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The Architecture of Time, Part 2: The Darian System for Mars

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ABSTRACT

The Darian calendar is a complete timekeeping system for the 24-hour, 39-minute, 35.244-second sol and the 668.5907-sol vernal equinox year on Mars. Features include:

- 24 months, normally containing 28 sols, with three to four 27-sol months spaced regularly throughout the year to total either 668 or 669 sols. This results in a month whose length is within 6 percent of the mean Gregorian calendar month, within 3 percent of the lunar month, and near the statistical mean of the human menstrual cycle.
- A nominal seven-sol week, with six-sol weeks ending the 27-sol months, thus allowing every month to begin on the first sol of the week. The numerical sol of any month always occurs on the same sol of the week.
- Since the new year always begins on the first sol of the week, there are only two types of calendar years: one common year and one bissextile or "leap" year. This is in marked contrast to Earth's Gregorian calendar, which actually comprises 14 different types of calendar years, one beginning on each of the seven days of the week for common years and leap years.
- The calendar year begins on the vernal equinox, a standard astronomical reference point.
- A set of intercalation formulas keep the calendar synchronized with the vernal equinox for up to 10,000 Martian years as the length of the Martian year increases.
- A defined epoch allows the Darian date and local time on Mars to be calibrated with the Gregorian date and local time on Earth. The defined epoch allows all historical telescopic observations of Mars to be expressed in non-negative Martian dates.

The above list of features is the optimum design for a human biomedical, socioeconomic, and historical organization of time on Mars. This assertion is supported by eight years of survey data (Gangale and Dudley-Rowley 2002; Gangale 2004, Gangale and Dudley-Rowley 2006). No other design incorporates all of these features.

Calibration tables showing equivalent dates and times in Earth and Mars for equinoxes, solstices, and perihelions from 1874 to 2127, and oppositions and conjunctions of Mars from 1610 to 2099, are provided. Intercalation precision and annual perturbations are discussed, as well as the solar equation of time throughout the year.

INTRODUCTION

Some time in the 21st century, there will be human settlements on Mars. Those pioneers will have left behind on Earth the familiar 24-hour day and the 365-day year, and they will be living and working according to the natural cycles of Mars. A work day will be 13 minutes longer than we're used to back here on Earth, but the work force on Mars will have an extra 26 minutes to show up the next morning. This is because Mars rotates a bit more slowly than Earth does. To devise a practical Martian clock, it's only necessary to take a terrestrial timepiece and slow it down sufficiently. The Martian clock therefore consists of the same units as we are used to on Earth -- 60 seconds per minute, 60 minutes per hour, and 24 hours per sol -- however, each of these Martian units of time are just slightly longer (2.7 percent) than their terrestrial counterparts. Most of the Martian clock applications on the World Wide Web use this system, although some authors, such as Bruce A. Mackenzie (1990), have proposed Martian "metric" clocks based on powers of ten.

A much bigger difference is the length of the year on Earth and Mars. Because Mars is nearly 80 million kilometers further from the sun, it takes nearly twice as long for Mars to travel once around in its orbit. It will not seem at all odd to the Martians that ten-year-olds have the vote, or that the retirement age is 35. This difference between years on Earth and Mars will require a new calendar to mark the progress of the Martian year.

Mine is just one of several dozen calendars that have been devised for Mars. First described in a paper published in 1986, I chose to name it the Darian calendar for my son Darius. Hopefully, his generation

will be the first to reach Mars. For a literature review, see Gangale 1997; Gangale and Dudley-Rowley 2003; 2004; 2005.

YEARS

While the Martian clock may be a "slam dunk", constructing a practical calendar for Mars is a bit more of a challenge. Astronomy tables give the length of the Martian year as 687 days. WARNING: these are Earth days, not Martian sols (you would be surprised how many Martian calendar designers have made that mistake)! The correct figure to use in expressing Martian time in consistently Martian units is 668.5907 sols per vernal equinox year (Note: earlier papers specified the 668.5921-sol tropical solar year). Now, just as Earth's Gregorian calendar uses a combination of common years of 365 days and leap years of 366 days to account for the 365.24219-day terrestrial tropical solar year, the same methodology can be applied on Mars to develop an accurate calendar. Since the Darian calendar year begins with the vernal equinox, the calendar should be based on the mean vernal equinox year rather than on the mean tropical year (for a discussion on the various astronomical years, see Allison 2001). Of course, since the fractional amount of sols in a Martian vernal equinox year of 668.5907 solar days is different than in a terrestrial solar year, the sequence of common years and leap years will necessarily be different. In the Darian calendar, all even numbered years are 668 sols except for those divisible by ten. All other years are 669 sols, so that in ten calendar years there are 6,686 sols. In ten Martian venal equinox years there are 6,685.907 sols, the difference thus being -0.093 sols. A further correction is therefore needed every 100 years, and so every year divisible by 100 is 668 sols instead of 669. With this correction, there are 66,859 sols in 100 calendar years, while there are 66,859.07 sols in 100 tropical solar years. Finally, by making every year that is divisible by 500 a leap year, there are 334,296 sols in 500 calendar years. To summarize, the intercalation formula for the above scheme is (Y-1)\2 + Y\10 - Y\100 + Y\500, where the backslash indicates integer division. Theoretically, with a mean calendar year of 668.5905 sols, this error amounts to only one sol in 5,000 Martian years; however, the actual error will depend on the changes in Mars' orbital elements, rotational period, and the rate of the precession of the pole vector over this period of time.

AN EXTENDED INTERCALATION SCHEME

At present, the mean vernal equinox year is 668.5907 sols; however, Allison estimates that the mean tropical year is increasing by 0.00042 sols per 1,000 Earth years, which times 1.88 (Earth years/Martian years) = 0.00079 sols per 1,000 Martian years. A simple intercalation formula of (Y-1)\2 + Y\10 - Y\100 + Y\1000 results in a mean calendar year of 668.5910 sols. This is a bit too long compared to the current mean vernal equinox year, so the calendar will slowly lose time at first. However, the rate at which the calendar loses time will slowly decrease until the mean vernal equinox year equals the mean calendar year. This will occur about the year 600 of the Telescopic period. The calendar will then begin to gain time at an ever-increasing rate as the vernal equinox year lengthens, eventually becoming off by more than one sol. Before this happens the intercalation formula will need to be changed, and as the year continues to lengthen, the intercalation formula will need to be changed again and again. The series of formulas in TABLE 1 would keep the date of the vernal equinox stable for 10,000 Martian years, as shown in FIGURE 1, assuming that the rate of increase in the vernal equinox year is constant. However, this is certainly not the case. Refinement of the intercalation series will need to await the determination of a value for the second order term for the variation of the Martian vernal equinox year. The table and figure are presented as an example of the accuracy that is achievable over long periods of time with simple formulas as our knowledge of Mars' solar orbit improves.

See Appendix 1 for a discussion of the precision of the 10-year intercalation cycle versus a 5-year cycle and the 4-year Gregorian cycle.

MONTHS AND SEASONS

Several of the calendars that have been devised for Mars stretch the months asymmetrically to reflect the changing angular velocity of Mars in its eccentric orbit around the sun. Such months would span equal arcs in Mars' orbit rather represent than equal spans of time. While this might appeal to the astronomical purist, it must be pointed out that, in all probability, as on Earth, comparatively few people on Mars will be concerned with astronomy. And let us be clear that we are discussing a civil timekeeping system, not a planetary ephemeris. No civil calendar will have the accuracy

TABLE 1. Extended Intercalation Formula Series.

Range of Years	Formula	Mean Length of Calendar Year
0-2000	(Y-1)\2 + Y\10 - Y\100 + Y\1000	668.5910 sols
2001-4800	(Y-1)\2 + Y\10 - Y\150	668.5933 sols
4801-6800	(Y-1)\2 + Y\10 - Y\200	668.5950 sols
6801-8400	(Y-1)\2 + Y\10 - Y\300	668.5967 sols
8401-10000	(Y-1)\2 + Y\10 - Y\600	668.5983 sols

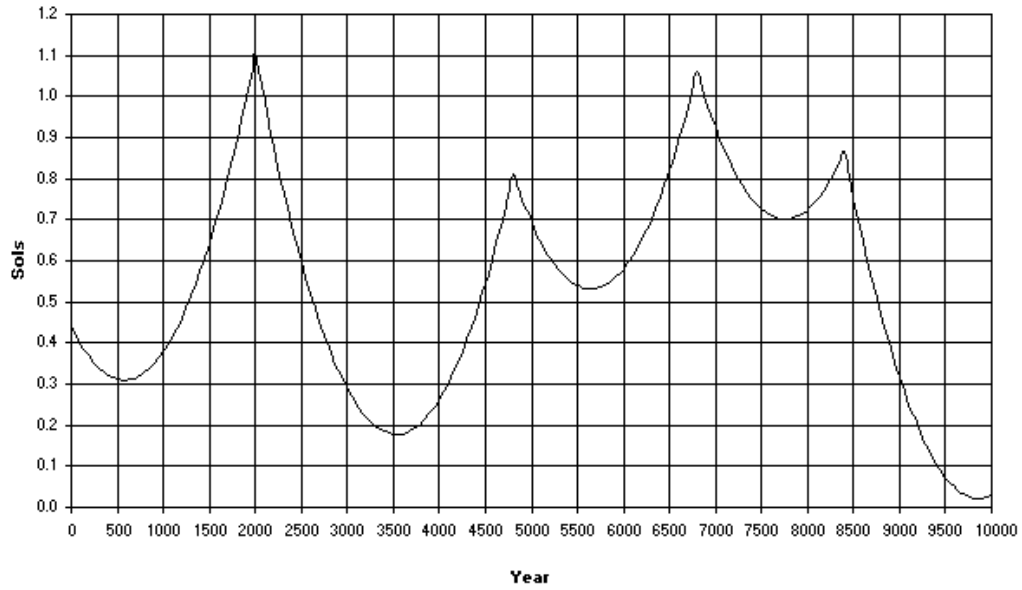

FIGURE 1. Cumulative Error of the Darian Calendar.

required for use by the space science community because of the need to insert leap sols. A timekeeping system is at least as much a societal construct as it is an astronomical one, and to be practical for the full spectrum of society, including those who can't program a VCR, a timekeeping system should be as simple as possible and as symmetrical as possible. As an analogy, here on Earth, few of us care, or even know, that on only four days of the year does the sun cross on the meridian at the precise moment that our clocks strike noon. We do not add or subtract minutes and seconds to our clocks throughout the year to adjust for the variable length of the solar day; rather, we set our timepieces according to the length of the mean solar day and let it go at that. Likewise, on Mars, we will find months whose lengths are nearly 50 percent longer than the shortest month. The stretched Gregorian calendar TABLE 2 is a typical example of these wildly changing months. Imagine the difficulty of working out monthly budgets in a such variable system, or trying to remember how many sols each month contains. A mnemonic poem would be of epic length!

Since a Martian year is nearly twice as long as an Earth year, a logical approach to dividing the Martian year into smaller units is to give the calendar twice as many months. An alternative would be to maintain the division of the year by twelve and have months that are nearly twice as long as they are on Earth; however, a 24-month calendar year is more desirable for several reasons. The mean Earth month of 30.4368 days is already a familiar cycle the humans. Dividing 668.5907 by 24 results in a mean month of 27.8579 sols, or 28.6238 Earth days, thus the difference between the mean Martian month and the mean Gregorian calendar month would be only 6 percent. Also, this is only 3 percent different from the lunar month. It will be much easier for humans to adjust to a slightly shorter month than to accept one that is nearly twice as long. Furthermore, although a 28-sol month has no astronomical basis on Mars, it will nevertheless be meaningful to human experience on Mars, since the statistical average of the human menstrual cycle is about 28 days. The purpose of a calendar is to mark the passage of time in human terms, so the more human factors that are designed into a calendar, the better.

In the Darian calendar, common years of 668 sols contain 20 months of 28 sols and four months of 27 sols. The 27-sol months occur at the end of each quarter. In leap years of 669 sols, the last month of the year (which also ends the fourth quarter, of course), instead of containing 27 sols, is a normal length of 28 sols. The leap sol is therefore the last sol of the year, rather than being stuck somewhere in the middle as it is on Earth's Gregorian calendar.

On the question of naming the 24 Martian months, the idea of using the names of the constellations of the zodiac naturally came to mind. Indeed, Robert Zubrin (1993) later adopted this idea for his own Martian calendar. These are the constellations through which the sun appears to pass as seen from Earth during the course of a year. This annual apparent path of the sun is called the ecliptic. Since Mars' orbit is inclined to Earth's by less than two degrees, as seen from Mars, the sun appears to pass through these same constellations along a very slightly different Martian ecliptic. There are only twelve such constellations, however, so two names must be used for each one. In the Darian calendar, twelve of the months bear the familiar Latin names of the zodiacal constellations. The names of the remaining twelve months are the Sanskrit names of these same constellations, and each appears in the calendar following its Latin counterpart. The nomenclature of the Darian calendar is thus a blend of Eastern and Western influences. Admittedly, the Sanskrit names are a bit

TABLE 2. The Gangale Asymmetric Gregorian Calendar (non-perpetual).

	Su	Mo	Tu	We	Th	Fr	Sa
January	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31	32	33	34	35
	36	37	38	39	40	41	42
	43	44	45	46	47	48	49
	50	51					
February			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31	32	33
	34	35	36	37	38	39	40
	41	42	43	44	45	46	47
	48	49	50	**51**			
March					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31
	32	33	34	35	36	**37**	38
	39	40	41	42	43	44	45
	46	47	48	49	50	51	52
	53	54	55	56	57	58	59
	60						
April		1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31	32	33	34
	35	36	37	38	39	40	41
	42	43	44	45	46	47	48
	49	50	51	52	53	54	55
	56	57	58	59	60	61	62

	Su	Mo	Tu	We	Th	Fr	Sa
May	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31	32	33	34	35
	36	37	38	39	40	41	42
	43	44	45	46	47	48	49
	50	51	52	53	54	55	56
	57	58	59	60	61	62	63
	64	65	**66**				
June				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30	31	32
	33	34	35	36	37	38	39
	40	41	**42**	43	44	45	46
	47	48	49	50	51	52	53
	54	55	56	57	58	59	60
	61	62	63				
July				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30	31	32
	33	34	35	36	37	38	39
	40	41	42	43	44	45	46
	47	48	49	50	51	52	53
	54	55	56	57	58	59	60
	61	62					
August			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31	32	33
	34	35	36	37	38	39	40
	41	42	43	44	45	46	47
	48	49	50	51	52	53	54
	55	56	57	58			

	Su	Mo	Tu	We	Th	Fr	Sa
September				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30	31	32
	33	34	35	36	37	**38**	39
	40	41	42	43	44	45	46
	47	48	49	50			
October						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
	31	32	33	34	35	36	37
	38	39	40	41	42	43	44
	45	46	47	48	49	50	
November							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30	31	32	33	34	35	36
	37	38	39	40	41	42	43
	44	45	46	47			
December						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
	31	32	33	**34**	35	36	37
	38	39	40	41	42	43	44
	45	46	47	48	49		

difficult to remember, and to make it even worse, in recent years I have changed the names of some of these months to reflect the predominant usage in the Hindu Solar calendar and in Vedic astrology.

In early Roman religion Mars was the god of vegetation and fertility, and his festivals signified the return of life to the land (this was before Rome became an imperial power, and Mars the farm boy got drafted into the army). Back in that more pastoral era, Romulus chose to begin his calendar with the vernal equinox, and the first month of the year was named for Mars, the provider and protector of the Roman people. In this same vein, the Darian calendar is intended to symbolize the beginning of life on the planet named for Mars (or if ancient life once did flourish there, the *return* of life to Mars), and so the vernal equinox is chosen as the beginning of the Martian year. Furthermore, on Earth the vernal equinox is a standard astronomical reference point that marks the beginning of the astronomical year, and it seems reasonable to carry this idea to Mars. The present position of the Martian vernal equinox is on the western edge of the constellation of Sagittarius. The first month of the Darian calendar year is therefore named Sagittarius, and the rest follow in their appropriate order as listed in FIGURE 2.

Because of the eccentricity of the Martian orbit, its seasons are of unequal lengths. Mars' furthest point from the Sun, known as the aphelion, occurs in late spring in the northern hemisphere (Kumbha 12). In accordance with Kepler's laws of orbital motion, Mars is at that time traveling at the slowest angular velocity in its orbit. This has the effect of making spring the longest season, and because aphelion occurs only 42 sols

TABLE 3. Annual Astronomical Events (Nominal Dates).

Event	**Date**
Vernal Equinox	Sagittarius 01
Aphelion	Kumbha 12
Summer Solstice	Pisces 27
Autumnal Equinox	Mithuna 11
Perihelion	Simha 12
Winter Solstice	Virgo 14

TABLE 4. The Martian Seasons.

Season	Sols
Spring	193.30
Summer	178.64
Autumn	142.70
Winter	153.95

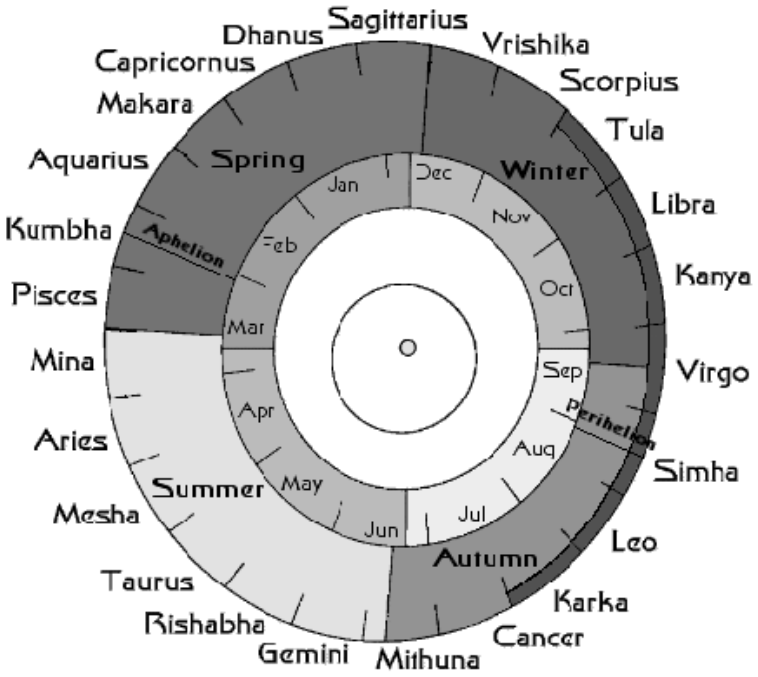

FIGURE 2. The Darian Months.

before the summer solstice, summer is the second longest season, beginning on Pisces 27. Similarly, perihelion, at which time Mars makes its closest approach to the Sun and attains its greatest orbital velocity, occurs 27 sols prior to the winter solstice (Simha 12). Autumn and winter are therefore the shortest and second shortest seasons, respectively. Spring in the northern hemisphere lasts 194 sols, and so the first sol of summer does not occur until the Pisces 28. Summer lasts 177 sols, so that although the autumnal equinox is in the constellation of Gemini it does not occur in the month of Gemini but on the 11th sol of Mithuna, the Sanskrit name of that same constellation. After 142 sols winter begins on Virgo 14 and lasts 156 sols. Of course, just as on Earth, the seasons in the southern hemisphere of Mars are exactly the opposite of those in the northern hemisphere, thus in the south of Mars, Sagittarius 01 marks the beginning of autumn, which lasts 194 sols, and so on. The actual dates of these events vary due to intercalation. The dates of annual astronomical events for specific years are given in the following tables:

- Appendix 3: Vernal Equinoxes of Mars
- Appendix 4: Summer Solstices of Mars
- Appendix 5: Autumnal Equinoxes of Mars
- Appendix 6: Winter Solstices of Mars
- Appendix 7: Perihelions of Mars

These dates were calculated from Meeus 1995. The error in the table may occasionally be as large as about 3 minutes of clock time. Note that the date of perihelion becomes progressively later (by one sol per 42 years) due to the anomalistic year (668.6146 sols being longer than the vernal equinox year (668.5907 sols).

Dates of synodic events are given in Appendix 8 (oppositions of Mars) and Appendix 9 (conjunctions of Mars).

Dust storm season lasts from Karka through Tula.

WEEKS

Still another familiar unit of time can be exported from Earth to Mars: the seven-day week. In fact, with a very minor adjustment, the seven-sol week can be made to work even better on Mars than on Earth, for there are exactly four such weeks in a 28-sol month. Now since Martian sols are longer than terrestrial days, it follows that a seven-sol Martian week is longer than its earthly counterpart. For this reason weeks on Mars will rarely and only briefly match up with weeks on Earth, and it will create confusion if on Mars the names of the sols of the week remain the same as on Earth; Monday on Mars might be Tuesday on Terra. In order to avoid this problem the Latin names of the days of the week are prescribed as a starting point: Dies Solis, Dies Lunae, Dies Martis, Dies Mercurii, Dies Jovis, Dies Veneris, and Dies Saturni. Since these names are the antecedents of those used in many of the European languages spoken today, they possess the familiarity that will enable their ready recognition by a large number of the cultures of humankind, yet being in the form of a language no longer spoken generally anywhere on Earth, they will not be mistaken to mean terrestrial days of the week. However, for Mars, the word "dies", which is Latin for

"day," is replaced by the word "sol". (Note: In earlier papers, the word "dies" was retained. Also, Sol Lunae was called Dies Phobotis, and Sol Martis was named Dies Terrae.)

And now for an unusual feature. Each month begins on exactly the same sol of the week: Sol Solis, which is the Martian equivalent of Sunday. The direct result of this is that regardless of the month, a given sol of the week can only occur on four invariable dates; for example, Sol Jovis, the Martian Thursday, will always be either the 5th, 12th, 19th, or 26th of the month... *any month*. No one on Mars will ever have to pause to consider, "Now let me see, the 10th of next month is Sol Martis, isn't it?" It always is! This has the great advantage of eliminating the sloppiness we on Earth have had to put up with in the Gregorian calendar. However, this arrangement requires that a 27-sol month end on Sol Veneris (the Martian equivalent of Friday), and that the following Sol Saturni (Martian Saturday) be skipped over, resulting in only a six-sol week in this very infrequent case. The next sol, being the first sol of the following month, is Sol Solis. This will happen at most only once every six months, sometimes only once in twelve months, but since no one wants a one-sol weekend, the last sol of the month should be a "holisol". That means that these unusual six-sol weeks will contain only four work sols, and not many people are going to object to that! It has been pointed out, however, that this system guarantees the Martian equivalent of Friday the 13th every month. Think of this as a plus, as it will surely dissuade the superstitious from emigrating to Mars. But does this unusual arrangement violate the Biblical commandment to observe the Sabbath every seven days? Well, to be very literal, there are no days on Mars, there are sols. Nevertheless, it turns out that this scheme actually keeps the average length of the Martian week closer to that of the terrestrial week. The occasional short week almost perfectly compensates for the longer Martian sol, resulting in an average Martian week that is less than one percent longer than the terrestrial week.

TABLE 5 shows the layout of the calendar for the entire Martian year.

