Requirements for UTC and Civil Timekeeping on Earth

A Colloquium Addressing a Continuous Time Standard

University of Virginia

29-31 May

2013

Jefferson Scholars Foundation

info@futureofutc.org

http://futureofutc.org

Organizing Committee

Rob Seaman
National Optical Astronomy Observatory

Ken Seidelmann
University of Virginia

John Seago
Analytical Graphics, Inc.

Steve Allen
UCO/Lick Observatory at UC Santa Cruz

Program design and printing sponsored by:

TABLE OF CONTENTS

GENERAL INFORMATION

Welcome to *Requirements for UTC and Civil Timekeeping on Earth: A Colloquium Addressing a Continuous Time Standard*, May 29-31, 2013.

This meeting is co-sponsored by American Astronautical Society (AAS), the American Institute of Aeronautics and Astronautics (AIAA), the National Optical Astronomy Observatory (NOAO), the Virtual Astronomical Observatory (VAO), the University of Virginia and the UVa Astronomy Department, and held at the Jefferson Scholars Foundation (JSF) at 12 Clarke Court, Charlottesville, Virginia, USA. JSF telephone: (434) 243-9029, JSF facsimile: (434) 243-9081.

Meeting information is maintained at **http://futureofutc.org/**.
Meeting contact e-mail: **info@futureofutc.org**.

Registration and Fees

Pre-registration is necessary to attend this meeting. A registration fee of $155 US ($175 after May 1) is payable by credit card through a URL provided to registered attendees. The meeting check-in table will be located in the vicinity of the main lobby and staffed according to the following schedule:

Wednesday	**May 29**	**8:00 AM – 8:30 AM**
Thursday	**May 30**	**8:00 AM – 8:15 AM**

Participants will receive orientation information and registration credentials upon confirmation of payment of the registration fee, including a name badge to be visibly worn while on the premises and returned at the end of each meeting day.

Sessions

The meeting is scheduled to present 23 papers allocated into seven sessions. Time has been allotted each morning and afternoon for roundtable discussions and to continue questions and answers from the session presentations. The morning programs begin at 8:00 a.m. and run until the luncheon breaks. The afternoon programs follow the scheduled luncheon breaks. Short breaks of 10 minutes follow each hour of presentations. All sessions are held in the JSF Foundation Hall. Please refer to the facilities floor plans for locations within JSF relative to the building entrance.

Presentations

Authors will need to supply the organizing committee with a digital copy of their presentations and preprint manuscripts at check-in or by email in advance. Each presentation is limited to twenty five (25) minutes. An additional five minutes is allotted between presentations for audience participation and speaker transition. The presentation area is equipped with a podium, a microphone, a laser pointer, and a video projector driven by a computer. The recommended electronic formats for presentation slides are Powerpoint (ppt, pptx) or Portable Document Format (pdf).

Manuscripts

Complete manuscripts are required by the time of the meeting and these shall conform to the AAS conference paper format available at http://www.univelt.com/FAQ.html#SUBMISSION. Per AAS meeting policy, if a complete manuscript is unavailable, then there shall be no colloquium presentation; likewise, if there is no presentation at the colloquium, then the associated manuscript shall be withheld from the published proceedings. Edited transcripts of discussions and responses during the question-and-answer periods may be included by the proceedings editors as part of the proceedings as a separate addendum to contributed manuscripts. A record of roundtable discussions may also be included in the proceedings.

Colloquium Proceedings

The registration fee covers the delivery of one (1) CD-ROM version of the colloquium proceedings by mail after the meeting. The AAS also publishes bound sets of printed proceedings for personal, institutional, and library usage, the availability of which enhances the longevity of the presented work and elevates the importance of colloquium contributions. For orders placed within sixty (60) days of the colloquium, a hardbound printed version of the proceedings with additional CD-ROM is available for attendees at a greatly reduced pre-publication price of $65 per set. Due to recent increases in postage rates, additional shipping charges apply for orders shipped *outside the USA*.

	List	AAS Member	Attendee (Pre-Publication)
CD-ROM version*	$80	$60	$35
Hardcover / CD-ROM combination†	$120	$90	$65

** Add $2 for each additional CD-ROM shipped to a single address **outside the USA**.*

*† Add $35 for first combo shipped to a single address **outside the USA**, $5 each additional combo.*

Discounted pre-publication orders may be placed through a special URL provided to registrants, or by contacting the publisher's sales department at sales@univelt.com after the colloquium.

JEFFERSON SCHOLARS FOUNDATION

Coordinates:
38.026894, -78.515522

12 Clarke Court
Charlottesville, Virginia

Because parking is extremely limited at JSF, attendees should ride the Charlottesville Area Transit (CAT) Trolley to JSF.

The trolleys are free and run a continuous circuit through downtown Charlottesville every 15 minutes. The JSF trolley stop is:

Maury Ave at Clark Court (#11223)

Entry into the Jefferson Scholars Foundation complex is found from the south side parking lot (white marker). Foundation Hall is on the left after entry.

LOCAL ACCOMMODATIONS

Some local accommodations on or near the CAT Free Trolley are as follows.

