(Preprint) AAS 13-517

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

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

RELIGIOUS TIMES

In the article "The Leap Second: Its History and Possible Future," Nelson *et al*. write "certain religious customs depend on the actual observation of the Sun or the moon and do not depend on clock time."[1] With this quote in mind, I want to offer three examples of religious individuals and their customs.

Nestled in a Queens neighborhood is an Islamic store that sells books, and other religious items. It serves a neighborhood with about a half-dozen mosques and several Islamic schools. The store is a bustling place and a place where Muslims congregate to talk. On the door are two signs. One reads "If there is no one in the store, please ring the bell"; the other sign reads "If no one comes, please wait a minute—we may be praying."

The owners of the store observe what are called the Five Pillars of Islam. These Pillars are described in the Qur'an and elaborated upon in the Hadiths. Hadiths are sayings or acts ascribed to the Prophet Mohammed that provide commentary and guidance about the teachings of the Qur'an. Of the Five Pillars of Islam, daily prayers are described in Hadiths as ranking second in importance only to the profession of belief in Allah. As one Hadith states, "Narrated Abdullāh: 'I asked the Prophet "Which deed is the dearest to Allāh?" He replied, "To perform the (daily compulsory) *Salāt* (prayers) at their (early) stated fixed times." ' "[2] Moreover, the fixed times of prayer in Islam are bounded periods during which one is to perform the obligatory prayers. These prayers must not span the beginning or ending boundary of the period.

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If New York was a Muslim city, then the people in the shop would have no problem knowing when to pray—there would be a call to prayer (*adhan*). One Muslim complained to me about this—she said she missed the sound of an *adhan* in her native land and disdainfully added, as she pulled her iPhone out of her purse, "I hate having to rely on this thing." Since the front of the Islamic store faces east on a tree-shaded street, even on clear days, there is no good way for the owners and their clientele to observe the position of the Sun or to judge the length of shadows. To know the apparent local solar time for their prayers, they need to rely on sources other than direct observation. These sources consist of tables with clock times and smartphone applications. Both of these sources convert the time of prayer into the clock time of the Eastern time zone of the United States. In effect, a cognitive problem of knowing the local apparent solar time is solved through tools that represent it in terms of offsets from UTC.

Jews face a similar set of challenges. Dr. Wallace Goldberg, the chair of the mathematics department at Queens College of the City University of New York, has an office with windows that face west. Rather than having an unobstructed view of the horizon, he looks across a plaza to another building. Dr. Goldberg is an Orthodox Jew and observes prayer times associated with *zmanim* (Hebrew for "times"). *Zmanim* are defined in terms of local apparent solar and sidereal time, but through a logic that differs from that which determines the Muslim time for prayers. Dr. Goldberg, too, is aided by smartphone applications that indicate the *zmanim* in terms of clock time. He does not solely rely upon his phone's alarm, however. He has become accustomed to the rhythms of his surroundings. Based on the habits of the departmental administrative staff, Dr. Goldberg is able to anticipate particular *zmanim*, and close his door to pray.

Hindus do not face the same need to determine times for daily cycles of prayer. Instead, Hindu concepts of time are linked with astrology and names. A Hindu told me of the moment when his niece—a woman of whom he is very fond and proud—was born. He was in the hospital to give his sister moral support, and when he learned of the girl's birth, he immediately called the family guru and told him the time and location of birth. After hours of calculation, the guru reported back the child's ruling planet, which determines the first syllable of a Hindu's name. The guru also predicted, "This girl will be achieving, but she is a child in danger of others looking upon her with envy." To do this calculation, the guru had to consult ephemerides and convert clock times into a Hindu timescale of *ghatis* (about 24 minutes) and *muhūrtas* (about 48 minutes) to know the ruling planet and the other astrological influences acting upon the girl.

All these examples involve actions that unfold in built environments not conducive to the direct observation of the sky. This leads to the reliance on devices that use the UTC timescale to ascertain the timing of moments, and some means of converting between UTC and traditional modes of reckoning time. In addition, while these examples could be labeled as anecdotal evidence, in all three there is reference to scriptural traditions of time reckoning and in all three there is a reliance on expert knowledge about those traditions.

The debate about the future of UTC is a debate about a timescale, not about the diversity of ways of reckoning time. Stratton defined a timescale as "a standard of measurement that is reasonably invariant to human experience and the creation of a measurement language capable of independent empirical reproduction so that one laboratory can share experience with another using only a written language to do so."[3] Guinot defined a timescale as "a system which makes it possible to assign without ambiguity a temporal coordinate to any event."[4] Recently, McCarthy has defined timescale as "the concept (and the means to achieve that concept) of a set of numerical values that relate changes in a designated four-dimensional reference system."[5] What these three definitions have in common is that timescales are unambiguous, are based on measurement, and define events in relationship to the passage of time in a reference system.

Many concepts of time involve logics that are not timescales. They either involve judgments not based on measurement, or on ambiguous criteria over which there is dispute. Often, the measurement of intervals is not a priority, but instead, the desire is to pinpoint a significant moment in terms of the coincidence of two or more observed phenomena. In recent decades, the social scientific study of time has emphasized the co-existence of multiple concepts of time in any ty.[6, 7, 8, 9, 10, 11, 12] To focus solely on timescales, then, is to focus too narrowly to capture the diversity of civil timekeeping.

In the cases of *zmanim* and Islamic prayer times, time determination is more like traditional shoreline navigation than a timescale. Ships navigate near shore by sighting angles for known landmarks, determining depth, and using such information to determine a fix on a chart. Sometimes, the fix is not a point, but a zone. Like many non-clock approaches to time, *zmanim* and *salāt* times use multiple sources of information about time, e.g., the position of the Sun, the length of shadows relative to the height of objects, the ability to perceive color in dim light, and travel times. Points in time are not defined solely by a single timescale, but by a process akin to triangulation—points are defined by intersecting phenomena.

The articulation of such religious timekeeping with UTC involves several kinds of experts. One group of experts consists of religious scholars who are familiar with their faith's traditions of timekeeping. Another group includes the specialists who contribute to the reliability and function of the global time system that produces and disseminates UTC. A third group consists of those with expert astronomical knowledge that is used to relate UTC to astronomical cycles.

Lay people are often only dimly aware of the knowledge needed to produce a representation of a religious time in terms of clock time. One Jewish woman admitted, "I'm always interrupting my day to pray at the right time,[*] but I don't know why I have to pray at those times." As the popularity of software applications that represent religious times as clock times increases, more and more religious experts are expressing concern about what they perceive to be a lack of knowledge of traditional timekeeping methods. Some of these experts resist the use of UTC to represent religiously significant times, and fear that the skills used to determine times by traditional methods may disappear among the laity. As Dr. Ali Mermer, the chaplain of the Queens College Muslim Student Association, said to me, "People are happy with gadgets and will use clocks, but these can interfere. There is less awareness and less spiritual training if one relies on the clock. We Muslims appreciate technology, and for practical reasons, technology can invade, but to keep pristine, one must keep from technology."

