Meeting Program

Decoupling Civil Timekeeping from Earth Rotation

A Colloquium Exploring Implications of Redefining UTC in Astrodynamics, Astronomy, Geodesy, Navigation, Remote Sensing and Related Fields

5-7 October 2011

Analytical Graphics, Inc.
220 Valley Creek Blvd,
Exton PA, 19341-2380

http://futureofutc.org

Lost time is never found again
- Poor Richard's Almanack & Ephemeris for the Bissextile Year, 1748

Organizing Committee

Rob Seaman
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American Astronautical Society

Program design and printing sponsored by:

agi

NOAO

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GENERAL INFORMATION

Welcome to *Decoupling Civil Timekeeping from Earth Rotation*—A Colloquium Exploring Implications of Redefining UTC, October 5-7, 2011.

This meeting is co-sponsored by American Astronautical Society (AAS), the American Institute of Aeronautics and Astronautics (AIAA), the National Optical Astronomy Observatory (NOAO), and the Virtual Astronomical Observatory (VAO), and held in the Boardroom at the headquarters of Analytical Graphics, Inc. (AGI) at 220 Valley Creek Boulevard, Exton, Pennsylvania, USA, telephone 610-981-8000, facsimile 610-981-8001, email info@futureofutc.org.

Detailed meeting information is maintained at http://futureofutc.org/.

Registration and Fees

Pre-registration is required to attend this meeting. A registration fee of $75 US payable by cash or a US-bank check is due upon arrival. The meeting check-in table will be located in the vicinity of the main lobby and staffed according to the following schedule:

Wednesday	**October 5**	**8:00 AM – 8:30 AM**
Thursday	**October 6**	**8:00 AM – 8:15 AM**

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

Sessions

This meeting is scheduled to present 21 papers in seven sessions and one paper at the special event. Two sessions run in series each morning and afternoon, excepting Thursday afternoon, which has only one session. 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 end at 12:30 p.m. The afternoon programs start at 1:30 p.m. following the luncheon break. On Wednesday evening, supper will be served at 6:00 p.m. following the regular sessions. Session breaks of 10 minutes follow each hour. All regular sessions are held in the AGI Boardroom. Please refer to the facilities floor plans for locations within the Headquarters Building relative to the building entrance and dining area.

Presentations

You will need to supply the organizing committee with a digital copy of your presentation and your preprint manuscript 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) 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 your contributed manuscript. A record of roundtable discussions may also be included in the proceedings.

Colloquium Proceedings

Your 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 your work and elevates the importance of your colloquium contribution. 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 reduced pre-publication price of $45 per set.

	List	**AAS Member**	**Attendee (Pre-Publication)**
CD-ROM version	$80	$60	$25
Hardcover / CD-ROM combination	$120	$90	$45

Discounted pre-publication orders may be placed when the registration fee is paid, or by contacting the publisher's sales department at sales@univelt.com after the colloquium.

URL Links

The following list of URLs direct to information that may help with your visit.

General

AGI Visitors Guide	http://www.agi.com/downloads/about-agi/offices/exton/AGI-Visitor-Guide.pdf
AGI Headquarters (Google Maps)	http://www.agi.com/about-agi/offices/exton/ http://maps.google.com/maps?q=40.038788,-75.596726
Longwood Gardens (Google Maps)	http://www.longwoodgardens.org/ http://maps.google.com/maps?q=39.871169,-75.67366

Lodging and Dining

AGI Hotel Listings	http://www.agi.com/about-agi/offices/exton/hotels.aspx
West Chester Dining	http://www.thebrandywine.com/WestChester/restaurants.html
Exton Dining	http://www.tripadvisor.com/Restaurants-g52619-Exton_Pennsylvania.html
Longwood Gardens' Terrace Restaurant	http://www.longwoodgardens.org/theterracerestaurant.html

FINDING AGI

Coordinates:
40.038788, -75.596726

220 Valley Creek Blvd
Exton, Pennsylvania, USA

Directions from the Philadelphia Airport:

- Take Interstate 95 South approximately 5 miles to Route 322 West
- Take Route 322 West approximately 5 miles and turn left on Route 1
- Follow Route 1 for 1/2 mile and turn right onto 202 North
- Follow 202 North
- **Do *not* exit at the Route 100 North / 30 West Exton exit**
- Travel 2 more exits and exit at Route 30/ Frazer Exit
- Turn left at the bottom of the ramp
- At second traffic light turn right onto Valley Creek Blvd
- At first traffic light turn left into complex for AGI

Directions from the Pennsylvania Turnpike:

- Exit Pennsylvania Turnpike, I-276 via ramp to I-76, Valley Forge Interchange and to South for .6 miles
- Continued on I-76, Valley Forge Interchange and go Southeast for .2 miles
- Continued on I-76, Schuylkill Expressway and go Southeast for .3 miles
- Exit I-76, Schuylkill Expressway via ramp at sign reading "Exit 328 US-202 South to West Chester" and go Southwest for .3 miles
- Proceed to Route 202 South
- Take 202 South 10.8 miles to Route 30 Frazer/Downingtown Exit
- Stay in left lane following 30 East/30 Business Exton/Frazer exit
- Exit left - following East 30/BUSINESS ROUTE 30 Exton/Frazer
- Make a right at the bottom of the ramp – West Business 30
- At first traffic light turn right onto Valley Creek Blvd.
- At first traffic light turn left into complex for AGI.

Directions from Washington D.C. & Points South:

- Follow I-95 North to West Chester 202 North exit (Concord Pike which becomes Wilmington Pike)
- Continue on 202 North 14.4 miles
- **Do *not* exit at the Route 100 North / 30 West Exton exit**
- Travel 2 more exits and exit at Route 30/ Frazer Exit
- Turn Left at the bottom of the ramp
- At second traffic light turn right onto Valley Creek Blvd
- At first traffic light turn left into complex for AGI

Directions from New York & Points North:

- Take New Jersey Turnpike to Pennsylvania Turnpike West
- Take Exit 326 to 202 South
- Proceed approximately 11 miles to Route 30 Frazer/Downingtown Exit
- Stay in left lane following 30 East/30 Business Exton/Frazer exit
- Exit left - following East 30/BUSINESS ROUTE 30 Exton/Frazer
- Make a right at the bottom of the ramp – West Business 30
- At first traffic light turn right onto Valley Creek Blvd.
- At first traffic light turn left into complex for AGI.