THE MARTIANA CALENDAR

TABLE 6 shows a variant of the Darian calendar that uses a modified form of Robert G. Aitken's (1936) scheme for reconciling the months and the sols of the week into a repeatable pattern. In Aitken's system, developed in 1936, both the biennial leap sol and the decennial epagomenal sol occurred in even-numbered years. This results in calendar years of three different lengths: 668 sols for odd-numbered years, 669 sols for even-numbered, non-decennial years, and 670 sols for decennial years. In the Martiana calendar, the leap sol is moved to odd-numbered years, which therefore contain 669 sols as do decennial years, while even-numbered,

TABLE 5. The Darian Calendar (perpetual).

	So	Lu	Ma	Me	Jo	Ve	Sa		So	Lu	Ma	Me	Jo	Ve	Sa		So	Lu	Ma	Me	Jo	Ve	Sa
Sagittarius	**1**	2	3	4	5	6	7	Aries	1	2	3	4	5	6	7	Leo	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27	28		22	23	24	25	26	27	28
Dhanus	1	2	3	4	5	6	7	Mesha	1	2	3	4	5	6	7	Simha	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	**12**	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27	28		22	23	24	25	26	27	
Capricornus	1	2	3	4	5	6	7	Taurus	1	2	3	4	5	6	7	Virgo	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	**14**
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27	28		22	23	24	25	26	27	28
Makara	1	2	3	4	5	6	7	Rishabha	1	2	3	4	5	6	7	Kanya	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27			22	23	24	25	26	27	28
Aquarius	1	2	3	4	5	6	7	Gemini	1	2	3	4	5	6	7	Libra	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27	28		22	23	24	25	26	27	28
Kumbha	1	2	3	4	5	6	7	Mithuna	1	2	3	4	5	6	7	Tula	1	2	3	4	5	6	7
	8	9	10	11	**12**	13	14		8	9	10	**11**	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27			22	23	24	25	26	27	28		22	23	24	25	26	27	28
Pisces	1	2	3	4	5	6	7	Cancer	1	2	3	4	5	6	7	Scorpius	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	**27**	28		22	23	24	25	26	27	28		22	23	24	25	26	27	28
Mina	1	2	3	4	5	6	7	Karka	1	2	3	4	5	6	7	Vrishika	1	2	3	4	5	6	7
	8	9	10	11	12	13	14		8	9	10	11	12	13	14		8	9	10	11	12	13	14
	15	16	17	18	19	20	21		15	16	17	18	19	20	21		15	16	17	18	19	20	21
	22	23	24	25	26	27	28		22	23	24	25	26	27	28		22	23	24	25	26	27	**28**

TABLE 6. The Martiana Calendar (perpetual).

Even-Numbered Years

	So	Lu	Ma	Me	Jo	Ve	Sa
Sagittarius	**1**	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
Dhanus	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
Capricornus	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
Makara	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
Aquarius	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
Kumbha	1	2	3	4	5	6	7
	8	9	10	11	**12**	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	
Pisces							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	
Mina							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	

	So	Lu	Ma	Me	Jo	Ve	Sa
Aries							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	
Mesha							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	
Taurus							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	
Rishabha							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27		
Gemini						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28		
Mithuna						1	2
	3	4	5	6	7	8	9
	10	**11**	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28		
Cancer						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28		
Karka						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28		

	So	Lu	Ma	Me	Jo	Ve	Sa
Leo							1
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28		
Simha							1
	3	4	5	6	7	8	9
	10	11	**12**	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27			
Virgo							1
	4	5	6	7	8	9	10
	11	12	13	**14**	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28			
Kanya							1
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28			
Libra							1
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28			
Tula							1
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28			
Scorpius							1
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28			
Vrishika							1
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27				
Epag.							

non-decennial years contain 668 sols. The other departure from Aitken's scheme is that the decennial epagomenal sol is moved from mid-year to the end of the year.

In the Darian calendar, each month begins on Sol Solis. This requires the last week of each 167-sol quarter to be shortened to only six sols, which is the same solution that was developed by I. M. Levitt in 1954 to devise a perpetual Martian calendar. The Martiana calendar uses Aitken's solution, in which all the months in a given quarter begin on the same sol of the week, but the sol that begins each month shifts from one quarter to the next. In even-numbered years, all six months of spring begin on Sol Solis, those of summer on Sol Saturni, of autumn on Sol Veneris, and of winter on Sol Jovis. In the even-numbered years, the months of spring, summer, autumn and winter begin, in order, on Sol Mercurii, Sol Martis, Sol Lunae, and Sol Solis. The leap sol occurs at the end of odd-numbered years as in the original Darian calendar. Since the last month of odd-numbered years contains 28 sols, the following year also begins on Sol Solis, resulting in a two-year cycle over which the relationship of the sols of the week to the months repeats. The sol that is added every tenth year is epagomenal and is not counted as part of the week, thus the two-year rotation of the sols of the week is not disrupted. The Martiana scheme avoids the Darian calendar's need to shorten the week to six sols three to four times per year. The disadvantage is that the scheme results in a two-year cycle for reconciling the sols of the week and the months, whereas the Darian calendar is repeatable from month to month.

THE TELESCOPIC EPOCH

The need to keep a Martian calendar of even a rudimentary form began with the landing of the *Viking 1* spacecraft in July 1976. The sol of the landing was designated "Sol 0", and the sols that followed were numbered successively. With the landing of this first unmanned spacecraft, humans began working on the surface of Mars, albeit by proxy, and thus it was that humans began working by Martian time. Originally, the

TABLE 6 (continued). The Martiana Calendar (perpetual).

Odd-Numbered Years

	So	Lu	Ma	Me	Jo	Ve	Sa		So	Lu	Ma	Me	Jo	Ve	Sa		So	Lu	Ma	Me	Jo	Ve	Sa
Sagittarius				**1**	2	3	4	Aries			1	2	3	4	5	Leo		1	2	3	4	5	6
	5	6	7	8	9	10	11		6	7	8	9	10	11	12		7	8	9	10	11	12	13
	12	13	14	15	16	17	18		13	14	15	16	17	18	19		14	15	16	17	18	19	20
	19	20	21	22	23	24	25		20	21	22	23	24	25	26		21	22	23	24	25	26	27
	26	27	28						27	28							28						
Dhanus				1	2	3	4	Mesha			1	2	3	4	5	Simha		1	2	3	4	5	6
	5	6	7	8	9	10	11		6	7	8	9	10	11	12		7	8	9	10	11	**12**	13
	12	13	14	15	16	17	18		13	14	15	16	17	18	19		14	15	16	17	18	19	20
	19	20	21	22	23	24	25		20	21	22	23	24	25	26		21	22	23	24	25	26	27
	26	27	28						27	28													
Capricornus				1	2	3	4	Taurus			1	2	3	4	5	Virgo	1	2	3	4	5	6	7
	5	6	7	8	9	10	11		6	7	8	9	10	11	12		8	9	10	11	12	13	**14**
	12	13	14	15	16	17	18		13	14	15	16	17	18	19		15	16	17	18	19	20	21
	19	20	21	22	23	24	25		20	21	22	23	24	25	26		22	23	24	25	26	27	28
	26	27	28						27	28													
Makara				1	2	3	4	Rishabha			1	2	3	4	5	Kanya	1	2	3	4	5	6	7
	5	6	7	8	9	10	11		6	7	8	9	10	11	12		8	9	10	11	12	13	14
	12	13	14	15	16	17	18		13	14	15	16	17	18	19		15	16	17	18	19	20	21
	19	20	21	22	23	24	25		20	21	22	23	24	25	26		22	23	24	25	26	27	28
	26	27	28						27														
Aquarius				1	2	3	4	Gemini		1	2	3	4	5	6	Libra	1	2	3	4	5	6	7
	5	6	7	8	9	10	11		7	8	9	10	11	12	13		8	9	10	11	12	13	14
	12	13	14	15	16	17	18		14	15	16	17	18	19	20		15	16	17	18	19	20	21
	19	20	21	22	23	24	25		21	22	23	24	25	26	27		22	23	24	25	26	27	28
	26	27	28						28														
Kumbha				1	2	3	4	Mithuna		1	2	3	4	5	6	Tula	1	2	3	4	5	6	7
	5	6	7	8	9	10	11		7	8	9	10	**11**	12	13		8	9	10	11	12	13	14
	12	13	14	15	16	17	18		14	15	16	17	18	19	20		15	16	17	18	19	20	21
	19	20	21	22	23	24	25		21	22	23	24	25	26	27		22	23	24	25	26	27	28
	26	27							28														
Pisces			1	2	3	4	5	Cancer		1	2	3	4	5	6	Scorpius	1	2	3	4	5	6	7
	6	7	8	9	10	11	12		7	8	9	10	11	12	13		8	9	10	11	12	13	14
	13	14	15	16	17	18	19		14	15	16	17	18	19	20		15	16	17	18	19	20	21
	20	21	22	23	24	25	26		21	22	23	24	25	26	27		22	23	24	25	26	27	28
	27	**28**							28														
Mina			1	2	3	4	5	Karka		1	2	3	4	5	6	Vrishika	1	2	3	4	5	6	7
	6	7	8	9	10	11	12		7	8	9	10	11	12	13		8	9	10	11	12	13	14
	13	14	15	16	17	18	19		14	15	16	17	18	19	20		15	16	17	18	19	20	21
	20	21	22	23	24	25	26		21	22	23	24	25	26	27		22	23	24	25	26	27	**28**
	27	28							28														

epoch (year zero) of the Darian calendar was set to the northern hemisphere vernal equinox prior to the Viking landings. There were several problems with this choice. First of all, celebrating the Viking landings was viewed in some quarters to have nationalistic overtones. A more substantive concern is the need to use a Martian dating system prior to these events. Although the Viking landers established the first sustained human remote presence on Mars, there are centuries of Earth-based observational data that it would be useful to organize in non-negative Martian terms. This is especially true for the observation of seasonally variable Martian phenomena. For example, Giacomo Maraldi noted the variability of Mars' appearance in the early 18th century. It was Maraldi who conducted the first thorough study of the poles. He observed white regions in both the north and south, and noted that these regions fluctuated in extent. Indeed, in 1719 August, which was late spring in the southern hemisphere of Mars (the Darian month of Leo), the south polar white spot disappeared entirely.

The Martian year corresponding to 1609/1610 is highly significant in the history of Mars. During this Martian year, Johannes Kepler published his first two laws of planetary motion. His work included years of studying the orbit of Mars in particular. The highly eccentric orbit of Mars provided the principle challenge to Renaissance astronomy, forcing the abandonment of the theory of circular orbits and epicycles (to which even Nicholas Copernicus had clung). Also, accurate characterization of the elliptical orbit of Mars inspired Isaac Newton's *Principia Mathematica,* from which much of modern mathematics and science has flowed.

The 1609/1610 period also marked the beginning of the history of the observation of Mars by telescope (Galileo Galilei observed the phases of Mars in 1610 December). Thus, by choosing the Martian vernal equinox occurring on 1609 March 11 as the epoch for the Darian calendar, any recorded telescopic observation of Mars can be expressed in a common chronological reference system without negative values.

Additionally, it should be noted that Galileo's discovery of the four large moons of Jupiter in 1610 provided startling observational evidence that Earth was not the

center of the universe, and that the Darian timekeeping system extends to the four Galilean moons of Jupiter (Gangale 1998).

Finally, the human history of Mars may be organized into four eras (see TABLE 7), defined in terms of how humans have thought about and acquired knowledge of Mars:

Yet to come is a fifth period, the Humic (Mars as explored by humans on the surface). There are no clear beginning dates for the Mythic and Gymnoptic periods, of course, and there is a great deal of overlap in any case. On the other hand, it is fairly certain that the Telescopic period began in 1610. Applying the 1609/1610 epoch to a Martian calendar not only celebrates the birth of the Telescopic Period, but also celebrates Kepler's laws as the crowning achievement of Gymnoptic astronomy.

1. Mythic (Mars as experienced by the bicameral mind).
2. Gymnoptic (Mars as studied in naked eye astronomy).
3. Telescopic (Mars as observed through telescopes).
4. Telemetric (Mars as explored by robotic spacecraft).

The 1609/1610 epoch was discussed in the Martian Time Virtual Conference in 1999 October. It seems to have first been suggested by Peter Kokh in a private message to another member of the conference. Two years later, the Mars Time Group adopted this epoch for their Utopian calendar (Moss 2001). Simultaneous with the Darian calendar and the Darian Defrost calendar (Blok 1999; 1999a) adopting the Telescopic epoch, the Utopian calendar has adopted the equal-quarter structure of the Darian calendar. As a result of these changes, these three Martian calendars now have the same structure. The only differences among the three calendars are nomenclatural.

TABLE 7. Historical Eras and Periods of Mars.

Gregorian	Darian	Era	Period
<40th c. BCE		Mythic	
40th c. BCE		Gymnoptic	Astrologic
6th c. BCE			Cosmologic
1609	0	Telescopic	Monographic
1800	101		Cartographic
1905	157		Photographic
1965	189	Telemetric	Sporadic
1997	206		Systematic
21st c.	3rd c.	Humic	

DARIAN-GREGORIAN CALENDAR DISPLAYS

Centuries from now, there may be Martian who have little to do with Earth in their daily lives, and for them a purely Darian calendar can be a simple display. However, for those who must contend with timekeeping on both planets, the Darian calendar must be a dual-calibrated display. In its basic calibration, it must relate the local date and time on the Martian prime meridian (Airy Mean Time) to Universal Coordinated Time on Earth. For most Earth-bound users this generic calibration will suffice. FIGURE 3 is an example of a Darian-calibrated Gregorian calendar, with the horizontal offset of the Darian dates in relation to the Gregorian dates denoting the occurrence of prime meridian midnight on the two planets.

Users on Mars, as well as some Earth-bound users, will need Gregorian-calibrated Darian calendars. Additionally, such users may be interested in calendars that are calibrated for specific points on Earth and Mars. For example, During a Mars surface mission, the Darian calendar display must relate the local date and time at the position of the surface vehicle to the local date and time at the mission control complex on Earth or for the location of some other user group. It must also express Martian sols as a numerical sequence beginning with the sol of the landing of the vehicle, as has been done during the Viking, Pathfinder/Sojourner, Spirit, and Opporortunity missions. This second example of a Darian calendar display takes us back to 2004 July, or the Darian month of 210 Aquarius (FIGURE 4). It expresses chronological information pertinent to the Mars Exploration Rover 1 *(Spirit)* mission in the format of the Darian calendar. For each Martian sol, local mean Martian midnight at the *Columbia* Station is expressed in terms of local Earth date and time at the Jet Propulsion Laboratory in California. The numerical sequence of sols for the mission is also displayed. Note that terrestrial days of the week appear in their normal positions only occasionally on this Darian-formatted display, so in order to readily orient the Earth-bound user, these are color-coded: Sunday -- red; Monday -- orange; Tuesday -- yellow; Wednesday -- green; Thursday -- blue; Friday -- indigo; Saturday -- violet. Also note that periodically a terrestrial day drops out of the calendar (Monday, June 28 in this case) as a Martian midnight occurring late in the evening of one terrestrial day is followed by the next Martian midnight striking early in the morning two terrestrial dates later. This results in a shifting to the left of the columns of terrestrial days of the week.

The quarters are equal in common years and contain an integral number An additional display that is available on the Martian Time website is a real-time clock showing the date and time on both Earth and Mars.

The quarters are equal in common years and contain an integral number An additional display that is available on the Martian Time website is a real-time clock showing the date and time on both Earth and Mars.

CHILDREN AND COLLATERAL RELATIVES

Although I read Robert A. Heinlein's *Red Planet* as a boy, by the time I developed the Darian calendar in 1985 I had forgotten his passing reference to a Martian calendar. It was only as I was putting the finishing touches on an article (Gangale 1988) for the British Interplanetary Society's magazine *Spaceflight* that this information surfaced from my unconscious:

"And with these proud strokes of the word processor keys I thought I was finished writing this article. I had looked through every astronomy book about Mars I could find, but could uncover no more calendars. The next morning, in the last REM period before waking, I dreamt of a calendar in Robert A. Heinlein's 1949 *Red Planet,* a juvenile novel I had not read in 20 years. I bounded out of bed in the predawn gloom, flipped on the light in our study, and instantly found the book, for I had earmarked it for re-reading as part of the research for a future writing project of mine. Sure enough, in the course of a conversation in Chapter 1:"

> Jim thought back over the twenty-four months of the Martian year. 'Since along toward the end of Zeus, nearly November.'
>
> 'And now here it is the last of March, almost Ceres, and the summer gone.'

Thus it was Heinlein who originated the 24-month Martian calendar in 1949, and his idea must be included in the genealogy of the Darian calendar.

Although not a 24-month calendar, I. M. Levitt's 12-month 1954 calendar must also be acknowledged as an antecedent. If one were to bisect each of the 12 months, the resulting structure would be nearly identical to the Darian calendar. The exceptions are that the first sol of the calendar year is tied to the beginning of the Julian period, and that Levitt's intercalation sequence provides for three leap years out of ever five years. I did not discover the Levitt calendar until after I had published my 1986 June *JBIS* article. I acknowledged Levitt's work in my 1988 July *JBIS* article, "The Lost Calendars of Mars." Levitt made a very simple error in calculating the Martian year. His epoch was intended to be the beginning of the Julian period on 1 January, 4713 BC (on the Julian calendar). To get the correct Levitt year, one should divide the Julian Day number by the number

FIGURE 3. Gregorian Calendar Display, UTC and AMT, 2005 September.

SAGITTARIUS						
Martian Year: 210 A.M. Earth Year: 2004 A.D.			Martian Site: Spirit, Gusev Crater Longitude 184.52			
Sol Solis	**Sol Lunae**	**Sol Martis**	**Sol Mercurii**	**Sol Jovis**	**Sol Veneris**	**Sol Saturni**
1 Sol 60 19:48:54 PST Wednesday March 3	2 Sol 61 20:28:29 PST Thursday March 4	3 Sol 62 21:08:05 PST Friday March 5	4 Sol 63 21:47:40 PST Saturday March 6	5 Sol 64 22:27:15 PST Sunday March 7	6 Sol 65 23:06:50 PST Monday March 8	7 Sol 66 23:46:26 PST Tuesday March 9
8 Sol 67 00:26:01 PST Thursday March 11	9 Sol 68 01:05:36 PST Friday March 12	10 Sol 69 01:45:11 PST Saturday March 13	11 Sol 70 02:24:47 PST Sunday March 14	12 Sol 71 03:04:22 PST Monday March 15	13 Sol 72 03:43:57 PST Tuesday March 16	14 Sol 73 04:23:32 PST Wednesday March 17
15 Sol 74 05:03:08 PST Thursday March 18	16 Sol 75 05:42:43 PST Friday March 19	17 Sol 76 06:22:18 PST Saturday March 20	18 Sol 77 07:01:53 PST Sunday March 21	19 Sol 78 07:41:29 PST Monday March 22	20 Sol 79 08:21:04 PST Tuesday March 23	21 Sol 80 09:00:39 PST Wednesday March 24
22 Sol 81 09:40:14 PST Thursday March 25	23 Sol 82 10:19:50 PST Friday March 26	24 Sol 83 10:59:25 PST Saturday March 27	25 Sol 84 11:39:00 PST Sunday March 28	26 Sol 85 12:18:35 PST Monday March 29	27 Sol 86 12:58:11 PST Tuesday March 30	28 Sol 87 13:37:46 PST Wednesday March 31

FIGURE 4. Darian Calendar Display, 210 Aquarius.

of Earth days in a Martian year, 686.98. The Julian Day for 6 May 1992 12:00 GMT was 2,248,749, so the correct Levitt year was 3564. Levitt mentioned in his May 1954 *Sky and Telescope* article that the current Martian year was 3641; however, 1 January 1954 was JD 2,434,379, and dividing this number by 686.98 yields the year 3544. Where did Levitt go wrong? He divided the Julian Day by the number of Martian sols in a Martian year (his *Sky and Telescope* article and the section on Martian time in his 1956 book give the same calculation). This is dimensionally incorrect, and doing so told him that it was the year 3641 on Mars. He was nearly a full Martian century off in his calculations.

Kim Stanley Robinson's 1993 novel *Red Mars* also outlines a 24-month Marian calendar, which he probably developed independently of my work. In Robinson's calendar, the year begins on the fictional date of the first human landing on Mars, and the 27-sol months occur at the end of each trimester (every eighth month), with no provision mentioned for the leap sol. The names of the months are simply duplicated from the Gregorian calendar: 1 January, 2 January, 1 February, 2 February, et cetera. However, the design of a Martian calendar is not central to Robinson's work of fiction, so he provides few other details.

Josef Šurán published his article, "A Calendar for Mars," in the peer-reviewed journal *Planetary and Space Science* in 1997. As with Robinson's calendar, this was probably developed independently of the Darian calendar. Šurán's calendar year begins on the northern hemisphere's winter solstice. In the leap sol/skip sol version, his months all contained 28 sols, except for the 12th month, which contained only 21 sols. His calendar included an epagomenal sol (i.e., not counted as one of the seven sols of the week) at the end of each quarter, with the sol at the end of the year being a leap sol. The calendar is thus perpetual, with each year beginning on the first sol of the week. The ten-year intercalation sequence is the same as the Darian calendar; however, further adjustment occurs on a 160-year cycle rather than a 100-year cycle. In the leap week/skip week version, an epagomenal week is added to the 12th month in leap years, which occur every even-numbered year and in the year before those divisible by 70. These leap-year cycles, being based on numbers other than centuries, are certainly are less convenient; moreover, there is no discussion of the secular change in the length of the Martian year, so the claims he makes for the accuracy of his calendar is invalid.

Miguel Angel Serra Martín published his two Martian calendars on the World Wide Web in 1997. The first option is a 12-month calendar, similar to Levitt's. The second option is a 24-month calendar beginning on the northern hemisphere's winter solstice. All months contain 28 sols except that the last month contained 25

sols in common years and 28 sols in leap years, which occur every five years. This was probably developed independently of the Darian calendar. Unfortunately, his calendar contains 669.6 days, which is the number of sidereal revolutions, not solar days, in a Martian year.

While a cadet at the United States Air Force Academy in 1997, Mickey D. Schmidt outlined a calendar similar to the Darian but independent of it. It uses a different intercalation scheme (involving both 670-sol and 671-sol leap years, rather than only one type of leap year), and does not have a defined epoch. The months of the year and the sols of the week are unnamed. The intercalation formula is 2 * Y\5 + Y\300 - Y\6000 - Y\36000.

William Woods' 1997 calendar is an independent development of the Darian calendar. It uses the same pattern of 27-sol and 28-sol months; however, all weeks contain seven sols, making the calendar non-perpetual. Also, the calendar year begins 77 days after the summer solstice, instead of on the vernal equinox, and the intercalation formula is Y\5 + (Y-2)\5 + (Y-4)\5 - Y\100 + Y\500. Finally, the calendar uses an alternative system of month and sol names.

In 1998, Anton Sherwood outlined four 24-month Martian calendars. Three of them reflected to varying extents the asymmetry of the Martian seasons. Variant C, which was developed independently of the Darian calendar, is similar to it in structure; however, the 27-day months and the leap sol are placed differently. The months are unnamed, and there is no mention of a weekly cycle. Sherwood specified neither an intercalation formula nor an epoch.