Because there are positions that do not accept UTC, and other positions that view UTC as a subsidiary tool for knowing the true time by traditional methods, Study Question ITU-R 236/7 is poorly framed when it asks "What are the requirements for globally-accepted timescales … for civil timekeeping?"[13] It would be better put "What are the requirements for globally available timescales?" And the subsequent questions are how are globally available timescales used, and who bears the burden of adapting such timescales to other time traditions?

The analysis of requirements for globally-available timescales involves how they articulate with other time systems, including those that are not timescales. The post-Enlightenment tradition has emphasized the measure of duration as the means of reckoning time. As Nelson *et al*. put it: "Two elements are needed to measure the passage of time: (a) a time 'reckoner,' which is a re-

[*] In fact, prayers must be performed within a bounded period, not at a specific moment. But this can be difficult for people with tight schedules, such as this woman.

peatable phenomenon whose motion or change of state is observable and obeys a definite law, and (b) a time reference, with respect to which the position or state of the time reckoner can be determined. These elements correspond to the two properties of time measurement: interval and epoch."[14]

The challenge of relating a timescale such as UTC to other time-reckoning traditions is that many do not have anything that conforms to Nelson *et al*.'s description of a time reckoner. For instance, in the Trobriand Islands, when the sea worms (*Eunice viridis*) do not show up on the expected full moon, the moon is said to have "gone silly."[15] This is not a reckoner that follows a definite law. Many cultural traditions emphasize epoch without emphasizing interval. This is true for the determination of the Muslim month of Ramadan—the crescent moon must be observed for Ramadan to officially start. Yet, much of the history of timescales projects the modern emphasis on the connection between time interval and time reference backwards, giving the false impression that time has always been reckoned as it is reckoned today by clocks, just more crudely. This is not the case.

Even in cultural traditions where both epoch and interval are present, the determination of epoch was treated as a separate task from the measure of interval, and the two were not always combined. The distinct applications of Roman clepsydrae and parapegmata are examples of this. Clepsydrae were used to measure the length of orations. Pliny the Younger's letter to Arrianus demonstrates this: "I spoke for almost five hours, for four further water-clocks were added to the twelve of the largest size already allotted to me."[16] In this case, sixteen clepsydrae equaled five hours—a proportion that does not allow easy conversion from one mode of time to the other. In the period before the Julian calendar reforms, parapegmata often provided information of the rising of a particular star in association with expected weather.[17] Before the Julian calendar revolution, parapegmata were distinct from civil calendars because the civil calendars were out of sync with natural cycles.[18]

The tasks of epoch and interval involve different tools which unwary historians of time sometimes conflate. The indication of epoch was a feature of sundials. These devices not only divided the day, but also indicated the time of year by the length of shadow cast by the gnomon. For instance, Vitruvius' detailed instructions for laying out a sundial make it clear that the purpose of the dial was not merely for daily time reckoning as indicated by hour lines, but charting the movement of the Sun, as indicated by the lines to measure the length of the shadows as well as the central boxes used to indicate the analemma.[19] What we call water clocks came in two varieties in the classical period. One was the simple clepsydrae already mentioned, which measured duration without reference to any celestial phenomena. These were commonly used to limit the length of speeches in courts, but were not used to indicate the time of day. The other so-called water clocks were given the same name as sundials—they were horologia. These were automata designed to mimic the movement of the Sun and to provide a means of reckoning time during inclement weather.

UTC stands in relation to ways of reckoning time that do not necessarily share the same assumptions about epoch and interval. In the debate about the future of the leap second, the concern that there might be a proliferation of independent times with specialized objectives has been expressed several times,[20, 21] and this is viewed as diminishing the acceptance of UTC as an international standard. In fact, that situation pre-exists UTC, and UTC has not changed the existence of multiple independent times with specialized objectives. For many purposes, UTC is not the sole standard, but a medium to convert between standards—a means by which a variety of points of time determined by a variety of means can be related. On the other hand, the SI second is a widely accepted standard of measure.

Time is not an affectless symbol. In many contexts the significance given to time is not merely the ability to reckon time but also issues of emotion and identity. In Hinduism, it is the time of birth that determines one's name and fate. Three of the Five Pillars of Islam involve time: the month of Ramadan, the Hajj during the month of Dhu al-Hijjah, and the daily obligatory prayers. In Judaism, the recitation of the Shema in association with lying down at night and rising up in the morning is, in a common phrase, "the keynote of all Judaism," and the *tzitzit* (ritual fringes) which are discussed in the final portion of the Shema are, among other things, a time-reckoning tool. According to the Talmud, "the precept of fringes is equivalent to all the precepts of the Torah,"[22] because Numbers 15:39 exhorts Jews to remember all the commandments when they look at the *tzitzit*.

ZMANIM

The Jewish definitions of *zmanim* are not a timescale. The Torah gives some indications about time, but the oral traditions compiled in the Mishnah and commented upon in the Gemara provide the most detailed information. Together, the Mishnah and Gemara form the Talmud. The daily recitation of the Shema is of great importance in Judaism, and the Shema itself implies two times it must be recited: upon lying down and upon rising.[*]

The destruction of the Temple in AD 70 put the burden of its functions into the daily practices of Jews. The Mishnah, the compilation of oral tradition, was written down after the Temple's destruction, and it plays an important role in conveying how piety is to be practiced in daily life in the Temple's absence. Throughout the Mishnah and its commentary, the Talmud, there are abundant discussions of time and timing. For instance, the Mishnah begins with:[23]

> From what time in the evening may the Shema be recited? From the time when the priests enter [the Temple] to eat of their Heave-offering until the end of the first watch.