Directions from Western Pennsylvania

- Take the Pennsylvania Turnpike East to Exit 312/Downingtown
- Follow Route 100 South for 4 miles to Route 30 East
- Travel East on Route 30 East (Lancaster Avenue becomes Lincoln Hwy.) for approximately 2 miles
- Turn left onto Valley Creek Blvd. at traffic light (Traffic light for Valley Creek Blvd. is prior to Rt. 202 overpass and exits)
- At first traffic light turn left into complex for AGI

Directions from Wilmington Train Station

- Take Martin Luther King Blvd. westbound
- Follow Directions from Washington D.C. & Points South:

VISITING AGI

The headquarters building of AGI is marked "220" and is on the left as you enter from Valley Creek Boulevard. The visitors' entrance faces the courtyard central to the complex. You may park your vehicle anywhere in the parking lot closest to the visitors' entrance.

Access into the headquarters building is controlled; please push the "call" intercom buzzer to gain access and clearly state your name and that you are attending the "UTC Colloquium". Please have identification available.

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

Colloquium participants may visit the Boardroom and Reception areas, the Lobby, the *Storytime* cafeteria and food-service areas, and the restrooms. During your stay, please do not board the elevators, enter stairwells, hallways or other areas of the building that are not displayed on the floor-plan map (right).

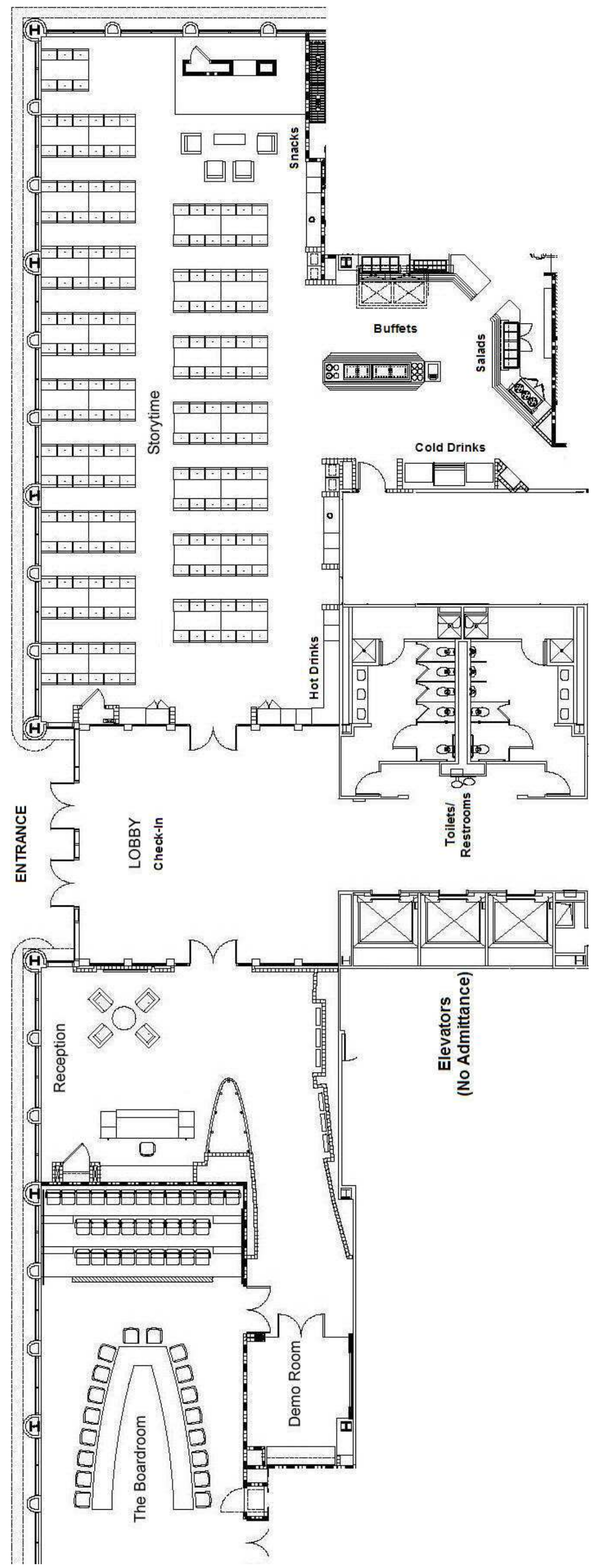
If you step outside, please use the lobby doors from which you entered and push the "call" intercom button to regain access.

Please do not hold open the doors for anyone entering the building. An alarm may sound.

Please do not smoke in the building.

Please do not leave the premises without informing the organizing committee or receptionist, and without returning your badge.

For your convenience, Wi-Fi access is planned for the meeting areas.



LOCAL ACCOMMODATIONS

Below are some hotel listings near AGI headquarters. Other hotel listings are available in the **AGI Visitors Guide**.

Staybridge Suites Malvern
20 Morehall Rd.
Malvern, PA 19355
Phone: 1.610.296.4343
Located 4.5 miles from AGI, Resort Style Hotel Suites including Full Living Room and Kitchen Free Hot Breakfast Buffet, Nightly Dinner Reception, Complimentary Shuttle
Special AGI rates available

Sheraton Great Valley Hotel
707 East Lancaster Pike
Route 202 & 30
Frazer, PA 19355
Phone: 1.610.524.5500, Fax: 1.610.524.1808
Special AGI rates available
Corporate #: 312956
Reference: AGI 2007

Hampton Inn Philadelphia/Great Valley
635 Lancaster Avenue
Frazer, PA 19355
Phone: 1.610.699.1300, Fax: 1.610.699.1313
Rate: $119 per night for friends of AGI
Corporate #: 0560079505
Reference: Analytical Graphics

Holiday Inn Express Exton
120 N. Pottstown Pike
Exton, PA 19341
Phone: 1.800.906.6672,Fax: 1.610.524.8264
Special AGI rates available
Corporate: IL599
Reference: AGI - Analytical Graphics, Inc.

AREA ATTRACTIONS

Exton resides past the terminal outskirts of the original *Philadelphia Main Line*, a collection of affluent towns built up during the 19th and early 20th centuries along the old Pennsylvania Railroad which ran northwest from downtown Philadelphia. Exton later became recognized as a strategically located intersection along the famous Lincoln Highway, the first transcontinental highway in the United States. Today, Exton is a major shopping district within Chester County.