Omni Charlottesville Hotel
235 West Main Street, Charlottesville, VA 22902
(434) 971-5500
Trolley Stop: West Water St. @ Omni (#11036)

Courtyard Charlottesville - University Medical Center
1201 West Main Street, Charlottesville, VA 22903
(434) 977-1700
Trolley Stop: West Main St. at 11th St. NW (#11129)

Dinsmore House Bed & Breakfast
1211 West Main Street, Charlottesville, VA 22903
(434) 974-4663
Trolley Stop: West Main St. at 11th St. NW (#11129)

Hampton Inn & Suites Charlottesville at the University
900 West Main Street, Charlottesville, VA 22903
(434) 923-8600
Trolley Stop: West Main St. opposite 9th St. SW (#11186)

Red Roof Inn
1309 West Main Street, Charlottesville, VA 22903
(434) 295-4333
Trolley Stop: West Main St. opposite 11th St. NW (#11129)

200 South Street Inn Bed & Breakfast
200 W South St, Charlottesville, VA 22902
(434) 979-0200
Trolley Stop West Water St. @ Omni (#11036)

DINING

Your registration fee covers food and beverage services while at JSF, including catered breakfasts both meeting days and an on-site luncheon for Wednesday. Snacks and beverages are also available during numerous breaks throughout each day. Thursday's schedule provides a luncheon break so attendees may eat their favorite local fare. Some options nearby JSF include:

Fry's Spring Station
2115 Jefferson Park Ave

Stylish decorating disguises this former service station's past. The chefs take pride in their massive brick oven and offer several styles of individual specialty pizzas. Gourmet salads, pasta, and paninis are also available. Indoor seating is spacious but the best tables are on the sunlit outdoor patio.

Guadalajara Mexican
2206 Fontaine Ave

Guadalajara, or, "the Guad" as it is known locally, features authentic Mexican food at reasonable prices. The expansive menu features burritos, quesadillas, taquitos, carnitas, enchiladas, and more. All meals are served with freshly made chips and salsa.

Thai '99 Restaurant
2210 Fontaine Ave

Large selection of Thai cuisine, stir fry

Anna's Ristorante & Pizzeria
115 Maury Ave

A true Charlottesville treasure, the menu of Anna's Pizza No. 5 boasts dozens of signature Italian dishes like Manicotti, Veal Parmesan, and Fettuccine Alfredo. As the name suggests, Anna's also does pizza, with a variety of toppings from meatball to artichoke.

Dürty Nelly's Pub & Wayside Deli
2200 Jefferson Park Ave

Large (the biggest & best) deli sandwiches, soups and salads and a large selection of domestic, micro & imported beers and wine.

Wayside Takeout (Ole Virginia Fried Chicken)
2203 Jefferson Park Avenue

Listed in *Southern Living*'s "Best of the South", for over 40 years this favorite eatery of Charlottesville remains best known for its fried chicken.

AREA ATTRACTIONS

Lined with shops, restaurants, art galleries and more, the Downtown Mall is Charlottesville's hub for culture and entertainment, attracting students, locals and visitors to create a distinctive atmosphere in the heart of town. The nearby UVa Rotunda—an architectural tribute to the Roman Pantheon— is a UNESCO World Heritage site offering free guided tours. Nearby presidential homesteads include Monticello (Thomas Jefferson), Ash Lawn-Highland (James Monroe), and Montpelier (James Madison). The Charlottesville area is also home to over 20 vineyards and micro-breweries offering tours and tastings. The Charlottesville Visitor's Bureau offers up-to-date information on events and many local attractions at http://www.visitcharlottesville.org.

Climate

The climate in late May is pleasantly temperate with an average high temperature of 80°F (27°C) and average low temperature of 58°F (14°C), with the possibility of rainfall.

SPECIAL EVENTS

McCormick Observatory Reception ***Tuesday May 28, 7:30 PM – 10:00 PM***

A twilight reception will be hosted at historic McCormick Observatory atop the summit of nearby Mount Jefferson, in cooperation with the University of Virginia Astronomy Department. The reception will feature an orientation regarding the history of McCormick Observatory by Ed Murphy, UVa Associate Professor, Education and Public Outreach, ISM, UV and Radio Astronomy. Weather permitting, attendees will enjoy views through McCormick Observatory's celebrated 26" refractor by Alvan Clark & Sons.

Directions: The observatory is reached by following McCormick Road up Mount Jefferson. Please note that roadside parking is not allowed except at designated areas immediately adjacent to the observatory. Detailed directions are available from: http://www.astro.virginia.edu/public_outreach/Geninfo/lmomap.php

Monticello Tour & Michie Tavern Luncheon ***Friday May 31, 9:00 AM – 2:00PM***

Attendees will enjoy an exclusive behind-the-scenes tour of Monticello, the famous plantation homestead of gentleman farmer, inventor, and 3rd U.S. President, Thomas Jefferson. Jefferson's interest in timekeeping is featured in two devices of his own design at Monticello: the Great Clock with its dual indoor/outdoor faces, hourly gong, and 7-day movement, and a reproduction of Jefferson's captivating spherical sundial. Day-pass and access to the recently opened Thomas Jefferson Visitor are included. Estimated cost ~$42 per person.

After our tour, attendees may stop for a group lunch at historic Michie Tavern, approximately one-half mile from Monticello at the foot of Carter's Mountain. The tavern features a plentiful all-you-can-eat buffet of genuine Southern fare. Estimated cost ~$20 per person.