In 1998, Bill Hollon, who is well-versed in the many calendars of Earth and their history, independently created a Martian calendar that was structurally identical to the Darian calendar, with the exceptions that no epoch is specified and that in place of an intercalation formula, leap years are to be determined each year by astronomical observation. Hollon does not name all of the months, but suggests that they be "named in alpha sequence from Aldrin thru Zubrin."

The Darian calendar became available on the World Wide Web in 1997. Within a few years, other authors created nomenclatural variants of it. Alan Hensel suggested a new system for naming the months. Shaun Moss created a new set of names for the sols of the week, which became the basis for the timekeeping system used in Scott Davis' Mars Simulation Project. Meanwhile, Frans Blok suggested a new naming system for both the months and the sols.

Leon Heron's 2001 variant of the Darian calendar suggests yet another nomenclature scheme. It also moves the leap sol to the third month, with the other 27-sol months being the 9th, 15th, and 21st. The beginning of the calendar year is specified to be "at a point in Mars's orbit so that the seasons on Mars occur (approximately) during the same months as they do on Earth." In 2001, Moss led a group of people who were interested in developing a common Martian calendar for three different websites, "VirtualMars," "The Republic of Mars," and "Martian Dreams (Naughton and O'Meara 2001)." The Mars Time Group developed a calendar, called the Utopian, that is structurally identical to the Darian calendar, with the exceptions that they adopted the Telescopic epoch, and rather than having 27-sol months at the end of each quarter, the group decided to have the last month of the year contain 24 or 25 sols (with the last week of the year comprising only three or four sols). The Mars Time Group also developed a nomenclatural schema distinct from the Darian calendar. While the group's effort was independent of the Darian calendar, the final result is not a great departure from Moss' Areosynchronous nomenclatural variant of the Darian calendar. However, this attempt at a common solution was not entirely successful. The "Martian Dreams" website opted for a calendar with 27-sol months spread evenly throughout the year, as in the Darian calendar, but with different names for the months and sols from either the Darian or Utopian schemata. The "Martian Dreams" site's calendar also increments the year count on the terrestrial rather than the Martian annual cycle, which means that the number of the year change once or twice during the Martian year, and the dates on which these changes occur vary from year to year. The "Republic of Mars" website never implemented either calendar and eventually disappeared from the Web, leaving "VirtualMars" as the only site featuring the Utopian calendar.

In a subsequent effort to achieve a common Martian calendar, the Darian and Utopian calendars each made a change in 2002. The Darian calendar adopted the Telescopic epoch, which is the Martian vernal equinox that occurred on 1609 March 11. The Utopian calendar switched to the equal-quarter scheme, with 27-sol months at the end of each quarter (Shaun Moss has since renamed it the Kepler calendar). These mutual changes brought the two calendars into structural alignment, with the only remaining differences being nomenclatural. Other users of the Darian calendar have been notified of the change.

I created the Martiana variant to the Darian calendar in 2002. The Martiana scheme avoids the Darian calendar's need to shorten the week to six sols three to four times per year. The disadvantage is that the scheme results in a two-year cycle for reconciling the sols of the week and the months, whereas the Darian calendar is repeatable from month to month. So far, there has been no popular support for this alternative intercalation method either in discussions in the Martian Time Virtual Conference or in responses to the Martian Time Survey (Gangale 2004; Gangale and Dudley-Rowley 2006), and the Darian calendar, incorporating the Telescopic epoch and including the various alternative nomenclatural schemata, remains the preferred solution.

Terry Phelan's 2002 Chromium calendar, like the 2001 Utopian calendar, has the last month of the year containing 24 or 25 sols. The other 23 months have 28 sols. The last month has only three weeks, and the last three of four sols are epagomenal. The calendar begins on the summer solstice, and the intercalation formula is (Y-1)\2 + Y\10 - Y\100. The months are named for the first 24 elements of the periodic table.

In 2003, Rachel Ann Welton developed a Martian calendar independently of the Darian for a science fiction novel. The first 12 months have Roman names, and the names of the last 12 are abbreviated Roman names with the prefix "tu-". The second month (February) contains 27 sols, while the 14th month (Tufeb) contains either 26 or 28 sols. The intercalation formula is 2*Y\3 + Y\45. The calendar is mistakenly based on the number of Martian sidereal days in a Martian year, and there is no mention of a weekly cycle.

The Martian business calendar developed by Bruce Mills in 2005 eschews epagomental sols as being "unacceptable to Jews, Christians and Muslims because it interrupts the cycle of the seven-day week." Instead, Mills opted for a leap week solution similar to Šurán's. The leap week occurs at the end of the 24 month, which can contain either 21 or 28 sols. There are 39 long years in each 76-year cycle. The calendar uses the Telescopic epoch. The names of the month are derived from Woods' schema.

CONCLUSION

In the twentieth century, the Gregorian calendar has achieved a distinction that is unique in human history. While several other calendars continue to be practiced in various parts of the world in order to maintain religious and cultural traditions, for civil functions the Gregorian calendar has become the universal calendar for humankind. However, with the coming colonization of the Solar System in the next century, the Gregorian calendar's monopoly on civil timekeeping will come to an end. On some of the new worlds it will be reasonable to ignore the local astronomical cycles as being useless for regulating human biological and social rhythms, and on such planets the use of Universal time and the Gregorian calendar can be maintained. But on Mars the need for a new convention of timekeeping is compelling, and there is a body of literature by dozens of authors that addresses this issue.

In addition to being based on the two natural cycles of Mars--its periods of rotation and revolution--the Darian calendar incorporates two social units of time--the week and the month. The Darian month of 28 sols is approximately the same duration as the human menstrual cycle, a natural unit of time.

The Darian calendar for Mars combines the advantages of the two major proposals for calendar reform here on Earth in the 20th century, the World calendar and International Fixed calendar:

- Every common year is the same, and every leap year is the same (World calendar and International Fixed calendar).
- To within one sol, each year divides evenly into halves, thirds, quarters, sixths, and twelfths, while simultaneously into an integral number of months (World calendar). Additionally, it divides into eighths. This is an important consideration, since an eighth of a Martian year approximates a quarter of an Earth year. As we all know, corporations issue financial reports on a quarterly basis, and one can predict that the emerging Martian economy will closely follow terrestrial financial practices in order to attract investment capital.
- The quarters are equal in common years and contain an integral number of months (World calendar). Each has exactly 167 sols, 24 weeks or 6 months. The quarters are identical in form with the week at the end of each quarter truncated to six sols.
- Each month begins on the first sol of the week (International Fixed calendar).
- The leap sol occurs at the end of the year (International Fixed calendar).

Far more than any other Martian calendar proposal, the Darian calendar has been both unconsciously repeated and consciously imitated by numerous authors, plus it has been cited by still other authors. Additionally, most of the structural features of the Darian calendar have consistently scored high in the Martian Time Survey. The following list shows the preferences for features of the Darian calendar over the nearest competing option:

- A 7-day week (6 to 1).
- 24 equal-duration months, nominally 28 days each (4 to 1).
- A 668-day non-leap year and a 669-day leap year (7 to 1).
- A leap-year pattern of odd-numbered years plus decennial years (6 to 1). A leap day added at the end of the year (7 to 1).
- A perpetual calendar with an integral number of weeks per month (2 to 1).
- Begin using a Martian calendar now rather than wait for a future event (1.7 to 1).
- Increment the numerical year on the Martian cycle (14 to 1).
- Begin the calendar year on the northern hemispheric vernal equinox (4 to 1).

Some have cautioned against the adoption of a Martian calendar any time soon, preferring instead to leave this decision to the Martians. Well, *we* are the Martians, aren't we? If a future generation of Martians determines that it is in their interest to modify a Martian calendar that was developed and adopted on Earth, or to adopt an entirely new calendar, they will certainly feel free to do so. Meanwhile, the decision is ours now. We know

enough about the astronomical cycles of Mars and the societal requirements for a calendar to make a pretty good stab at it. Furthermore, I assert that the necessity to move forward far outweighs any arguments to hold back.

The enterprise of sending human expeditions to Mars and of permanently settling that planet will obviously require broad political support among many nations, sustained over several decades. I believe that the early institution of a Martian calendar will serve a significant political and social purpose as a symbol of the human commitment to establish a permanent presence on that new world in the coming decades. Mars will become more of a *human* place in the public imagination as familiar human references are adapted for that planet. The realization will become more widespread that the concept of colonies on Mars is transitioning from the realm of science fiction to that of imminent accomplishment. Although much engineering development remains to be done before the first human landing can be achieved, the process of humanizing Mars and laying the foundation for a new culture can and should begin now. The early promulgation of a human-oriented Martian calendar can be a symbol of a spreading awareness that human beings will not be going to Mars merely as visitors, but that we are going there with every intention of staying, putting down our roots, and flourishing on that new world.

REFERENCES

1. Aitken, Robert G. 1936. "Time Measures on Mars." *Astronomical Society of the Pacific Leaflets,* December. Internet. Available from http://pweb.jps.net/~gangale3/other/aitken_frm.htm; accessed 20 June 2005.
2. Allison, Michael. 2001. "What is a 'Year' (on Earth or Mars)?" Internet. Available from http://pweb.jps.net/~gangale3/other/allison2_frm.htm; accessed 20 June 2005.
3. Davis, Scott. 1999. "Mars Simulation Project - User Guide." Internet. Available from http://mars-sim.sourceforge.net/timetool.html; accessed 1 August 2003.
4. Gangale, Thomas. 1986. "Martian Standard Time." *Journal of the British Interplanetary Society,* June. Internet. Available from http://www.geocities.com/SoHo/Museum/5192/mst.html; accessed 20 July 2003.
5. Gangale, Thomas. 1988. "The Lost Calendars of Mars." *Spaceflight,* July. Internet. Available from http:www.martiantime.net/mst/ Lost_Calendars.htm; accessed 20 June 2005.
6. Gangale, Thomas. 1989. "Martian Daylight Time." *Journal of the British Interplanetary Society,* pp. 337-340. Internet. Available from http:www.martiantime.net/mst/daylight.htm; accessed 20 July 2003.
7. Gangale, Thomas. 1997. "Mare Chronium: A Brief History of Martian Time." AAS 90-287. Presented at The Case for Mars IV Conference, University of Colorado, Boulder, Colorado, June 4-8, 1990. In *The Case for Mars IV: The International Exploration of Mars,* ed. Thomas R. Meyer. San Diego. Univelt, Incorporated. Internet. Available from http://www.martiantime.net/mars/chronium/chronfrm.htm; accessed 20 July 2005.
8. Gangale, Thomas. 1998. "The Calendars of Jupiter." Internet. Available from http:www.martiantime.net/jupiter/jupifrm.htm; accessed 30 June 2005.
9. Gangale, Thomas. 2004. "Preference Patterns for Martian Time Architecture." Internet. Available from http://pweb.jps.net/~md-r/ps2/Gangale_PLSI493_Final.pdf; accessed 24 January 2005.
10. Gangale, Thomas, and Marilyn Dudley-Rowley. 2002. "The Martian Time Poll: One Martian Year of Data." Presented at the Third International Convention of the Mars Society, Ryerson University, Toronto, Ontario, August 10-13, 2000. In *On to Mars: Colonizing a New World,* ed. Robert Zubrin and Frank Crossman. Burlington, Ontario: Apogee Books. Internet. Available from http:www.martiantime.net/MartianTimePoll/; accessed 20 July 2005.
11. Gangale, Thomas, and Marilyn Dudley-Rowley. 2003. "Bad Time on Mars." Internet. Available from http://www.martiantime.net/mars/mst/bad_time.htm; accessed 4 January 2006.
12. Gangale, Thomas, and Marilyn Dudley-Rowley. 2004. "The Architecture of Time: Design Implications for Extended Space Missions." SAE 2004-01-2533. Presented at the 34th International Conference on Environmental Systems. Colorado Springs, Colorado, 19 July 2004. In *SAE Transactions: Journal of Aerospace,* 2005.
13. Gangale, Thomas, and Marilyn Dudley-Rowley. 2005. "Issues and Options for a Martian Calendar." *Planetary and Space Science,* December 2005.
14. Gangale, Thomas, and Marilyn Dudley-Rowley. 2006. "The Social Construction of Time for Mars: Results of Martian Time Survey v1.0 and v2.0-2.2 Compared." American Institute of Aeronautics and Astronautics. Space 2006. San Jose, California. 20 September. Internet. Available from http://pweb.jps.net/~gangale4/MartianTimeSurvey2/index.htm; accessed 20 June 2005.
15. Heinlein, Robert A. 1949. *Red Planet.* New York: Charles Scribner's Sons. Internet. Excerpt available from http://pweb.jps.net/~gangale3/other/heinlein.htm; accessed 20 June 2005.
16. Heron, Leon G. 2001. "An Easily Understood Calendar and Time System for Mars." Internet. Available from http://pweb.jps.net/~gangale3/other/heron.htm; accessed 20 June 2005.
17. Levitt, I. M. 1954. "Mars Clock and Calendar." *Sky & Telescope,* May. Internet. Available from http://pweb.jps.net/~gangale3/other/levitt_frm.htm; accessed 20 June 2005.
18. Mackenzie, Bruce A. 1989. "Metric Time for Mars." In *The Case for Mars III: Strategies for Exploration,*

ed. Carol Stoker. San Diego: Univelt, Inc. Internet. Available from http://pweb.jps.net/~gangale3/other/mcknzfrm.htm; accessed 20 June 2005.
19. Meeus, Jean. 1995. *Astronomical Tables of the Sun, Moon, and Planets.* Wilmann-Bell, Richmond.
20. Mills, Bruce. 2005. "The Martian Business Calendar." Internet. Available from http://members.ozemail.com.au/~starmouse/calendar/MarsCalendar.htm; accessed 8 April 2005.
21. Moss, Shaun. 1999. "The Areosynchronous Calendar." Internet. Available from http://pweb.jps.net/~gangale3/Virtual_Mars/Calendar.asp; accessed 20 June 2005.
22. Moss, Shaun, et al. 2001. "The Utopian Calendar." Internet. Available from http://pweb.jps.net/~gangale3/Utopian_Calendar/index.asp; accessed 20 June 2005.
23. Naughton, Linda, and Robert O'Meara. 2001. "Martian Dreams Time System." Internet. Available from http://www.martiandreams.com/mush/articles/time.shtml; accessed 20 July 2003.
24. Phelan, Terry. 2002. "Elemental Martian Calendars." Internet. Available from http://pweb.jps.net/~gangale3/other/phelan.htm; accessed 20 June 2005.
25. Robinson, Kim Stanley. 1993. *Red Mars.* New York: Bantam Books. Internet. Excerpt available from http://pweb.jps.net/~gangale3/other/robinson.htm; accessed 20 June 2005.
26. Schmidt, Mickey D. 1997. "Martian Clock and Calendar." Internet. Available from http://pweb.jps.net/~gangale3/other/schmidt.htm; accessed 20 June 2005.
27. Sherwood, Anton. 1998. "Martian Calendar." Internet. Available from http://pweb.jps.net/~gangale3/other/sherwood.htm; accessed 20 June 2005.
28. Serra Martín, Miguel Angel. 1997. “Calendario en Marte.” Internet. Available from http://www.mallorcaweb.net/masm/CALMAR.htm; accessed 20 July 2003.
29. Šurán, Josef. 1997. "A Calendar for Mars." *Planetary and Space Science,* Vol. 45, No. 6, pp. 705-708. Internet. Available from http://pweb.jps.net/~gangale3/other/suranfrm.htm; accessed 20 June 2005.
30. Weidner, Richard. 1999. “A Mars Calendar.” Internet. Available from http://pweb.jps.net/~gangale3/weidner/index.html; accessed 20 July 2003.
31. Welton, Rachel Ann. 2004. "Martian Calendar for SHARDS Universe." Internet. Available from http://shardsuniverse.net/calendar.htm; accessed 24 January 2005.
32. Woods, William. 1997. "Options for Martian Timekeeping." Internet. Available from http://pweb.jps.net/~gangale3/other/woodsfrm.htm; accessed 20 June 2005.
33. Zubrin, Robert. 1993. "A Calendar for Mars." *Ad Astra,* November/December. Internet. Available from http://www.harborcom.net/~jroche/Zubrin.html; accessed 20 June 2005.

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APPENDIX 1. INTERCALATION PRECISION FOR MARS.

Having addressed the accuracy of the Darian calendar's intercalation formulae, let's now take a look at its precision. It must be said up front that precision was not a criterion in developing the intercalation scheme. Rather, the scheme emphasizes simplicity and accuracy; an algebraic expression containing only four terms ((Y-1)\2 + Y\10 - Y\100 + Y\1000) results in an accuracy of one sol over several thousand years. Referring to FIGURE A1-1, one can see that in the year 200, the vernal equinox occurs on the numerical date 1.12673, which corresponds to early on the evening (03:02:29 to be precise) of the first sol of the calendar year, 200 Sagittarius 01. The year 200, being a centennial year, contains 668 sols, whereas the vernal equinox year is 668.5907 sols. This has the effect of causing the next vernal equinox (beginning the year 201) to occur a fraction of a sol later in the next calendar year, at 16:49:08 on 201 Sagittarius 01. The year 201, being odd-numbered, is a leap year, so the next vernal equinox (beginning the year 202) occurs earlier on the next Sagittarius 01, at 07:31:51. The year 202, being even-numbered, contains 668 sols, so the vernal equinox beginning the year 203 occurs at 21:28:18 on Sagittarius 01. The problem is that one can only either push the vernal equinox back relative to the calendar 0.5906 sols or advance it by 0.4094 (1 - 0.5906) sols. The combined effect in a two-year period is for the equinox to slip further into the calendar year by 0.1812 (0.5906 - 0.4094) sols. As a result, in the year 205 the equinox occurs at 01:38:03 on Sagittarius 02. The equinox occurs on Sagittarius 02 in the years 207 and 209 as well. At this point, three successive leap years bring the vernal equinox to the morning of Sagittarius 01 in the year 212, then the decade-long cycle begins again. In the course of a decade, the combined fluctuation in the time of the vernal equinox comes to 1.1342105 sols. This makes it impossible to keep the vernal equinox on the same date. Moreover, the result of the decennial cycle is to advance the equinox by -0.094 sols (4 * 0.5906 - 6 * 0.4094), causing it to occur progressively earlier in the calendar year. In fact, in the year 242, the vernal equinox occurs a few hours before the end of the calendar year, at 21:32:02 on 241 Vrishika 28. The year 249 is the last time in the third century that the vernal equinox occurs on Sagittarius 02, but as the century advances, the vernal equinox occurs on Vrishika 28 with increasing frequency. However, for most of the third century (75 years), the vernal equinox occurs on the first sol of the calendar year, Sagittarius 01. The vernal equinox occurs on Sagittarius 02 ten times, and on Vrishika 28 fifteen times.

A slightly more complicated intercalation scheme can reduce the wandering of the vernal equinox across the calendar, but not by much. In the Darian intercalation scheme, three successive leap years bracket the decennial years. Using a five-year cycle, in which there are never more than two successive leap years, one can decrease the total travel of the vernal equinox relative to the calendar date. This scheme can be algebraically expressed as Y\5 + (Y-1)\5 + (Y-3)\5, i.e., the leap years are the 0th, 1st, and 3rd, compared with the Darian calendar's cycle of odd-numbered years and decennial years, (Y-1)\2 + Y\10. The total fluctuation of the vernal equinox in the quintennial intercalation scheme during the course of the century is 1.7104 sols, which is not a lot better than the total travel of 1.9789 sols to which the Darian calendar restricts the vernal equinox. This slightly better precision does not guarantee better performance in any given century however. Referring to FIGURE A1-2, it happens that the vernal equinox occurs on the first day of the calendar year only 71 times (the equinox

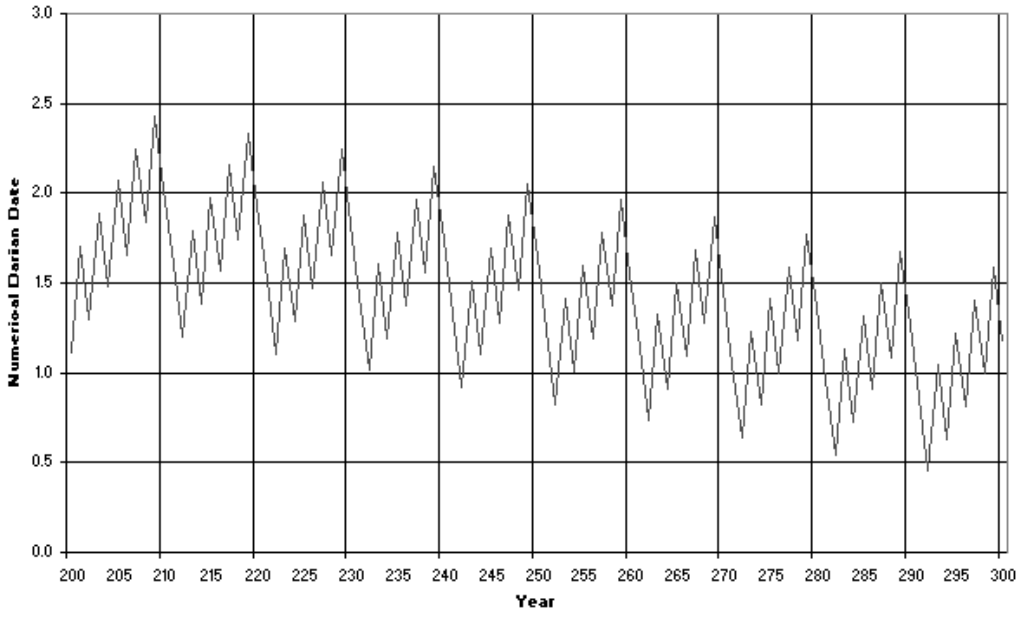

FIGURE A1-1. Precision of the Darian Calendar in the 3rd Century.

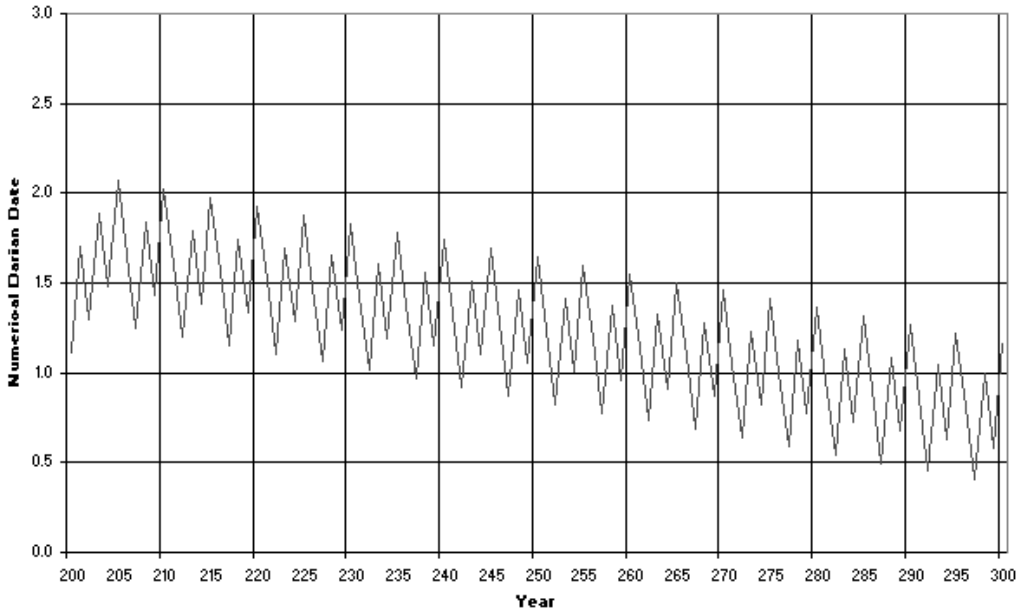

FIGURE A1-2. Precision of a Five-Year Intercalation Cycle in the 3rd Century.