While the urban cultural centers of downtown Philadelphia reside to the east, a short drive west will take the tourist into the heart of rural Amish country, renowned for horse-and-buggy transportation, hand-made crafts, and Pennsylvania Dutch cooking. The surrounding areas are well known for several battles that took place during the American Revolutionary War, and the 1777-78 winter campsite of George Washington's American Continental Army at Valley Forge.

The **AGI Visitors Guide** informs our guests of interesting places and various entertainment options in and around the Exton area, including detailed information on traveling into Philadelphia. A nearby attraction of potential interest to Colloquium attendees not mentioned in the AGI Visitors Guide is the **National Watch & Clock Museum**, about 1.25 hours west by car along Lincoln Highway / Route 30. http://www.nawcc.org/index.php/museumlibrary

Climate

In early October, Exton temperatures tend to reach 71ºF (21.7 C) during the day and 48ºF (8.6 C) at night on average. The chance of rainfall is moderate and evenly distributed throughout the year.

DINING

Your registration fee covers unlimited food and beverage services while at AGI, including catered breakfast and luncheon for both meeting days, and a dinner buffet Wednesday evening. Self-service snacks and a variety of hot and cold beverages are also available throughout the day. Tastykake® pastries and snacks feature as a Philadelphia-area favorite!

Breakfast is served daily for meeting participants from 8 a.m. until 9 a.m. Wednesday's continental breakfast menu features assorted bagels and cream cheese flavors, plus oatmeal and Cream of Wheat with toppings bar. Thursday's breakfast menu features a full breakfast including made-to-order omelets, frittatas, French toast, waffles, pastries; bacon and sausage; fresh fruit, etc. Yogurt, milk, cereal, and fresh fruit are always available in the food-service areas.

Lunch is served daily for meeting participants from 12:30 p.m. until 1:30 p.m., featuring hot entrees and side dishes *du jour* from AGI's house caterer. Pizza, soups, and full sandwich and salad bars are also available.

Supper is served for meeting participants Wednesday from 6 p.m. to 7 p.m., offering fully catered selections of seafood, fowl, beef and/or pork, bread, hot vegetables, and salad bar.

The **AGI Visitors Guide** also recommends many places to eat in and around the Exton area.

SPECIAL EVENT

Longwood Gardens Tour and Presentation ***Friday October 7, 9:00 AM – 1:00 PM***

This event includes a special orientation and tour of the renowned **Longwood Gardens** facilities by staff historian Colvin Randall, and features a guest presentation by Dr. Ken Seidelmann regarding the history of the calibration and reconstruction of its grand analemmatic sundial. This dial is speculated to be the largest and most accurate analemmatic dial in the world maintaining standard time. These group activities are expected to be completed before 1:00 p.m., although you are encouraged to stay and explore the gardens and exhibits afterwards. Admission is free of charge for paid colloquium registrants.

Individual luncheon dining is available at the **Terrace Restaurant** at additional cost after the tour. The Café features an ever-changing selection of fresh local salads, soups, sandwiches, hot entrees, pastries, and more ($10–$18). The 1906 Fine Dining Room provides a formal, full-service dining experience with a new menu highlighting local fruits, vegetables, and meats (~$25 and up).

Carpools traveling from AGI must depart *promptly* from the front of AGI Headquarters by 9:00 a.m. Those not traveling from AGI must be at the Longwood Gardens entrance by 9:30 a.m.

Directions from AGI to Longwood Gardens (0.5 hours):

- Head southeast on Valley Creek Blvd about 1/2 miles. Turn left onto Lincoln Hwy and travel 0.3 miles.
- Turn left, merging onto US-202 S toward W Chester. After 7 miles, 202 veers left onto US-202 S/US-322 E.
- Continue 5 miles and turn right onto US-1 S/E (Baltimore Pike),
- Travel 7 miles and take the ramp for the Longwood Gardens entrance.

Schedule of Activities

Time		Activity	Location
Wed. Oct. 5			
8:00 AM –	8:30 AM	Check-in / Registration	Lobby
8:00 AM –	9:00 AM	Breakfast	*Storytime* Cafeteria
9:00 AM –	9:10 AM	Orientation / Introductions / Opening Comments	Boardroom
9:10 AM –	10:20 AM	**Session 1: Setting the Stage**	Boardroom
10:20 AM –	12:00 PM	**Session 2: The Past, Present, & Far Future**	Boardroom
12:00 PM –	12:30 PM	Roundtable Discussions	Boardroom
12:30 PM –	1:30 PM	Luncheon	*Storytime* Cafeteria
1:30 PM –	3:10 PM	**Session 3: Earth Orientation**	Boardroom
3:10 PM –	5:30 PM	**Session 4: Time Scale Applications**	Boardroom
5:30 PM –	6:00 PM	Roundtable Discussions	Boardroom
6:00 PM –	7:00 PM	Supper	*Storytime* Cafeteria
6:30 PM –	7:00 PM	*GMT by Observation: The Historical Method of Lunars, by Frank Reed*	*Storytime* Cafeteria
To be	announced	Sextant Demonstration (weather permitting)*	To be announced
Thu. Oct. 6			
8:00 AM –	8:30 AM	Check-in / Registration	Lobby
8:00 AM –	8:30 AM	Breakfast	*Storytime* Cafeteria
8:30 AM –	10:20 AM	**Session 5: Space Operations**	Boardroom
10:20 AM –	12:00 PM	**Session 6: Ground-based Operations**	Boardroom
12:00 PM –	12:30 PM	Roundtable Discussions	Boardroom
12:30 PM –	1:30 PM	Luncheon	*Storytime* Cafeteria
1:30 PM –	3:10 PM	**Session7: Contingency Proposals**	Boardroom
3:10 PM –		Concluding Roundtable Discussions	Boardroom
To be	announced	Sextant Demonstration (alternate)*	To be announced
Fri. Oct. 7			
9:00 AM –	9:30 AM	Travel to Longwood Gardens	AGI Parking Lot
9:30 AM –	10:00 AM	Sundial visit and photos	Longwood Gardens
10:00 AM –	11:00 AM	Presentations	*Catalpa* Classroom
11:00 AM –	12:30 PM	Tour	Longwood Gardens

* *Frank Reed, a navigation instructor with Reed Navigation and Mystic Seaport Museum, will offer a demonstration for attendees who would like to try their hand at determining time using the historical lunar-distance observation using a sextant (weather permitting). The exact time and location will be announced.*

Session 1: Setting the Stage

09:10 **AAS 11 - 661** **System Engineering for Civil Timekeeping**
Rob Seaman, National Optical Astronomy Observatory

The future of Coordinated Universal Time has been a topic of energetic discussions for more than a dozen years. Different communities view the issue in different ways. Diametrically opposed visions exist for the range of appropriate solutions that should be entertained. Rather than an insoluble quandary, we suggest that well-known system engineering best practices would provide a framework for reaching consensus. This starts with the coherent collection of project requirements.

