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Issues and options for a Martian calendar

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Abstract

In the past 125 years, more than 70 authors have published ideas for keeping time on Mars, describing how to divide the Martian day and Martian year into smaller units. The Martian prime meridian was established in the mid-19th century, and the design of the Martian clock has been standardised at least since the Viking missions of the 1970s. Scientists can tell time on Mars; however, despite the constant stream of data that is downlinked from Mars these days, there is still no standardised system for expressing the date on Mars. Establishing a standard epoch—at a specific time of year on Mars, and a specific Martian year—should be the next priority in Martian timekeeping as a minimal system required for the physical sciences. More elaborate ideas, including the number and length of weeks and months, and names thereto, can be deferred for the present, but may become important considerations in coming years.

Keywords: Mars; Calendar; Timekeeping; Epoch; Social measurement

1. Overview

The subject of Martian time breaks down into five major sets of problems.

The first step was the establishment of a prime meridian. This was settled within the scientific community in the mid-19th century. Indeed, Mars had a universally standardised prime meridian a few decades before this question was settled for Earth! Of course, the definition of the Martian prime meridian has been successively refined over the years.

Once a standard reference meridian was established, the next question was how to divide the Martian solar day (sol) into subunits. The system that has arisen through long-standing custom and use is to divide the sol into 24 h, each containing 60 min, each of which in turn comprises 60 s. In essence, the 24:60:60 Earth clock has simply been stretched by 2.75 percent to fit the slightly longer Martian sol (Allison and Schmunk, 1997). The scientific world has a common method for expressing the time of day on Mars.[1]

The third problem of Martian time is to establish a common expression of date on Mars. This requires agreement on a heliocentric longitude (L_S) defining the first sol of the Martian year, and an agreement on which specific revolution of Mars to define as the beginning of the calendar year count. These may be considered separately or together, and may not need to be resolved in any particular order. Another issue, which may seem trivial, is whether the calendar year count should begin with 0 or 1. The time for setting this third set of standards is upon us. With all of the data that has been and continues to be returned from the various instruments on the surface of Mars and in orbit around Mars, the correlation of data between various space missions, past, present, and future, will be greatly facilitated by

[1]Some groups in the scientific community express the Martian sol in terms of 24 h and decimals (e.g. local time is 8.31 Martian hours), but of course that is done on Earth as well. In both cases, there is really one system; it is simply that decimals are used in lieu of the subordinate units for convenience of calculation.

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a common system of Martian dates—in essence, a rudimentary Martian calendar. Indeed, it is not a little surprising that this has not yet been accomplished. The current situation is analogous to the ships of each seafaring nation navigating on the basis of its own capital city as the prime meridian.

The fourth stage in the development of Martian time will be the promulgation of a fully characterised calendrical structure, including an intercalation formula, the number of months in a year and the number of sols per month, the number of sols per week, and whether such weeks should be integral to the months and the years or simply float through the months and the years as in the Gregorian calendar. This complete structural description of a Martian calendar must be arrived at via a social process. Perhaps, at first blush, this would place this discussion outside the scope of a physical science journal. Yet well-known names in the physical and life sciences have weighed in on these issues, and logical argument can and should be applied to the problem of constructing a Martian calendar (Aitken, 1936; Allison, 1998; Briggs and Houben, 1997; Forward, 1991; Graham and Elliot, 1999; Hartmann, 1997; Levitt, 1954; Lovelock and Allaby, 1984; Moore, 1977; Šurán, 1997; Weidner, 1999; Zubrin, 1993).

Stage 5, on the other hand, belongs entirely to the realm of social and cultural considerations. This will be the debate over nomenclature. We have long had an accepted term for the Martian solar day, but what shall we call the Martian year, month, and week? What names shall we apply to the sols of the week and the months of the year? In general, such issues may not be of interest to the readers of this journal, although since we have a term for the Martian solar day, it may be convenient for the scientific community to coin a term for another natural unit of Martian time—the Martian year—to distinguish it from the terrestrial year. Since the basis of areographic nomenclature is Latin, the Martian year might be called the "annus;" on the other hand, given the common practice of naming units after prominent scientists, the Martian year might be called the "lowell."

2. The third problem of Martian time

Two thousand years ago, a Roman would have referred to the Battle of Actium as having occurred on the fourth day before the Nones of September, in the year of the consulship of Gaius Julius Caesar Octavianus (his third) and Marcus Valerius Messalla Corvinus. Today, we express this date simply as September 2, 31 BCE. Anyone who were to seriously propose that we revert to the ancient Roman system would certainly be considered eccentric, to put it diplomatically. And yet, it is just this sort of cumbersome system that we have on Mars today. The awkwardness of describing the time of season and the specific year on Mars in terms of the Earth date, for the want of a standardised Martian system, can hardly be more vividly portrayed than in this passage by Pickering in 1892 (emphasis added):

> Early in 1890 the entire region enclosed between the arms of the Syrtis Major, as far as the snow cap, was of a brilliant green color. On June 27, however, or *eleven days before the vernal equinox of the southern hemisphere*, a yellow spot appeared at the extreme northern point of the triangular area. As the season advanced this yellow spot increased in area, till it covered the whole region as far south as could be seen. This year when first observed, this area was entirely green, but on May 9, *or seventeen days before the vernal equinox*, the yellow or perhaps reddish spot appeared in the same place, and it will be interesting to determine if, as the season advances, this color again progresses towards the pole. Changes to the east of the Syrtis Major have also here been noticed by Schiaparelli. These he ascribes to extensive floods. On June 8, 1890, *thirty days before the autumnal equinox in the northern hemisphere*, there was a large greenish area visible in longitude 180°, latitude 30° north. By July 16, or *eight days after the equinox*, this spot could not be found, the whole region appearing of a yellow tint.