SCHEDULE OF ACTIVITIES

Time		***Activity***	***Location***
Tue. May 28			
7:30 PM –		Reception	McCormick Observatory
Wed. May 29			
8:00 AM –	8:30 AM	Check-in / Registration	Lobby
8:00 AM –	9:00 AM	Breakfast	JSF
9:00 AM –	9:10 AM	Orientation / Introductions / Opening Comments	Foundation Hall
9:10 AM –	10:50 AM	**Session 1: Retrospectives on Time**	Foundation Hall
10:50 AM –	12:30 PM	**Session 2: The Terminology of Time**	Foundation Hall
12:30 PM –	1:00 PM	Roundtable Discussions	Foundation Hall
1:00 PM –	1:30 PM	Luncheon	JSF
1:30 PM –	4:30 PM	**Session 3: The Application of Time**	Foundation Hall
4:30 PM –		Roundtable Discussions	Foundation Hall
Thu. May 30			
8:00 AM –	8:30 AM	Check-in / Registration	Lobby
8:00 AM –	8:30 AM	Breakfast	JSF
8:30 AM –	10:50 AM	**Session 4: The Perception of Time**	Foundation Hall
10:50 AM –	11:50 AM	**Session 5: The Programming of Time I**	Foundation Hall
11:50 PM –	12:20 PM	Roundtable Discussions	Foundation Hall
12:20 PM –	2:00 PM	Luncheon Break	
2:00 PM –	3:10 PM	**Session 6: The Programming of Time II**	Foundation Hall
3:10 PM –	4:50 PM	**Session 7: The Future of Time**	Foundation Hall
4:50 PM –		Concluding Roundtable Discussions	Foundation Hall
Fri. May 31			
9:00 AM –	12:30 PM	Special Event	Monticello
1:00 PM –	2:00 PM	Luncheon	Michie Tavern

SESSION 1: RETROSPECTIVES ON TIME

09:10 **AAS 13 - 502** **Planes Will Crash! Things That Leap Seconds Didn't, and Did, Cause**
Steve Allen, UCO/Lick Observatory at UC Santa Cruz

In 1970 August, a few months after 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 system for 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.

09:40 **AAS 13 - 503** **Experiences of Leap Second Adjustment Operations and Questionnaires in Japan**
Yasuhiro Koyama, Tsukasa Iwama, Hiroyuki Ito, Yuko Hanado, and Mizuhiko Hosokawa, National Institute of Information and Communications Technology

National Institute of Information and Communications Technology (NICT) in Japan has responsibilities for Japan Standard Time (JST) and is trying to generate and maintain stable and reliable time scale. NICT has been trying to perform smooth operations of the past leap second adjustments to the JST and there has been no major confusions in Japan. Along with these efforts, questionnaires were conducted to gather information concerning the influences from leap second adjustments and opinions towards the possible future changes to UTC twice in 2001 and in 2007. The results of these questionnaires will be reported along with the experiences of the operations of leap second adjustments.

10:10 **Break**

10:20 **AAS 13 - 504** **Technical Aspects of Leap Second Propagation and Evaluation**
Martin Burnicki, Meinberg Funkuhren GmbH & Co. KG

Leap seconds are scheduled by the International Earth Rotation Service (IERS) whenever the difference between true earth rotation and UTC 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 using different timing signals, protocols, *etc*. For example, the GPS satellites transmit a specific point in time when a leap second is to be inserted or deleted, but other timing signals may just provide a leap second warning flag which is set during a certain interval before the leap event, where the warning interval depends on the specification of the protocol. Also, there are different implementations how leap seconds are handled, which especially affect the sequence of timestamps across the leap second event. The clock can be stepped at the beginning or end of the leap second, can be slowed down or even stopped during a leap second insertion, or time can be slewed across a leap second. This makes it difficult to compare time stamps which have been taken on different systems during a leap second. Last, but not least, there are implementations of time keeping code which don't always work correctly, *e.g*. invalid leap second warnings are generated, leap seconds are not handled at all, or severe bugs occur due to side effects of the leap second handling.

SESSION 2: THE TERMINOLOGY OF TIME

10:50 **AAS 13 - 505** **Diplomacy of Legal Translations: GMT v. UT**
Paul Gabor, Vatican Observatory

This paper aims to communicate the results of our investigation into a question that arose at the 2011 colloquium in Exton. 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?

11:20 **Break**

11:30 **AAS 13 - 506** **Practical Elements of Coordinated Universal Time**
David Finkleman, Center for Space Standards and Innovation; Kara Warburton, Termologic

The definition and use of Coordinated Universal Time is more than a technical matter. Practical considerations are as important as technical requirements; terminology is one of the most important practical elements. Noted terminological authorities have examined and judged proposed changes to the definition of Coordinated Universal Time, offering the normative terminological position that deprecating the connection between UTC and Earth Rotation would be "pseudonymous" if the name were not changed. *Pseudonymity* means literally a state of false identity. (In medicine and the Internet, *pseudonymization* is a procedure by which the most identifying fields in data records are replaced by artificial identifiers with the intent of rendering data less identifying and therefore less vulnerable to user objections to its use.) In the case of UTC, if the definition is changed without changing the term, there will be two indistinguishable elements of information with the same name; UTC with Earth Rotation embodied with leap seconds and more precise corrections now commonly available, and UTC after a change without any connection to Earth rotation. Proleptic analyses common in many fields of endeavor will be confounded and uncountable reference documents and currently authoritative sources will be invalidated. Apart from cogent technical objections to deprecating Earth rotation, such a change will have significant practical, societal, and legal consequences, almost all traceable to terminological issues. This paper will trace the evolution of terminology for Universal Time and justify objectively why the technical change proposed must be accompanied by terminological rigor if it is adopted.