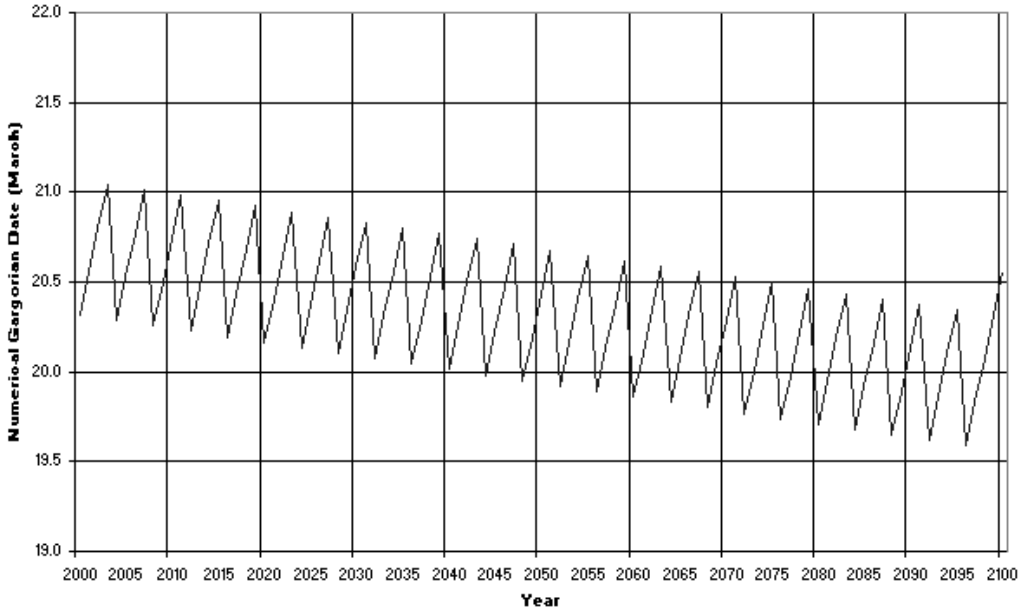

FIGURE A1-3. Precision of the Gregorian Calendar in the 21st Century.

occurs on the first day of the calendar year only 71 times (the equinox occurs twice on Sagittarius 02 and 27 times on Vrishika 28), actually fewer times than using the Darian decennial intercalation formula.

In comparison, the vernal equinox shifts 1.4568 days in a century on the Gregorian calendar. In the 21st century, for instance (FIGURE A1-3), the vernal equinox occurs as early as March 19 and as late as March 21.

Both the decennial and quintennial Martian schemes need to subtract a leap day every century. Comparing FIGURE A1-4 and FIGURE A1-5 shows that over a 500-year period, both of the schemes allow the vernal equinox to occur on the three different calendar dates previously mentioned.

The Gregorian calendar also eliminates one leap day every one hundred years, but then adds the subtracted centennial leap day ever four hundred years. As a result, the 20th century began with the vernal equinox occurring as late as March 22, while the 21st century will end with the vernal equinox occurring as early as March 19 (FIGURE A1-6). During this period, the vernal equinox takes place on four distinct dates, with a total travel of 2.2168 days.

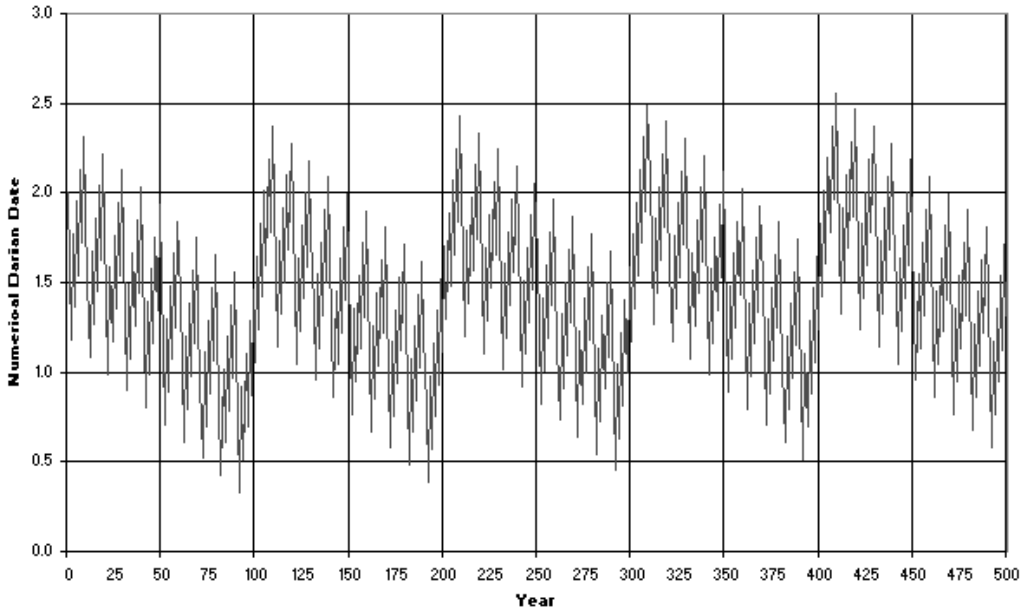

FIGURE A1-4. Precision of the Darian Calendar, Years 0 to 500.

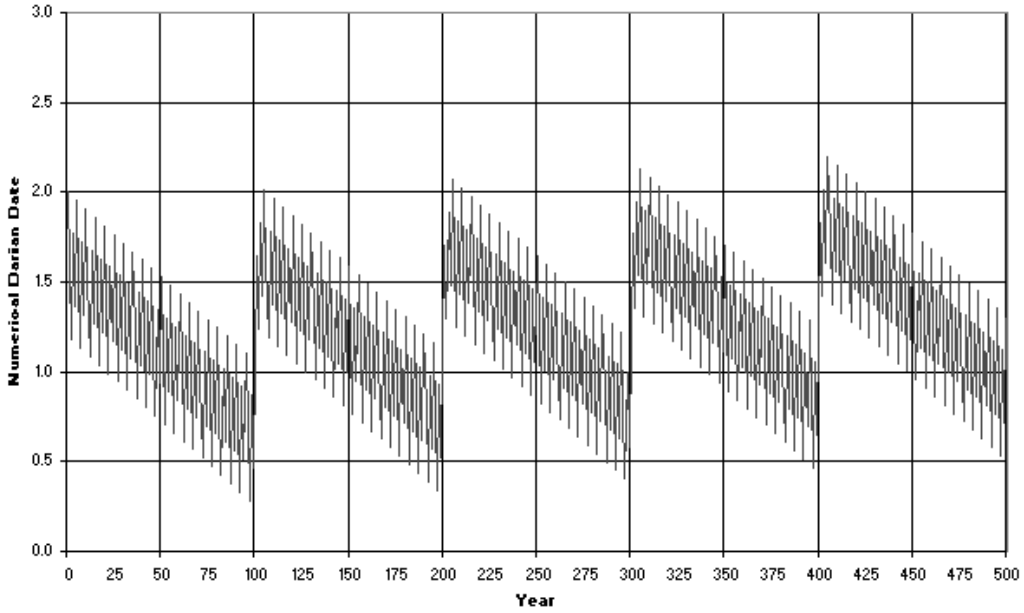

FIGURE A1-5. Precision of a Five-Year Intercalation Cycle, Years 0 to 500.

The Gregorian calendar also eliminates one leap day every one hundred years, but then adds the subtracted centennial leap day ever four hundred years. As a result, the 20th century began with the vernal equinox occurring as late as March 22, while the 21st century will end with the vernal equinox occurring as early as March 19 (FIGURE A1-6). During this period, the vernal equinox takes place on four distinct dates, with a total travel of 2.2168 days.

An intercalation scheme developed by Richard Weidner that guarantees the occurrence of the vernal equinox on the first sol of the calendar year is far more complex, and is probably too unwieldy to gain wide acceptance for civil use. While it is important that the seasons not drift unchecked in relation to the calendar, variations of a sol one way or the other is of little consequence to most people. Thos who need greater accuracy than that provided by a civil calendar would refer to ephemerides in any case.

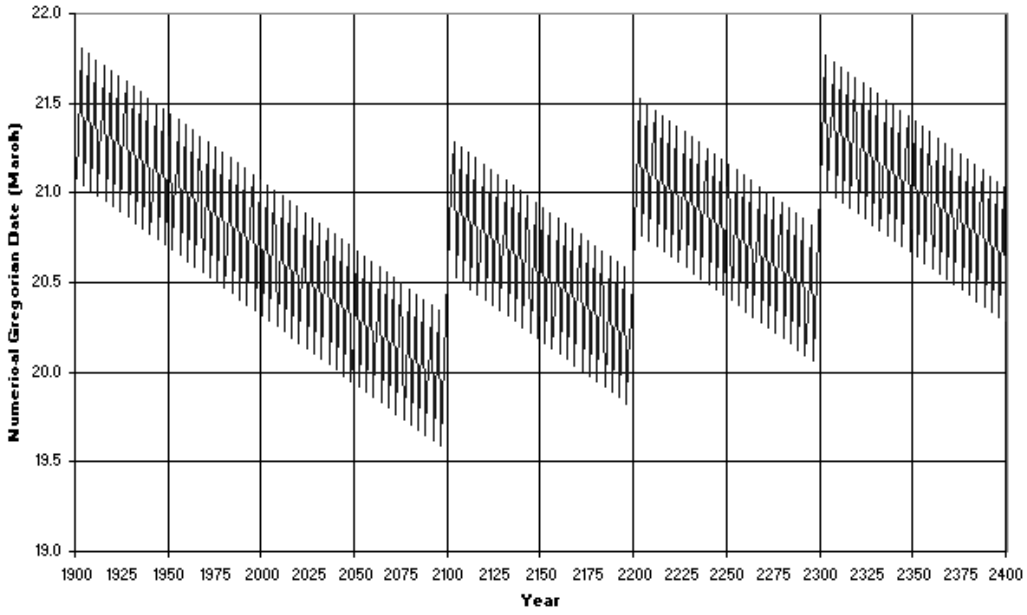

FIGURE A1-6. Precision of the Gregorian Calendar, Years 1900 to 2400.

APPENDIX 2. MARTIAN DAYLIGHT TIME.

(Updated from Gangale 1989)

The eccentricity of Earth's orbit and the inclination of its spin axis to the plane of its orbit affect the apparent motion of the Sun along Earth's ecliptic and cause annual -variations in the correlation of Solar time to mean time. The sum of these effects constitute Earth's equation of time, shown in FIGURE A2-1. With a Martian calendar now fully developed, it may now be considered how the slightly greater inclination of Mars' axis and the far greater eccentricity of its orbit would affect sundials on Mars. FIGURE A2-1 also depicts the Martian equation of time and its two components. Solar time agrees with mean time on approximately Aquarius 07 (Sol 119) and Simha 16 (Sol 490). A Martian sundial will read about 39.5 minutes slow on Mithuna 21 (Sol 383) and approximately 52.5 minutes fast on Tula 28 (Sol 613).

Perhaps sundials will never be in vogue on Mars, and there will obviously be far more practical and accurate instruments for timekeeping on that world. However, during the Mars Exploration Rover missions *Spirit* and *Opportunity* in 2004-2006, mission clocks operated on local solar time rather than local mean time, and it is the variation between the two that the equation of time displays. Also, one of the calibration targets for the imaging system was a sundial (FIGURE A2-2). While it is quite likely that early Martian technology will require that colonies be built below the surface, the Martians will surely move to the surface of their world as soon as technology permits. Thus, the shape of the Martian equation of time raises interesting questions with regard to the need for seasonal adjustments to the setting of clocks in the Martian colonies.

Since Mars has an axial tilt comparable to Earth's, it also experiences changes in the duration of daylight throughout the year. This suggests that the periodic alternation between standard time and daylight time might be practiced in the Martian colonies, much as do many nations on Earth. Probably, since Mars is a much colder world than Earth, early Martian colonies will be clustered near the equator and the tropic circles. Just as in the tropics of Earth, the seasonal fluctuation in the length of day and night in minimal at these Martian latitudes. States situated in the tropical regions of Earth do not bother with daylight time for this reason, so one might deduce that this will be true on Mars as well.

It can be seen from FIGURE A2-1 that the effects of orbital eccentricity and axial inclination combine on Mars to produce a naturally occurring daylight time of up to 52 minutes in the southern hemisphere's summer and autumn. The reverse phenomenon happens during the other portion of the year, when solar time can be as much as 31 minutes ahead of mean time. To anyone who recalls the brief experiment with year-round daylight time by the US in the early 1970s, it is disturbing to realize that this natural Martian daylight time occurs during winter in the northern hemisphere. Equally so is the revelation that there is a natural reverse daylight

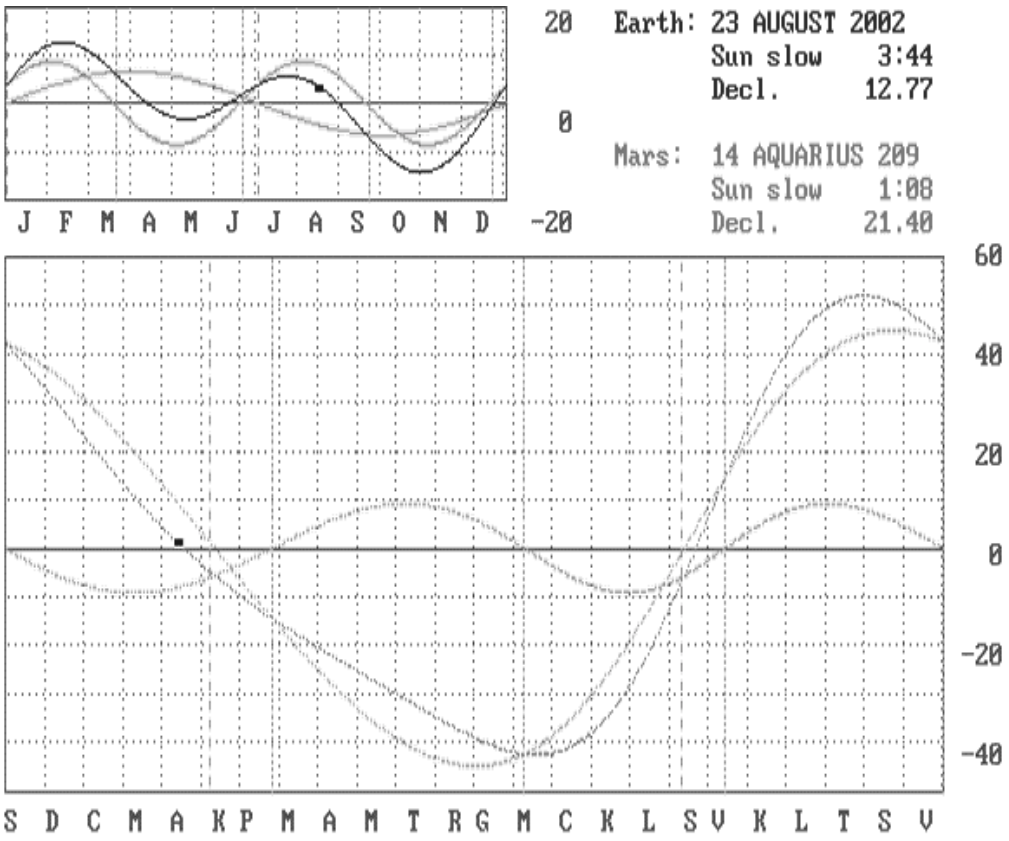

FIGURE A2-1. The Equations of Time for Earth and Mars.

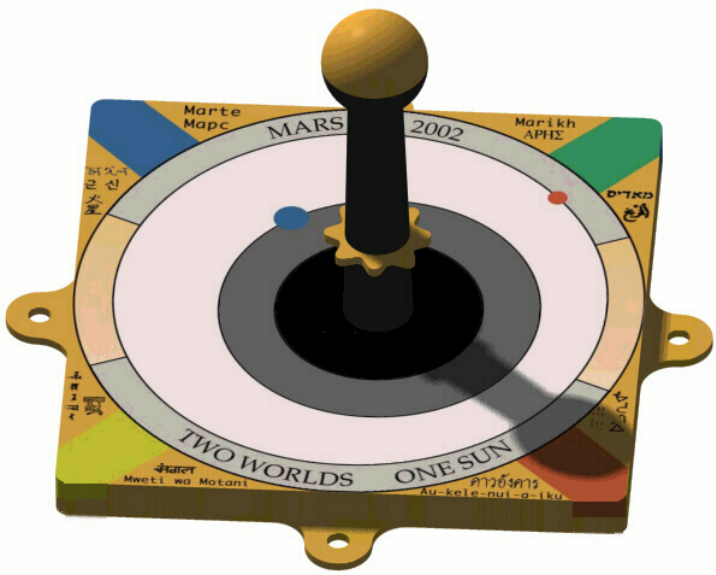

FIGURE A2-2. Mars Exploration Rover Sundial.

time in the northern hemisphere's summer. Based on these facts, the preliminary conclusion that, huddled between the tropic circles, the Martian colonies will have no need of a seasonal adjustment to their clocks, deserves to be examined in detail.

An alternate diagram to the equation of time is the analemma (FIGURE A2-3), which depicts the deviation of solar time from mean time along the x-axis, and the variation in the declination of the sun along the y-axis. Thus, it represents the figure of the sun's apparent motion from noon to noon throughout the year.

FIGURE A2-4 through FIGURE A2-7 depict deviations in the time of sunrise and sunset for various latitudes on Mars and Earth, throughout the year, from the average times of 06:00 and 18:00, respectively. One can see (FIGURE A2-4 and FIGURE A2-5) that the combination of the equation of time and the seasonal variation in the duration of daylight causes the hour of dawn to be more stable in the southern hemisphere of Mars for, as the period of daylight lengthens, solar time gets later with respect to mean time. The hour of dusk, however, fluctuates considerably more throughout the year in the Martian southern hemisphere. For example, FIGURE A2-4 shows that on Tropicus Virginis, the southern tropic circle of Mars, the Sun rises earliest at about 04:57 on Karka 23 (Sol 441) and rises latest on Capricornus 01 (Sol 57) at about 06:44, a variation of only 1h 47m. On the other hand, sunset on Tropicus Virginis varies from 16:51 on Aries 08 (Sol 231) to 19:26 on Libra 16 (Sol 573), a total fluctuation of 2h 35m. Meanwhile, in the northern hemisphere the situation is much the opposite in that the time of sunrise is more variable and that of sunset is more constant. On Tropicus Piscium, sunrise varies from as early as 04:51 on Aries 08 to as late as 07:26 on Libra 16 (a difference of 2h 35m) while sunset occurs at its earliest time at 16:57 on Karka 23 and at its latest on Capricornus 01 at 18:44 (a variation of only 1h 47m).

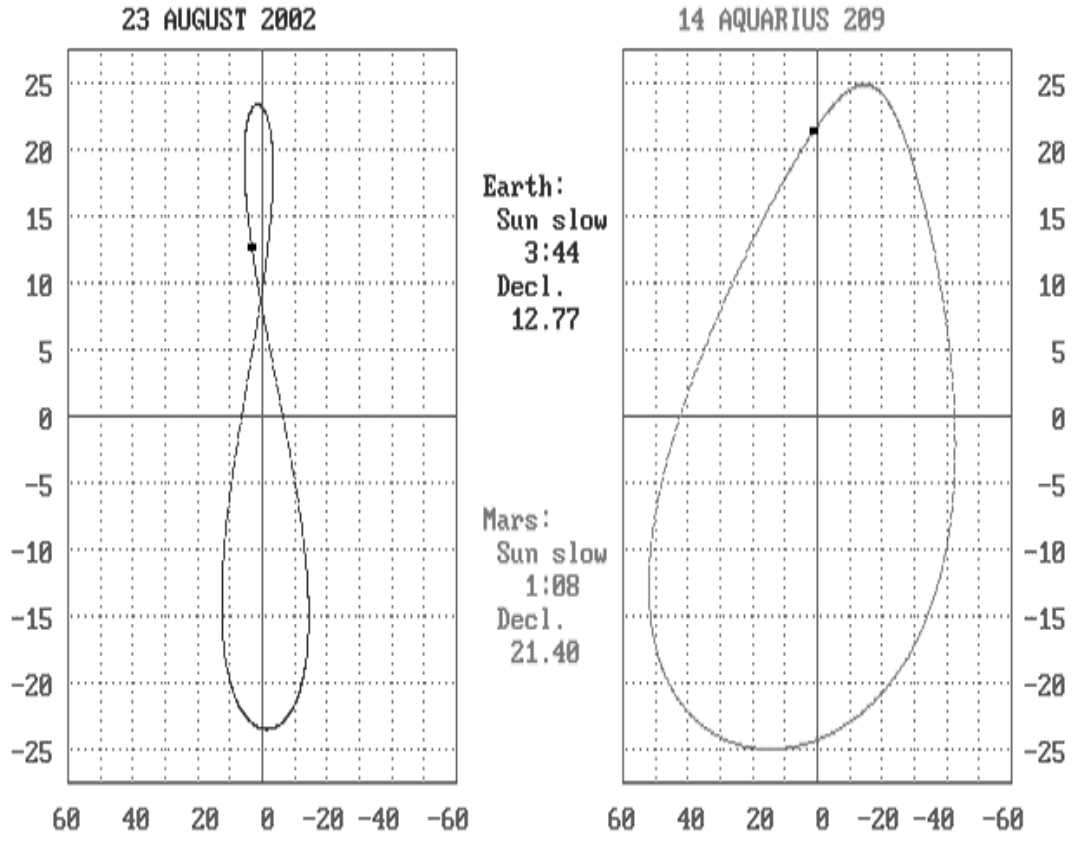

FIGURE A2-3. The Analemmas of Earth and Mars.