In the Gemara on this passage, the timing of the priests entering their houses is discussed in great detail. They may eat their Terumah once the stars have appeared. But there is also a debate about whether the priests eat their Terumah after they have taken their ritual bath, and the relationship of that bath to twilight: "The Master said: 'R. Judah said to him: "When the priests take their ritual bath it is still daytime!"' The objection of R. Judah to R. Meir seems well founded? — R. Meir may reply as follows: 'Do you think that I am referring to the twilight [as defined] by you? I am referring to the twilight [as defined] by R. Jose. For R. Jose says: "The twilight is like the twinkling[†] of an eye. This enters and that departs—and one cannot exactly fix it." ' "[24] Rav Judah defined twilight in terms of the time it took to walk half a mil[‡], which is shorter than an English mile.[25] Rav Jose defines twilight as a blinking of an eye that cannot be fixed. This debate refers to a passage in the *Tractate Shabbat*:[26]

> Our Rabbis taught: As to twilight [period] it is doubtful whether it is partly day and partly night, or the whole of it [belongs to the] day, or the whole of it night: [therefore] it is cast upon the stringencies of both days. And what is twilight? From sunset as long as the face of the east has a reddish glow: when the lower [horizon] is pale but not the upper, it is twilight; [but] when the upper [horizon] is pale and the same as the lower, it is night: this is the opinion of R. Judah. R. Nehemiah said: "For as long as it takes a man to walk half a

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[*] The Shema consists of Deuteronomy 6:4-9, 11:13-21, and Numbers 15:37-41.
[†] A better translation is "blinking of an eye."
[‡] A "mil" is similar to a Roman mile, which is the distance a legion could march in 2000 steps—about 1480 meters.

> mil from sunset." R. Jose said: "Twilight is as the twilight* of an eye, one entering and the other departing, and it is impossible to determine it."

Just looking at the means of time reckoning involved in this debate, one notes time reckoning by the Sun combined with time reckoning by the time it takes to walk a specified distance. This is not a timescale, but a system that uses multiple sources of information in order to determine a moment in time.

Another reason why *zmanim* do not make up a timescale is that these hours are not durations, *per se*. The daylight hours are divided into twelve proportional hours of equal length, and consequently, their duration varies based on the time of year and the latitude. *Shaot zmaniot* define religiously important time, called halachic time. In noting the challenges the change to daylight saving time poses to religious observance, Rabbi Tzvi Weinreb, Executive Vice President Emeritus of the Orthodox Union, notes "Halachic times do not care about clock time."

At night, *zmanim* are often described in the Talmud as the time it takes to walk a set number of miles. The reckoning of time by means of *zmanim* is complemented by other ways of ascertaining time of day like pre-sunrise visibility. Religious significance is not attributed directly to *zmanim* but to points or periods in time that are reckoned by means of *zmanim*.

Zmanim or prayer times can serve as anchors for the use of uniform duration. For instance, the Sabbath candle must be lit 18 minutes before the beginning of the Sabbath and the traditional use of walking times to measure duration have been converted into clock times. The one point in time that does not vary with the season is *Chatzos*, but UTC changes in relationship to *Chatzos*. The reason for this is that *Chatzos* is always local apparent solar noon, not mean solar noon. In effect, to understand the relationship between UTC or UT1 noon and *Chatzos*, one has to use the equation of time.

The calculation of daylight *zmanim* is based on dividing the daylight into twelve equal segments, with the solar culmination coinciding with the end of the sixth hour. While this sounds straightforward, it poses another cognitive problem, namely, how to determine the end points of daylight.

The determination of the beginning of the night and the beginning of daylight is a problem of picking a point in a gradual process. The *Astronomical Almanac* defines points in this process. As described in the *Explanatory Supplement to the Astronomical Almanac*, "At the tabulated times of sunrise and sunset, the geocentric zenith distance of the center of the Sun is 90°50' … the Sun's apparent upper limb is thus on the horizon."[27] The *Astronomical Almanac* offers three types of twilight: civil, nautical, and astronomical. Each is defined by an altitude of the center of the Sun.[28] These definitions are based on angle measurements, but Judaism's definition of points in this process use additional ways of knowing time.

According to the Mishnah, the morning Shema may be recited beginning when a blue thread can be distinguished from a white or green thread.[29] This is related to the blue thread in the tzitzit. The Gemara on this section of the Mishnah adds additional wrinkles, such as distinguishing between a wolf and a dog, an ass and a wild ass, or recognizing a friend 4 cubits away.[30] The use of color perception is not simply a matter of the amount of light, but also a feature of the human eye called the Purkinje effect. As Purkinje originally described it: "The degree of objective illumination has a great influence on the intensity of color quality. In order to prove this most vividly, take

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* A better translation would be "blinking of an eye."

some colors before daybreak, when it beings slowly to get lighter. Initially, one sees only black and gray. Then the brightest colors, red and green, appear darkest. Yellow cannot be distinguished from a rosy red. Blue looks to me to be the most noticeable."[31, 32] As Purkinje discovered, our sense of sight relies on two different types of visual receptors, rods and cones. Rods are very sensitive to light but not to color; cones are very sensitive to color but not as sensitive to light as rods. In dim light, we only perceive shades of gray. In bright light we perceive the full range of color. But there is an in-between condition in which we perceive blue and yellow with the perception of blue occurring in dimmer conditions than yellow. Consequently, the Talmud is referring to a physiological feature of human perception—a moment after sunrise when our ability to perceive color begins, and since it begins with blue, blue takes on particular significance in the determination of the beginning of the day.

The different Jewish positions on twilight are not based solely on the altitude of the center of the Sun but are instead based on using judgment in relating different phenomena, some of which are not astronomical, such as walking times or perceptual abilities in dim light. There is also an implied encouragement of non-experts to rely on cues from the behaviors of experts. The time to recite the Shema is tied to the behavior of priests—in effect, non-priests only need to watch the priests to know when the time one can recite the Shema begins.

How do these Jewish traditions get converted into clock times and what are the requirements of clock time for reliable conversion of these traditions? As Dovid Eisikowitz, the designer of MyZmanim.com, warns in an essay on his Web site, "Mathematical definitions for the times of [the three stars] and [the times for *tzitzit* and the tefillin] are not given by the Gemara and early *Poskim*. Many different *minhagim* exist."[*] *Poskim* are respected authorities on Jewish law, and *minhagim* are accepted customs. When comparing the time of the three stars to the twilight times listed in the *Astronomical Almanac*, one must recognize that the civil twilight time is when the center of the Sun is 96° below the zenith, and the time of the three stars is calculated as the center of the Sun being 8.5° below the horizon. At some latitudes, there is a rough relationship between the *Tzeit* at 72 minutes after sunset and the time of nautical twilight in the *Astronomical Almanac.* There is also a practice of defining the appearance of the three stars to the sun being a set number of degrees below the horizon that can easily be related to the twilight times given in the *Astronomical Almanac*.

There is a range of Web sites and applications that represent *zmanim* in terms of clock time. Users of these resources are aware that they may reflect different rabbinical opinions for the determination of *zmanim*. When I interviewed Dr. Goldberg, he showed me one application on his Blackberry and then said, "Let me pull up another app. See—the times are different from the first one. They are not the same for evening prayer. This is why it is not sufficient for the Sun to go down, but we look for the three stars to determine whether it is night or not. This is a Rabbinic precaution." He told me this in the context of explaining how "different times have different amounts of holiness" and the importance of knowing the proper time.