12:00 **AAS 13 - 507** **Vocabulary for Time-Scales**
Russell Redman, NRC of Canada

Much of the discussion regarding the future of 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 time-scale into its component parts.

12:30 **Discussions**

13:00 **Luncheon**

SESSION 3: THE APPLICATION OF TIME

13:30 **AAS 13 - 508** **Robust Navigation Issues in the Event of GNSS Failures**
James Kiessling (Washington, DC)

Given both the potential span of variability of the natural environment to include repetition of the 1859 super flare, and application of unnatural environments willfully imposed by human agencies such as HAND, and the more mundane GPS jamming done by North Korea, suitable and robust navigation backup means beyond GNS 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.

14:00 **AAS 13 - 509** **The GPS SVN59 Satellite Anomaly of 17 June 2012**
Stephen Malys, US National Geospatial-Intelligence Agency

This paper discusses the root cause of an erroneous broadcast message from GPS satellite SVN59 on June 17, 2012. This occurred due to an improper application of the leap second in the NGA Earth Orientation Parameter Predictions, which NGA delivers to the USAF for their use in generating GPS satellite broadcast message. The error was limited due to quick discovery and resolution of the problem. NGA has since changed its procedures to ensure that this error does not happen again.

14:30 **Break**

14:40 **AAS 13 - 510** **The Leap Minute**
John H. Seago, Analytical Graphics, Inc.

Amidst the contentious proposal to eliminate leap seconds from Coordinated Universal Time (UTC), the so-called *leap minute* has been tendered as an alternative method for reconciling atomic timekeeping with astronomical time-of-day. This paper discourses the civil-timekeeping requirements addressed by intercalary minutes, and the supposed advantages and disadvantages of such a compromise proposal. Ultimately, the inaugural leap minute is expected to happen beyond the professional lifetimes of current advocates, and like the leap hour nominated a decade before, there is no evidence that the official endorsement of such a prescription now would summon its future operational acceptance.

15:10 **AAS 13 - 511** **Adapted Universal Time (UTA) - Stretching Each Day with Milliseconds**
Servando Diaz, University of Arkansas, Fayetteville; Chris Tuason, University of Texas at Austin

Leap seconds have become increasingly problematic to a society dependent on electronic systems that are often not well adapted to time discontinuities in adjusting to the planet's rotation. "Adapted Universal Time" (UTA) adapts the passing of time to the perception of a full day, closely maintaining planetary rotation synchronous with civil timescale. UTA calculates an algorithmic mean difference between UTC and UT1, adding that imperceptible duration of milliseconds, termed a "millistretch," to each day. An old timekeeping system is re-introduced where hours are letters, with an additional 25th letter "Y" which includes that millistretch. This new "Letter Time Format" would be globally uniform and initially used only for NTP and GPS, but eventually adopted as our civil time standard.

15:40 **Break**

15:50 **AAS 13 - 512** **Recommendations on UTC Definition from IAG Working Group 1.1.1**
Henno Boomkamp, European Space Operations Centre

This paper presents the points of view on UTC from the International Association of Geodesy (IAG) Working Group on precise orbit estimation that existed from 2004-2012. The IAG organisation of commissions, sub-commissions and working groups is regularly restructured, and in the most recent reorganisation this Working Group has been superseded by various new entities. However, the reply from the Working Group 1.1.1 to a questionnaire on the possible discontinuation of leap seconds will be of interest to current study, and is presented here.

16:20 **Presentation** **The Smithsonian Exhibition on Time & Navigation**
Stephen Malys, US National Geospatial-Intelligence Agency

16:30 **Discussions**

SESSION 4: THE PERCEPTION OF TIME

08:30 **AAS 13 - 514** **Impractical Precision of Calendars**
Paul Gabor, Vatican Observatory

What are calendars for? The question has at least two strata: practical and 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.

09:00 **AAS 13 - 515** **The Meaning of a Day**
Rob Seaman, National Optical Astronomy Observatory

Springing from the day-and-night cadence of our calendars, civil timekeeping is time kept for a multitude of cultural and technical 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 to the varying and aperiodic rhythms of nature. 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.

09:30 **Break**

09:40 **AAS 13 - 516** **The Princess and the Pea: Strategies for the Study of Non-Experts' Use of Time Scales**
Kevin Birth, Dept. of Anthropology, Queens College, CUNY

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 time scales 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.

10:10 **AAS 13 - 517** ***Zmanim*, *Salāt*, *Jyotish* and UTC: The Articulation of Religious Times and the Global Time Scale**

Kevin Birth, Dept. of Anthropology, Queens College, CUNY

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. 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 performed with people from a variety of constituencies, including members of religious communities (Orthodox Jewish, Muslim, and Hindu) mentioned in the leap-second debate.