09:40 **AAS 11 - 662** **Legislative Specifications for Coordinating with Universal Time**
John H. Seago, Analytical Graphic, Inc.; P. Kenneth Seidelmann, University of Virginia Department of Astronomy; Steve Allen, UCO/Lick Observatory at UC Santa Cruz

The abolition of intercalary (leap) seconds within Coordinated Universal Time (UTC) would create a new civil timekeeping standard fundamentally different from solar timekeeping or Earth rotation. Such a standard has no known civil precedent and would present national governments with certain legal, technical and philosophical questions brought by the abandonment of the long-standing solar-time standard. This paper elevates awareness of some of these questions; specifically, the laws of some nations and international unions require time based on the mean solar time at the meridian of Greenwich, or, if one prefers, Universal Time (UT). Since statutory specifications have not demanded ultra-precise uniformity of rate for civil timekeeping based on mean solar time, the continued synchronization of atomic UTC with Universal Time has allowed UTC to proliferate as a legally acceptable world standard. It is presumable that some nations promoted the legal status of "UTC" in the belief that a time scale named "Coordinated Universal Time" might remain coordinated with Universal Time in perpetuity. For this reason, a civil broadcast standard no longer coordinated with UT might not be easily reconciled with existing national statutes, thus requiring changes to statues or exceptional broadcast realizations. Civil broadcast standards failing to approximate Universal Time would best avoid the label "Coordinated Universal Time" and its acronym "UTC", since these descriptions have always implied a realization of Universal Time, in title and purpose, both inside and outside statutory and regulatory prescriptions.

10:10 **Break**

Session 2: The Past, Present, and Far Future

10:20 **AAS 11 - 663** **The Heavens and Timekeeping, Symbolism and Expediency**
Paul Gabor, Vatican Observatory

Timekeeping has always followed the heavens for reasons of practicality and symbolism. These two motivations can have different implications for the concrete implementation of timekeeping mechanisms. One question in this eminently pragmatic age is why symbolism should be maintained. Recognizing the validity of both symbolism and expediency, however, might be a better way forward. This paper proposes to examine a few episodes in the long history of timekeeping compromise, and test the merits of various approaches not just in the immediate case of the leap second but also in more extreme cases (e.g., timekeeping on Mars).

10:50 **AAS 11 - 664** **Leap Seconds in Literature**
John H. Seago, Analytical Graphic, Inc.

The advent of electronic textbooks and the digitization of less-recent scholarly documents has resulted in significantly increasing amounts of archived information searchable via computer networks. Internet search-engine technology can therefore be used to casually discover hundreds of archival references that make reference to *status-quo* UTC with leap seconds. While searchable electronic documents represent only a fraction of literature actually published, such reviews suggest a wide range of technical fields that may rely on UTC, the literature of which would be need to be revised should UTC be redefined.

11:20 **Break**

11:30 **AAS 11 - 665** **Time in the 10,000-Year Clock**
Danny Hillis, Applied Minds

The Long Now Foundation, an organization dedicated to the promotion of long-term thinking, is building a mechanical clock that is designed to keep time for the next 10,000 years. The clock maintains its long-term accuracy by synchronizing to the Sun. The 10,000-year clock keeps track of five different types of time: Pendulum Time, Uncorrected Solar Time, Corrected Solar Time, Display Time and Orrery Time. Pendulum time is generated from the mechanical pendulum and adjusted according to the equation of time to produce Uncorrected Solar Time, which is in turn mechanically corrected by the sun to create Corrected Solar Time. Display Time advances each time the clock is wound, at which point it catches up with Corrected Solar Time. The clock uses Display Time to compute various time indicators to be displayed, including the azimuth of the sun and Gregorian calendar date. Orrery Time is an approximation of Terrestrial Time, computed from Display Time, with a correction for the slowing of the earth’s rotation. Orrery Time is used to compute displayed positions of the moon, planets and stars, and the phase of the moon. This paper describes how the clock reckons time over the 10,000-year design lifetime, in particular, how it reconciles the dynamical time generated by its mechanical pendulum with the unpredictable rotation of the earth.

12:00 **Discussions**

12:30 **Lunch**

Session 3: Earth Orientation

13:30 **AAS 11 - 666** **Using UTC to Determine the Earth's Rotation Angle**
Dennis McCarthy, United States Naval Observatory

Knowing Earth's rotation angle is required to relate terrestrial and celestial reference systems. It is defined using UT1 and in practice, UT1-UTC provides a convenient means to obtain UT1, knowing UTC. Services currently provide daily updates of UT1-UTC with accuracy of the order of ten microseconds and predictions with accuracy better than 1 millisecond up to ten days in advance. Since UTC is adjusted to keep |UT1-UTC| < 0.9 seconds, UTC provides automatic access to UT1 with accuracy of one second. Should it be defined without that restriction, the low-accuracy estimate of UT1 would no longer be assured. The relationship of UT1 to the Earth's rotation angle is reviewed; past, current and likely future capabilities are outlined, and the potential for future developments in observing, predicting and distributing the Earth's rotation angle are presented.

14:00 **AAS 11 - 667** **The IERS, the Leap Second, and the Public**
Wolfgang R. Dick, Bundesamt fuer Kartographie und Geodaesie

Bulletin C with announcements of leap seconds is the most popular of IERS products. A large part of requests from the public received by the IERS Central Bureau concerns the Leap Second. Although other IERS products may be of more importance, the Leap Second Announcements produce a maximum of attention with a minimum of efforts. IERS has plans for an UT1 time service in case that UTC would be redefined. However, with respect to public relations of the IERS, a possible abolishment of the Leap Seconds has to be compensated by other news which may cause similar attention of the public.