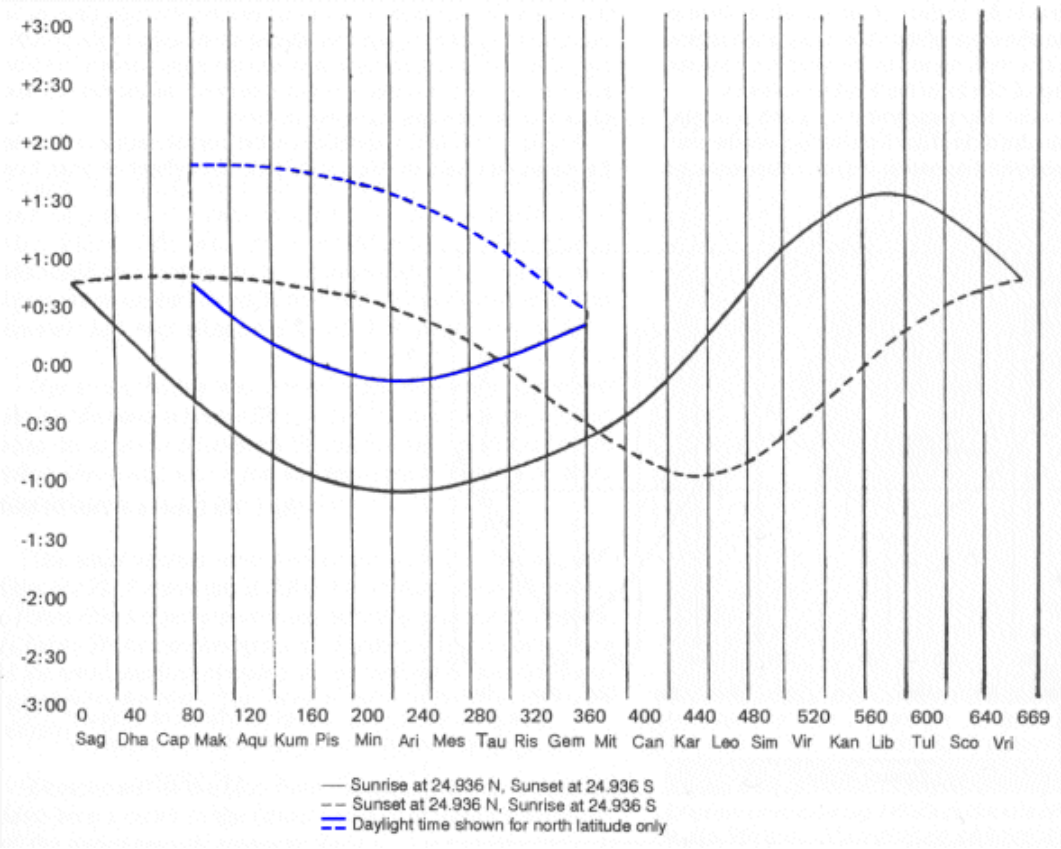

FIGURE A2-4. Variation in Times of Sunrise and Sunset, 24.936 Degrees Latitude, Mars.

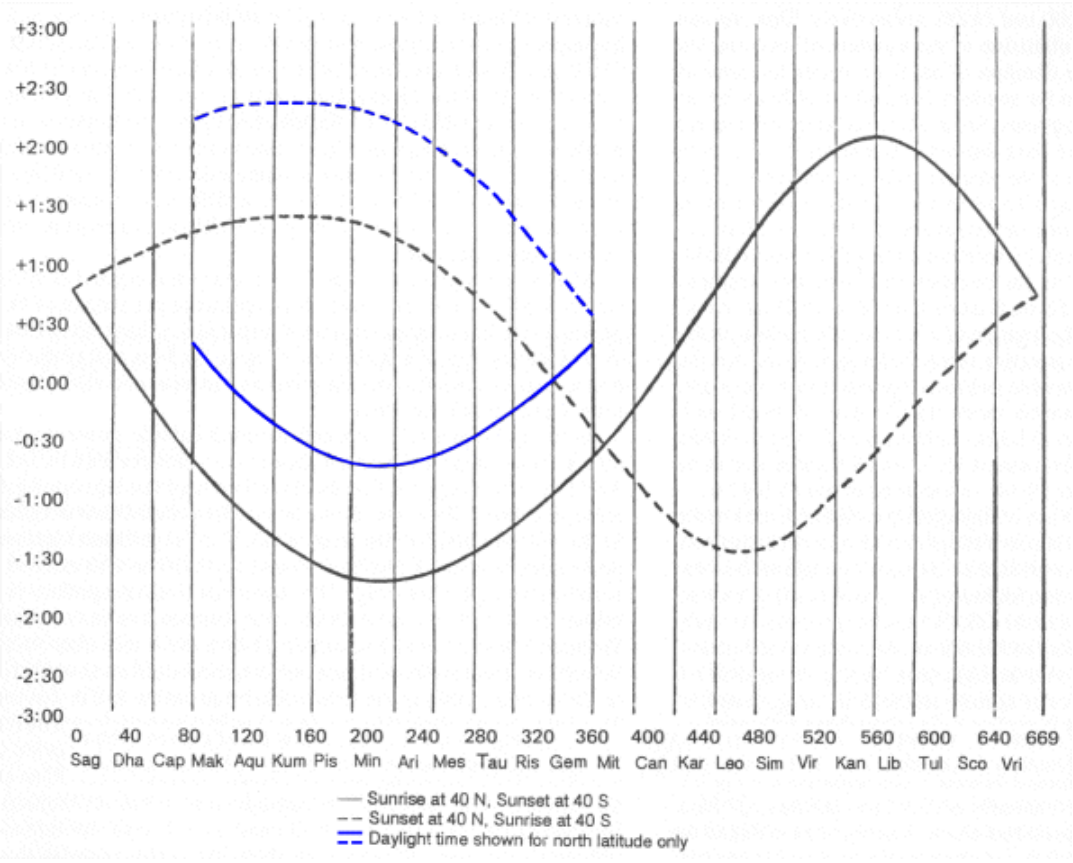

FIGURE A2-5. Variation in Times of Sunrise and Sunset, 40 Degrees Latitude, Mars.

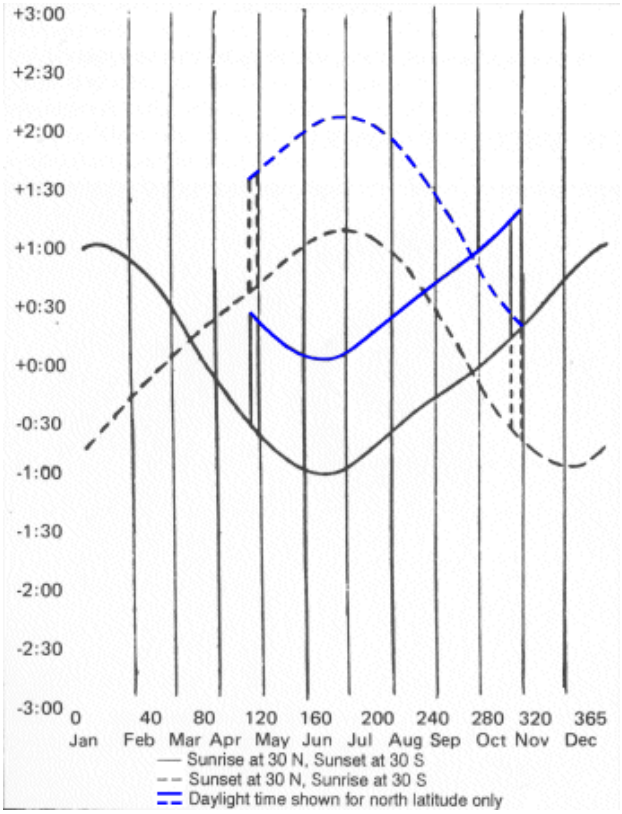

FIGURE A2-6. Variation in Times of Sunrise and Sunset, 30 Degrees Latitude, Earth.

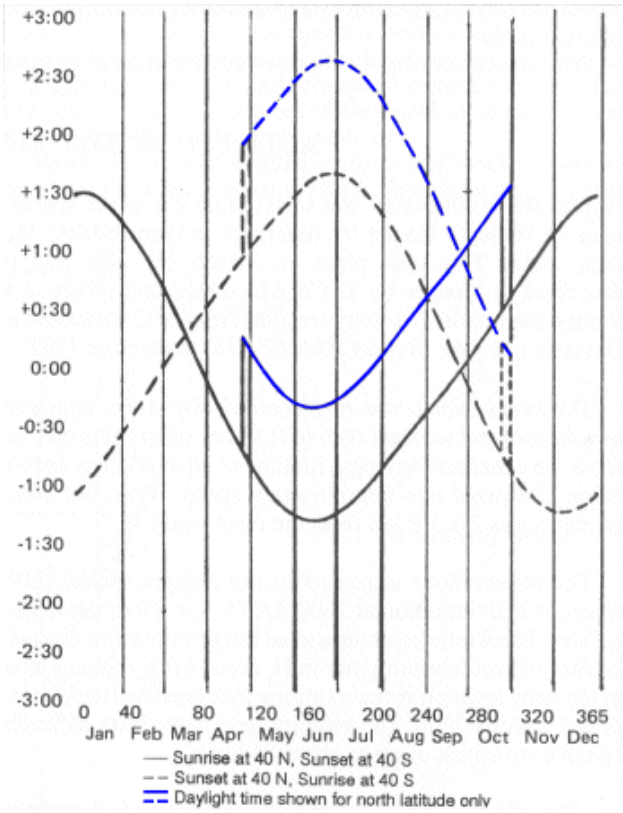

FIGURE A2-7. Variation in Times of Sunrise and Sunset, 40 Degrees Latitude, Earth.

The intent of the civil use of daylight time on Earth is to make the hour of sunrise more stable throughout the year. For instance, FIGURE A2-6 depicts how the time of sunrise changes throughout the year on Earth at 30° north latitude, including the seasonal adjustment of daylight time as observed in the USA. Of the contiguous states, only those on the coast of the Gulf of Mexico are this close to the equator; yet at this latitude, even with daylight time helping to stabilize the time of sunrise, it may occur as early as 05:18 in the last week of April and as late as 07:14 in the last week of October—a fluctuation of nearly two hours. FIGURE A2-7 shows the variation in the time of sunrise on the 40th parallel, a latitude more representative of the USA. Here the Sun may rise as early as 05:02 and as late as 07:28, a difference of nearly two and a half hours. Bearing in mind that some areas of the contiguous USA are nearly as far north as 50°, and that the 50th parallel cuts right through Western Europe, where a similar daylight time scheme is used, a variation of three hours serves as a reasonable benchmark for the maximum desirable change in the hour of sunrise.

In the case of Mars, FIGURE A2-5 shows the varying times of sunrise and sunset at 40° north and south latitude. At this latitude in the southern hemisphere, sunrise fluctuates from 04:25 on Leo 17 (Sol 463) to 07:19 on Kumbha 17 (Sol 154), a change of 2h 54m, and sunset varies from 16:10 on Mina 09 (Sol 204) to 20:01 on Kanya 28 (Sol 557), a difference of 3h 51m. As in the example of the tropic circles of Mars, the total change in time of sunrise and sunset are reversed at 40° north latitude, where dawn is at its earliest at 04:10 on Mina 09 and at its latest at 08:01 on Kanya 28, a difference of nearly four hours, and dusk varies from as early as 16:25 on Leo 17 to as late as 19:19 on Kumbha 17.

Martian demographics of the late 21st century and beyond is difficult to predict, but even if there is a significant percentage of the population living as far south as the 40th parallel, a fluctuation in the time of sunrise throughout the year of up to 2h 54m will probably be acceptable, as against inducing the complication of civil daylight time to reduce this variation.

Between Tropicus Piscium and 40° north latitude, however, the total annual change in the hour of dawn varies between 2h 35m and 3h 51m, which suggests that daylight time might be legislated for these latitudes if there is a sizable population located near or north of the 40th parallel. On the other hand, if the significant Martian population centers are confined to well south of the 40th northern parallel, daylight time might be dispensed with altogether. As shown in FIGURE A2-4, were daylight time to be instituted on and north of Tropicus Piscium from Makara 01 (Sol 85) to Gemini 28 (Sol 362), the earliest dawn on the northern tropic circle would occur at 05:17 on Gemini 28, limiting the total annual fluctuation to 2h 9m on Tropicus Piscium. Similarly, FIGURE A2-5 shows that the earliest sunrise on the 40th parallel of the northern hemisphere would take place on Makara 01 at

05:11, limiting the total annual variation to 2h 52m at this latitude. The institution of daylight time north of Tropicus Piscium from Makara through Gemini thus brings the annual change in the hour of sunrise to about the same value as that experienced below Tropicus Virginis.

APPENDIX 3. VERNAL EQUINOXES OF MARS.

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1874 May 25	16:33	2405668.690	141 Sagittarius 01	05:59	94272.250
1876 April 11	16:19	2406355.680	141 Vrishika 28	20:36	94940.859
1878 February 27	16:04	2407042.670	143 Sagittarius 01	11:13	95609.468
1880 January 15	15:23	2407729.641	144 Sagittarius 01	01:24	96278.058
1881 December 02	14:51	2408416.619	145 Sagittarius 01	15:44	96946.656
1883 October 20	13:52	2409103.578	146 Sagittarius 01	05:38	97615.235
1885 September 06	12:28	2409790.520	147 Sagittarius 01	19:08	98283.797
1887 July 25	12:04	2410477.503	148 Sagittarius 01	09:35	98952.400
1889 June 11	11:45	2411164.490	149 Sagittarius 02	00:08	99621.006
1891 April 29	10:42	2411851.446	150 Sagittarius 01	13:57	100289.582
1893 March 16	09:56	2412538.414	151 Sagittarius 01	04:03	100958.169
1895 February 01	09:46	2413225.407	151 Vrishika 28	18:45	101626.781
1896 December 19	08:28	2413912.353	153 Sagittarius 01	08:20	102295.348
1898 November 06	07:45	2414599.323	153 Vrishika 28	22:29	102963.937
1900 September 24	07:33	2415286.315	155 Sagittarius 01	13:09	103632.548
1902 August 12	06:48	2415973.284	156 Sagittarius 01	03:17	104301.137
1904 June 29	05:54	2416660.246	157 Sagittarius 01	17:15	104969.719
1906 May 17	05:26	2417347.227	158 Sagittarius 01	07:39	105638.319
1908 April 03	04:09	2418034.173	159 Sagittarius 01	21:15	106306.886
1910 February 19	03:31	2418721.147	160 Sagittarius 01	11:29	106975.479
1912 January 07	03:38	2419408.152	161 Sagittarius 01	02:27	107644.103
1913 November 24	03:05	2420095.129	161 Vrishika 28	16:46	108312.699
1915 October 12	01:56	2420782.081	163 Sagittarius 01	06:30	108981.271
1917 August 29	01:23	2421469.058	163 Vrishika 28	20:49	109649.868
1919 July 17	00:24	2422156.017	165 Sagittarius 01	10:43	110318.447
1921 June 02	23:06	2422842.963	166 Sagittarius 01	00:18	110987.013
1923 April 20	22:42	2423529.946	167 Sagittarius 01	14:45	111655.615
1925 March 07	22:27	2424216.936	168 Sagittarius 01	05:23	112324.224
1927 January 23	21:51	2424903.911	169 Sagittarius 01	19:39	112992.819
1928 December 10	21:11	2425590.883	170 Sagittarius 01	09:51	113661.410
1930 October 28	20:25	2426277.851	170 Vrishika 28	23:57	114329.998
1932 September 14	18:59	2426964.791	171 Vrishika 28	13:24	114998.559
1934 August 02	18:24	2427651.767	173 Sagittarius 01	03:41	115667.154
1936 June 19	18:15	2428338.761	173 Vrishika 28	18:24	116335.767
1938 May 07	17:26	2429025.727	175 Sagittarius 01	08:27	117004.353
1940 March 24	16:32	2429712.689	175 Vrishika 28	22:25	117672.935
1942 February 09	16:32	2430399.689	177 Sagittarius 01	13:16	118341.553
1943 December 28	15:23	2431086.641	178 Sagittarius 01	03:00	119010.126
1945 November 14	14:24	2431773.600	179 Sagittarius 01	16:54	119678.704
1947 October 02	14:11	2432460.591	180 Sagittarius 01	07:32	120347.315
1949 August 19	13:35	2433147.566	180 Vrishika 28	21:49	121015.909
1951 July 07	12:34	2433834.524	181 Vrishika 28	11:41	121684.487
1953 May 24	12:05	2434521.504	183 Sagittarius 01	02:04	122353.086
1955 April 11	10:56	2435208.456	183 Vrishika 28	15:48	123021.659
1957 February 26	09:56	2435895.414	185 Sagittarius 01	05:40	123690.236
1959 January 14	09:57	2436582.415	185 Vrishika 28	20:33	124358.856
1960 December 01	09:33	2437269.398	187 Sagittarius 01	11:00	125027.459
1962 October 19	08:25	2437956.351	188 Sagittarius 01	00:45	125696.032
1964 September 05	07:45	2438643.323	189 Sagittarius 01	14:57	126364.623
1966 July 24	07:01	2439330.293	190 Sagittarius 01	05:06	127033.213
1968 June 10	05:41	2440017.237	190 Vrishika 28	18:39	127701.777

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1970 April 28	05:09	2440704.215	191 Vrishika 28	08:59	128370.375
1972 March 15	05:00	2441391.209	192 Vrishika 28	23:42	129038.988
1974 January 31	04:35	2442078.191	193 Vrishika 28	14:08	129707.589
1975 December 19	03:48	2442765.159	195 Sagittarius 01	04:14	130376.177
1977 November 05	03:14	2443452.135	195 Vrishika 28	18:31	131044.772
1979 September 23	01:49	2444139.076	197 Sagittarius 01	08:00	131713.333
1981 August 10	01:01	2444826.043	197 Vrishika 28	22:05	132381.920
1983 June 28	00:56	2445513.039	199 Sagittarius 01	12:50	133050.535
1985 May 15	00:15	2446200.011	200 Sagittarius 01	03:02	133719.127
1987 April 01	23:09	2446886.965	201 Sagittarius 01	16:49	134387.701
1989 February 16	23:00	2447573.959	202 Sagittarius 01	07:31	135056.314
1991 January 04	22:04	2448260.920	203 Sagittarius 01	21:28	135724.895
1992 November 21	20:49	2448947.868	204 Sagittarius 01	11:06	136393.463
1994 October 09	20:29	2449634.854	205 Sagittarius 02	01:38	137062.068
1996 August 26	20:03	2450321.836	206 Sagittarius 01	16:03	137730.669
1998 July 14	19:04	2451008.795	207 Sagittarius 02	05:57	138399.248
2000 May 31	18:33	2451695.773	208 Sagittarius 01	20:17	139067.846
2002 April 18	17:41	2452382.737	209 Sagittarius 02	10:18	139736.430
2004 March 05	16:27	2453069.686	210 Sagittarius 01	23:58	140404.999
2006 January 21	16:24	2453756.684	211 Sagittarius 01	14:46	141073.616
2007 December 09	16:13	2454443.676	212 Sagittarius 01	05:26	141742.227
2009 October 26	15:14	2455130.635	213 Sagittarius 01	19:20	142410.806
2011 September 13	14:25	2455817.601	214 Sagittarius 01	09:23	143079.391
2013 July 31	13:55	2456504.580	215 Sagittarius 01	23:45	143747.990
2015 June 18	12:34	2457191.524	216 Sagittarius 01	13:17	144416.554
2017 May 05	11:45	2457878.490	217 Sagittarius 02	03:21	145085.140
2019 March 23	11:32	2458565.481	218 Sagittarius 01	17:59	145753.750
2021 February 07	11:12	2459252.467	219 Sagittarius 02	08:31	146422.355
2022 December 26	10:19	2459939.430	220 Sagittarius 01	22:30	147090.938
2024 November 12	09:46	2460626.407	221 Sagittarius 01	12:49	147759.534
2026 September 30	08:29	2461313.354	222 Sagittarius 01	02:26	148428.102
2028 August 17	07:24	2462000.309	223 Sagittarius 01	16:14	149096.677
2030 July 05	07:17	2462687.304	224 Sagittarius 01	06:58	149765.291
2032 May 22	06:50	2463374.285	225 Sagittarius 01	21:22	150433.891
2034 April 09	05:44	2464061.239	226 Sagittarius 01	11:09	151102.465
2036 February 25	05:26	2464748.227	227 Sagittarius 02	01:43	151771.072
2038 January 12	04:52	2465435.203	228 Sagittarius 01	16:01	152439.668
2039 November 30	03:33	2466122.148	229 Sagittarius 02	05:35	153108.233
2041 October 17	03:08	2466809.131	230 Sagittarius 01	20:02	153776.835
2043 September 04	02:54	2467496.121	231 Sagittarius 01	10:39	154445.444
2045 July 22	01:58	2468183.082	232 Sagittarius 01	00:36	155114.025
2047 June 09	01:14	2468870.052	233 Sagittarius 01	14:45	155782.615
2049 April 26	00:34	2469557.024	234 Sagittarius 01	04:57	156451.206
2051 March 13	23:08	2470243.964	235 Sagittarius 01	18:24	157119.767
2053 January 28	22:50	2470930.952	236 Sagittarius 01	08:58	157788.374
2054 December 16	22:45	2471617.948	237 Sagittarius 01	23:44	158456.989
2056 November 02	21:51	2472304.911	238 Sagittarius 01	13:43	159125.572
2058 September 20	20:51	2472991.869	239 Sagittarius 02	03:35	159794.150
2060 August 07	20:25	2473678.851	240 Sagittarius 01	18:01	160462.751
2062 June 25	19:10	2474365.799	241 Sagittarius 01	07:39	161131.319
2064 May 12	18:10	2475052.757	241 Vrishika 28	21:32	161799.897
2066 March 30	17:55	2475739.747	243 Sagittarius 01	12:09	162468.506
2068 February 15	17:48	2476426.742	244 Sagittarius 01	02:53	163137.120

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2070 January 02	17:00	2477113.709	245 Sagittarius 01	16:58	163805.707
2071 November 20	16:30	2477800.688	246 Sagittarius 01	07:19	164474.305
2073 October 07	15:30	2478487.646	247 Sagittarius 01	21:12	165142.883
2075 August 25	14:15	2479174.594	248 Sagittarius 01	10:50	165811.452
2077 July 12	13:59	2479861.583	249 Sagittarius 02	01:26	166480.060
2079 May 30	13:40	2480548.570	250 Sagittarius 01	15:58	167148.666
2081 April 16	12:34	2481235.524	251 Sagittarius 01	05:45	167817.240
2083 March 04	12:00	2481922.500	251 Vrishika 28	20:03	168485.835
2085 January 19	11:39	2482609.486	253 Sagittarius 01	10:34	169154.441
2086 December 07	10:14	2483296.427	254 Sagittarius 01	00:02	169823.002
2088 October 24	09:34	2483983.399	255 Sagittarius 01	14:14	170491.594
2090 September 11	09:21	2484670.390	256 Sagittarius 01	04:53	171160.204
2092 July 29	08:29	2485357.354	257 Sagittarius 01	18:54	171828.788
2094 June 16	07:36	2486044.317	258 Sagittarius 01	08:53	172497.370
2096 May 03	07:04	2486731.295	259 Sagittarius 01	23:13	173165.968
2098 March 21	05:44	2487418.239	260 Sagittarius 01	12:46	173834.532
2100 February 06	05:18	2488105.221	261 Sagittarius 01	03:12	174503.133
2101 December 25	05:21	2488792.223	261 Vrishika 28	18:06	175171.754
2103 November 12	04:43	2489479.197	263 Sagittarius 01	08:20	175840.348
2105 September 29	03:40	2490166.153	263 Vrishika 28	22:10	176508.924
2107 August 17	03:14	2490853.135	265 Sagittarius 01	12:36	177177.525
2109 July 04	02:12	2491540.092	266 Sagittarius 01	02:26	177846.102
2111 May 22	00:59	2492227.041	267 Sagittarius 01	16:06	178514.671
2113 April 08	00:38	2492914.027	268 Sagittarius 01	06:38	179183.276
2115 February 24	00:34	2493601.024	269 Sagittarius 01	21:24	179851.892
2117 January 10	23:48	2494287.992	270 Sagittarius 01	11:31	180520.480
2118 November 28	23:06	2494974.963	271 Sagittarius 01	01:41	181189.071
2120 October 15	22:16	2495661.928	271 Vrishika 28	15:43	181857.655
2122 September 02	20:47	2496348.866	273 Sagittarius 01	05:08	182526.214
2124 July 20	20:16	2497035.845	273 Vrishika 28	19:29	183194.812
2126 June 07	20:05	2497722.837	275 Sagittarius 01	10:09	183863.423

APPENDIX 4. SUMMER SOLSTICES OF MARS.