10:40 **Break**

SESSION 5: THE PROGRAMMING OF TIME I

10:50 **AAS 13 - 518** **Programming Perspective on Time Scales**
Andrew Main, The Perl Foundation

Present non-specialist software libraries for processing time are inadequate for the job, regardless of what happens with leap seconds. Their designs suffer greatly from muddled thinking arising from a pre-Newcomb conception of time scales. This paper outlines how the software of the future can do better. Both software and "wetware" benefit from a rethink from a thoroughly modern point of view. This analysis challenges the notion that there is a meaningful decision to be made on whether to abolish leap seconds. This paper identifies some technical requirements, and some non-requirements that are often mistaken for requirements.

11:20 **AAS 13 - 519** **Time, Timestamps, Timescales**
Harlan Stenn, Network Time Foundation

This paper focuses on the distribution and dissemination of Time and the various aspects of what that really means. We'll be looking 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'll be discussing what is needed to compare and convert timestamps that may be in 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.

11:50 **Discussions**

12:20 **Luncheon**

SESSION 6: THE PROGRAMMING OF TIME II

14:00 **AAS 13 - 520** **UTC in Astronomical Metadata Standards**
Arnold Rots, Smithsonian Astrophysical Observatory

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.

14:30 **AAS 13 - 521** **Date and Time for Nine Million Java Developers**
Stephen Colebourne, OpenGamma Ltd & Andrew Main, The Perl Foundation

The Java programming platform is used by nine million developers worldwide. The next release v1.8, later this 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.

15:00 **Break**

SESSION 7: THE FUTURE OF TIME

15:10 **AAS 13 - 522** **Improving the Predictability of Leap Seconds Announcements**
Daniel Gambis, Observatoire de Paris

The IERS Earth Orientation Center is in charge of monitoring Earth Orientation Parameters and in particular UT1−UTC for the leap second announcement to be introduced in UTC; this in order to maintain the difference UT1−UTC smaller than 0.9^s. The occurrences and non-occurrences of the events are announced in the Bulletin C with so far a prediction time span of 6 months. In the different surveys that were organized about the leap second procedure, many users, in particular in the software community, expressed they would be satisfied with the current system if leap seconds announcements could be extended to two or three years in advance rather than 6 months which is the present situation. We have investigated different prediction algorithms to see the possibility to extend the time span of announcements of the leap seconds occurrences to 3 years. The main limitation comes from the difficulty to accurately predict decadal variations due to the core-mantle interaction.

15:40 **AAS 13 - 523** **Considering Timescale Requirements for the Future**
Dennis McCarthy, USNO (retired)

Requirements for timescales 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.

16:10 **Break**

16:20 **AAS 13 - 524** **Future Options for Civil Timekeeping: UTC and the Alternatives**
P. Kenneth Seidelmann, University of Virginia; John H. Seago, Analytical Graphics, Inc.

The 2012 Radiocommunication Assembly and World Radiocommunication Conference of International Telecommunication Union January recommended further studies concerning the future of UTC. Issues regarding the UTC definition are not restricted to telecommunication, but have broad impact scientifically, publicly, and legally. In response to the recommendation of the ITU-R, various requirements, options, and issues expressed in publicly available papers are summarized, and an approach is proposed that appears to meet requirements and is consistent with current practices. The proposed approach officially recognizes an atomic time scale with a constant offset from TAI, without leap seconds, for the users who require such a time scale, with the definition of UTC left unaltered. The atomic scale could be realized by transmissions or services distinct from UTC, or as an encoded correction to UTC as currently defined. This latter approach is already recommended by the current version of ITU-R Recommendation 460.6

16:50 **Discussions**

ABOUT THE CONTRIBUTORS

Steve Allen tracked asteroids in the Summer Science Program before proceeding through the California Institute of Technology to the University of California Santa Cruz, where he is now a programmer/analyst for UCO/Lick Observatory. As a recognized researcher on 20th-century timekeeping, he makes routine use of Lick's considerable historical library. Mr. Allen wrote precision metrology software that enabled the figuring of Keck secondary mirrors and other aspheres in instrument cameras. He designed and maintains the real-time readout code for Keck CCD mosaics and the precision milling code for Keck spectrograph slitmasks. He oversees several web/database applications needed for ongoing operation of the two observatories. He is a member of the IAU *Flexible Image Transport System* (FITS) working group and co-author of the FITS MIME (RFC 4047) and World Coordinate System papers. (Session 1)

Kevin Birth is a professor of anthropology at Queens College of the City University of New York. He received his Ph.D. in anthropology in 1993 from the University of California, San Diego. He specializes in the study of cultural concepts of time. He has published two books on research in Trinidad: *Any Time is Trinidad Time*, and *Bacchanalian Sentiments*. His recent projects and publications include work on chronobiology, archaeology, and the history of non-clock timekeeping techniques. His recent book, *Objects of Time: How Things Shape Temporality*, addresses how the objects used to tell time allow expert knowledge about timekeeping to be used by non-experts, but also how the use of these objects shape how non-experts think about time in unanticipated ways. (Session 4)

Henno Boomkamp has an M.Sc. in aerospace engineering from Delft University of Technology (NL) and a Ph.D. in computer science from Aston University (UK), followed by twenty years of professional experience in the area of precise orbit estimation of satellites. From 1997 to 2001 he was in charge of the design and implementation of the orbit determination and prediction module of the European EGNOS satellite augmentation system. He then moved to the Navigation Office of the European Space Operations Centre (ESOC) in Germany, which hosts one of the global Analysis Centers of the International GNSS Service (IGS). Via his activities at this Analysis Centre, he was chairman of the IGS Working Group for Low Earth Orbiters, and a member of the IGS Governing Board from 2003-2010. He also chaired the Working Group on precise orbit estimation from the International Association of Geodesy over the period 2004-2011, and in that position initiated for instance the GPS Dancer system for distributed analysis of GPS data on the internet. He continues to work as senior consultant at ESOC, and is directly involved in most ESA missions that require precise tracking and orbit determination. (Session 3)