14:30 **Break**

14: 40 **AAS 11 - 668** **Results of the 2011 IERS Questionnaire Concerning a Possible Redefinition of UTC**
Daniel Gambis, Observatoire de Paris

The Earth Orientation Product Center is responsible for the prediction and announcement of the leap second (Bulletin C) and the announcement of the value of DUT1 truncated at 0.1s for transmission with time signals. A first survey made in 2002 show that 89% of IERS users were satisfied by the current determination of UTC, including leap seconds introductions. With the increasing number of users belonging to the various communities, it was felt necessary to make a new survey to find out the strength of opinion for maintaining or changing the present system before the proposal of redefining UTC be adopted at the ITU-R meeting which will be held in Geneva in January 2012.

Session 4: Time Scale Applications

15:10 **AAS 11 - 669** **Traditional Celestial Navigation and UTC**
Frank Reed, Reed Navigation / Mystic Seaport Museum

Traditional celestial navigation depends on accurate knowledge of some standard mean time. While transitioning to a time gradually decoupled from the Earth's rotation should present no serious problems for users who actively practice celestial navigation at sea, there are issues concerning possible confusion in the literature, textbooks, and other educational materials already published. Celestial navigation, though a backup of last resort, is still widely taught at maritime academies worldwide and in less formal classes. When the time comes to use it in some emergency in future decades, will changes in UTC decoupling it from the Earth's rotation leave navigators so confused that they are unable to navigate properly or worse calculate their vessels' positions incorrectly?

15:40 **Break**

15: 50 **AAS 11 - 670** **The Consequences of Decoupled UTC on Sundials**
Denis Savoie, Palais de la découverte and Observatoire de Paris; Daniel Gambis, Observatoire de Paris

Severing the link between the rotation of the Earth and time-signal broadcasts will require a fourth correction to convert between solar time and standard legal time in the long term. For sundials, this is an additional layer of complexity, both with the public and with those who use these instruments as a means of teaching or for those who calculate. Knowing the precision that can be expected of sundials, what are the limits beyond which this decoupling of UTC will be sensitive?

16:20 **AAS 11 - 671** **Time Scales in Astronomical and Navigational Almanacs**
George H. Kaplan, International Astronomical Union – Commission 4

Commission 4 (Ephemerides) of the International Astronomical Union (IAU) includes astronomers from many countries responsible for the production of printed almanacs, software, and web services that provide basic data on the positions and motions of celestial objects, and the times of phenomena such as rise and set, eclipses, phases of the Moon, etc. The data produced is used by a variety of people that have a broad range of scientific sophistication. In the almanacs, software, and web services that Commission 4 members produce, data that are independent of the rotation of the Earth are generally provided as a function of Terrestrial Time (TT). In practice, TT is based on atomic time (TT = TAI + 32.184s) and as such, it can be extended indefinitely into the future without ambiguity or error. On the other hand, data that depend on the rotation of the Earth, such as Greenwich hour angles or the topocentric coordinates (zenith distance and azimuth) of celestial objects, have traditionally been provided as a function of Universal Time, specifically UT1. For many users and software applications, the approximation UT1=UTC is adequate and is assumed. Many users, particularly navigators, are probably not even aware of the distinction between UTC and UT1. A change in the definition of UTC that allows it to diverge from UT1 without bound therefore creates a challenge as to how to provide future data that are a function of the rotational angle of the Earth, and how to educate users on the change. Several ideas circulated among Commission 4 members about how to proceed will be explored.

16:50 **Break**

17:00 **AAS 11 - 672** **Issues Concerning the Future of UTC**
P. Kenneth Seidelmann, University of Virginia Department of Astronomy, John H. Seago, Analytical Graphic, Inc.

Historically, civil timekeeping has been based on mean solar time. With the discovery that the rotation of the Earth was not perfectly uniform, time scales based on the rotation of the Earth were differentiated from more uniform scales, with astronomical time still serving as the basis of calendars and time of day. A proposal to redefine UTC without leap seconds has been forwarded for final consideration by the Radiocommunication Assembly of the International Telecommunication Union (ITU) without having reached a consensus within the study group commissioned to resolve the study question, without a public record of an analysis of requirements, and without cost estimates of the various alternative options. The status of the leap second issue, user considerations and perspectives, and the unresolved issues concerning the proposed change to UTC are overviewed in this paper. Due to the pervasiveness of the UTC time scale, concern is expressed that a fundamental change to UTC will require much technical activity, review, testing, and documentation changes. This will occur regardless of whether or not certain systems or applications functionally benefit from the change in definition, and may create additional work for applications who may not ordinarily deal with these technical details, or who are already satisfied and compliant with the status quo.

17:30 **Discussions**

18:00 **Supper**

18:30 **Presentation** **GMT by Observation: The Historical Method of Lunars**
Frank Reed, Reed Navigation / Mystic Seaport Museum

Session 5: Space Operations

08:30 **AAS 11 - 673** **UTC and the Hubble Space Telescope Flight Software**
David Simpson, NASA Goddard Space Flight Center

The Hubble Space Telescope currently maintains Coordinated Universal Time (UTC) in flight software in its on-board 486 computer. This on-board UTC clock is used to time-tag the downlinked data stream, and is also used as the independent variable in on-board ephemeris calculations. For these calculations, UTC is implicitly understood to be roughly equivalent to UT1, to within the accuracy of the models used. If leap seconds were to be discontinued from UTC, then software changes would be required to both the on-board flight software and to the supporting ground software, to include support for separate UTC and UT1 on-board clocks. Separate on-board calibration parameters would need to be periodically uplinked for both clocks, requiring changes to both flight and ground software, and adding to the load of periodic uplinks. Other spacecraft using similar on-board ephemerides would be similarly affected, and flight software developers would need to be aware of the need to implement these changes when re-using heritage software. This paper will discuss some of the details of on-board ephemeris calculations and how they implicitly assume UTC to be an approximation of UT1. The results of an error analysis will also be presented, showing the possible consequences of failing to make the necessary changes should leap seconds be discontinued.