3. A minimal solution

Amazingly, despite the keen interest in observing Mars via telescope that developed in the late 19th century, continued through the 20th, and was augmented by the robotic exploration of the Red Planet in the late 20th century, and despite the flood of data streams that are daily downlinked from Mars in the 21st century, the problem of the Martian calendar remains unresolved. The timing of various phenomena on Mars is often given in terms of Earth dates. Even when a Martian date reference is given, the system on which it is based is often ad hoc, e.g., as in the number of sols elapsed since the landing of a spacecraft on the surface of Mars. Furthermore, there is no universally agreed-upon standard for referencing specific Martian years. Consider how much simpler and more comprehensible Pickering's passage might have been if we had a standard for referencing the time of year on Mars and the specific Martian year. The resulting paragraph would be shorter, yet gain considerable clarity. Establishing such standards of Martian timekeeping ought to make the lives of planetary scientists considerably easier. Pickering himself, along with his associate at the Lowell Observatory, Andrew E. Douglass, invented a Martian calendar. Cited by Maggini (1939), the calendar probably dates from the turn of the 20th century.

4. L_S options

On both Earth and Mars (or any other planet for that matter), solar longitude is referenced from the sun's passage from the southern to the northern hemisphere ($L_S = 0°$), an event known as the vernal equinox in the northern hemisphere. It is not terribly daring to suggest that the same idea should be adopted in formulating a standard for Mars. Indeed, Percy Greg described exactly this system in his 1880 utopian novel about a Martian civilisation, *Across the Zodiac*. In such a system, Sol 0 denotes the northern hemispheric vernal equinox (we endeavour to always be specific regarding hemispheres, lest we slight our colleagues "down under").

Table 1 lists all Martian calendar proposals known to the authors that define an L_S and/or epoch, a total of 57. All but one define a Sol 0, and 25 (45%) of these define the vernal equinox of the northern hemisphere as Sol 0. Another 13 (23%) define an L_S between 272.1° and 281.0° in a rough analogy to the position of January 1 on the Gregorian calendar. Eight proposals (14%) begin the Martian calendar year on the northern hemisphere's winter solstice ($L_S = 270°$), and two each on the summer solstice ($L_S = 90°$) and autumnal equinox ($L_S = 180°$).

The authors have conducted two online Martian time surveys regarding preferences for a timekeeping system for Mars (Gangale and Dudley-Rowley, 2002, 2003). The first survey was conducted from September 1998 to August 2000. The second survey began collecting data in February 2001 and is ongoing. Fig. 1 shows the results from survey 1 regarding preferences for the L_S beginning the calendar year, and Fig. 2 shows the results from survey 2 as of January 2005. The $L_S = 0°$ responses accounted for 47% of the total in the first survey and 39% in the second survey. In both surveys, this choice was far ahead of the second-place choice.

Adding to the argument in favour of adopting the vernal equinox is the fact that the vernal equinox year (Fig. 3) is nearly as stable as the summer solstice year (Fig. 4), considerably more stable than the autumnal equinox year (Fig. 5) and the winter equinox year (Fig. 6), and much more stable than the anomalistic year (Fig. 7).

Given the popularity of the northern hemispheric vernal equinox among both calendar designers and survey respondents, a consensus on this issue would seem to be readily achievable. However, Thomson (1995) indicates that for much of Earth, the dominant seasonal period is the anomalistic year, and this may be true of Mars as well (Yoder and Standish, 1997; Folkner et al., 1997; Yoder et al., 2003). This would suggest using the perihelion passage to define the beginning of the year. On the other hand, the annual peak in the Mars pressure cycle occurs shortly before the northern winter solstice (Wood and Paige, 1992; Tillman et al., 1993). In any case, the object is to reach a consensus that spans numerous user communities regarding an L_S reference for the beginning of the calendar year, a "January 1," if you will, from which specific user communities could baseline their own peculiar years, just as on Earth we have academic years, fiscal years, etc., that begin on dates other than January 1. Standardisation does not necessarily imply the imposition of a single standard, but may encompass a manageably small number of standards within the set.

5. Epoch options

The second part of "the third problem," standardising a historical epoch, will probably generate more debate because it is not obvious that there is one best choice from the standpoint of physics. Thus, consideration of this question moves us further on the path of the social construction of Martian time, although, to some extent, all previous issues of Martian time have been socially constructed within the space science community. A resolution to the L_S issue appears more readily attainable because a choice can have some physical basis, but this second issue is more of a political one than a physical one.

There are two principal issues in choosing an epoch, and unfortunately, they are in direct conflict with each other. Selecting a recent epoch yields greater precision; however, the disadvantage is that such a system results in a lot of historical dates—and the many telescopic observations of Mars defined by them—being marked by negative numbers. On the other hand, the further back in time that an epoch is retroactively defined, the more uncertainty there is in its physical accuracy, due to slight irregularities in the rotations of both Earth and Mars. A way of finessing this conundrum is to select a recent epoch that has been precisely determined, then assign to that moment a year integer that is sufficiently greater than zero to eliminate any negative dates that might reasonably be considered as belonging to the historical study of Mars. Proleptic dates and times (i.e., before the epoch) would then be defined based on the state of our knowledge of the complex motions of Earth and Mars at the time of the adoption of the epoch. After all, no one can say exactly how many SI seconds have occurred since noon on January 1 of the year 4713 BCE, yet we use Julian day numbers as a matter of course.[2]

The general acceptance of such an epoch would nearly complete the minimum definition of Martian time necessary for physical scientific applications. Since there

[2] Allison and McEwen (2002) have proposed a "Mars Sol Date" (MSD) chronological system analogous to Earth's Julian day. The MSD is counted from their 1873 December 29 epoch, which is marked by the near-coincidence of Mars mean solar midnight at 0° longitude (Airy Mean Time) and noon UTC on 2000 January 6 (Allison 1997).