Martin Burnicki completed his *Diplom-Ingenieur* studies for Electrical Engineering at the University of Paderborn, Germany. He is employed as a developer for time and frequency synchronization solutions at Meinberg Funkuhren in Bad Pyrmont, Germany, where he has gained broad experience in the development of micro-controller hardware and firmware for radio clocks and GPS receivers. Today, his primary focus is the implementation and enhancement of device drivers for Meinberg's PCI cards under different operating systems, as well as related programs used to achieve the highest possible time synchronization accuracy, and working on computer time synchronization concepts in general. Martin's hobbies include playing around with Linux, taking photos and managing them with the digiKam program, and his music collection, which is maintained using the Amarok music player. (Session 1)

Stephen Colebourne studied Physics at the University of York, UK, graduating in 1994. Since then, he has worked in the software industry building business applications for the insurance, travel and finance industries. He has used the Java programming language since it first became popular in 1996. He is a frequent conference speaker and blogger on Java topics and is a member of the select group of Java Champions. His work on date and time in Java began in 2001 and continues to this day with JSR-310. (Session 5)

Servando A. Diaz holds a degree in Mechanical Engineering and Mathematics, placing first in the 2001 Technical Summit competition of the University of Arkansas, Fayetteville. He is an Air Force veteran and has worked for Lockheed Martin Space Systems working on the Space Shuttle program for NASA and the US Department of Defense. Servando is an inventor and CAD designer for research and development using finite-element analysis and product life-cycle reliability. An avid night-sky enthusiast and meticulous time keeper, he seeks one harmonious timescale suitable for our world’s future. (Session 3)

David Finkleman is a senior scientist at the Center for Space Standards and Innovation. He has extensive experience in satellite operations, having served as Chief Technical Officer and Director of Analysis for United States Space Command for nearly 18 years as a member of the Federal Senior Executive Service. He retired from the USAF as a Colonel, Assistant Director of Laboratories. As chairman of the Space Operations Working Group of the International Organization for Standardization, he led development of standards and best practices for astrodynamics, collision avoidance, and debris mitigation. These duties entailed the employment of precise time and its correlation with astronomical benchmarks, leading to his contributions to the definition and future of Coordinated Universal Time. (Session 2)

Fr. Paul Gabor, S.J., Ph.D., studied particle physics at Charles University in Prague, Czech Republic (M.Sc.) and joined the Jesuits in 1995. He studied philosophy in Cracow, Poland, theology in Paris, France, where he also obtained his Ph.D. in astrophysics in 2009. He is Vice Director of the Vatican Observatory in charge of its site in Tucson, Arizona. His primary field is astronomical instrumentation but he also teaches history and philosophy of astronomy at the University of Arizona. Timekeeping has been one of the constant interests of papal and Jesuit astronomers since Fr. Christoph Clavius, S.J., and the Gregorian calendar reform of 1582. (Sessions 2 & 4)

Daniel Gambis is an astronomer at Paris Observatory. His domains of investigation concern the effects of geophysical excitation of Earth rotation. He is also employed in the analysis of the Earth rotation variations determined by the various geodetic techniques: satellite laser tracking, GNSS, DORIS and VLBI techniques for applications requiring accurate reference systems. He is the current director of the Earth Orientation Center of the International Earth Rotation and Reference Systems Service (IERS) in charge of monitoring the earth rotation variability and has the responsibility of the prediction and announcement of leap seconds in UTC. (Session 7)

Yuko Hanado received a M.Sci. degree from Tohoku University in 1989 and a Ph.D. degree from the University of Electro-Communications in 2008. Since 1989, she has been a researcher at the National Institute of Information and Communications Technology. Her major research area is Time and Frequency Metrology. (Session 2)

Mizuhiko Hosokawa received M.Sci. and Ph.D. degrees from Tohoku University in 1985 and 1988, respectively. Since 1990, he has been a researcher at the National Institute of Information and Communications Technology. His major research areas are Precise Space-Time Measurements, and Time and Frequency Metrology. He was elected as the President of Commission 31 (Time) of International Astronomical Union (IAU) for three years from 2012 to 2015. (Session 2)

Hiroyuki Ito received a Ph.D. from Tokyo Institute of Technology in 1999. Since 1999, he has been a researcher at the National Institute of Information and Communications Technology (NICT). His major research areas are Atomic Frequency Standards and Precise Frequency Measurements. (Session 2)

Tsukasa Iwama received a Master of Engineering degree from Tokyo Institute of Technology and then joined Radio Research Laboratory (now NICT) in 1985. He is engaged in research on mobile propagation measurements and modeling, trusted time stamping systems, time transfer applications, and related activities. He is a member of IEEE and holds a Doctorate of Engineering. (Session 2)

George H. Kaplan retired from the U.S. Naval Observatory in 2005, having worked as an astronomer there since 1971 in a number of research and management positions. He earned his Ph.D. in astronomy from the University of Maryland in 1985. His work at USNO involved a wide variety of projects related to positional astronomy, including planetary orbit computations, Earth- rotation measurements, radio and optical interferometry, binary star motions, and the mathematics of celestial navigation. He specialized in algorithm development and software tools. Currently he is a contractor to USNO, serving as a consultant to the Astronomical Applications Department. He is a member of the American Astronomical Society, the American Association for the Advancement of Science, the Institute of Navigation, the International Astronomical Union, and Sigma Xi. He is past president of Commission 4, Ephemerides, of the IAU, and is currently serving on the IAU Working Group on the Redefinition of UTC.