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1874 December 10	11:28	2405867.478	141 Pisces 27	17:15	94465.719
1876 October 27	10:52	2406554.453	142 Pisces 27	07:31	95134.313
1878 September 14	10:07	2407241.422	143 Pisces 27	21:39	95802.902
1880 August 01	09:23	2407928.391	144 Pisces 27	11:46	96471.491
1882 June 19	09:07	2408615.380	145 Pisces 28	02:22	97140.099
1884 May 06	08:16	2409302.345	146 Pisces 27	16:24	97808.684
1886 March 24	06:59	2409989.291	147 Pisces 28	05:59	98477.250
1888 February 09	05:54	2410676.246	148 Pisces 27	19:48	99145.825
1889 December 27	05:13	2411363.218	149 Pisces 28	09:59	99814.417
1891 November 14	04:40	2412050.195	150 Pisces 28	00:18	100483.013
1893 October 01	04:13	2412737.176	151 Pisces 27	14:43	101151.613
1895 August 19	03:38	2413424.152	152 Pisces 27	05:00	101820.209
1897 July 06	02:29	2414111.104	153 Pisces 27	18:44	102488.781
1899 May 24	01:23	2414798.058	154 Pisces 27	08:31	103157.355
1901 April 11	00:37	2415485.026	155 Pisces 27	22:37	103825.943
1903 February 26	23:55	2416171.997	156 Pisces 27	12:47	104494.533
1905 January 13	23:21	2416858.973	157 Pisces 28	03:05	105163.129
1906 December 01	23:15	2417545.969	158 Pisces 27	17:50	105831.744
1908 October 18	22:23	2418232.933	159 Pisces 28	07:51	106500.328
1910 September 05	21:10	2418919.882	160 Pisces 27	21:31	107168.897
1912 July 23	20:21	2419606.848	161 Pisces 27	11:34	107837.482
1914 June 10	19:43	2420293.822	162 Pisces 27	01:49	108506.076
1916 April 27	18:57	2420980.790	163 Pisces 27	15:55	109174.664
1918 March 15	18:36	2421667.775	164 Pisces 27	06:25	109843.268
1920 January 31	17:38	2422354.735	165 Pisces 27	20:20	110511.848
1921 December 18	16:27	2423041.686	166 Pisces 27	10:03	111180.419
1923 November 05	15:43	2423728.655	167 Pisces 28	00:11	111849.008
1925 September 22	14:57	2424415.623	168 Pisces 27	14:17	112517.595
1927 August 10	14:09	2425102.590	169 Pisces 28	04:22	113186.182
1929 June 27	13:48	2425789.575	170 Pisces 27	18:52	113854.786
1931 May 15	13:10	2426476.549	171 Pisces 27	09:06	114523.380
1933 April 01	11:57	2427163.498	172 Pisces 26	23:46	115191.949
1935 February 17	10:50	2427850.452	173 Pisces 27	12:33	115860.523
1937 January 04	10:10	2428537.424	174 Pisces 27	02:45	116529.115
1938 November 22	09:43	2429224.405	175 Pisces 27	17:09	117197.715
1940 October 09	09:17	2429911.387	176 Pisces 27	07:35	117866.316
1942 August 27	08:55	2430598.372	177 Pisces 27	22:05	118534.921
1944 July 14	07:52	2431285.328	178 Pisces 27	11:55	119203.497
1946 June 01	06:43	2431972.280	179 Pisces 28	01:38	119872.069
1948 April 18	05:51	2432659.244	180 Pisces 27	15:39	120540.652
1950 March 06	05:05	2433346.212	181 Pisces 27	05:45	121209.240
1952 January 22	04:19	2434033.180	182 Pisces 26	20:52	121877.828
1953 December 09	04:10	2434720.174	183 Pisces 27	10:34	122546.441
1955 October 27	03:27	2435407.144	184 Pisces 27	00:43	123215.030
1957 September 13	02:06	2436094.088	185 Pisces 27	14:16	123883.595
1959 August 01	01:09	2436781.048	186 Pisces 27	04:11	124552.175
1961 June 18	00:30	2437468.021	187 Pisces 27	18:24	125220.767
1963 May 05	23:42	2438154.988	188 Pisces 27	08:29	125889.354
1965 March 22	23:18	2438841.971	189 Pisces 27	22:57	126557.956
1967 February 07	22:36	2439528.942	190 Pisces 27	13:07	127226.547
1968 December 25	21:30	2440215.896	191 Pisces 27	02:54	127895.121

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1970 November 12	20:44	2440902.864	192 Pisces 26	18:00	128563.709
1972 September 29	20:03	2441589.836	193 Pisces 27	07:12	129232.300
1974 August 17	19:23	2442276.808	194 Pisces 26	22:24	129900.892
1976 July 04	18:54	2442963.788	195 Pisces 27	11:47	130569.491
1978 May 22	18:28	2443650.770	196 Pisces 27	02:13	131238.092
1980 April 08	17:15	2444337.719	197 Pisces 27	15:52	131906.662
1982 February 24	16:01	2445024.668	198 Pisces 27	05:32	132575.231
1984 January 12	15:12	2445711.634	199 Pisces 27	19:35	133243.817
1985 November 29	14:44	2446398.614	200 Pisces 27	09:58	133912.416
1987 October 17	14:11	2447085.591	201 Pisces 28	00:17	134581.012
1989 September 03	13:48	2447772.575	202 Pisces 27	14:46	135249.616
1991 July 22	12:47	2448459.533	203 Pisces 28	04:38	135918.194
1993 June 08	11:34	2449146.482	204 Pisces 27	18:18	136586.763
1995 April 26	10:36	2449833.442	205 Pisces 28	08:13	137255.343
1997 March 13	09:54	2450520.413	206 Pisces 27	22:24	137923.933
1999 January 29	09:10	2451207.382	207 Pisces 28	12:31	138592.522
2000 December 16	09:01	2451894.376	208 Pisces 28	03:14	139261.135
2002 November 03	08:35	2452581.358	209 Pisces 28	17:40	139929.736
2004 September 20	07:20	2453268.306	210 Pisces 28	07:18	140598.305
2006 August 08	06:20	2453955.264	211 Pisces 27	21:10	141266.882
2008 June 25	05:39	2454642.236	212 Pisces 27	11:22	141935.474
2010 May 13	04:53	2455329.204	213 Pisces 28	01:28	142604.062
2012 March 30	04:22	2456016.182	214 Pisces 27	15:49	143272.659
2014 February 15	03:48	2456703.159	215 Pisces 28	06:08	143941.256
2016 January 03	02:39	2457390.111	216 Pisces 27	19:51	144609.828
2017 November 20	01:45	2458077.073	217 Pisces 28	09:49	145278.410
2019 October 08	01:00	2458764.042	218 Pisces 27	23:57	145946.998
2021 August 25	00:15	2459451.011	219 Pisces 28	14:05	146615.587
2023 July 12	23:35	2460137.983	220 Pisces 28	04:17	147284.178
2025 May 29	23:15	2460824.969	221 Pisces 27	18:48	147952.784
2027 April 16	22:10	2461511.924	222 Pisces 27	08:36	148621.359
2029 March 03	20:57	2462198.873	223 Pisces 27	22:16	149289.928
2031 January 19	20:06	2462885.838	224 Pisces 27	12:18	149958.513
2032 December 06	19:40	2463572.820	225 Pisces 28	02:44	150627.114
2034 October 24	19:13	2464259.801	226 Pisces 27	17:08	151295.714
2036 September 10	18:50	2464946.785	227 Pisces 28	07:37	151964.318
2038 July 29	18:02	2465633.752	228 Pisces 27	21:42	152632.904
2040 June 15	16:50	2466320.702	229 Pisces 28	11:23	153301.475
2042 May 03	15:48	2467007.659	230 Pisces 28	01:14	153970.051
2044 March 20	15:05	2467694.629	231 Pisces 27	15:23	154638.641
2046 February 05	14:18	2468381.596	232 Pisces 27	05:28	155307.228
2047 December 24	13:56	2469068.581	233 Pisces 27	19:58	155975.832
2049 November 10	13:37	2469755.568	234 Pisces 27	10:31	156644.438
2051 September 28	12:21	2470442.515	235 Pisces 28	00:07	157313.006
2053 August 15	11:12	2471129.467	236 Pisces 27	13:51	157981.578
2055 July 03	10:26	2471816.435	237 Pisces 28	03:58	158650.165
2057 May 20	09:43	2472503.405	238 Pisces 27	18:07	159318.755
2059 April 07	09:02	2473190.377	239 Pisces 28	08:19	159987.347
2061 February 22	08:41	2473877.362	240 Pisces 27	22:49	160655.951
2063 January 10	07:40	2474564.320	241 Pisces 27	12:41	161324.529
2064 November 27	06:44	2475251.281	242 Pisces 27	02:37	161993.110
2066 October 15	06:02	2475938.252	243 Pisces 27	16:48	162661.700
2068 September 01	05:19	2476625.222	244 Pisces 27	06:57	163330.290

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2070 July 20	04:37	2477312.193	245 Pisces 27	21:07	163998.880
2072 June 06	04:23	2477999.183	246 Pisces 27	11:44	164667.490
2074 April 24	03:30	2478686.146	247 Pisces 28	01:44	165336.072
2076 March 11	02:15	2479373.094	248 Pisces 27	15:22	166004.641
2078 January 27	01:16	2480060.053	249 Pisces 28	05:16	166673.220
2079 December 15	00:43	2480747.030	250 Pisces 27	19:35	167341.816
2081 November 01	00:12	2481434.009	251 Pisces 27	09:56	168010.414
2083 September 18	23:41	2482120.987	252 Pisces 27	00:16	168679.012
2085 August 05	23:00	2482807.959	253 Pisces 27	14:28	169347.603
2087 June 23	21:47	2483494.908	254 Pisces 27	04:08	170016.173
2089 May 10	20:39	2484181.861	255 Pisces 27	17:53	170684.746
2091 March 28	19:53	2484868.829	256 Pisces 27	08:00	171353.333
2093 February 12	19:10	2485555.799	257 Pisces 27	22:09	172021.923
2094 December 31	18:38	2486242.777	258 Pisces 27	12:29	172690.520
2096 November 17	18:31	2486929.772	259 Pisces 28	03:13	173359.134
2098 October 05	17:26	2487616.727	260 Pisces 27	17:01	174027.709
2100 August 23	16:16	2488303.678	261 Pisces 27	06:43	174696.281
2102 July 11	15:30	2488990.646	262 Pisces 26	21:50	175364.868
2104 May 28	14:54	2489677.621	263 Pisces 27	11:06	176033.463
2106 April 15	14:09	2490364.590	264 Pisces 27	01:14	176702.051
2108 March 02	13:52	2491051.578	265 Pisces 27	15:48	177370.659
2110 January 18	12:56	2491738.539	266 Pisces 27	05:44	178039.239
2111 December 06	11:54	2492425.496	267 Pisces 27	19:35	178707.816
2113 October 23	11:09	2493112.465	268 Pisces 27	09:43	179376.405
2115 September 10	10:22	2493799.432	269 Pisces 27	23:48	180044.992
2117 July 28	09:36	2494486.400	270 Pisces 27	13:54	180713.579
2119 June 15	09:14	2495173.385	271 Pisces 27	04:24	181382.184
2121 May 02	08:29	2495860.354	272 Pisces 26	19:32	182050.772
2123 March 20	07:13	2496547.301	273 Pisces 27	08:09	182719.340
2125 February 04	06:07	2497234.255	274 Pisces 26	22:55	183387.914
2126 December 23	05:28	2497921.228	275 Pisces 27	12:08	184056.506

APPENDIX 5. AUTUMNAL EQUINOXES OF MARS.

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1875 June 11	13:19	2406050.555	141 Mithuna 10	21:32	94643.898
1877 April 28	12:46	2406737.532	142 Mithuna 10	11:51	95312.494
1879 March 16	12:37	2407424.526	143 Mithuna 11	02:34	95981.107
1881 January 31	11:19	2408111.472	144 Mithuna 10	16:09	96649.673
1882 December 19	10:35	2408798.441	145 Mithuna 11	06:17	97318.262
1884 November 05	10:52	2409485.453	146 Mithuna 10	21:25	97986.893
1886 September 23	09:57	2410172.415	147 Mithuna 11	11:23	98655.474
1888 August 10	08:32	2410859.356	148 Mithuna 11	00:51	99324.036
1890 June 28	08:06	2411546.338	149 Mithuna 11	15:17	99992.637
1892 May 15	07:42	2412233.321	150 Mithuna 11	05:44	100661.239
1894 April 02	06:57	2412920.290	151 Mithuna 10	19:52	101329.828
1896 February 18	07:10	2413607.299	152 Mithuna 10	10:56	101998.456
1898 January 05	06:33	2414294.273	153 Mithuna 11	01:10	102667.049
1899 November 23	05:08	2414981.214	154 Mithuna 10	14:39	103335.611
1901 October 11	04:26	2415668.185	155 Mithuna 11	04:49	104004.201
1903 August 29	04:00	2416355.167	156 Mithuna 10	19:15	104672.802
1905 July 16	02:41	2417042.112	157 Mithuna 11	08:49	105341.368
1907 June 03	02:54	2417729.121	158 Mithuna 10	23:53	106009.995
1909 April 20	03:25	2418416.143	159 Mithuna 11	15:15	106678.636
1911 March 08	02:11	2419103.091	160 Mithuna 11	04:53	107347.204
1913 January 23	01:00	2419790.042	161 Mithuna 10	18:35	108015.775
1914 December 11	00:38	2420477.027	162 Mithuna 10	09:06	108684.379
1916 October 27	23:28	2421163.978	163 Mithuna 10	22:48	109352.950
1918 September 14	22:56	2421850.956	164 Mithuna 10	13:08	110021.548
1920 August 01	23:09	2422537.965	165 Mithuna 11	04:12	110690.175
1922 June 19	22:10	2423224.924	166 Mithuna 10	18:06	111358.754
1924 May 06	21:17	2423911.887	167 Mithuna 11	08:05	112027.337
1926 March 24	21:08	2424598.881	168 Mithuna 10	22:48	112695.950
1928 February 09	20:06	2425285.838	169 Mithuna 11	12:39	113364.527
1929 December 27	19:00	2425972.792	170 Mithuna 11	02:25	114033.101
1931 November 14	19:22	2426659.807	171 Mithuna 10	17:37	114701.735
1933 October 01	18:47	2427346.783	172 Mithuna 10	07:55	115370.330
1935 August 19	17:19	2428033.722	173 Mithuna 10	21:20	116038.890
1937 July 06	16:42	2428720.696	174 Mithuna 10	11:35	116707.483
1939 May 24	16:29	2429407.687	175 Mithuna 11	02:14	117376.093
1941 April 10	15:41	2430094.654	176 Mithuna 10	16:19	118044.680
1943 February 26	15:48	2430781.659	177 Mithuna 11	07:17	118713.304
1945 January 13	15:33	2431468.648	178 Mithuna 10	21:52	119381.912
1946 December 01	14:12	2432155.592	179 Mithuna 11	11:25	120050.476
1948 October 18	13:16	2432842.553	180 Mithuna 11	01:21	120719.057
1950 September 05	12:54	2433529.538	181 Mithuna 10	15:52	121387.661
1952 July 23	11:34	2434216.482	182 Mithuna 10	05:24	122056.225
1954 June 10	11:18	2434903.471	183 Mithuna 10	20:00	122724.834
1956 April 27	12:00	2435590.500	184 Mithuna 10	11:32	123393.481
1958 March 15	11:00	2436277.459	185 Mithuna 11	01:25	124062.060
1960 January 31	09:36	2436964.400	186 Mithuna 10	14:54	124730.621
1961 December 18	09:10	2437651.382	187 Mithuna 11	05:20	125399.222
1963 November 05	08:13	2438338.343	188 Mithuna 10	19:16	126067.803
1965 September 22	07:20	2439025.306	189 Mithuna 11	09:15	126736.386
1967 August 10	07:39	2439712.319	190 Mithuna 11	00:25	127405.017
1969 June 27	06:57	2440399.290	191 Mithuna 10	14:35	128073.608

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1971 May 15	05:57	2441086.248	192 Mithuna 10	04:27	128742.186
1973 April 01	05:48	2441773.242	193 Mithuna 10	19:10	129410.799
1975 February 17	05:11	2442460.216	194 Mithuna 10	09:25	130079.393
1977 January 04	03:50	2443147.160	195 Mithuna 10	22:57	130747.957
1978 November 22	04:04	2443834.170	196 Mithuna 10	14:03	131416.585
1980 October 09	03:48	2444521.159	197 Mithuna 11	04:38	132085.194
1982 August 27	02:19	2445208.097	198 Mithuna 10	18:03	132753.752
1984 July 14	01:23	2445895.058	199 Mithuna 11	07:59	133422.333
1986 June 01	01:12	2446582.050	200 Mithuna 10	22:39	134090.944
1988 April 18	00:25	2447269.018	201 Mithuna 11	12:45	134759.532
1990 March 06	00:12	2447956.009	202 Mithuna 11	03:24	135428.142
1992 January 22	00:11	2448643.008	203 Mithuna 11	18:13	136096.760
1993 December 08	22:56	2449329.956	204 Mithuna 11	07:52	136765.328
1995 October 26	21:46	2450016.907	205 Mithuna 11	21:34	137433.899
1997 September 12	21:25	2450703.893	206 Mithuna 11	12:06	138102.504
1999 July 31	20:21	2451390.848	207 Mithuna 12	01:54	138771.079
2001 June 17	19:39	2452077.819	208 Mithuna 11	16:04	139439.670
2003 May 05	20:32	2452764.856	209 Mithuna 12	07:47	140108.325
2005 March 22	20:00	2453451.834	210 Mithuna 11	22:07	140776.922
2007 February 07	18:34	2454138.774	211 Mithuna 11	11:34	141445.483
2008 December 25	18:00	2454825.750	212 Mithuna 11	01:52	142114.078
2010 November 12	17:18	2455512.721	213 Mithuna 11	16:02	142782.669
2012 September 29	16:04	2456199.670	214 Mithuna 11	05:42	143451.238
2014 August 17	16:17	2456886.679	215 Mithuna 11	20:46	144119.865
2016 July 04	15:51	2457573.661	216 Mithuna 11	11:12	144788.467
2018 May 22	14:42	2458260.613	217 Mithuna 12	00:55	145457.039
2020 April 08	14:24	2458947.600	218 Mithuna 11	15:28	146125.645
2022 February 24	13:56	2459634.581	219 Mithuna 12	05:53	146794.245
2024 January 12	12:27	2460321.519	220 Mithuna 11	19:17	147462.804
2025 November 29	12:18	2461008.513	221 Mithuna 11	10:00	148131.417
2027 October 17	12:21	2461695.515	222 Mithuna 11	00:54	148800.038
2029 September 03	11:03	2462382.461	223 Mithuna 11	14:29	149468.604
2031 July 22	09:56	2463069.414	224 Mithuna 11	04:14	150137.177
2033 June 08	09:48	2463756.409	225 Mithuna 11	18:58	150805.791
2035 April 26	09:18	2464443.388	226 Mithuna 11	09:20	151474.389
2037 March 13	08:51	2465130.369	227 Mithuna 11	23:45	152142.990
2039 January 29	09:02	2465817.377	228 Mithuna 11	14:47	152811.616
2040 December 16	08:02	2466504.335	229 Mithuna 12	04:39	153480.194
2042 November 03	06:41	2467191.279	230 Mithuna 11	18:12	154148.759
2044 September 20	06:12	2467878.259	231 Mithuna 11	08:35	154817.358
2046 August 08	05:22	2468565.224	232 Mithuna 10	22:37	155485.943
2048 June 25	04:16	2469252.178	233 Mithuna 11	12:24	156154.517
2050 May 13	05:00	2469939.209	234 Mithuna 11	03:58	156823.166
2052 March 30	04:50	2470626.202	235 Mithuna 11	18:40	157491.778
2054 February 15	03:17	2471313.137	236 Mithuna 11	08:00	158160.333
2056 January 03	02:25	2472000.101	237 Mithuna 11	22:00	158828.917
2057 November 20	01:55	2472687.080	238 Mithuna 11	12:22	159497.516
2059 October 08	00:36	2473374.025	239 Mithuna 12	01:56	160166.081
2061 August 25	00:36	2474061.025	240 Mithuna 11	16:47	160834.700
2063 July 13	00:33	2474748.023	241 Mithuna 11	07:35	161503.317
2065 May 29	23:31	2475434.980	242 Mithuna 10	21:26	162171.894
2067 April 16	23:05	2476121.962	243 Mithuna 11	11:52	162840.495
2069 March 03	22:49	2476808.951	244 Mithuna 11	02:28	163509.103

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2071 January 19	21:28	2477495.895	245 Mithuna 11	16:01	164177.667
2072 December 06	20:57	2478182.873	246 Mithuna 11	06:21	164846.265
2074 October 24	21:12	2478869.884	247 Mithuna 11	21:27	165514.894
2076 September 10	20:09	2479556.840	248 Mithuna 11	11:17	166183.470
2078 July 29	18:50	2480243.785	249 Mithuna 12	00:51	166852.036
2080 June 15	18:31	2480930.772	250 Mithuna 11	15:24	167520.642
2082 May 03	18:08	2481617.756	251 Mithuna 11	05:52	168189.245
2084 March 20	17:19	2482304.722	252 Mithuna 10	19:56	168857.831
2086 February 05	17:29	2482991.729	253 Mithuna 11	10:57	169526.456
2087 December 24	16:43	2483678.697	254 Mithuna 11	01:03	170195.044
2089 November 10	15:17	2484365.637	255 Mithuna 11	14:30	170863.605
2091 September 28	14:38	2485052.610	256 Mithuna 11	04:43	171532.197
2093 August 15	14:06	2485739.588	257 Mithuna 11	19:04	172200.795
2095 July 03	12:51	2486426.536	258 Mithuna 11	08:42	172869.363
2097 May 20	13:20	2487113.556	259 Mithuna 12	00:01	173538.001
2099 April 07	13:40	2487800.570	260 Mithuna 11	15:12	174206.634
2101 February 23	12:14	2488487.510	261 Mithuna 11	04:39	174875.194
2103 January 11	11:11	2489174.466	262 Mithuna 10	18:28	175543.770
2104 November 28	10:49	2489861.451	263 Mithuna 11	08:58	176212.374
2106 October 16	09:36	2490548.400	264 Mithuna 10	22:38	176880.943
2108 September 02	09:14	2491235.385	265 Mithuna 11	13:08	177549.548
2110 July 21	09:25	2491922.393	266 Mithuna 11	04:10	178218.174
2112 June 07	08:28	2492609.353	267 Mithuna 11	18:06	178886.754
2114 April 25	07:46	2493296.324	268 Mithuna 11	08:16	179555.345
2116 March 12	07:27	2493983.311	269 Mithuna 11	22:49	180223.951
2118 January 28	06:18	2494670.263	270 Mithuna 11	12:33	180892.523
2119 December 16	05:19	2495357.222	271 Mithuna 11	02:26	181561.102
2121 November 02	05:41	2496044.237	272 Mithuna 10	17:39	182229.735
2123 September 20	04:56	2496731.206	273 Mithuna 11	07:46	182898.324
2125 August 07	03:30	2497418.146	274 Mithuna 10	21:13	183566.885
2127 June 25	03:00	2498105.125	275 Mithuna 11	11:35	184235.483

APPENDIX 6. WINTER SOLSTICES OF MARS.