Table 1
Proposals for L_S, year count start, and epoch

Calendar	Mean L_S of beginning of year	Year count start	Epoch (CE & UTC)	Epoch (JD)
Aitken (1936)	0.0	Undefined	Undefined	Undefined
Allison (1998)	277.2	0	1873 December 29, 12:02:23	2405521.502
Areosynchronous (Moss, 1999)	0.0	0	1609 March 10, 18:00:40	2308804.25046
Arih (1999)	273.4	1	2000 January 1	2451545
Bauregger (1997)	281.0	Undefined	Undefined	Undefined
Becker (1994)	270.0	1	0 August 2	1721272
Blort (2001)	351	1	1 January 1	1721424
Briggs and Houben (1997)	264–268	1	1975 July 7	2442601
Chromium (Phelan, 2002)	90.0	Undefined	Undefined	Undefined
Clancy et al. (2000)	0.0	0	1955 April 11	2435208.456
Coletti (2004)	277.2	1	1873 December 29, 12:02:23	2405521.502
Cronin (2001)	274.0	1	0 July 28	1721265
Darian (Gangale, 1986, 1999, updated in 2002)	0.0	0	1609 March 10, 18:00:40	2308804.25046
Darian Defrost (Blok (1999)	0.0	0	1609 March 10, 18:00:40	2308804.25046
Darian Hensel (1999)	0.0	0	1609 March 10, 18:00:40	2308804.25046
Dechert (1996)	274.0	0	1999 December 31, 20:42:25	2451544.36279
Douglass and Pickering (c. 1900)[a]	0.0	Undefined	Undefined	Undefined
Elysium Mars (1998)	298.2	Undefined	1975 August 30,	2442669
Forget (2001)	0.0	Undefined	Undefined	Undefined
Forward (1991)	270.0	0	1999 December 24	2451537
Gangale Stretched Gregorian (1997)	280.4	0	1975 August 14	2442639
Greg (1880)	0.0	Undefined	−22981	
Hartmann (1997)[b]	Undefined	1	1	1721424
Heron (2001)	278.30	0	1975 July 26	2440429
Hollon (1998)	0.0	Undefined	Undefined	Undefined
Kretsch (1999)	0.0	Undefined	Undefined	Undefined
Kuiper (2001)	270.0	Undefined	Undefined	Undefined
Levitt (1954, 1956)	58.3	1	−4712 January 1,	0
Lowell (1895)	278.3	Undefined	Undefined	Undefined
Mars Pulse 1 (Kokh, 1999a, b)	90.0	Undefined	Undefined	Undefined
Mars Pulse 2 (Kokh, 1999a, b)	270.0	Undefined	Undefined	Undefined
Mars Pulse 3 (Kokh, 1999a, b)	270.0	Undefined	Undefined	Undefined
Mars QS (Oosthoek, 2003)	0.0	1	2022 December 26	2459940
Martiana (Gangale and Dudley-Rowley, 2002)	0.0	0	1609 March 11, 18:40:36	2308805.27819
Millennium Mars (Graham and Elliot, 1998, 1999)	0.0	0	1975 December 24	2442771
Naughton and O'Meara (2001)[b]	0.0	0	1 January 1	1721424
Pavonian (Knoke, 1999a)	0.0	Undefined	Undefined	Undefined
Potassium Option 1 (Phelan, 2002)	270.0	Undefined	Undefined	Undefined
Potassium Option 2 (Phelan, 2002)	180.0	Undefined	Undefined	Undefined
24 month Robinson (1993)	272.1	1	2026 April 30	2461161
L_S Robinson (1993)	0.0	1	2026 September 29	2461313
Rohrer (1977)	180.0	Undefined	Undefined	Undefined
Salvas (2001)	273.4	0	2000 January 1	2451545
Savard (2002)	0.0	Undefined	Undefined	Undefined
Schmidt (1997)	0.0	Undefined	Undefined	Undefined
Serra Martín (1997)	270.0	0	1971 October 6	2441231
Sherwood (1998)	0.0	Undefined	Undefined	Undefined
Ström (1998)	0.0	0	2011 September 13	2455817
Šurán (1997)	270.0	Undefined	Undefined	Undefined
Titanium (Phelan, 2002)	0.0	Undefined	Undefined	Undefined
Utopian (Moss et al., 2001)	0.0	0	1609 March 10, 18:00:40	2308804.25046
Vanadium (Phelan, 2002)	0.0	Undefined	Undefined	Undefined
Vophick (Knoke, 1999b–d)	280.2	1	1975 July 25	2440428
Weidner (1999)	0.0	0	−4224 August 22, 05:54:39	178509.746282
Welton (2004)	236.4	1	2050 August 13	2470033.5
Woods (1997)	125.8	0	0 November 29	1721391
Zubrin (1993), Zubrin and Wagner (1996)	0.0	1	1961 January 1	2437301

[a]Cited in Maggini (1939).
[b]Year count increments on the terrestrial cycle.

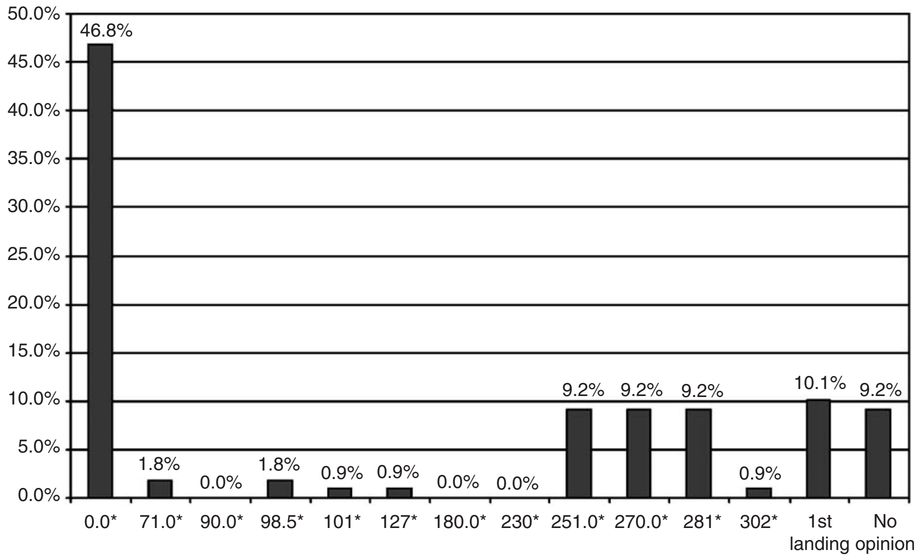

Fig. 1. Preferences for L_S beginning the calendar year (survey 1).