09:00 **AAS 11 - 674** **Computation Errors in Look Angle and Range Due to Redefinition of UTC**
Mark Storz, Air Force Space Command, Analyses and Assessments Division

With the decision on whether or not to discontinue leap seconds scheduled for January 2012, it is important to develop a tool to evaluate the error that can be expected in operational software that tracks space objects from the ground or ground objects from space. This tool focuses on the error occurring in software that uses Coordinated Universal Time (UTC) as an approximation to Universal Time (UT1). This error evaluation tool inputs the difference (in seconds) between UT1 and redefined UTC and a constant altitude for space objects. From these inputs the tool plots a grid of look angles in polar coordinates thus generating a “sky plot” as seen from a particular ground location. The tool shows the true position in the sky when one uses UT1 to compute Earth orientation and the biased position in the sky when one uses redefined UTC to compute Earth orientation. The two positions are connected by an arc from the true position to the biased position. This arc is the path the biased position would take as one gradually increases the separation of redefined UTC from UT1. The color of the arc changes according to the bias in range. The farther away the biased position is relative to the true position, the redder that portion of the arc; the closer the biased position is relative to the true position, the bluer that portion of the arc. In addition to plotting the effect of the difference between UT1 and redefined UTC, the tool outputs the true and biased values for range, azimuth angle and elevation angle at all the grid points. This tool provides the user a sense of the adverse operational impacts as the biased position deviates more and more from the true position. The paper also describes various potential stop gap measures for mitigating these adverse operational impacts.

09:30 **Break**

09:40 **AAS 11 - 675** **Proposal for the Redefinition of UTC: Influence on NGA Earth Orientation Predictions and GPS Operations**

Stephen Malys, National Geospatial-Intelligence Agency

The WGS 84 terrestrial reference frame is realized by a global, self-consistent set of highly-accurate coordinates for the DoD GPS Monitor Station antennas attached to the crust of the rotating Earth. The GPS time scale used for all GPS orbit processing is directly tied to UTC (USNO) through well-established, operational processes. The orbit determination process requires transformation between the WGS 84 terrestrial reference frame and the Earth-centered inertial reference frame and therefore knowledge and accurate prediction of small changes to the Earth's rotation angle (UT1). The quantity UT1-UTC is used in these transformations and will remain essential for GPS and other high-accuracy orbit determination. Over the past several decades, procedures, Interface Control Documents, and operational, configuration-controlled software have been designed to deal with leap seconds. In some cases, automated 'limit checks' have been established which test for the UT1-UTC quantifies to be less than 1.0; eliminating this 'sanity check' will require changes to the code, documentation and execution of thorough testing, impacting operational software and automated transfer of Earth Orientation Prediction Parameters between NGA, the GPS OCS, and other DoD organizations. A significant amount of time, effort, and funding will be required for NGA and the other organizations to identify and assess all operational software that references, tests for, or applies the UT1-UTC parameter in high-accuracy orbit determination processes. The costs and time needed for the initial investigation and subsequently to make the required changes to the operational software are unknown at this time and are not programmed in anyone's budget. While the proposal may benefit other communities, a redefinition of UTC offers no benefits or improvements to NGA or GPS operations.

Session 6: Ground Operations

10: 10 **AAS 11 - 676** **UTC at the Harvard-Smithsonian Center for Astophysics (CfA) and Environs**
Arnold Rots,Smithsonian Astrophysical Observatory

At the CfA, SAO operates (or is a partner in the operations of) observatories across the entire spectrum. Some of these "run on" UTC, but there are differences when it comes to whether the observatories depend on |DUT| < 0.9 s. The Sub-Millimeter Array (SMA) synchronizes its clock to GPS and keeps track of leap seconds and DUT as published by IERS, so as long as IERS continues to publish DUT there should be no impact. The Chandra X-Ray Observatory is space-based and presumed to be better off without leap seconds. The optical ground-based observatories are not terribly sensitive to UTC definition changes, but it would help them if a timescale were maintained related to Earth rotation. VERITAS is ground-based and observes at the very high energy end; its use of UTC is under investigation. The Minor Planet Center (MPC) converts times to Terrestrial Time (TT), but still prefers UTC to stay close to earth rotation, because its proximity to UT1 reduces chances for confusion. There is strong involvement in the Virtual Observatory (VO) at CfA; although the VO can ensure through its metadata standards that time is handled correctly in principle, data in the VO comes from many places all over the world and there can be no guarantees. CfA has a close relationship with the American Association of Variable Star Observers (AAVSO), whose input is under investigation. There is a consideration regarding ground-based moderately-high accuracy timing data: with the observatory's ITRS coordinates and UTC, one can get timing accurate to $4/(30\times86400) \times \cos(lat)$ s: say, about 1 μs. That won't hold true anymore if |DUT| is not constrained to be less than 0.9 s.

10:40 **Break**

10:50 **AAS 11 - 677** **An Inventory of UTC Dependencies for IRAF**
Rob Seaman, National Optical Astronomy Observatory

The Image Reduction and Analysis Facility is a scientific image processing package widely used throughout the astronomical community. IRAF has been developed and distributed by the National Optical Astronomy Observatory in Tucson, Arizona since the early 1980's. Many dozens of layered external application packages have been written by other observatories and projects. More than ten thousand journal articles acknowledge the use of IRAF and thousands of professional astronomers rely on it. As with many other classes of astronomical software, IRAF depends on Universal Time (UT) in many modules throughout its codebase. The author was the Y2K lead for IRAF in the late 1990's. A conservative underestimate of the initial inventory of UTC "hits" in IRAF (e.g., from search terms like "UT", "GMT", "MJD") contains three times as many files as the corresponding Y2K ("millennium bug") inventory. We will discuss dependencies of IRAF upon Coordinated Universal Time, and implications of these for the broader astronomical community.

11:20 **AAS 11 - 678** **Telescope Systems at Lick Observatory and Keck Observatory**

Steve Allen, UCO/Lick Observatory at UC Santa Cruz

The telescopes in active use at Lick Observatory and Keck Observatory were constructed over an interval spanning over a century. All of the telescope systems were designed in an era when systems which provide civil time were based on the rotation of the earth. Older telescopes are generally pointed by human operators. Although this is now done with the assistance of software there are still significant needs for human interaction to get on target. Much of the software is locally-written and maintained. The combination of these factors makes the older telescopes relatively insensitive to a world where UTC has no leap seconds. It will be several years before the necessary changes in the procedures used by the humans and the software are large enough to adversely affect the pointing. Some newer telescopes are operated entirely by software that presumes particular characteristics for the celestial reference system used to acquire targets. In some cases the source code for these telescopes is proprietary to a vendor who supplied the hardware and software as a whole system which relies on existing distribution schemes for time. Lick Observatory is currently operating such a telescope. It relies on a commercial GPS receiver that provides time signals to software which enforces a requirement that $|UTC - UT1| < 0.9$ s. Without leap seconds this telescope will fail to acquire targets within a year. If the underlying software cannot be upgraded then a change in the meaning of UTC will require prompt remedy to allow ongoing operation.