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1875 November 05	02:36	2406197.109	141 Virgo 14	12:43	94786.530
1877 September 22	01:52	2406884.078	142 Virgo 14	02:51	95455.119
1879 August 10	01:26	2407571.060	143 Virgo 14	17:17	96123.720
1881 June 27	01:10	2408258.049	144 Virgo 14	07:53	96792.329
1883 May 14	23:29	2408944.979	145 Virgo 14	21:06	97460.879
1885 March 31	23:15	2409631.969	146 Virgo 14	11:43	98129.488
1887 February 16	23:22	2410318.974	147 Virgo 15	02:41	98798.112
1889 January 03	22:17	2411005.929	148 Virgo 14	16:29	99466.687
1890 November 21	21:05	2411692.879	149 Virgo 15	06:10	100135.257
1892 October 08	21:17	2412379.887	150 Virgo 14	21:12	100803.884
1894 August 26	20:28	2413066.853	151 Virgo 14	11:16	101472.470
1896 July 13	19:46	2413753.824	152 Virgo 14	01:26	102141.060
1898 May 31	19:58	2414440.832	153 Virgo 14	16:29	102809.687
1900 April 18	19:16	2415127.803	154 Virgo 14	06:39	103478.277
1902 March 06	17:58	2415814.749	155 Virgo 14	20:15	104146.844
1904 January 22	17:41	2416501.737	156 Virgo 14	10:49	104815.451
1905 December 09	16:49	2417188.701	157 Virgo 15	00:49	105484.035
1907 October 27	15:40	2417875.653	158 Virgo 14	14:33	106152.607
1909 September 13	16:30	2418562.688	159 Virgo 15	06:13	106821.260
1911 August 01	16:29	2419249.687	160 Virgo 14	21:03	107489.878
1913 June 18	15:05	2419936.629	161 Virgo 14	10:33	108158.440
1915 May 06	14:19	2420623.597	162 Virgo 14	00:39	108827.028
1917 March 23	13:59	2421310.583	163 Virgo 14	15:11	109495.633
1919 February 08	12:27	2421997.519	164 Virgo 14	04:32	110164.189
1920 December 26	12:18	2422684.513	165 Virgo 14	19:15	110832.802
1922 November 13	12:21	2423371.515	166 Virgo 14	10:09	111501.423
1924 September 30	11:38	2424058.485	167 Virgo 15	00:18	112170.013
1926 August 18	10:59	2424745.458	168 Virgo 14	14:31	112838.605
1928 July 05	10:52	2425432.453	169 Virgo 15	05:15	113507.219
1930 May 23	09:18	2426119.388	170 Virgo 14	18:35	114175.775
1932 April 09	08:41	2426806.362	171 Virgo 14	08:50	114844.368
1934 February 25	09:00	2427493.375	172 Virgo 13	00:59	115513.000
1936 January 13	08:13	2428180.343	173 Virgo 14	14:06	116181.588
1937 November 30	06:53	2428867.287	174 Virgo 14	03:38	116850.152
1939 October 18	06:54	2429554.288	175 Virgo 14	18:31	117518.772
1941 September 04	06:31	2430241.272	176 Virgo 14	08:59	118187.375
1943 July 23	05:29	2430928.229	177 Virgo 14	22:50	118855.952
1945 June 09	05:41	2431615.237	178 Virgo 14	13:53	119524.579
1947 April 27	05:15	2432302.219	179 Virgo 15	04:19	120193.180
1949 March 14	03:59	2432989.166	180 Virgo 14	17:55	120861.747
1951 January 30	03:25	2433676.143	181 Virgo 14	08:14	121530.344
1952 December 17	02:55	2434363.122	182 Virgo 13	23:36	122198.942
1954 November 04	01:26	2435050.060	183 Virgo 14	12:00	122867.500
1956 September 21	01:55	2435737.080	184 Virgo 14	03:19	123536.139
1958 August 09	02:11	2436424.091	185 Virgo 14	18:26	124204.768
1960 June 26	00:56	2437111.039	186 Virgo 14	08:04	124873.337
1962 May 13	23:51	2437797.994	187 Virgo 14	21:52	125541.912
1964 March 30	23:44	2438484.989	188 Virgo 14	12:36	126210.526
1966 February 15	22:16	2439171.928	189 Virgo 15	02:02	126879.085
1968 January 03	21:48	2439858.909	190 Virgo 14	16:26	127547.685
1969 November 20	22:00	2440545.917	191 Virgo 14	07:29	128216.312

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1971 October 08	21:28	2441232.895	192 Virgo 13	22:49	128884.909
1973 August 25	20:42	2441919.863	193 Virgo 14	11:55	129553.497
1975 July 13	20:38	2442606.860	194 Virgo 14	02:42	130222.113
1977 May 30	19:26	2443293.810	195 Virgo 14	16:23	130890.683
1979 April 17	18:25	2443980.768	196 Virgo 14	06:16	131559.261
1981 March 04	18:47	2444667.783	197 Virgo 14	21:28	132227.895
1983 January 20	18:18	2445354.763	198 Virgo 14	11:51	132896.494
1984 December 07	16:52	2446041.703	199 Virgo 15	01:18	133565.054
1986 October 25	16:30	2446728.688	200 Virgo 14	15:48	134233.659
1988 September 11	16:26	2447415.685	201 Virgo 15	06:35	134902.275
1990 July 30	15:10	2448102.632	202 Virgo 14	20:12	135570.842
1992 June 16	15:10	2448789.632	203 Virgo 15	11:03	136239.461
1994 May 04	15:00	2449476.625	204 Virgo 15	01:44	136908.073
1996 March 21	13:48	2450163.575	205 Virgo 15	15:25	137576.643
1998 February 06	12:57	2450850.540	206 Virgo 15	05:27	138245.228
1999 December 25	12:44	2451537.531	207 Virgo 15	20:06	138913.838
2001 November 11	11:11	2452224.466	208 Virgo 15	09:26	139582.393
2003 September 29	11:18	2452911.471	209 Virgo 16	00:24	140251.017
2005 August 16	11:55	2453598.497	210 Virgo 15	15:51	140919.661
2007 July 04	10:59	2454285.458	211 Virgo 15	05:48	141588.242
2009 May 21	09:44	2454972.406	212 Virgo 14	19:26	142256.810
2011 April 08	09:40	2455659.403	213 Virgo 15	10:13	142925.426
2013 February 23	08:28	2456346.353	214 Virgo 14	23:54	143593.996
2015 January 11	07:32	2457033.314	215 Virgo 15	13:51	144262.577
2016 November 28	07:45	2457720.323	216 Virgo 15	04:54	144931.205
2018 October 16	07:20	2458407.306	217 Virgo 15	19:22	145599.807
2020 September 02	06:31	2459094.272	218 Virgo 15	09:25	146268.393
2022 July 21	06:15	2459781.261	219 Virgo 16	00:01	146937.001
2024 June 07	05:25	2460468.226	220 Virgo 15	14:03	147605.586
2026 April 25	04:00	2461155.167	221 Virgo 15	03:31	148274.147
2028 March 12	04:13	2461842.176	222 Virgo 14	18:35	148942.775
2030 January 28	04:03	2462529.169	223 Virgo 15	09:16	149611.387
2031 December 16	02:41	2463216.112	224 Virgo 14	22:47	150279.950
2033 November 02	01:59	2463903.083	225 Virgo 15	12:58	150948.541
2035 September 20	02:18	2464590.096	226 Virgo 15	04:07	151617.172
2037 August 07	01:04	2465277.045	227 Virgo 15	17:47	152285.741
2039 June 25	00:53	2465964.037	228 Virgo 15	08:27	152954.352
2041 May 12	00:57	2466651.040	229 Virgo 15	23:22	153622.974
2043 March 29	23:57	2467337.998	230 Virgo 15	13:14	154291.552
2045 February 13	22:50	2468024.952	231 Virgo 15	03:01	154960.126
2047 January 01	22:40	2468711.945	232 Virgo 14	17:42	155628.738
2048 November 18	21:15	2469398.886	233 Virgo 15	07:11	156297.300
2050 October 06	20:49	2470085.868	234 Virgo 14	21:37	156965.901
2052 August 23	21:36	2470772.900	235 Virgo 15	13:13	157634.551
2054 July 11	20:55	2471459.872	236 Virgo 15	03:25	158303.142
2056 May 28	19:29	2472146.812	237 Virgo 15	16:52	158971.703
2058 April 15	19:10	2472833.799	238 Virgo 15	07:24	159640.309
2060 March 02	18:20	2473520.764	239 Virgo 15	21:27	160308.894
2062 January 18	17:02	2474207.710	240 Virgo 15	11:02	160977.460
2063 December 06	17:12	2474894.717	241 Virgo 15	02:03	161646.086
2065 October 23	17:05	2475581.712	242 Virgo 14	16:47	162314.700
2067 September 10	16:24	2476268.684	243 Virgo 15	06:59	162983.291
2069 July 28	16:00	2476955.667	244 Virgo 14	21:26	163651.894

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2071 June 15	15:36	2477642.650	245 Virgo 15	11:54	164320.496
2073 May 02	13:59	2478329.583	246 Virgo 15	01:11	164989.049
2075 March 20	13:58	2479016.582	247 Virgo 15	16:00	165657.667
2077 February 04	14:02	2479703.585	248 Virgo 15	06:56	166326.289
2078 December 23	12:50	2480390.535	249 Virgo 15	20:37	166994.859
2080 November 09	11:47	2481077.491	250 Virgo 15	10:26	167663.435
2082 September 27	12:07	2481764.505	251 Virgo 15	01:37	168332.068
2084 August 14	11:03	2482451.461	252 Virgo 14	15:26	169000.644
2086 July 02	10:26	2483138.435	253 Virgo 15	05:41	169669.237
2088 May 19	10:33	2483825.440	254 Virgo 14	20:39	170337.861
2090 April 06	09:44	2484512.406	255 Virgo 15	10:43	171006.447
2092 February 22	08:26	2485199.352	256 Virgo 15	00:18	171675.013
2094 January 09	08:12	2485886.342	257 Virgo 15	14:55	172343.622
2095 November 27	07:10	2486573.299	258 Virgo 15	04:46	173012.199
2097 October 14	06:20	2487260.264	259 Virgo 15	18:48	173680.784
2099 September 01	07:12	2487947.300	260 Virgo 15	10:30	174349.438
2101 July 20	06:57	2488634.290	261 Virgo 15	01:07	175018.047
2103 June 07	05:32	2489321.231	262 Virgo 14	14:35	175686.608
2105 April 24	04:56	2490008.206	263 Virgo 15	04:51	176355.203
2107 March 12	04:30	2490695.188	264 Virgo 14	19:17	177023.804
2109 January 27	03:01	2491382.126	265 Virgo 15	08:42	177692.363
2110 December 15	03:00	2492069.125	266 Virgo 14	23:31	178360.980
2112 November 01	03:04	2492756.128	267 Virgo 15	14:27	179029.602
2114 September 19	02:25	2493443.101	268 Virgo 15	04:40	179698.195
2116 August 06	01:43	2494130.072	269 Virgo 15	18:50	180366.785
2118 June 24	01:29	2494817.062	270 Virgo 15	09:27	181035.394
2120 May 10	23:51	2495503.994	271 Virgo 14	22:43	181703.947
2122 March 28	23:22	2496190.974	272 Virgo 14	13:06	182372.546
2124 February 13	23:36	2496877.984	273 Virgo 15	04:11	183041.175
2125 December 31	22:43	2497564.947	274 Virgo 14	18:11	183709.758
2127 November 18	21:27	2498251.894	275 Virgo 15	07:48	184378.325

APPENDIX 7. PERIHELIONS OF MARS.

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1875 October 04	21:07	2406165.880	141 Simha 11	03:17	94756.137
1877 August 21	17:31	2406852.730	142 Simha 10	15:38	95424.610
1879 July 09	19:12	2407539.800	143 Simha 11	07:07	96093.297
1881 May 26	20:38	2408226.860	144 Simha 10	00:22	96761.974
1883 April 13	14:38	2408913.610	145 Simha 11	08:23	97430.350
1885 February 28	18:00	2409600.750	146 Simha 11	02:30	98099.105
1887 January 16	21:21	2410287.890	147 Simha 11	20:38	98767.860
1888 December 03	17:31	2410974.730	148 Simha 11	07:44	99436.323
1890 October 21	15:50	2411661.660	149 Simha 11	20:57	100104.874
1892 September 07	20:24	2412348.850	150 Simha 11	16:15	100773.677
1894 July 26	16:04	2413035.670	151 Simha 11	02:54	101442.121
1896 June 12	16:33	2413722.690	152 Simha 10	19:13	102110.759
1898 April 30	21:07	2414409.880	153 Simha 11	13:30	102779.563
1900 March 18	19:12	2415096.800	154 Simha 11	02:29	103448.104
1902 February 03	15:07	2415783.630	155 Simha 11	13:22	104116.557
1903 December 22	18:43	2416470.780	156 Simha 11	07:43	104785.322
1905 November 08	15:50	2417157.660	157 Simha 11	19:46	105453.824
1907 September 26	13:12	2417844.550	158 Simha 11	08:03	106122.336
1909 August 13	19:26	2418531.810	159 Simha 12	04:59	106791.208
1911 July 01	20:24	2419218.850	160 Simha 11	20:46	107459.866
1913 May 18	15:21	2419905.640	161 Simha 11	06:43	108128.280
1915 April 05	16:48	2420592.700	162 Simha 10	23:58	108796.957
1917 February 20	17:31	2421279.730	163 Simha 11	14:31	109465.605
1919 January 08	12:14	2421966.510	164 Simha 11	00:14	110134.010
1920 November 25	16:19	2422653.680	165 Simha 11	19:03	110802.794
1922 October 13	19:12	2423340.800	166 Simha 11	12:43	111471.530
1924 August 30	16:04	2424027.670	167 Simha 12	00:32	112140.022
1926 July 18	15:36	2424714.650	168 Simha 11	14:55	112808.622
1928 June 04	18:43	2425401.780	169 Simha 12	08:48	113477.367
1930 April 22	12:57	2426088.540	170 Simha 11	18:03	114145.752
1932 March 09	14:09	2426775.590	171 Simha 11	10:04	114814.420
1934 January 25	18:43	2427462.780	172 Simha 11	05:21	115483.224
1935 December 13	16:33	2428149.690	173 Simha 11	18:06	116151.755
1937 October 30	12:43	2428836.530	174 Simha 11	05:13	116820.218
1939 September 17	17:02	2429523.710	175 Simha 12	00:17	117489.012
1941 August 04	14:24	2430210.600	176 Simha 11	12:34	118157.524
1943 June 22	12:28	2430897.520	177 Simha 12	01:33	118826.065
1945 May 09	17:16	2431584.720	178 Simha 11	21:04	119494.878
1947 March 27	17:16	2432271.720	179 Simha 12	11:55	120163.497
1949 February 11	12:43	2432958.530	180 Simha 11	22:20	120831.931
1950 December 30	15:21	2433645.640	181 Simha 11	15:45	121500.657
1952 November 16	14:52	2434332.620	182 Simha 11	06:08	122169.256
1954 October 04	10:19	2435019.430	183 Simha 11	16:33	122837.690
1956 August 21	15:36	2435706.650	184 Simha 11	12:33	123506.523
1958 July 09	18:14	2436393.760	185 Simha 12	05:58	124175.249
1960 May 26	13:55	2437080.580	186 Simha 11	16:37	124843.693
1962 April 13	13:12	2437767.550	187 Simha 12	06:46	125512.282
1964 February 29	16:04	2438454.670	188 Simha 12	00:25	126181.018
1966 January 16	10:33	2439141.440	189 Simha 12	09:54	126849.413
1967 December 04	12:28	2439828.520	190 Simha 12	02:37	127518.109
1969 October 21	16:19	2440515.680	191 Simha 11	21:12	128186.884

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1971 September 08	14:09	2441202.590	192 Simha 11	09:57	128855.415
1973 July 26	11:45	2441889.490	193 Simha 11	22:28	129523.937
1975 June 13	15:50	2442576.660	194 Simha 11	17:18	130192.721
1977 April 30	11:31	2443263.480	195 Simha 12	03:57	130861.165
1979 March 18	10:19	2443950.430	196 Simha 11	17:38	131529.735
1981 February 02	15:36	2444637.650	197 Simha 12	13:37	132198.568
1982 December 21	15:07	2445324.630	198 Simha 12	04:00	132867.167
1984 November 07	10:19	2446011.430	199 Simha 12	14:11	133535.591
1986 September 25	13:26	2446698.560	200 Simha 12	08:04	134204.337
1988 August 12	13:12	2447385.550	201 Simha 12	22:41	134872.946
1990 June 30	09:21	2448072.390	202 Simha 12	09:48	135541.409
1992 May 17	14:09	2448759.590	203 Simha 13	05:20	136210.222
1994 April 04	15:36	2449446.650	204 Simha 12	21:35	136878.900
1996 February 20	11:16	2450133.470	205 Simha 13	08:14	137547.343
1998 January 07	11:31	2450820.480	206 Simha 12	23:19	138215.972
1999 November 25	13:26	2451507.560	207 Simha 13	16:02	138884.669
2001 October 12	07:40	2452194.320	208 Simha 13	01:17	139553.054
2003 August 30	11:02	2452881.460	209 Simha 13	19:24	140221.809
2005 July 17	15:36	2453568.650	210 Simha 13	14:42	140890.613
2007 June 04	12:28	2454255.520	211 Simha 13	02:31	141559.105
2009 April 21	09:50	2454942.410	212 Simha 12	14:48	142227.617
2011 March 09	13:55	2455629.580	213 Simha 13	09:37	142896.401
2013 January 24	09:07	2456316.380	214 Simha 12	19:48	143564.825
2014 December 12	08:24	2457003.350	215 Simha 13	09:57	144233.415
2016 October 29	13:12	2457690.550	216 Simha 13	05:28	144902.228
2018 September 16	12:43	2458377.530	217 Simha 13	19:51	145570.828
2020 August 03	09:07	2459064.380	218 Simha 13	07:12	146239.301
2022 June 21	12:57	2459751.540	219 Simha 14	01:48	146908.075
2024 May 08	10:48	2460438.450	220 Simha 13	14:33	147576.606
2026 March 26	07:12	2461125.300	221 Simha 13	01:53	148245.079
2028 February 11	12:14	2461812.510	222 Simha 12	21:39	148913.902
2029 December 29	13:12	2462499.550	223 Simha 13	13:26	149582.560
2031 November 16	08:09	2463186.340	224 Simha 12	23:23	150250.975
2033 October 03	09:21	2463873.390	225 Simha 13	15:24	150919.642
2035 August 21	11:45	2464560.490	226 Simha 13	08:35	151588.358
2037 July 08	06:43	2465247.280	227 Simha 13	18:32	152256.773
2039 May 26	10:19	2465934.430	228 Simha 13	12:53	152925.537
2041 April 12	13:26	2466621.560	229 Simha 14	06:47	153594.283
2043 February 28	09:50	2467308.410	230 Simha 13	18:08	154262.756
2045 January 15	07:55	2467995.330	231 Simha 13	07:07	154931.297
2046 December 03	11:16	2468682.470	232 Simha 13	01:14	155600.052
2048 October 20	06:00	2469369.250	233 Simha 13	10:57	156268.456
2050 September 07	07:12	2470056.300	234 Simha 13	02:58	156937.124
2052 July 25	12:43	2470743.530	235 Simha 13	23:11	157605.967
2054 June 12	11:16	2471430.470	236 Simha 13	12:38	158274.527
2056 April 29	07:12	2472117.300	237 Simha 13	23:31	158942.980
2058 March 17	10:48	2472804.450	238 Simha 13	17:53	159611.745
2060 February 02	07:55	2473491.330	239 Simha 14	05:56	160280.247
2061 December 20	04:48	2474178.200	240 Simha 13	17:45	160948.740
2063 November 07	09:50	2474865.410	241 Simha 13	13:30	161617.563
2065 September 24	10:48	2475552.450	242 Simha 13	05:17	162286.221
2067 August 12	07:12	2476239.300	243 Simha 13	16:38	162954.693
2069 June 29	09:21	2476926.390	244 Simha 13	09:35	163623.400

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2071 May 17	09:50	2477613.410	245 Simha 14	00:54	164292.038
2073 April 03	04:19	2478300.180	246 Simha 13	10:23	164960.433
2075 February 19	08:24	2478987.350	247 Simha 14	05:13	165629.217
2077 January 06	10:48	2479674.450	248 Simha 13	22:24	166297.934
2078 November 24	06:43	2480361.280	249 Simha 14	09:17	166966.387
2080 October 11	05:45	2481048.240	250 Simha 13	23:12	167634.967
2082 August 29	09:50	2481735.410	251 Simha 13	18:01	168303.751
2084 July 16	05:02	2482422.210	252 Simha 13	04:12	168972.175
2086 June 03	06:28	2483109.270	253 Simha 13	20:27	169640.853
2088 April 20	10:33	2483796.440	254 Simha 13	15:17	170309.637
2090 March 08	08:24	2484483.350	255 Simha 14	04:02	170978.168
2092 January 24	04:48	2485170.200	256 Simha 13	15:22	171646.641
2093 December 11	08:24	2485857.350	257 Simha 14	09:44	172315.406
2095 October 29	04:48	2486544.200	258 Simha 13	21:05	172983.879
2097 September 15	03:36	2487231.150	259 Simha 14	10:46	173652.449
2099 August 03	09:36	2487918.400	260 Simha 14	07:27	174321.311
2101 June 21	09:50	2488605.410	261 Simha 13	22:32	174989.939
2103 May 09	05:02	2489292.210	262 Simha 13	08:43	175658.364
2105 March 26	06:57	2489979.290	263 Simha 14	01:26	176327.060
2107 February 11	06:43	2490666.280	264 Simha 13	16:04	176995.669
2108 December 29	01:55	2491353.080	265 Simha 14	02:14	177664.094
2110 November 16	06:14	2492040.260	266 Simha 13	21:18	178332.888
2112 October 03	08:38	2492727.360	267 Simha 14	14:29	179001.604
2114 August 21	05:31	2493414.230	268 Simha 14	02:18	179670.096
2116 July 08	05:31	2494101.230	269 Simha 14	17:09	180338.715
2118 May 26	08:09	2494788.340	270 Simha 14	10:34	181007.441
2120 April 12	02:09	2495475.090	271 Simha 13	19:35	181675.816
2122 February 28	04:19	2496162.180	272 Simha 13	12:32	182344.523
2124 January 16	08:24	2496849.350	273 Simha 14	07:22	183013.307
2125 December 03	05:45	2497536.240	274 Simha 13	19:39	183681.819
2127 October 21	02:38	2498223.110	275 Simha 14	07:28	184350.311

APPENDIX 8. OPPOSITIONS OF MARS (INFERIOR CONJUNCTIONS OF EARTH).