One of the most popular sources is MyZmanim.com. The designer of this site, Dovid Eisikowitz, explained that many years ago he attended a lecture on one of the Talmudic passages that deals with calculating *zmanim* times. As he wrote me, "It occurred to me that the same calculations that were done manually for over 3000 years could today be performed more easily using a computer." He first developed an application for Windows, and then converted it into the Web site MyZmanim.com. The services MyZmanim offers have expanded considerably, and now

[*] http://myzmanim.com/messagebox.aspx?messageid=sources

many Jewish organizations rely on the work of MyZmanim for tailoring calendrical and time information to their locations.

In how MyZmanim converts Jewish time into clock time, Mr. Eisikowitz explained to me, "We've done lots of research: studying many astronomy works, speaking with astronomers throughout the U.S., and selecting the sources that we felt were most accurate, as corroborated by our independent live observations." For understandable reasons, he was not willing to share the exact sources and algorithms with me, but I have explored other applications that provide *zmanim* information, and for them the source information for astronomical times was the USNO or NOAA. Yet, they do not claim to independently corroborate these times through direct observation, whereas Mr. Eisikowitz states that MyZmanim does. I do not know to what extent this indicates that some Jews are content to use astronomical tables from highly regarded sources while others view such data as not superseding traditional techniques for determining time, and must be checked against these techniques. That is a question for further research.

MyZmanim provides features to compensate for the altitude of the observer and refraction. For those who seek to recite the Amidah at the moment of sunrise, this precision is important. In these cases, a rabbi checks the effects of refraction just before the morning prayer begins so that the timing of the prayers culminates with the Amidah coinciding with the Sun's appearance. With MyZaminim's algorithms, it is possible to achieve a high level of accuracy in real time, but it also offers an important caveat to its accuracy: "Although our times are compiled to the highest accuracy standards, one should not rely on *zmanim* to the last moment. Many factors influence the *zmanim* and some cannot practically be measured or forecasted. *It goes without saying that zmanim can only be as accurate as your clock, so having an accurate clock is important.*"[*]

In terms of the accuracy of clocks, there is a growing generational gap. Older Jews still rely on watches for time and complement their watches with smartphone and computer applications. Younger Jews rely almost exclusively on portable electronics. So the accuracy of individuals' clocks varies depending on cell phone carriers or to the time source to which a clock is set. Synagogues seem to be different, however. I have gotten indications that they prefer clocks that receive radio signals from NIST to automatically set their time.

Current software applications make use of the UTC timescale and astronomical predictions in UT1 from the *Astronomical Almanac* to convert *zmanim* into clock time, but *zmanim* exist independently of clock time. As long as the astronomical tables are set to a known meridian from which local apparent solar cycles can be calculated accurately, and as long as there is a continued practice of corroborating the astronomical information with direct observation using traditional methods, Jews will continue to do what they have done for thousands of years—as Dr. Goldberg put it: "There are always people whose job it is to look after these things. Many in the Orthodox Jewish community are into science. They will study the problem and adapt to it. The world is constantly in flux, and we must constantly adjust. If I can write a program to do what we do now, then we can write a program to adapt." Adaptation does not mean a change in Jewish law, however—Dr. Goldberg was quick to add that "Jewish law doesn't change, but we must be clever when situations change so that we can adapt to those situations. The Jewish calendar doesn't change—it has remained accurate, but its relationship to other times can change. Our organizations will educate us."

[*] http://www.myzmaim.com/messagebox.aspx?messageid=accuracy, emphasis added.

The source of concern is with those Jews who use sources that rely entirely on astronomical tables without any independent corroboration. These tables must be kept up to date, and the burden of this falls partially on those who publish the tables, but also on those who use these tables making sure that they have the latest versions.

Eliminating the leap second practice, then, will not affect all Jews in the same way. Experts who continue to corroborate astronomical prediction with direct observation using traditional methods will continue to adjust their algorithms accordingly. Those who rely on the USNO will need to pay attention to updates, and the USNO will need to maintain a means of disseminating updated tables. In addition, whereas presently UT1 can be treated as UTC for purposes of calculating *zmanim*, if the leap second is eliminated, then the difference between UT1 and UTC will need to be included in any calculations based on the *Astronomical Almanac*. Consequently, there is a shared responsibility of the USNO continuing current practices such as its annual almanac and probably enhancing the Internet availability of its most recent data and updates, particularly updates concerning UT1−UTC. There is also a need of those developing *zmanim* applications to keep their applications up to date. There is a potential problem for some applications, because they treat UT1 as published in the *Astronomical Almanac* as UTC. As a result, there may be a desire for the *Astronomical Almanac* to include UTC as a timescale, although the preparation and production schedule of this reference makes this difficult.

With regard to ontological issues of decoupling Earth's rotation from clock time, from the perspective of Jewish time reckoning, that decoupling occurred with the emergence of mean time and time zones. Since the daytime and nighttime lengths of the Jewish hours vary throughout the year according to the season, and since they are tied to the true solar day and not the mean solar day, a local mean time offset from UTC does not indicate a Jewish time, but the moment of a local solar event which is associated with a Jewish time. Rabbinical rulings after the emergence of clock time have defined these important moments in reference to clock time, but there are several different traditions, and they are not in complete agreement.

Yet, since some Jewish time reckoning does use measures of standard duration, for instance, the night beginning 72 minutes after sunset, the SI second has clearly been accepted as the standard unit. Even though the option of changing the length of the second to address the drift of Earth's rotation from UTC is not popular in the scientific community, it is worth mentioning that of all the options on the table, I think it would be the most disruptive to current Jewish practices of reckoning time.

SALĀT

There is a resemblance between the Jewish and Islamic timing of prayer. Both incorporate apparent solar time, and both make use of travel time and sensory perception. Of the Five Pillars of Islam, two are tied to time of day: prayer and fasting. A Muslim is obligated to pray 5 times a day. These times are *Fajr*, *Zuhr*, *Asr*, *Maghrib*, and *Isha*. Each of these is a carefully defined time interval during which the compulsory prayers must be performed. As Mohammad Ilyas has pointed out, the need to clearly define these times fostered Muslim science.[33] At least through the medieval period, many mosques had an official known as a *muwāqqīt* who were astronomers that reckoned time for the calls to prayer, the determination of the beginning of the month, and the duration of fasts during Ramadan.[34, 35] *Fajr* is prayed between the first light of dawn and when the sun rises; *Zuhr* is prayed in a period following the solar culmination up until the time when shadows equal the length of the object casting the shadow; definitions of when the period of *Asr* begin vary, but all definitions refer to the length of an objects shadow being longer than the object's height, and *Asr* ends before sunset; *Isha* is prayed at night. Fasting during the month of Ramadan

extends from the time when a white and black thread can be distinguished in the early morning light until night. This tradition is reminiscent of the blue thread in the *tzitzit* of Jews, but because of how human color perception works, the moment when black and white can be distinguished is earlier than when blue can be distinguished.