11:50 **Break**

12:00 **Discussions**

12:30 **Lunch**

Session 7: Contingency Proposals

13:30 **AAS 11 - 679** **Automating Retrieval of Earth Orientation Predictions**

David Terrett, RAL Space/LBTO

Bulletin A contains more than just UT1-UTC and is somewhat intimidating for the non-specialist. A programmer who is told that UT1-UTC is needed and is given the URL of the Bulletin A is likely to be a bit uncertain as to whether the column labeled UT1-UTC is, in fact, all they need or whether other information contained in the bulletin is somehow relevant. Once UT1-UTC is imported into a software system automatically, the consequences of the process failing in some way have to be considered; particularly the case where the failure goes undetected and an erroneous value gets inserted into the system. If critical systems are disrupted by a corrupted copy of the bulletin, what measures can be taken to ensure that this does not happen? Alternatives to Bulletin A that would address the issues described above should be explored and implemented within the resources available to the IERS. Suitable standards-based technologies exist but must have both a long expected lifetime and be practical to implement both for the producer and the consumer. The presentation will include a concrete proposal based on XML standards.

14:00 **AAS 11 - 680** **Dissemination of DUT1 Through the Use of Virtual Observatory**

Florent Deleflie, J. Berthier, Observatoire de Paris - IMCCE, C. Barache, Observatoire de Paris – GRGS; D. Gambis, Observatoire de Paris.

Information concerning DUT1 and the occurrence of the leap seconds are currently made available via IERS Bulletins D and C which are sent to users in ASCII format. However, this procedure does not satisfy automatic systems very well. We have instigated the way to developing a new service based on the concept of Virtual Observatory (VO). This concept, provided by the International Virtual Observatory Alliance (IVOA), allows scientists and the public to access and retrieve DUT1 information using on-line distributed computational resources. We describe here how we derived the concept using the XML-based VOTable format to develop this new operationally dedicated DUT1 service.

14:30 **Break**

14:40 **AAS 11 - 681** **Timekeeping System Implementations: Options for the *Pontifex Maximus***

Steve Allen, UCO/Lick Observatory at UC Santa Cruz

Rules for handling time representation is built into many operational systems -- civil, legal, hardware, software, etc. Many of these systems have avoided implementing the complexity required to handle leap seconds, yet some demand their existence. A plausible change to the scheme of UTC must be compatible with existing systems and should be easy to implement. During the past decade the ITU-R efforts to redefine UTC have triggered other organizations to conduct surveys of the effects. Among all of the surveys there is a paucity of analysis by professionals in the arena of information technology. Nearly all computer systems implement a complex scheme of lookup tables and code known as “tz” or “zoneinfo” for converting the internal system time to external civil time. It is distributed multiple times each year by system vendors as part of routine software updates. The tz code and tables already describe leap seconds, they are deployed and tested on almost every computer, but POSIX rules require systems not to use them. I propose a small change to the representation of leap seconds which allows the tz code to describe them in a way that alleviates the underlying problems with information processing systems. It preserves the traditional meaning of civil time as earth rotation. It allows for trivial testing of the effects of leap seconds on software and hardware systems. It is a compromise that gives easy access to all forms of time information. It is not without consequences that must be handled.

15:10 **Conclusion**

Special Session

HH:MM **AAS 11 - 682** **The Longwood Gardens Analemmatic Sundial**

P. Kenneth Seidelmann, University of Virginia Department of Astronomy

The analemmatic sundial at Longwood Gardens was originally built in 1939, based on the design of a sundial at the Cathedral of Brou, France originally constructed in the early 16th century. The Longwood sundial is 24 by 37 feet with a gnomon movable along an analemma. The hour markers are moveable for daylight saving time. However, the sundial did not tell time correctly and in 1968 the US Naval Observatory was contacted by the director of maintenance at Longwood Gardens about the problem. After measuring the sundial and computing a solar ephemeris for the location, computations were made to determine the correct locations for the gnomon. Analemmas very different from the current ones were determined for the morning and afternoon hours. After contact with a historian in Brou, France, it was determined that the sundial there had been rebuilt twice, and the current design did not tell the correct time either. The inaccurate sundial design from France was revised by computer technology to give an analemmatic sundial at Longwood Gardens that told mean solar time directly, including the correction for the equation of time.

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. (Sessions 6 and 7)

Florent Deleflie developed with Pierre Exertier a theory of mean orbital motion expressed in non-singular elements for eccentricity for his Ph.D. In 2005, he was appointed an astronomer with Observatoire de la Côte d'Azur, directing the French Official Analysis Center of the International Laser Ranging Service, which provides daily solutions of Earth-orientation parameters and station coordinates based on post-fit residuals analysis of geodetic satellite trajectories. He also organized the Virtual Observatory (called OV-GAFF), establishing a cooperative with all colleagues in France to routinely produce space-geodetic data-based results, particularly terrestrial and celestial reference frame and long-wavelength gravity field information. In 2010, Dr. Deleflie joined IMCCE at Paris Observatory to apply mean-orbit theory to the problem of space debris using astronomical images, leveraging many years of research by colleagues working on the small solar-system bodies. He developed a model based on the official software provided by CNES in the framework of the French Space Act, which is used to design appropriate disposal orbits for spacecraft before launch. (Session 7)

Wolfgang R. Dick, physicist, received his Ph.D. in astronomy in 1989. He worked in photographic astrometry from 1982 to 1991 at the Institute of Astrophysics, Potsdam, and from 1991 to 1992 at the Institute of Astronomy of Bonn University. From 1992 to 2000 he analyzed Satellite Laser Ranging at the Institut fuer Angewandte Geodaesie/Bundesamt fuer Kartographie und Geodaesie (BKG) at Potsdam. Since 2001, Dr. Dick has been at the IERS Central Bureau (hosted by BKG in Frankfurt am Main), working on IERS publications, websites, the data center, and public relations. He is a member of IAU Commissions 8, 19, 31, and 41, and was a member of the IAU Working Group on the Definition of UTC (2000-2006). (Session 3)

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. At the Vatican Observatory, his primary field is astronomical instrumentation but he also teaches history and philosophy of astronomy at the University of Arizona in Tucson. 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. (Session 2)

Daniel Gambis, Ph.D., is an astronomer at the Paris Observatory and Head of the Earth Orientation Center of the International Earth Rotation and Reference Systems Service (IERS). His research activity explores the use of geodetic techniques for monitoring Earth-orientation and the excitation of Earth-rotation variability due to geophysical processes, including mass transport within atmosphere and ocean, solar activity, and earthquakes. He is a member of IAU Division I Commissions 19 (Rotation of the Earth) and 31 (Time). (Sessions 3, 4, and 7).