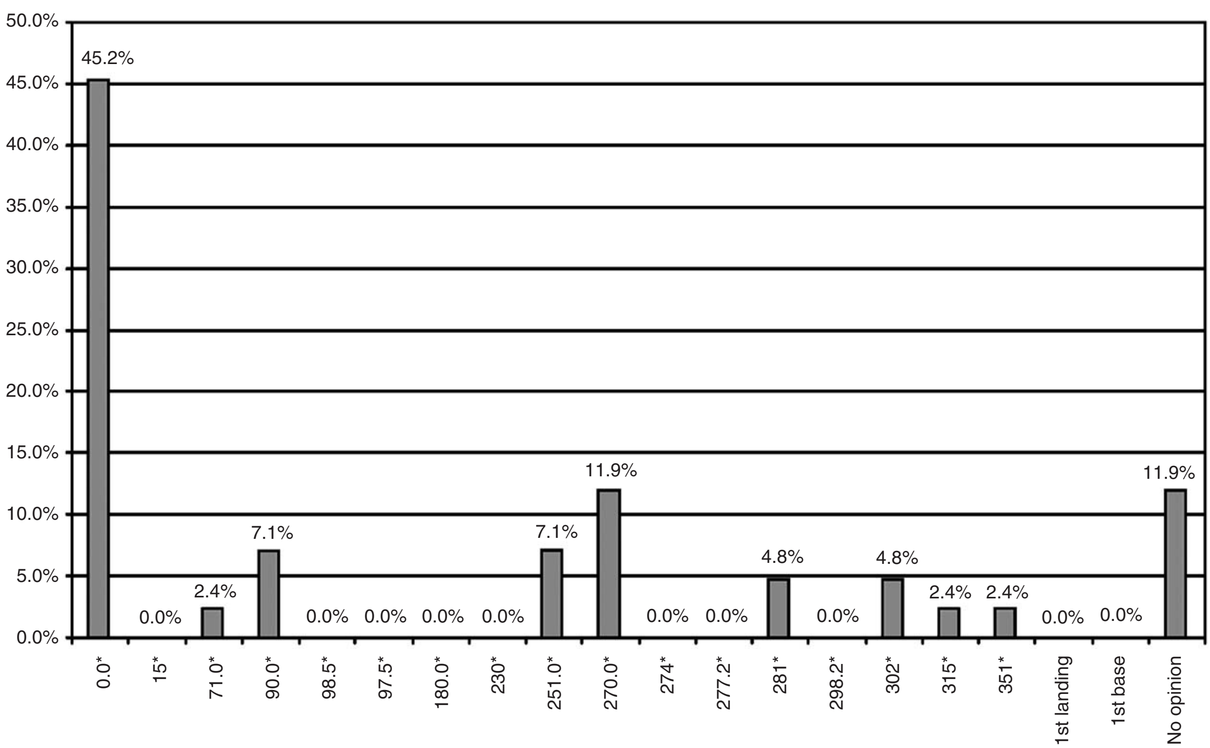

Fig. 2. Preferences for L_S beginning the calendar year (survey 2).

is no "right" physical solution to this issue, it may be one that is best resolved via a social process: the development of a consensus. Our purpose in this article is to call attention to the specific issues surrounding the definition of a minimal system of Martian dates, stimulate debate, and facilitate eventual convergence on a consensus. A brief outline of each of the proposed epochs may help propel the debate forward (see Table 2).

The Martian time survey, available at http://www.martiana.org/mars/, is a tool for informing the development of a broad-based consensus, rather than one limited to a narrow interest. Fig. 8 gives the results obtained from survey 1, and Fig. 9 shows epoch preferences recorded by the survey 2 as of January 2005. The epoch defined by the landing of Viking 1 in 1976 was favoured in survey 1 over other historical dates; however, support for using the as-yet-unrealised

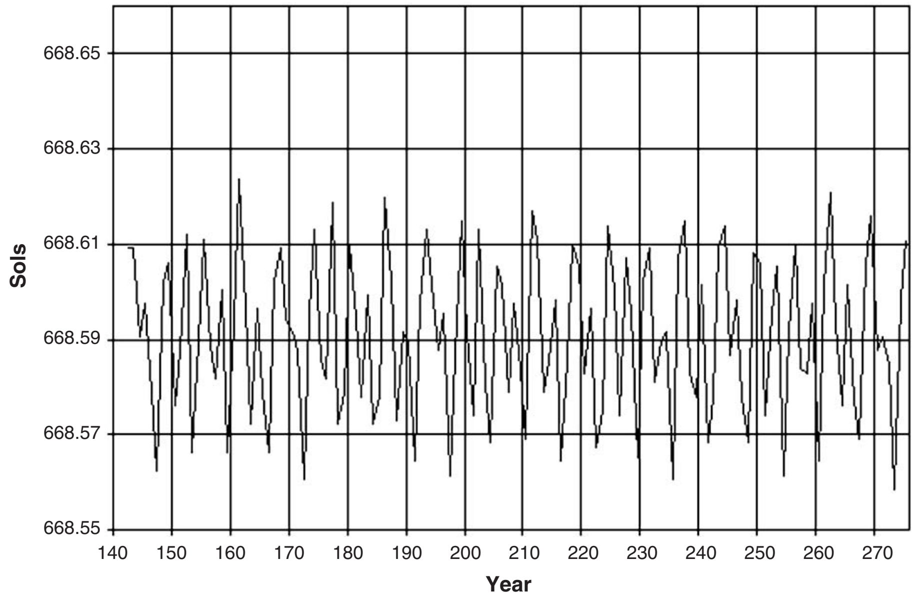

Fig. 3. Variation in the vernal equinox year, derived from Meeus (1995).