As is the case with Jewish tradition, the times described in Islam pre-date the use of clocks and reflect a non-durationally based system of reckoning time that favors dividing the day into fractions of daylight. The fixed times of prayers are windows between points of time. The Qur'an and Hadiths define periods during which each prayer should be made. For instance, the following Hadith gives a synopsis of the prayer times:[36]

> Narrated Abu Al-Minhāl: Abū Barza said, 'The Prophet used to offer the *Fajr* (early morning prayer) when one could recognize the person sitting by him [after the *Salāt* (prayer)], and he used to recite between 60 to Āyāt (Verses) of the Qur'ān. He used to offer the *Zuhr* prayer as soon as the sun declined (at noon) and the *'Asr* prayer at a time when a man might go and return from the farthest place in Al-Madīna and find the sun still hot. (The sub-narrator forgot what was said about the *Maghrib).* He did not mind delaying the *Ishā* prayer to one-third of the night or the middle of the night.'

There are points of time during which prayers are forbidden: sunrise, when the sun is at its highest, and sunset. So the morning prayer, *Fajr*, be performed between true dawn and sunrise. Islam distinguishes between *subh khadib* (false dawn) and *suhb sadiq* (true dawn). False dawn is when white light appears above the horizon—a period which could be called first light. *Fajr* is not supposed to be made before true dawn, which is when the color of the light changes from white to pink and yellow. The midday prayer must be performed after noon, and the evening prayer before sunset. This is a repeated theme in many Hadiths. Here is one example:[37]

> For prayer is attended and witnessed (by the angels) until the sun rises, then it rises between the two horns of the *Shaitân* [Satan], that is the time when the disbelievers pray, so do not pray until the sun has risen to the height of a spear and its rays have disappeared. Then prayer is attended and witnessed (by the angels) until the sun is directly overhead at midday, and that is the time when the gates of Hell are ovened and it is stoked up. So do not pray until the shadows appear. Then prayer is attended and witnessed (by the angels) until the sun sets, and it sets between the horns of a *Shaitân,* and that is the time when the disbelievers pray."

All of the prayer periods mentioned so far are defined in relationship to local apparent solar time, but solar time is not the only logic employed in defining prayer times.

There are three other ways of reckoning time that are used to determine prayer time. In other Hadiths, both a walking time and the heat of the day are indicated, for instance: "He [the Prophet] used to pray *Zuhr* when the sun had passed its zenith, and (he would pray) *'Asr* and a man could walk to the farthest point in Al-Madînah and the sun would still be clear and hot."[38]

Second, too much heat is an indication of hellfire and not an appropriate time to pray: "Narrated Abū Hurairah and 'Abdullāh bin 'Umar: Allah's Messenger said, 'If it is very hot, then offer the *Ẓuhr* prayer when it becomes (a bit) cooler, as the severity of the heat is from the raging of the Hell-fire.' "[39]

Third, the Qur'an teaches that sunrise and sunset are processes: "He merges Night into Day, and He merges Day into Night."[40] Islam teaches techniques for knowing the proper points within these processes for prayer or the beginning of the fast during Ramadan. With regard to fasting, the Qur'an states, "And seek what God hath ordained for you, and eat and drink, until the white thread of dawn appear to you distinct from its black thread; then complete your fast till the night appears."[41] Being certain of the dawn is important, but once one is certain, there is a preference

for praying early so that the prayers are complete before the light of day is too bright. Not only is the time of dawn indicated by distinguishing threads, but the ideal time by which to complete the prayer is still when visibility is limited, as indicated in the following Hadith: "Narrated *'Āishah*: Allāh's Messenger used to offer the *Fajr* prayer and some believing women covered with their veiling sheets used to attend the *Fajr* prayer with him and then they would return to their homes unrecognized."[42] Shaukat addresses the difficulty in relating sky brightness, twilight light levels, and the definitions of civil, nautical, and astronomical twilight found in the *Astronomical Almanac*,[43] and Ilyas points out that the duration of sunlight and twilight varies with latitude.[44]

If a Muslim misses a prayer time, there is an allowance called Qada by means of which the Muslim can make up the prayer that was missed.

Since the advent of clocks, the points that define the different prayer periods have been converted into clock time, but the logics vary, particularly with the start times for *Fajr*, *Asr*, and *Isha*. For *Isha* and *Fajr*, there are two main logics for determining their times: the one-seventh rule and the angle-based rule. The one-seventh rule divides the night into 7 segments of equal length. *Isha* begins after $1/7^{th}$ of the night, and *Fajr* is prayed during the last seventh of the night. For *Asr* there are also two methods for determining it according to two Sunni traditions of jurisprudence, *Hanafi* and *Shafi'i*. *Hanafi* defines the start of *Asr* as when the shadow of an object is greater than twice the height of the object. *Shafi'i* defines the start of *Asr* as when the shadow of an object exceeds its height. Shi'a practice is for *Asr* to be when the shadow of an object is 4/7 the height of an object.

Determining the time of true dawn is a challenge that remains hidden from most Muslims who use software applications or tables, but Moonsighting.com offers a discussion of the problem faced in representing this moment as a clock time. Within recent years, astronomical approach of relating the angle of the Sun with the horizon to calculate a clock time has emerged within Islam, but the developers of Moonsighting.com have concluded:[*]

> Observations of *Subh-Sadiq* [true dawn] and disappearance of *Shafaq* [morning twilight] at various locations on earth have confirmed that it is not right to calculate *Fajr* & *Isha*, assuming any fixed degree (whether 18° or 15°) or any fixed minutes (like 90 minutes or 75 minutes). Although, 18° is correct at equator, it is not correct to use that for every latitude, especially for higher latitudes. Research and observations by Moonsighting.com members have confirmed that 18° should be used for every day at equator, but not for all latitudes.

In response to this challenge, Moonsighting.com is developing algorithms that account for one's latitude in determining the correct time for *Fajr* and *Isha*.