James Kiessling is a senior technical professional with significant background and interests in the results of remote sensing and the means of performing remote sensing. His particular interests in time standards arose when he performed multiple sensor analysis of hypervelocity impact events where keen understanding of working time standards and reference frames was required to unfold the physical processes as observed. Later he led the development of an airborne sensor suite that supports various test activities where the astronomical quality optical system is aligned against celestial references inflight to achieve common frames needed for multiple sensor event analysis. Mr Kiessling achieved a B.S. in Geophysics / Geophysics and Space Physics specialty from UCLA in 1984. (Session 3)

Yasuhiro Koyama received a Masters of Engineering degree from Kyoto University in 1988 and his Ph.D. from Graduate University for Advanced Studies in 2004. Since 1988, he has been a researcher at the National Institute of Information and Communications Technology (NICT). His major research areas are Space Geodesy using the Very Long Baseline Interferometry, Radio Science, and Time and Frequency Metrology. He served as a vice-chair of Commission A (Electromagnetic Metrology) of International Union of Radio Science (URSI) from 2011 to 2014. (Session 2)

Andrew Main (a.k.a. Zefram) is a software engineer with a particular interest in the rigorous processing of precise time. He has been programming professionally since 1997. He is active in the culture surrounding the Perl programming language, speaking at Perl conferences, occasionally on the subject of time. He has published time-related Perl code on CPAN. His other programming foci are programming language design, extensibility, and correctness. (Sessions 5 & 6)

Stephen Malys serves as Senior Scientist for Geodesy and Geophysics at the National Geospatial-Intelligence Agency (NGA) and represents NGA on the Department of Defense Positioning, Navigation and Timing (PNT) Executive Committee. He has played a strong leadership role on improvements to the US government's global geospatial reference frame known as WGS 84, and continues to guide geophysical research programs focused on new capabilities for Defense and Intelligence Community applications. He has received more than 20 awards for technical excellence and unique scientific contributions from NGA and external organizations, including the Institute of Navigation (ION), the American Institute of Aeronautics and Astronautics (AIAA), and the Office of the Director of National Intelligence, where he was designated a Science and Technology Fellow in 2007. One of his more recent accomplishments was the successful coordination of NGA's role in the Smithsonian's Exhibit on *Time and Navigation*.

Dennis D. McCarthy studied astronomy at Case Institute of Technology and the University of Virginia and received his Ph.D. in 1972. He served as Head of the Earth Orientation Department and Director of the Directorate of Time of the U. S. Naval Observatory, developing the USNO's Very Long Baseline Interferometry (VLBI) program and its use of Global Positioning System observations for the determination of Earth orientation. He has served as President of the International Astronomical Union (IAU) Commission on Time, President of the IAU Commission on the Rotation of the Earth, Secretary of the International Association of Geodesy Section on Geodynamics, and Chairman of the IAU Working Group on Nutation. He was Chairman of the Directing Board of the National Earth Orientation Service (NEOS), the head of the International Earth Rotation Service (IERS) Product Center for Conventions, and Chairman of the IAU Working Group on the Definition of Coordinated Universal Time. He served as Vice-president and President of IAU Division 1 on Fundamental Astronomy, and is a co-author of *Time: from Earth Rotation to Atomic Physics*. He has served as chairman of international working groups, and as a member of the Directing Board of the International Earth Rotation Service. He is currently a co-chair of an IAU Working Group on Coordinated Universal Time and the IAU representative to the Consultative Committee on Time and Frequency. (Session 7)

Russell O. Redman, PhD., is an astronomer working for the National Research Council (NRC) of Canada. Working closely with his colleagues in the Measurement Science and Services Program of the NRC, he has been a technical advisor to Industry Canada on the UTC issue, serving at the Radiocommunications Assembly 2012 and subsequently as delegate on Study Group 7, Working Party 7A. His current efforts are directed to finding a compromise position that allows the continued use of UTC with its current definition for applications that require it, while encouraging the use of leap-second-free time-scale(s) for those applications that are not tolerant of the unpredictability that leap seconds introduce. (Session 2)

Arnold Rots started out as a radio astronomer with expertise in spectral line aperture synthesis techniques. He worked at the University of Groningen, the Netherlands Foundation for Radio Astronomy (WSRT), the National Radio Astronomy Observatory (Green Bank and VLA), and the Tata Institute of Fundamental Research. After switching to X-ray astronomy, he worked at the Rossi X-ray Timing Explorer where he wrote the timing code, performed the astronomical clock calibration, and worked on pulsars. Currently, he is archive astrophysicist at the Chandra X-ray Center. He is the author of the IVOA Space-Time Coordinates metadata standard and lead author of the FITS WCS Time standard (in preparation). (Session 6)