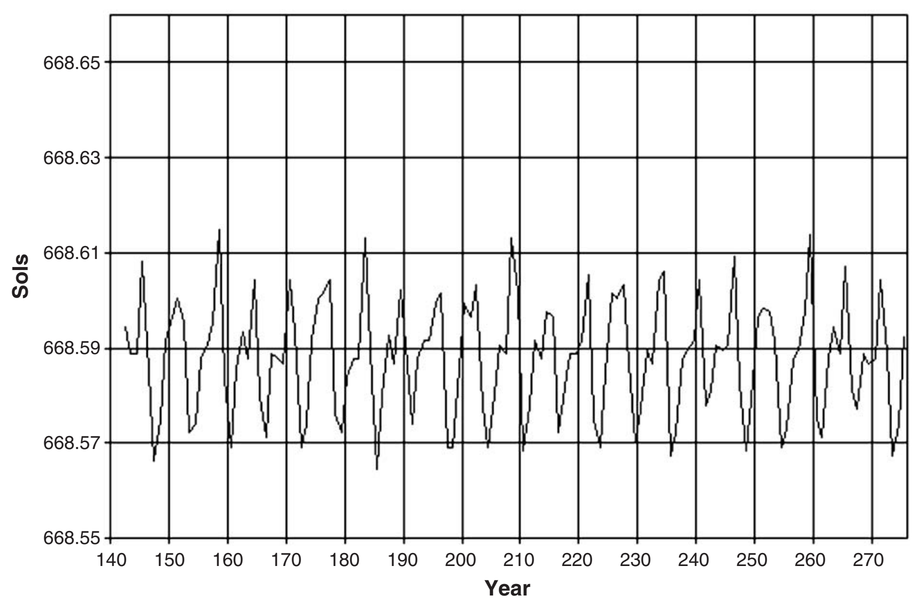

Fig. 4. Variation in the summer solstice year, derived from Meeus (1995).

first human landing was twice as strong. Survey 2 appears to reflect an increased awareness of the necessity for a historical epoch upon which to base a Martian calendar for immediate use rather than waiting for the first human landing or the first permanent base. At the same time, however, the Viking 1 epoch is no longer the clear favourite among historical dates. New competitors are dates further back in time. The 1609 epoch marks Kepler's publication of his first two laws of planetary motion and Galileo's first telescopic observations of Mars. On 1873 December 29 at 12:02:23 at 0° longitude on Earth, midnight at 0° longitude on Mars occurred (Allison, 1998).

6. Zero or one?

A final issue of "the third problem of Martian time" is whether the calendar year count should begin with 0 or 1. To most, the answer is self-evident … like whether to

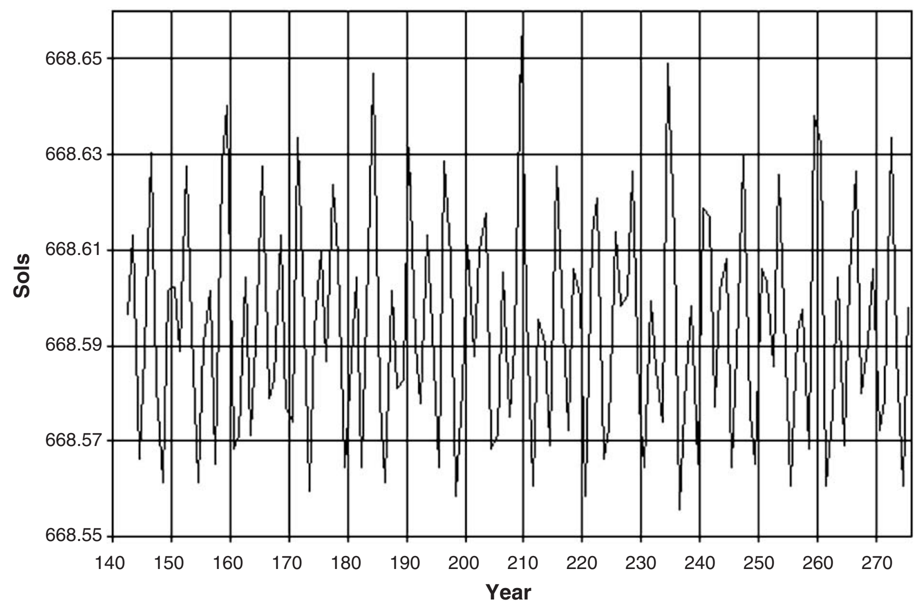

Fig. 5. Variation in the autumnal equinox year, derived from Meeus (1995).

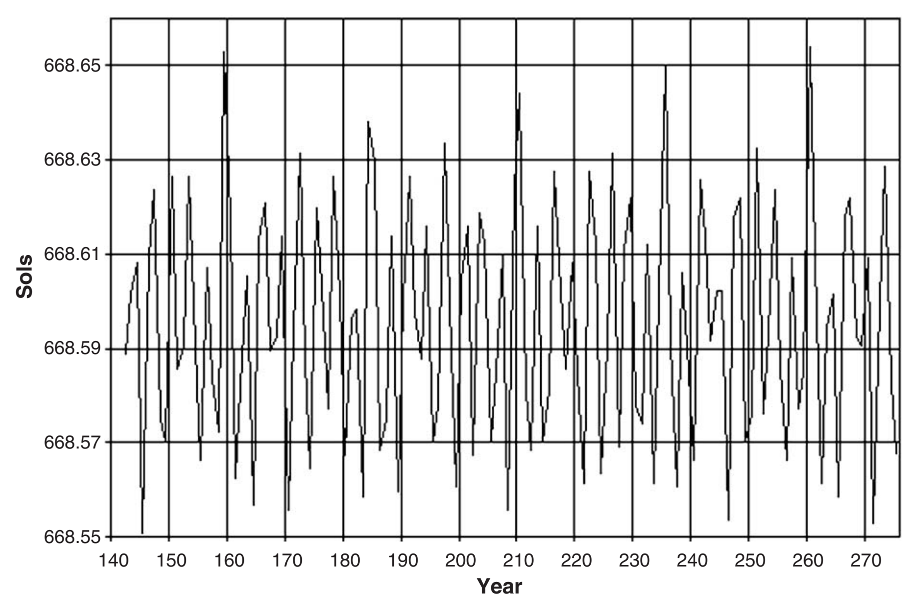

Fig. 6. Variation in the winter solstice year, derived from Meeus (1995).

drive on the left or the right, and there is as much division on the issue. Fig. 10 shows that in survey 1, there was an even split between 0 and 1, although Fig. 11 shows 0 being favoured by nearly 2:1 in survey 2.