The development of algorithms and techniques for converting the traditional times into clock time is still the subject of much debate. Khalid Shaukat, the developer of Moonsighting.com, writes "The *Qur'an* and the *Sunnah* did not fix any degrees of the sun's depression for these prayers [*Fajr* and *Isha*]. Calculations based on the degree of the sun's depression are relatively recent phenomenon."[45] Guided Ways Technologies writes of their Prayer Times software application "*there is no timing or calculation method that one can say is absolutely 100% correct!* The

[*] http://moonsighting.com/how-we.html

reason for this is that there is so much detail involved in calculating prayer timings that even the most powerful computer will have an error rate of a couple of minutes."*

As with Judaism, Islam uses UTC to represent moments in local apparent solar time. With regard to Islamic civil timekeeping, Ilyas notes, "the civil use of non-uniform solar time did not produce any problems until the development of mechanical clocks in the seventeenth century, when 'mean solar time' was introduced."[46] Shaukat writes that during the 20th century, prayer times were calculated "often without considering the implications of using astronomical terms for Islamic terms."[47]

Changing the definition of UTC is only of concern if the algorithms for representing local apparent solar time do not recognize the drift of UTC from UT1. Also, as with Judaism, when I have been able to learn the origin of the source data for sunrise and sunset, it is from the *Astronomical Almanac*. If UT1 and UTC are decoupled, those creating Islamic time tables will face challenges similar to the Jewish calculation of *zmanim*, namely, that they will either need a source of astronomical information represented in UTC or they will need to convert astronomical data represented in UT1 into UTC. Finally, if the equation of time is relied upon to determine solar noon, then it will need to be adjusted according to UT1−UTC in order to avoid *Zuhr* being prayed at this moment associated with hellfire.

In contrast to Jews, there are very few instances in which the SI second is a measure of Islamic time, although the development of algorithms to convert traditional time reckoning into clock times is increasing. Even with the increased use of clock times, some sources are reluctant to represent any prayer time with a stable phase relationship represented in SI time from a fixed moment, whether it be sunrise or sunset or noon. There are some Muslim authorities who use durations as measured by the SI second to divide the night into two parts, but for the most part, Islamic time reckoning does not emphasize the measure of intervals. Ilyas writes, "as the Islamic time intervals are related directly to the true natural (solar) phenomena and not to the day length, it simply boils down to the daily determination of the times of various astronomical phenomena according to whatever day-time system is used, e.g., time-hours or time-degrees would be equally applicable."[48]

HINDU ASTROLOGY

Hindu astrology is called *Jyotish*. The *Sûrya-Siddhânta*, one of the earliest Hindu treatises on astronomy and astrology, describes the study of the movement of heavenly bodies as "That chief auxiliary of the scripture."[49] In this system, time is not measured by a single reckoner, but by intersecting cycles. In the words of the *Ārtabhatīya*, a respected fifth-century astronomical treatise, "Time, which has no beginning and no end, is measured by (the movements of) the planets and the asterisms on the sphere."[50]

The significance and relationship of celestial objects to spiritual beings is described in the *Vishnu Purana.*[51] *Jyotish* is based on this connection between divine forces and astronomical bodies. The sixth-century author Varahamihira is a leading figure, having written many mathematical, astronomical, and astrological treatises. Varahamihira named the *Sûrya-Siddhânta*, *Romaka Siddhânta*, and *Pauliśa Siddhânta* as the superior works on the subject.[52] Of these, only the

* http://www.guidedways.com/kb/article/why-are-the-timings-given-by-your-prayer-times-service-mobile-pc-and-online-different-from-my-local-mosque.html.

Sûrya-Siddhânta has been translated into English, but Varahamihira summarizes the others in his work. In addition to works on *Jyotish* are treatises on astronomy such as the *Ārtabhatīya*.

In Hinduism there are auspicious times of day, such as sunset, but the primary challenge of converting between traditional Hindu concepts of time and UTC involves astrology. For most non-Hindus, astrology is seen as a means of understanding the present or predicting the future. These ideas are part of Hindu astrology but since astrology gets linked to ideas of dharma and karma, astrological knowledge is not limited to divination. As one Hindu man told me, "From the Hindu perspective regarding humans on a day-to-day basis, whatever happens is an effect of astronomy. It is based on the time of your birth—the time, the day, the year. These things determine your ruling planet." Moreover, there are debates within Hinduism over the extent to which astrological knowledge can be used to change one's fate. Yet there is no debate over the use of astrology to determine names and to schedule important events in life, such as marriages or major business transactions.

Hindu astrology involves the interaction of *grahas*, *nakshatras*, *rāśis*, and *bhavas*. *Grahas* are moveable celestial objects. There are nine *grahas* which correspond to the Sun, the Moon, Mercury, Venus, Mars, Jupiter, Saturn, the ascending lunar node, and the descending lunar node. The *nakshatras* are asterisms—group of stars "that have no movements."[53] *Rāśis* are like the zodiac—there are twelve of them, and they divide the sky into segments of 30° each. Finally, the twelve *bhava* are "houses" which represent mental and emotional dispositions and faculties related to life stages. The *bhavas* are also related to *rāśis*. When an astrologer draws a chart, it is divided into twelve segments which represent both *bhava* and *rāśis*. The *rāśis* in which a *graha* is located corresponds to that *graha* exerting influence over a disposition or life stage as defined by a *bhava*. The different parts of a chart also indicate parts of the body,[54] so there is a coincidence between *bhava, rāśis,* dispositions, life stages, and parts of the body.

When a child is born, the time, date, and location are recorded. The parents use this information to consult a pandit to learn the child's *lagna*. *Lagna* refers to the connection between a soul and its existence on Earth as defined by astrological alignments of the *grahas*, *nakshatras*, and *rāśis*. The *nakshatra* of the ruling *graha* is used to determine the beginning of a child's name. The charting of the alignments of a specific moment in a specific location in relationship to *bhava* predicts the child's future. *Jyotish* emphasizes local lunar, planetary, sidereal, and apparent solar cycles.

Lagnas differ based on one's position on the globe. Longitude affects the ruling *graha* and latitude affects the relationship of a location to the ecliptic. As a result, all Hindu astrology involves locally-based calculations.

A Hindu's name then indicates a person's *lagna*. I was told "The name will stay with you the rest of your life and it must be based on a correct calculation. Whoever you meet—say, you meet a Hindu astrologer—they will know your ruling star by your name."

In some cases, the time of birth is uncertain. One man with whom I talked described how he was born in a rural area, and nobody wrote down the exact time of his birth. In such cases, according to Varahamihira, a sixth-century astronomer and compiler and commentator on astrological works, "When a person is ignorant of the time of his conception or birth, the time of birth shall, when duly questioned about, be determined from the Prasna Lagna."[55] The *prasna langa* is the time when an individual queries an astrologer.

Major events are also scheduled according to astrological cycles. For instance, when scheduling a wedding, one wants to choose a day and time when Venus is ruling. Again, since the duration of a planet's influence does not coincide to clock hours, there has to be conversion between

the two concepts of time. In the case of scheduling the time of a wedding, the pandit converts between traditional Hindu ideas and UTC.