John H. Seago studied aerospace engineering at the University of Texas at Austin with specialization in orbital mechanics. As an astrodynamics engineer at Analytical Graphics, Inc. (AGI), he pursues research interests related to astrodynamics, orbit determination, and statistical inference. Prior to joining AGI in 2006, he was a space-systems engineer with Honeywell Technology Solutions, Inc., supporting NASA and US Department of Defense activities utilizing high-precision timekeeping and Earth rotation in projects related to precision orbit determination and tracking, space surveillance, and remote sensing. (Sessions 1 & 7)

Rob Seaman studied astronomy and physics at Villanova University and the University of Massachusetts. As Five College Observer in Residence at the Wyoming Infrared Observatory he used the long, cold nights to port the Image Reduction and Analysis Facility to System V Unix. Since joining the IRAF group at the National Optical Astronomy Observatory in 1988, Mr. Seaman has tackled diverse projects of CCD data acquisition, image processing and archiving, astronomical image and table compression, data and metadata standards, and complex observing modes such as heliocentric time series cadencing. He was Y2K remediation lead for IRAF and chaired the IVOA celestial transient event working group (http://voevent.org). His current position is data and software systems engineer in the Science Data Management group of the NOAO System Science Center. (Session 4)

P. Kenneth Seidelmann received his Ph.D. in Dynamical Astronomy in 1968 from the University of Cincinnati. After military service as a Research and Development Coordinator at the U. S. Army Missile Command from 1963 to 1965, he joined the Nautical Almanac Office of the U.S. Naval Observatory. In February 1976 he was named Director of the Nautical Almanac Office and in September 1990 he became director of the Orbital Mechanics Department. In June 1994 Dr. Seidelmann became Director of the Directorate of Astrometry involving three departments dealing with astrometry and astronomical data. In 2000 he retired from the USNO to become a research professor in the Astronomy Department of the University of Virginia. He is coauthor of two books, *Fundamentals of Astrometry* and *Time: from Earth Rotation to Atomic Physics*, and co-editor of the *Explanatory Supplement to the Astronomical Almanac*, 3rd edition. Minor planet 3217 is named *Seidelmann* in his honor. (Session 7)

Dava Sobel is a science writer whose Harvard Magazine article on the 1993 Longitude Symposium in Cambridge, Massachusetts, led to the book-length treatment *Longitude* (1995). This title won the 1997 British Book of the Year award, and led to *The Illustrated Longitude* (1998) co-authored with William J. H. Andrewes. She has since devoted her time to several books that count astronomers as heroes, including *Galileo's Daughter* (1999), *The Planets* (2005), and *A More Perfect Heaven*: *How Copernicus Revolutionized the Cosmos* (2011).

Harlan Stenn began programming computers in 1971, and has been active in the public domain software and open-source communities since 1976. He holds a Bachelors degree in Business Administration (Accounting) from The Colorado College in Colorado Springs, and an MSE in Computer Science from Washington University in St. Louis. He has launched several successful businesses and has been an Information-Technology consultant and contractor for decades. During the 1980s, he started using and submitting bug fixes and portability improvements to the Network Time Protocol codebase, and has worked directly with NTP since 1992, and in 1996 became NTP's Project Manager and Release Engineer. In 2011, he started the Network Time Foundation (http://nwtime.org) which supports the efforts of NTP, PTPd, LinuxPTP, GPSD, and RADclock. (Session 5)

Chris Tuason was certified in celestial navigation by the US Air Force and flew FB-111's during the Cold War when he began independent work on improving global time standards. He became an F-16 fighter pilot, attended test pilot school, and transitioned to the space shuttle at NASA in Houston flying simulator missions alongside astronauts. One of his patent applications was a new global time standard, improving on Sanford Fleming's concepts. He graduated from the US Air Force Academy, double majoring in physics and electrical engineering, with an aerospace engineering masters from the University of Texas in Austin, publishing an orbital mechanics thesis on the restricted three-body problem. His Ph.D. program was in mechanical engineering at Rice University, specializing in control theory. (Session 3)

Kara Warburton is the International Chair of ISO TC 37, which is responsible for standards in the area of language resources. She holds university degrees in Translation, Terminology Management, and Education, and is currently completing a PhD in Terminology Management. She has nearly thirty years' experience in technical writing, translation, terminology and lexicography, including fifteen years as the chief terminologist for IBM. She is widely published and has taught professional workshops and university courses on the topic of terminology management. Through her company Termologic, she offers consultancy services in the development and management of terminologies and other language resources to support enterprise-level content management strategies. (Session 2)

RECORD OF MEETING EXPENSES

Requirements for UTC and Civil Timekeeping on Earth

A Colloquium Addressing a Continuous Time Standard

May 29-31, 2013

University of Virginia
Jefferson Scholars Foundation
12 Clarke Court, Charlottesville, VA 22903

Attendee: _____

Affiliation: _____

Registration Fee: _____

Registration Fee includes one (1) CD-ROM proceedings.

Additional Proceedings (Hardcover & CD-ROM): ____ @ $65 _____

International Shipping (Hardcover & CD-ROM): _____

Additional Proceedings (CD-ROM only): ____ @ $35 _____

International Shipping (CD-ROM only): _____

TOTAL: _____

Payment by ____CC___ cash

Recorded by: _____

_____


NOAO
VAO
AIAA
agi
American Astronomical Society
UNIVERSITY OF VIRGINIA
Jefferson Scholars Foundation