7. Comprehensive solutions

Choosing the point in Mars' orbit for beginning the calendar year, selecting the specific revolution for the epoch, and defining the epochal year as either 0 or 1, establish a minimum solution to the problem of the Martian date system. These are issues that can and should be resolved in the near term, just as the design of the Martian clock has long since been settled.

As briefly discussed earlier, there are other issues of Martian time. These involve establishing a system of weeks and months, together with a system of names for the sols of the week and the months of the Martian year, and even distinctive terms for the Martian week, month, and year as units of time. Weeks and months are units of time that are necessary to a functioning human society, but not to machines operating on the surface of Mars or in orbit around it. Even though we are decades away

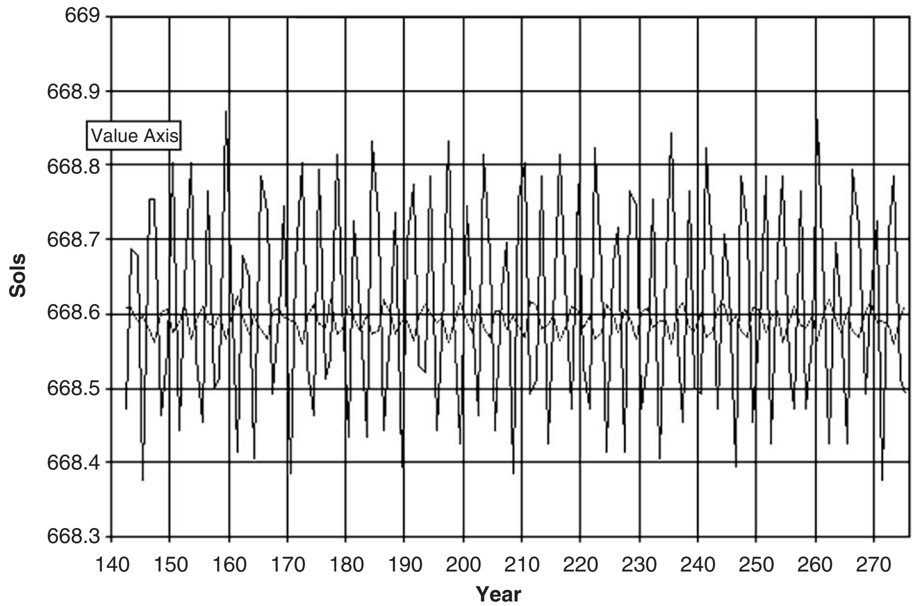

Fig. 7. Variation in the anomalistic year vs. vernal equinox year, derived from Meeus (1995).

Table 2
Description of proposed epochs

Year (CE)	Description
−4712	Beginning of the Julian period (Levitt, 1954, 1956).
−4224	Based on the regression of ten intercalation cycles of 310 Martian years each. However, Weidner (1999) states that his 310-year series does not repeat.
1	Beginning of the Common Era (Becker, 1994; Hartmann, 1997; Woods, 1997; Blort, 2001; Cronin, 2001; Naughton and O'Meara, 2001).
1609	During the Martian year encompassing 1609–1610, Kepler published his first two laws of planetary motion, and Galileo made the first telescopic observations of Mars (Kokh, 1999a, b; Moss, 1999; Moss et al., 2001).
1701	Most recent northern hemispheric martian vernal equinox occurring on January 1 (Gangale, 1997). The year 1961 was proposed by Zubrin (1993) and Zubrin and Wagner (1996), but reflects 31 days of accumulated error due to his oversimplified 8:15 ratio of Mars years to Earth years.
1873	On 1873 December 29 at 12:02:23 at 0° longitude on Earth, midnight at 0° longitude on Mars occurred (Allison, 1998; Coletti, 2004).
1955	Proposed by Clancy et al. (2000), it is now used by teams dealing with climate observations of Mars (Smith, 2004).
1971	Mariner 9 was the first robotic spacecraft to orbit Mars. Mars 3 was the first robotic spacecraft to land on Mars, although transmissions ceased after only 20 s (Serra Martín, 1997).
1976	Viking 1 was the first robotic spacecraft to achieve a successful landing on Mars and return useful scientific data from its surface (Gangale, 1986; Briggs and Houben, 1997; Gangale, 1997; Graham and Elliot, 1998; Gangale, 1999; Graham and Elliot, 1999; Knoke, 1999a–d; Heron, 2001).
2000	Last year of the second millennium (Forward, 1991; Dechert, 1996; Arih, 1999; Salvas, 2001).

from the first human landing on Mars, and perhaps a century or more from the establishment of a human society on Mars, there is a rich body of literature regarding such comprehensive solutions to the Martian calendar problem, consisting of more than 80 proposals over the course of the past 125 years. Whilst the consideration of these ideas can be a fascinating intellectual exercise at the confluence of the space sciences and the social sciences, is a full-blown Martian calendar really needed right now? Are the number of sols in a week, months in a Martian year, and the names associated with them, issues that need to be decided in the near term?

One school of thought considers these to be issues best deferred until there is a sustained and abundant human presence on Mars requiring these social constructs of timekeeping. Others contend that resolving such issues expeditiously and promulgating a human-oriented timekeeping system for Mars could be an important symbol of humanity's aspiration to incorporate Mars into its