Converting date and clock time into the Vedic astrological system involves many different steps. For most purposes, the number of *grahas* is reduced to seven (the two corresponding to lunar nodes are dropped), and each one corresponds to a day of the week. On that day, the ruling *graha* is associated with the first part of the day starting at sunrise. For instance, Sunday is associated with the Sun, and the first part of the day is ruled by the Sun. The second part is then ruled by the Moon, the third by Mercury, and so on. The duration of *graha* are generally represented in units of *muhūrta* and *ghatis* which correspond to 48 minutes and 24 minutes respectively. There are 30 *muhūrtas* in a day.

Rāśis are typically determined directly by angle rather than time. *Nakshatras* are calculated from the *nakshatra* of *Ashvini,* a fixed point on the ecliptic. The traditional method, as recorded in the *Siddhanta Siromani* is to take the longitude of a *graha* in minutes of arc, and divide by 800 to determine the *nakshatra* of the *graha*.[56] The reason for this is that when 360 is multiplied by 60 and then divided by 27 (the number of *nakshatras*) the result is 800. So if the longitude is represented in terms of minutes of arc rather than degrees, the *nakshatra* in which the *graha* is located is easily calculated.

Traditional Hindu astrology, then, uses time reckoning for some purposes and calculations of angle for others. Angle could be represented as time, and modern astrological practice uses time tables such as those found in the *Lahiri Ephemeris* rather than angle. In his notes on the 17th-century astrological text, *Prasna Marga*, Raman (the founder of *The Astrological Magazine* and a highly regarded Vedic astrologer) writes, "The method prescribed by the author is both impractical as well as impossible in present times. There are standard ephemerides available with which the Ascendant for the time of query can be determined with greater ease and better accuracy."[57] In fact, in the 19th century, Indian astronomers began to note that the tables based on ancient texts did not give the correct time of ephemerides, and new tables were published based on the British Nautical Almanac.[58]

Unlike *zmanim* or *salāt* times, there are no applications for converting Gregorian date and UTC into Hindu time units. Instead, there are some Web sites that offer software representing astrological cycles in clock time based on information from ephemerides. That said, there is a cultural inclination among some Hindus to have greater respect for old astrology tables over new ones. In other words, the older the book an astrologer consults when making calculations, the more respected that astrologer is. As a result, of all the groups I have discussed, the likelihood of outdated astronomical tables being used is probably the greatest with pandits. This is partially because pandit is a hereditary occupation of those of brahmanic descent, so the training and books are often passed from one generation to the next. This leads to concern about a lack of knowledge and training in some pandits. For instance, one Hindu confided in me, "Local pandits may not be sound."

There is a growing recognition among some Hindu organizations that there needs to be formal training. This may have been one of the rationales behind the 2001 decision of the high court of the Indian state of Andra Pradesh allowing astrology to be taught as a science at Indian universities. In Trinidad, where I first did field research in the late 1980s, the concern about adequate training of pandits has long been expressed, particularly among lay Hindus.

Whereas in Judaism and Islam the conversion between traditional times and UTC is done to inform lay people so that they can faithfully uphold their religion, in Hinduism, the conversion is done by experts who offer their knowledge as a service on a case-by-case basis. Some of the

knowledge is freely available. For instance, auspicious days for marriages, buying a home, or starting a business are commonly displayed on Hindu adaptations of the Gregorian calendar, but the finer and more personal astrological calculations are in the hands of pandits, not lay people. Admittedly, I am presently unsure the extent to which astrologers convert ephemerides represented in clock time into traditional Hindu times. Given the reputation of many storefront astrologers among Hindus, I suspect that many use readily available Western astrological systems rather than engage in all the calculation necessary to convert between clock time, *muhūrtas*, and the periods of *nakshatras*.

I anticipate that changes to UTC will affect Hindu astrology—particularly when making calculations about a UTC time to determine *lagnas* from out-of-date ephemerides. Yet, this would not be an unusual state of affairs in Hinduism—one could even argue that it is expected for the age of Kaliyuga, the present age in which the influence of the deota Kali causes a degeneration in spirituality. Traditional Vedic astrology reflected an astronomy based on a geocentric model as indicated by Varahamihira's discussion of how, "if the earth revolved in one day, flags and similar things would, owing to the quickness of the revolution, stream constantly towards the west."[59] Vedic astrology also is based on circular rather than elliptical orbits. As a result, it was, decoupled from actual celestial movements until the 19th century when ephemerides from sources such as the *Nautical Almanac* started to be employed by astrologers. Lacking widespread standards and training, the consequences of a redefinition of UTC on such calculations will likely be incorporated into the claims and counterclaims competing astrologers make about their skills, and to most lay Hindus, this will not be different from the present situation in which they often judge astrologers by the veracity of predictions rather than by technical knowledge.

UTC

Islamic, Jewish, and Hindu time reckonings indicate that UTC is one way of thinking about time among many currently in existence. UTC and its predecessors have not erased other ways of reckoning time. Hinduism, Judaism and Islam retain traditional ways of defining and determining time that continue to have religious significance. Where UTC is employed it is a result of converting the traditionally-determined times into representations that non-experts can use and which can be easily disseminated.

UTC is viewed as a useful tool in the process of calculating local apparent solar times and converting between different time systems. For the vast majority of purposes, there is no use of UTC as a representation of mean solar time—it is used as an abstract timescale. The exception to this is with the calculation of apparent solar noon, which can employ the equation of time. If UTC is decoupled from UT1, then there will be a need for the experts behind the religious calculations to keep track of UT1−UTC, or for ephemerides and almanacs to indicate the time of solar noon.

As a result of the conversion into UTC and dissemination using time-service providers, time experts in Judaism, Islam, and Hinduism have come to employ the precise timekeeping technology managed by national laboratories and the BIPM as a means of representing traditional religious times. There are three reasons for this: 1) understanding a clock time representation is something that even young children are expected to master; 2) the computers and portable electronics which are used to indicate traditional times operate using clock time; and 3) the UTC timescale allows a greater precision than previously possible and the religiously observant have taken advantage of this greater precision.

The timekeeping applications used in Islam, Judaism, and Hinduism, then, involve much higher levels of accuracy than those involved in the leap second debate may have imagined. The applications are expected to be accurate in indicating local apparent solar time to a couple of

minutes or less. In one case, MyZmanim.com, to achieve maximum accuracy, gives users the option to input elevation, temperature, and barometric pressure in order to have the calculations adjusted for line of sight to the horizon and refraction.

