, and legally. In response, various requirements, options, and issues are summarized, with one approach appearing to meet requirements and having consistency with current practices. This approach would officially sanction an atomic time scale with a constant offset from TAI, without leap seconds, for the users who require such a time scale, leaving the current definition of UTC unaltered. The additional scale might be realized by transmissions or services distinct from UTC, but it would be best realized as an encoded correction to UTC as currently defined. This latter approach is already recommended by ITU-R Recommendation TF.460-6. [View Full Paper]

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† Astrodynamics Engineer, Analytical Graphics, Inc., 220 Valley Creek Blvd., Exton, Pennsylvania 19341-2380, U.S.A.

ROUND-TABLE DISCUSSION OF MAY 30, 2013

ROUND-TABLE DISCUSSION OF MAY 30, 2013

In the discussion concluding the Colloquium on *Requirements for UTC and Civil Timekeeping*, attendees asked parting questions and expressed thoughts related to topics raised during earlier presentations and discussions. The issues discussed included non-technical timekeeping nomenclature, short-term and long-term ΔT behavior, time-signals and its recipients, future timekeeping technologies, the timekeeping role of GNSS, and the politics of time. [View Full Discussion]