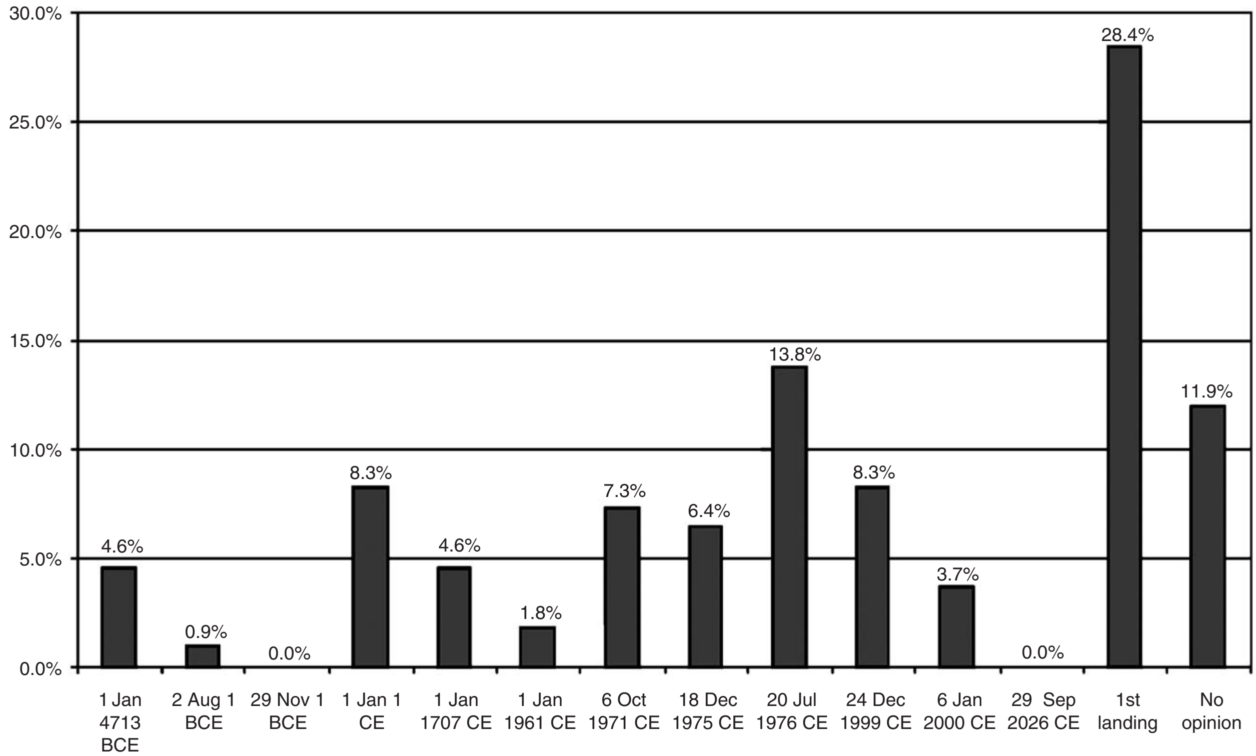

Fig. 8. Preferences for epoch (survey 1).

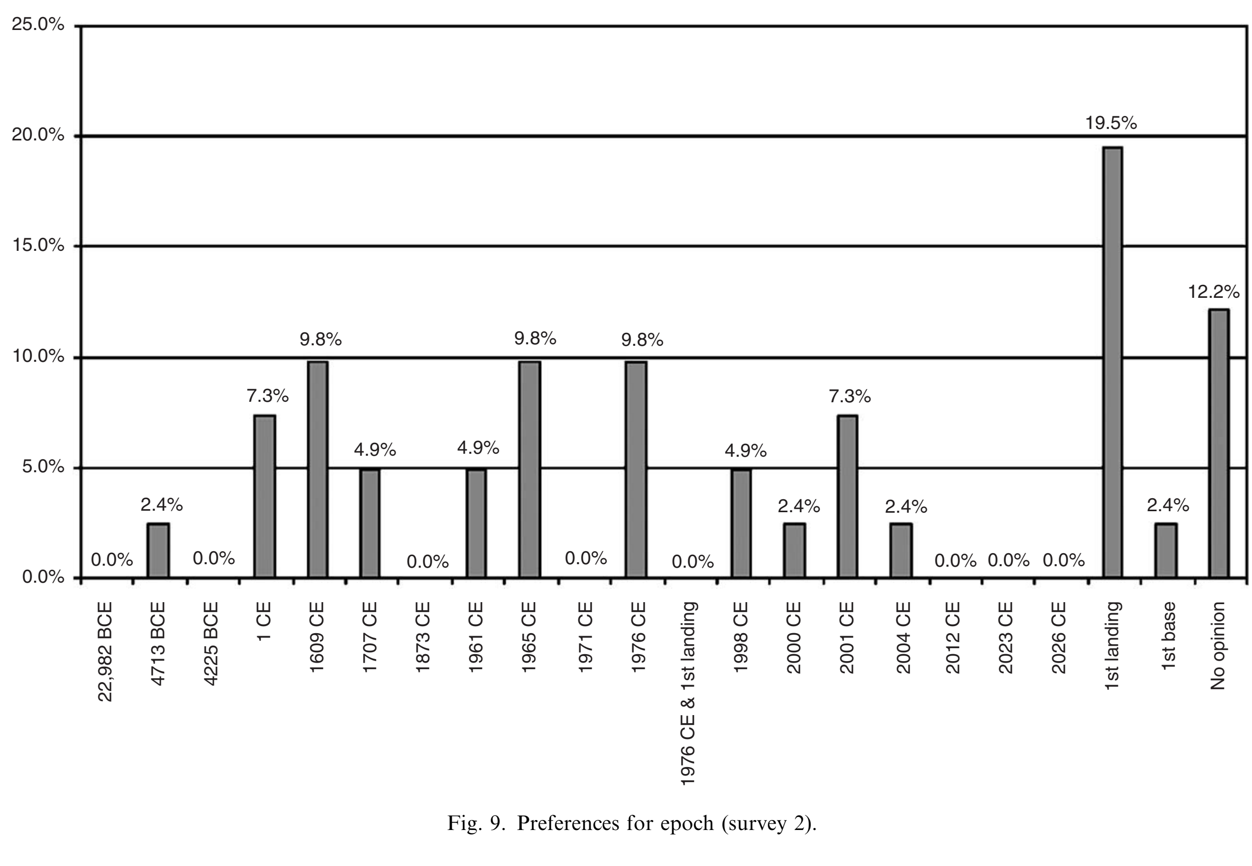

Fig. 9. Preferences for epoch (survey 2).