Thus, while most Muslims and Jews do not have a high level of knowledge about timekeeping, they rely on tools that translate their traditional times into UTC with an great deal of accuracy and these tools are designed by those with a great deal of knowledge about different timescales. In effect, the religiously observant person on the street is much like other people on the street in relying on precise and accurate clocks that run on electronic devices. Where they differ from other people on the street is that their experience of time includes direct observation. If the Sun does not rise when predicted by a software application, this is a problem for a Jew or Muslim. And in the case of the popular sites MyZmanim.com and Moonsighting.com, those who run the sites check their algorithms against direct observation.

In the case of Hinduism, the person on the street has only a rudimentary knowledge of how astrology works, but not the knowledge necessary to calculate *lagnas*. For that purpose, Hindus rely on pandits, and they value pandits that exhibit great technical knowledge, scholarship, and above all, the veracity in their divination.

The case that has sometimes been made that abolishing the leap second would not be noticed by these populations is false. The experts within these religions will notice. With the levels of precision now available to them through their computer systems as a result of Network Time Protocol, they will notice quite quickly.

Yet, the claim that abolishing the leap second would disrupt the practices of these populations would be equally false. My impression is that the software developers for providing Muslim and Jewish times continue to hone their algorithms. As long as there is a reliable source of up-to-date astronomical data that can be represented in UTC, these developers should be able to adjust to the absence of leap seconds by taking into account UT1−UTC. Because Islamic, Jewish and Hindu timekeeping do not rely on mean solar time, mean solar time has no theological significance. The main concern is that the software applications will need to represent religious time in terms of UTC, and those developers who do not take into account the difference between UT1 and UTC will be providing the faithful with bad information. That said, since direct observation of the sky is important in both Islam and Judaism, any software application that would not take into account the difference between UT1 and UTC would quickly be identified and earn a bad reputation.

This suggests that UTC has no ontological importance for many religious groups. Instead, it is a convenient and ubiquitous representation of time. From the perspective of most of the population of most of the world, UTC is a useful European and North American creation and a symptom of globalization. Religious experts who know multiple ways of reckoning time seem to view UTC as arbitrary in a semiotic sense. Indeed, "arbitrary" is exactly the term Rabbi Weinreb uses to describe clock time. In the semiotic sense of the term, *arbitrary* refers to a relationship between a symbol and its meaning when that relationship is established by convention.[60] So the relationship between the word *chair* and the things on which people sit is arbitrary. To say that UTC is arbitrary is to emphasize that it is defined by convention. To religious experts, this makes it quite different from the concept of a solar day, which is divinely ordained. Religions may differ on how they define the beginnings and endings of day, but these definitions are not seen as arbitrary.

Those involved in timekeeping in Judaism, Hinduism, and Islam are used to adjusting conversions between traditional times and other timescales and changing time policies—time zones, daylight savings time, redefinitions of the second, and leap seconds. One, Dr. Mohammad Ilyas, who is a leader in developing tools for Islamic timekeeping, serves on two IAU commissions—

Commission 4 on ephemerides and Commission 46 on education. Such experts are aware of the Earth's secular deceleration and the need for not only adjusting their traditions to changing time policies but to the Earth itself. One can understand why Rabbi Weinreb sees clock time as arbitrary. From his perspective, Jewish timekeeping pre-exists clock time and its techniques and calculations have been unchanged for 2000 years. In contrast TAI, UTC and UT1 appear fickle and temporary. They appear as products of constant tweaking and adjusting if not outright meddling. When compared to the long traditions of timekeeping in Hinduism, Judaism and Islam, the timescales that have been managed by the BIH and then the BIPM are short-lived and have gone through significant redefinitions. In just the last 130 years we have seen the creation of time zones, the adoption and decline of GMT, the definition of UTC, and the redefinition of the second. All that time, the ontological anchors of *zmanim* and *salāt* have remained unchanged.

So much of the world's population gets traditional times from experts used to adjusting to the management of UTC and changes in the globally available timescale. Most of the world already adjusts. This need for vigilance and adjustment makes the experts in these religious traditions seem more competent than many computer systems administrators. The crashes due to the leap second are not because of the leap second, but because of negligence and ignorance in systems administrators. For every leap second, there are announcements; there are protocols; there are patches. The leap second problem exists because most systems administrators understand this, but for the few that do not, when a leap second occurs, they find their timestamps being rejected by all the systems run competently, and that creates problems. Whatever is done about the leap second will not solve this problem. From the perspective of religious time experts, automation of timekeeping—pushing it outside of consciousness—is a weakness, not a strength, of the current time system. In this context, Hindu, Jewish, and Muslim timekeepers have an advantage in reliability and stability because they recognize the need for frequent adjustments and corrections of their algorithms and systems.

To religious experts already accustomed to adjusting their calculations of time in relationship to UTC, the argument for eliminating leap seconds on the grounds that leap second adjustments create problems is specious. Moreover, a system that is not monitored and adjusted is seen as untrustworthy by some of these religious experts. As a result, these populations are unlikely to be convinced of the necessity to eliminate the leap second, and are likely to wonder about other motives behind the proposed change. Since the effort to redefine UTC has largely emerged out of the United States and Europe, the imagination of these other motives is shaped by postcolonial sentiments and politics. This fosters insurmountable inertia, particularly in contexts where resentment is felt about perceived Western paternalism. Since the nations pushing for change in UTC are not even close to a majority of the membership of the ITU-R, and since for much of the world, these nations represent the colonizers of the not so distant past, these nations will be consistently outvoted, not because they should be, not because their arguments are weak, not because the science is no good, but because of the complex variety of resistances (scientific, moral, religious, and historical) to anything proposed by former colonizers. This resistance is made all the more powerful by nations that celebrate their own scientific traditions in contrast to European science.

In addition, the goal of a continuous, uniform timescale is not as globally shared as ITU-R Working Party 7A might think. Indeed, to borrow a turn of phrase from Adolf Bastian, a 19th-century ethnologist, maybe the question about the nature of timescales "is to be decided by the majority; in that case Europeans/Americans would be the eccentric ones."[61] Those involved in the debate about the future of UTC come from nations that represent a minority of the world's population.

The decision of international bodies such as the ITU-R is shaped by postcolonial politics. Just as it took Great Britain 170 years to adopt the Gregorian calendar because of British antagonism toward anything emanating from the Pope, any change to UTC originating out of Europe or North America could take a long time, as well, because of the lingering memories of colonialism.

Finally, since there is no solution to the leap second issue that will make all constituencies happy, there will be those who join the religiously observant in having to continue to be vigilant and make adjustments to their calculations for their purposes. They will have lots of company.

ACKNOWLEDGEMENTS

I thank Dovid Eisikowitz and John Seago for their comments on this paper, my students for their discussions about this project, and all the people who agreed to participate in this study.

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