Danny Hillis is Co-Chairman and Chief Technology Officer of Applied Minds, Inc., a research and development company creating a range of new products and services in software, entertainment, electronics, biotechnology and mechanical design. Considered a legendary designer of computer architecture, Dr. Hillis is an inventor, scientist, author, and engineer. He pioneered the concept of parallel computers that is now the basis for most supercomputers. He holds over 100 U.S. patents, covering parallel computers, disk arrays, forgery prevention methods, and various electronic and mechanical devices. Previously, he was vice president of research and development at Walt Disney Imagineering, co-founder of Thinking Machines Corp., and an adjunct professor at the MIT Media Lab. Dr. Hillis has also worked as a consultant to many companies developing technology-related business strategies, and has served on the Presidential Information Technology Advisory Committee. He earned his Ph.D. in computer science from MIT. (Session 2)

George H. Kaplan, Ph.D., 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, astrometry of Jupiter's satellites, binary star motions, and the mathematics of celestial navigation. He specialized in algorithm development and software tools. Currently he is a part-time 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 currently serving as president of IAU Commission 4, Ephemerides. (Session 4)

Stephen Malys holds a BS from The Pennsylvania State University and an MS in geodetic science from The Ohio State University. During his 30-year career in the federal government he has contributed to advancements in the geodetic exploitation of satellite systems, including the Navy's TRANSIT system and the Navstar Global Positioning System (GPS). He has played leading roles in the implementation of refinements to the global coordinate system known as the World Geodetic System 1984 (WGS 84) and improvements to the GPS Precise Positioning Service. He has authored or co-authored more than 23 technical papers dealing with accuracy analysis of GPS and geodetic applications of TRANSIT and GPS. He is a member of the editorial advisory board for the journal *GPS Solutions*. He was selected as a Science and Technology Fellow by the Director of National Intelligence in 2007. (Session 5)

Dennis D. McCarthy studied astronomy at Case Institute of Technology and the University of Virginia and received his Ph.D. in 1972. He is currently President of International Astronomical Union (IAU) Division 1 on Fundamental Astronomy and is a co-author of the book *Time: from Earth Rotation to Atomic Physics*. He served as Head of the Earth Orientation Department and Director of the Directorate of Time of the U.S. Naval Observatory (USNO), developing the USNO’s VLBI program and the use of GPS observations for the determination of Earth orientation. He has served as President of the IAU Commission on Time, President of the IAU Commission on the Rotation of the Earth, Chairman of the IAU Working Group on Nutation, Chairman of the IAU Working Group on the Definition of UTC, and Secretary of the International Association of Geodesy Section on Geodynamics. He has also served as Chairman of the Directing Board of the National Earth Orientation Service, the head of the International Earth Rotation Service (IERS) Product Center for Conventions, and as a member of the Directing Board of the IERS. (Session 3)

Frank Reed teaches celestial navigation at various locations around Chicago, Illinois and at the Treworgy Planetarium at the Mystic Seaport Museum in Mystic, Connecticut. He has practiced celestial navigation for over thirty years and has extensive experience in the history, practice, and theoretical basis of traditional celestial navigation. He has organized three bi-annual *Navigation Weekend* seminars at Mystic Seaport, delivering presentations primarily focused on lunar distance navigation historically and in present practice. Mr. Reed is the head cartographer, developer, and owner of the *Centennia Historical Atlas* software. Mr. Reed holds a Bachelor of Arts in Physics from Wesleyan University, Middletown, Connecticut, his high-honors thesis being on hydrogen spectra in strongly curved space-time. (Session 4)

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)

Denis Savoie, Ph.D., is the head of the Astronomy Department at the Palais de le découverte science museum in Paris. He is an associated researcher at the SYRTE at the Paris Observatory, and is a corresponding member of the International Academy of History of Science. He is a renowned specialist on sundials, from both a theoretical and historical perspective, and was the president of the Sundial Commission of the French Astronomical Society (established 1887) from 1990 to 2010. He has written numerous papers about gnomonics, has made celebrated sundials, and has published several books valued as reference works on dialing. (Session 4)

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 at Honeywell Technology Solutions, Inc., supporting NASA and DoD activities utilizing high precision timekeeping and Earth rotation in projects related to precision orbit determination, space surveillance, and remote sensing. (Sessions 1 and 2)

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 senior software systems engineer in the Science Data Management group of the NOAO System Science Center. (Sessions 1 and 6)

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 editor of the *Explanatory Supplement to the Astronomical Almanac*. Minor planet 3217 is named *Seidelmann* in his honor. (Session 4 and Special Session)

David Simpson, Ph.D., is a physicist at the NASA Goddard Space Flight Center in Greenbelt, Maryland, doing space physics research with the Cassini mission to Saturn and supporting the upcoming Magnetospheric Multiscale Mission. Prior to that he worked on the flight software of the Hubble Space Telescope's DF-224 and 486 computers, along with the on-board computers of several other NASA spacecraft. He has authored on-board computer software to compute UTC and spacecraft and planetary ephemerides. Dr. Simpson has also served as an adjunct professor of physics at Prince George's Community College in Maryland since 1991. (Session 5)

Mark F. Storz worked in the Space Control Analysis Branch at Air Force Space Command from 1993 to 2004 and now is Chief of the Force Enhancement Analysis Branch. He is currently responsible for analysis of GPS, communications satellites, weather satellites, and space-based intelligence, surveillance and reconnaissance. (Session 5)

David Terrett is a software engineer in the space science department of Rutherford Appleton Laboratory. He has been writing software for astronomy research since about 1980, initially applications for science data analysis and, for the last 15 years, control software for ground-based telescopes and instrumentation. Projects he has worked on include the control systems for the Gemini telescopes, the Large Binocular Telescope and the VISTA survey telescope and instruments for Gemini and the European Southern Observatory. (Session 7)

RECORD OF MEETING EXPENSES

Decoupling Civil Timekeeping from Earth Rotation
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