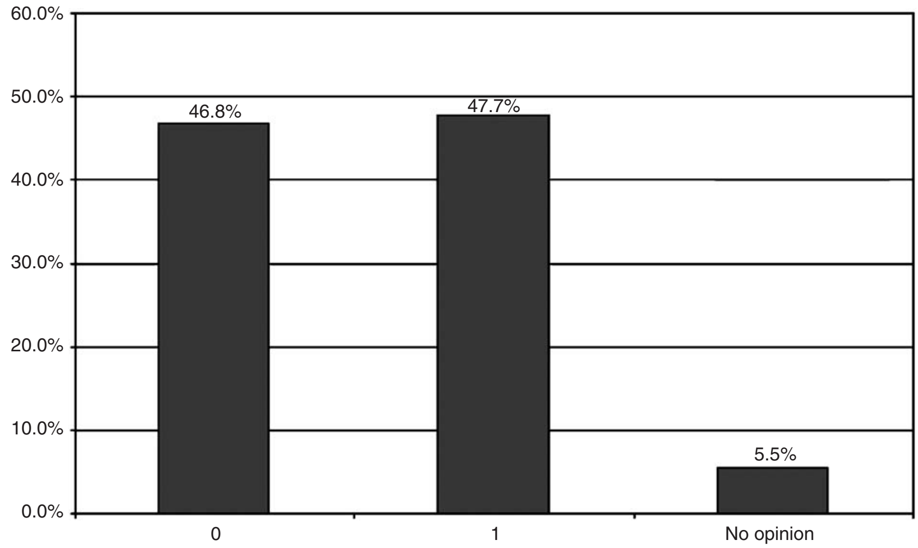

Fig. 10. Preferences for starting year count (survey 1).

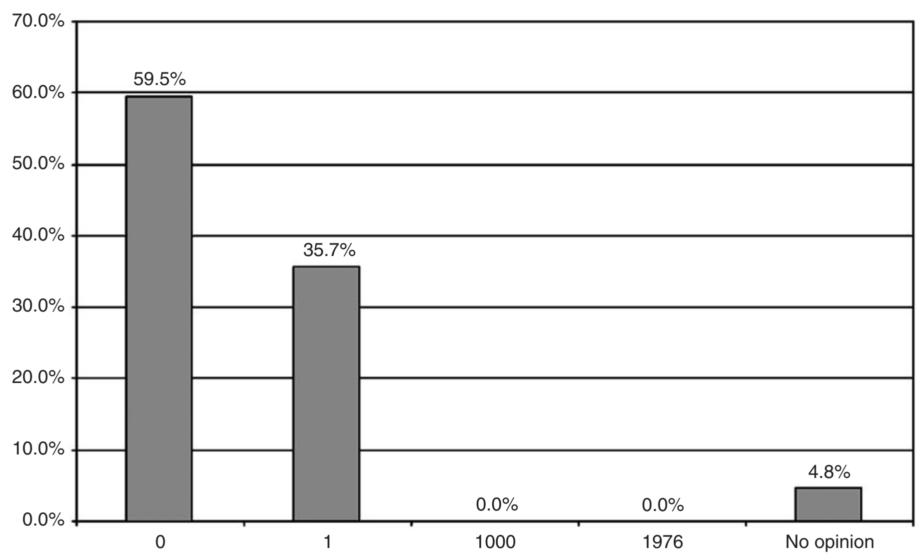

Fig. 11. Preferences for starting year count (survey 2).

ecology and culture, and might serve to hasten the human acquisition of Mars. These are matters of philosophy, politics, and culture, and are likely to provoke a lively and extended debate, especially in coming decades as the prospect of the human habitation of Mars becomes more real.

One can postulate that a comprehensive solution might be officially adopted by international agreement, either via an ad hoc conference involving NASA, RKA, ESA, JAXA, etc., or via existing mechanisms within the IAU. However, such an international agreement would probably be decades—even centuries—in coming, since some nations will have more of an interest than others in implementing such a system. As a practical matter, the nation most involved in the exploration of Mars will have the greatest need for a comprehensive solution. A country could unilaterally implement such a solution, and as we mentioned earlier, there would be political and cultural components to such an implementation decision. Even in this case, such a decision might be a long time in coming. The political will to officially establish such a system would likely come only in the context of a substantial societal commitment to colonise Mars. There are political risks to such an implementation mandated from above, because it can easily flop; the French Revolutionary and two Soviet calendars are the most famous examples (Steel, 2000, pp. 293–295). The lesson of history is that a comprehensive solution, i.e., a calendar consisting of weeks and months, complete with names of the days of the week and the months of the year, must be socially constructed if it is to be successful.

A more plausible and earlier scenario for implementing a comprehensive Martian timekeeping system is that some user community could implement such a comprehensive solution for its own purposes, and the practice might spread to other communities as they became more involved in the exploration of Mars. For example, the word "sol" originated somewhere within the Viking program circa 1975, and in the years since it has become the generally accepted term. The use of the word "sol" was not mandated from above; it propagated via a social process. In fact, three decades later, it is not known exactly where the term originated. Similarly, the stretched 24:60:60 clock for Mars was an idea that circulated in the scientific community for decades. Once it became necessary to operationalise a system during Viking missions on the surface of Mars, choosing the system that had already been socially constructed was a "no-brainer."

With regard to implementations mandated from above, incremental solutions have historically met with more success. The Gregorian calendar was a small correction to the Julian calendar, whereas more sweeping reform proposals have never received much support (Steel, 2000, pp. 305–321). A minimal solution for Mars along the lines we describe is thus the next logical step.

8. Conclusion

The Martian calendar problem may be considered by some to be a far-out, fanciful, futuristic topic, yet it has a long history. That history may have been sparse and sporadic in its early development, yet it has had its luminaries, and the discovery of forgotten work continues. To some, it may seem as useful an exercise as medieval arguments over the number of angels dancing on a pin, yet we look forward to a future when humans walk on Mars. And more than just walk, but are born and learn to walk, grow up and get married, have children and mark all of the other human events that make a calendar necessary.

Readers are invited to explore the many clock and calendar systems that have been invented for Mars on the Martian time website, http://www.martiana.org/mars/, and join the online discussion.

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