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1610 October 19	02:19	2309391.597	000 Libra 14	15:09	570.631
1612 December 08	07:48	2310172.825	001 Vrishika 21	22:59	1330.957
1615 January 15	16:02	2310941.168	003 Capricornus 17	17:49	2078.743
1617 February 17	21:13	2311705.384	004 Kumbha 08	12:17	2822.511
1619 March 25	03:05	2312470.628	005 Aries 02	06:45	3567.281
1621 May 05	05:17	2313242.720	006 Taurus 28	17:10	4318.715
1623 July 04	08:32	2314032.856	007 Cancer 18	17:02	5087.710
1625 September 22	05:05	2314843.712	008 Virgo 27	20:54	5876.871
1627 November 21	14:29	2315634.103	009 Scorpius 17	02:46	6646.115
1630 January 01	14:16	2316406.094	011 Dhanus 15	10:50	7397.451
1632 February 05	17:49	2317171.242	012 Aquarius 07	03:03	8142.127
1634 March 10	23:41	2317935.487	013 Pisces 27	22:10	8885.923
1636 April 17	11:40	2318703.986	014 Mesha 22	20:40	9633.861
1638 June 07	17:14	2319485.218	015 Mithuna 04	04:34	10394.191
1640 August 21	22:53	2320291.453	016 Simha 07	20:31	11178.855
1642 November 01	05:30	2321092.729	017 Tula 08	16:36	11958.692
1644 December 17	12:39	2321870.027	019 Sagittarius 13	04:37	12715.192
1647 January 23	11:01	2322636.959	020 Makara 06	14:30	13461.605
1649 February 25	12:04	2323401.003	021 Kumbha 25	04:56	14205.206
1651 April 02	15:02	2324167.126	022 Aries 18	19:57	14950.831
1653 May 16	09:00	2324941.875	023 Rishabha 20	20:25	15704.851
1655 July 21	09:52	2325737.911	024 Karka 15	14:07	16479.588
1657 October 07	23:39	2326547.485	025 Kanya 24	12:03	17267.502
1659 December 01	23:57	2327332.498	026 Vrishika 07	12:16	18031.511
1662 January 09	18:45	2328102.281	028 Capricornus 04	16:45	18780.698
1664 February 13	07:22	2328866.807	029 Aquarius 24	18:27	19524.768
1666 March 19	00:16	2329631.511	030 Mina 17	00:18	20269.012
1668 April 27	07:57	2330401.831	031 Taurus 13	17:20	21018.722
1670 June 22	03:24	2331187.642	032 Mithuna 26	12:11	21783.508
1672 September 08	22:58	2331997.457	033 Virgo 07	15:44	22571.656
1674 November 13	04:17	2332792.678	034 Tula 28	14:25	23345.601
1676 December 26	07:15	2333566.802	036 Dhanus 02	00:17	24099.012
1679 January 31	03:16	2334332.636	037 Makara 23	08:32	24844.356
1681 March 05	04:34	2335096.690	038 Pisces 14	23:12	25587.967
1683 April 11	11:41	2335863.987	039 Mesha 09	17:37	26334.734
1685 May 28	12:47	2336642.033	040 Gemini 14	23:06	27091.963
1687 August 08	12:59	2337444.041	041 Leo 14	12:18	27872.513
1689 October 22	05:23	2338249.724	042 Libra 18	15:21	28656.639
1691 December 11	15:35	2339030.149	043 Vrishika 26	04:24	29416.183
1694 January 17	17:00	2339798.208	045 Capricornus 21	16:37	30163.693
1696 February 20	21:14	2340562.385	046 Kumbha 12	10:08	30907.423
1698 March 27	06:25	2341327.767	047 Aries 06	07:51	31652.327
1700 May 08	19:36	2342100.317	048 Rishabha 05	04:57	32404.206
1702 July 09	00:58	2342891.540	049 Cancer 24	06:15	33174.260
1704 September 26	21:51	2343702.410	050 Kanya 05	10:26	33963.435

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1706 November 25	05:32	2344491.731	051 Scorpius 20	15:16	34731.636
1709 January 04	17:35	2345263.231	053 Dhanus 19	11:52	35482.494
1711 February 08	17:32	2346028.231	054 Aquarius 11	00:38	36227.026
1713 March 14	01:14	2346792.551	055 Mina 03	21:32	36970.897
1715 April 21	20:55	2347561.372	056 Mesha 27	03:31	37719.147
1717 June 11	21:03	2348343.377	057 Mithuna 09	05:30	38480.229
1719 August 27	22:35	2349150.441	058 Simha 13	16:47	39265.700
1721 November 05	02:34	2349950.607	059 Tula 13	10:57	40044.457
1723 December 21	18:44	2350727.281	061 Sagittarius 16	08:24	40800.350
1726 January 26	11:40	2351493.986	062 Makara 09	13:00	41546.542
1728 February 29	11:57	2352257.998	063 Pisces 02	02:41	42290.112
1730 April 05	19:32	2353024.314	064 Aries 22	22:11	43035.924
1732 May 20	03:39	2353799.652	065 Rishabha 25	12:26	43790.518
1734 July 26	08:37	2354596.859	066 Karka 21	09:29	44566.395
1736 October 12	08:37	2355405.859	067 Libra 01	17:59	45353.750
1738 December 05	10:01	2356189.917	068 Vrishika 11	20:00	46116.830
1741 January 12	20:08	2356959.339	070 Capricornus 08	15:58	46865.665
1743 February 16	07:10	2357723.799	071 Aquarius 27	16:06	47609.671
1745 March 22	02:30	2358488.604	072 Mina 20	00:20	48354.014
1747 May 01	18:58	2359259.290	073 Taurus 18	01:55	49104.080
1749 June 26	13:45	2360046.073	074 Cancer 03	19:28	49869.811
1751 September 14	20:19	2360856.347	075 Virgo 13	09:44	50658.405
1753 November 16	22:20	2361650.431	076 Scorpius 05	05:50	51431.243
1755 December 30	12:05	2362424.003	078 Dhanus 06	02:51	52184.119
1758 February 03	03:20	2363189.639	079 Makara 27	06:27	52929.269
1760 March 08	05:36	2363953.733	080 Pisces 18	22:04	53672.919
1762 April 14	19:28	2364721.311	081 Mesha 12	23:03	54419.960
1764 June 01	12:50	2365500.035	082 Gemini 18	20:22	55177.848
1766 August 13	13:44	2366303.072	083 Leo 20	09:36	55959.400
1768 October 26	07:32	2367107.814	084 Libra 23	14:37	56742.610
1770 December 14	23:19	2367887.472	086 Sagittarius 02	09:47	57501.408
1773 January 20	18:03	2368655.252	087 Capricornus 25	15:30	58248.646
1775 February 23	20:57	2369419.373	088 Kumbha 16	07:44	58992.322
1777 March 30	09:17	2370184.887	089 Aries 10	08:30	59737.354
1779 May 12	10:09	2370957.923	090 Rishabha 09	16:58	60489.707
1781 July 12	18:49	2371750.284	091 Cancer 28	20:50	61260.868
1783 October 01	12:00	2372561.000	092 Kanya 09	21:25	62049.893
1785 November 27	18:02	2373349.251	093 Scorpius 25	01:18	62817.054
1788 January 07	19:56	2374120.331	095 Dhanus 23	12:03	63567.502
1790 February 10	17:15	2374885.219	096 Aquarius 14	22:12	64311.925
1792 March 16	02:51	2375649.619	097 Mina 07	20:57	65055.873
1794 April 24	06:03	2376418.752	098 Taurus 03	10:16	65804.428
1796 June 15	02:15	2377201.594	099 Mithuna 14	07:47	66566.324
1798 August 31	23:48	2378009.492	100 Simha 19	14:33	67352.606
1800 November 09	00:55	2378808.538	101 Tula 18	06:34	68130.274
1802 December 25	01:03	2379584.544	103 Sagittarius 21	12:24	68885.517
1805 January 29	11:59	2380350.999	104 Makara 14	11:10	69631.465

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1807 March 04	12:25	2381115.017	105 Pisces 07	00:59	70375.041
1809 April 09	01:10	2381881.549	106 Aries 28	01:31	71121.063
1811 May 24	23:16	2382657.469	107 Gemini 04	05:22	71876.224
1813 July 31	06:58	2383455.790	108 Karka 28	04:27	72653.185
1815 October 17	15:12	2384264.133	109 Libra 07	21:37	73439.900
1817 December 08	19:23	2385047.308	110 Vrishika 17	02:53	74202.120
1820 January 16	21:55	2385816.413	112 Capricornus 12	15:33	74950.648
1822 February 19	06:42	2386580.779	113 Kumbha 04	13:30	75694.563
1824 March 25	04:24	2387345.683	114 Mina 25	00:02	76439.001
1826 May 05	06:53	2388116.787	115 Taurus 23	11:22	77189.473
1828 July 01	02:16	2388904.594	116 Cancer 10	04:52	77956.203
1830 September 19	16:21	2389715.181	117 Virgo 20	02:26	78745.102
1832 November 20	14:33	2390508.106	118 Scorpius 10	19:28	79516.811
1835 January 02	15:22	2391281.140	120 Dhanus 11	03:54	80269.162
1837 February 06	02:56	2392046.622	121 Aquarius 03	03:55	81014.163
1839 March 12	06:34	2392847.587	122 Aries 02	16:44	81793.698
1841 April 18	02:05	2393578.587	123 Mesha 18	03:20	82505.139
1843 June 06	12:26	2394358.018	124 Gemini 24	17:11	83263.716
1845 August 18	15:17	2395162.137	125 Leo 27	07:41	84046.320
1847 October 31	09:25	2395965.892	126 Tula 01	13:42	84828.571
1849 December 18	07:03	2396744.794	128 Sagittarius 07	15:10	85586.632
1852 January 24	18:56	2397512.289	129 Makara 02	14:13	86333.592
1854 February 26	20:42	2398276.363	130 Kumbha 21	05:20	7077.223
1856 April 02	13:30	2399042.063	131 Aries 14	10:27	87822.436
1858 May 16	02:51	2399815.619	132 Rishabha 14	07:05	88575.295
1860 July 17	13:18	2400609.054	133 Karka 07	12:02	89347.501
1862 October 06	00:30	2401419.521	124 Kanya 16	06:48	90136.283
1864 December 01	06:14	2402206.760	135 Vrishika 02	11:01	90902.459
1867 January 10	22:25	2402977.434	137 Dhanus 28	12:20	91652.514
1869 February 13	16:46	2403742.199	138 Aquarius 19	19:36	92396.816
1871 March 20	03:57	2404506.665	139 Mina 12	19:53	93140.829
1873 April 27	14:46	2405276.115	140 Taurus 08	16:36	93889.692
1875 June 20	08:34	2406059.857	141 Mithuna 19	11:08	94652.464
1877 September 05	23:43	2406868.488	142 Simha 25	11:02	95439.460
1879 November 12	20:11	2407666.341	143 Tula 22	23:10	96215.966
1881 December 27	05:20	2408441.722	145 Sagittarius 25	14:25	96970.601
1884 February 01	11:44	2409207.989	146 Makara 18	08:46	97716.366
1886 March 06	12:31	2409972.022	147 Pisces 10	22:57	98459.956
1888 April 11	06:16	2410738.761	148 Mesha 04	04:21	99206.181
1890 May 27	19:06	2411515.296	149 Gemini 08	22:32	99961.939
1892 August 04	06:14	2412314.760	150 Leo 06	00:18	100740.013
1894 October 20	22:16	2413122.428	151 Libra 12	01:42	101526.071
1896 December 11	05:42	2413904.738	152 Vrishika 20	10:47	102287.449
1899 January 18	23:32	2414673.481	154 Capricornus 16	14:59	103035.624
1901 February 22	06:11	2415437.758	155 Kumbha 08	10:52	103779.452
1903 March 29	07:31	2416202.813	156 Aries 01	00:55	104524.038
1905 May 08	20:07	2416974.338	157 Taurus 27	22:05	105274.921

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1907 July 06	15:28	2417763.144	158 Cancer 15	14:56	106042.622
1909 September 24	10:09	2418573.923	159 Virgo 25	16:59	106831.707
1911 November 25	04:59	2419365.708	160 Scorpius 15	07:23	107602.307
1914 January 05	18:35	2420138.274	162 Dhanus 14	04:53	108354.204
1916 February 10	02:39	2420903.610	163 Aquarius 07	01:30	109099.063
1918 March 15	06:44	2421667.781	164 Pisces 26	18:53	109842.787
1920 April 21	08:43	2422435.863	165 Mesha 22	07:39	110590.319
1922 June 10	14:10	2423216.090	166 Mithuna 01	16:05	111349.670
1924 August 23	17:02	2424021.210	167 Simha 05	05:58	112133.248
1926 November 04	09:30	2424823.896	168 Tula 06	10:59	112914.458
1928 December 21	13:35	2425602.066	170 Sagittarius 11	19:23	113671.808
1931 January 27	19:06	2426369.296	171 Makara 05	12:14	114418.510
1933 March 01	20:28	2427133.353	172 Kumbha 24	02:58	115162.124
1935 April 06	17:34	2427899.232	173 Aries 18	12:16	115907.511
1937 May 19	18:37	2428673.276	174 Rishabha 18	20:17	116660.845
1939 July 23	08:03	2429467.835	175 Karka 13	03:30	117434.146
1941 October 10	12:47	2430278.033	176 Kanya 21	15:58	118222.665
1943 December 05	18:31	2431064.272	177 Vrishika 06	20:50	118987.868
1946 January 14	00:52	2431834.536	179 Capricornus 04	12:34	119737.524
1948 February 17	16:16	2432599.178	180 Aquarius 23	16:58	120481.707
1950 March 23	05:44	2433363.739	181 Mina 15	19:29	121225.812
1952 May 01	01:31	2434133.563	182 Taurus 12	00:56	121975.039
1954 June 24	17:21	2434918.223	183 Mithuna 24	16:54	122738.704
1956 September 10	21:58	2435727.415	184 Virgo 04	05:54	123526.246
1958 November 16	14:32	2436524.106	185 Tula 27	14:53	124301.620
1960 December 30	10:21	2437298.931	187 Dhanus 01	17:10	125055.715
1963 February 04	11:57	2438064.998	188 Makara 22	06:50	125801.285
1965 March 09	12:29	2438829.020	189 Pisces 14	20:46	126544.865
1967 April 15	11:30	2439595.979	190 Mesha 08	07:17	127291.304
1969 May 31	15:50	2440373.160	191 Gemini 12	16:34	128047.690
1971 August 10	06:53	2441173.787	192 Leo 10	21:30	128826.896
1973 October 25	03:27	2441980.644	193 Libra 17	03:58	129612.165
1975 December 15	13:58	2442762.082	194 Vrishika 24	16:41	130372.695
1978 January 22	00:11	2443530.549	196 Capricornus 20	14:27	131120.602
1980 February 25	05:43	2444294.738	197 Kumbha 12	08:16	131864.344
1982 March 31	10:13	2445059.926	198 Aries 05	01:24	132609.059
1984 May 11	08:52	445832.286	199 Rishabha 04	18:06	133360.754
1986 July 10	05:28	2446621.728	200 Cancer 21	01:46	134129.074
1988 September 28	03:31	2447432.647	201 Kanya 03	07:06	134918.296
1990 November 27	20:33	2448223.356	202 Scorpius 19	20:23	135687.849
1993 January 07	22:42	2448995.446	204 Dhanus 19	06:45	136439.281
1995 February 12	02:31	2449760.605	205 Aquarius 11	23:14	137183.968
1997 March 17	07:55	2450524.830	206 Mina 03	17:53	137927.745
1999 April 24	17:37	2451293.234	207 Mesha 27	14:10	138675.590
2001 June 13	17:46	2452074.240	208 Mithuna 07	16:48	139435.700
2003 August 28	17:59	2452880.249	209 Simha 12	03:27	140220.144
2005 November 07	07:57	2453681.831	210 Tula 12	06:42	141000.279

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2007 December 24	19:47	2454459.324	212 Sagittarius 15	23:16	141756.970
2010 January 29	19:43	2455226.322	213 Makara 10	10:41	142503.445
2012 March 03	20:10	2455990.340	214 Pisces 02	00:32	143247.022
2014 April 08	21:03	2456756.377	215 Aries 23	13:31	143992.563
2016 May 22	11:17	2457530.970	216 Rishabha 24	10:21	144746.431
2018 July 27	05:13	2458326.717	217 Karka 19	21:19	145520.888
2020 October 13	23:26	2459136.476	218 Kanya 27	23:33	146308.981
2022 December 08	05:41	2459921.737	219 Vrishika 12	05:33	147073.232
2025 January 16	02:38	2460691.610	221 Capricornus 08	12:09	147822.506
2027 February 19	15:51	2461456.160	222 Aquarius 27	14:25	148566.601
2029 March 25	07:49	2462220.826	223 Mina 20	19:22	149310.807
2031 May 04	12:03	2462991.002	224 Taurus 17	09:02	150060.376
2033 June 28	01:29	2463776.562	225 Cancer 02	22:02	150824.918
2035 September 15	19:38	2464586.318	226 Virgo 11	00:12	151613.009
2037 November 19	09:09	2465381.881	227 Scorpius 05	06:52	152387.286
2040 January 02	15:27	2466156.144	229 Dhanus 06	19:59	153140.833
2042 February 06	12:04	2466922.003	230 Makara 27	04:49	153886.200
2044 March 11	12:50	2467686.035	231 Pisces 18	18:58	154629.790
2046 April 17	18:06	2468453.254	232 Mesha 12	11:34	155376.482
2048 June 03	14:50	2469231.118	233 Gemini 18	12:49	156133.534
2050 August 14	07:51	2470032.827	234 Leo 17	19:01	156913.792
2052 October 28	06:33	2470838.773	235 Libra 23	04:11	157698.175
2054 December 17	22:14	2471619.426	237 Sagittarius 02	22:35	158457.941
2057 January 24	01:31	2472387.563	238 Capricornus 25	12:37	159205.526
2059 February 27	05:30	2473151.729	239 Kumbha 17	05:54	159949.246
2061 April 02	12:52	2473917.036	240 Aries 10	01:50	160694.077
2063 May 14	22:20	2474689.431	241 Rishabha 08	19:20	161445.805
2065 July 13	21:02	2475480.376	242 Cancer 26	14:08	162215.589
2067 October 02	19:54	2476291.329	243 Kanya 08	20:15	163004.844
2069 November 30	10:19	2477080.930	244 Scorpius 24	07:38	163773.318
2072 January 11	01:03	2477852.544	246 Dhanus 23	06:53	164524.287
2074 February 14	01:57	2478617.581	247 Aquarius 15	20:32	165268.855
2076 March 19	08:54	2479381.871	248 Mina 07	16:42	166012.696
2078 April 27	01:37	2480150.567	249 Taurus 03	19:49	166760.825
2080 June 16	20:26	2480932.351	250 Mithuna 12	16:37	167521.692
2082 September 01	17:38	2481739.235	251 Simha 16	23:41	168306.987
2084 November 10	06:06	2482539.754	252 Tula 16	02:07	169086.088
2086 December 27	02:36	2483316.608	254 Sagittarius 20	03:46	169842.157
2089 January 31	20:21	2484083.348	255 Makara 14	09:10	170588.382
2091 March 06	20:13	2484847.342	256 Pisces 05	22:26	171331.935
2093 April 11	02:19	2485613.597	257 Aries 27	16:30	172077.687
2095 May 26	06:25	2486388.767	258 Gemini 02	02:50	172832.118
2097 July 31	03:37	2487185.651	259 Karka 25	16:19	173607.680
2099 October 18	08:05	2487994.837	260 Libra 05	05:11	174395.216

APPENDIX 9. CONJUNCTIONS OF MARS (SUPERIOR CONJUNCTIONS OF EARTH).

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1611 October 08	07:15	2309745.802	001 Aries 24	08:38	915.360
1613 November 18	22:55	2310518.455	002 Rishabha 23	08:09	1667.339
1616 January 14	14:16	2311305.094	003 Karka	22:22	2432.932
1618 March 27	13:19	2312108.055	004 Kanya 11	09:48	3214.409
1620 May 27	04:44	2312899.697	005 Vrishika 01	20:53	3984.870
1622 July 11	18:22	2313675.265	007 Capricornus 04	16:30	4739.687
1624 August 17	23:54	2314443.496	008 Aquarius 27	08:43	5487.363
1626 September 23	13:47	2315210.074	009 Mina 22	10:21	6233.431
1628 November 01	06:57	2315979.790	010 Taurus 18	13:15	6982.552
1630 December 21	03:47	2316759.658	011 Mithuna 25	13:18	7741.554
1633 February 26	16:11	2317558.174	012 Simha 21	16:57	8518.706
1635 May 06	15:35	2318357.149	013 Tula 20	07:18	9296.304
1637 June 25	08:31	2319137.855	015 Sagittarius 28	02:55	10056.121
1639 August 04	14:50	2319908.118	016 Makara 24	18:37	10805.776
1641 September 09	06:20	2320674.764	017 Pisces 19	21:49	11551.909
1643 October 17	02:33	2321442.606	018 Mesha 14	04:59	12299.207
1645 November 29	21:24	2322217.392	019 Gemini 17	06:18	13053.263
1648 January 29	18:42	2323008.279	020 Leo 05	23:45	13822.990
1650 April 11	20:41	2323811.362	021 Libra 07	14:03	14604.585
1652 June 07	07:34	2324598.815	022 Vrishika 20	23:17	15370.970
1654 July 20	16:07	2325372.172	024 Capricornus 21	15:14	16123.634
1656 August 26	02:42	2326139.613	025 Kumbha 16	13:00	16870.542
1658 October 01	21:59	2326906.416	026 Aries 10	19:54	17616.829
1660 November 11	02:30	2327677.604	027 Rishabha 09	09:12	18367.384
1663 January 03	12:43	2328461.030	028 Cancer 19	20:21	19129.848
1665 March 15	02:59	2329262.624	029 Virgo 20	23:53	19909.995
1667 May 19	05:00	2330057.708	030 Scorpius 13	19:21	20683.806
1669 July 04	21:01	2330835.376	032 Dhanus 17	16:00	21440.667
1671 August 12	21:47	2331604.408	033 Aquarius 14	02:57	22189.123
1673 September 17	10:13	2332334.926	034 Pisces 01	02:17	22900.095
1675 October 26	04:20	2333139.681	035 Taurus 04	07:38	23683.318
1677 December 11	13:50	2333917.076	036 Mithuna 08	21:57	24439.914
1680 February 14	20:50	2334712.368	037 Simha 02	22:16	25213.927
1682 April 26	07:31	2335513.813	038 Tula 02	22:18	25993.929
1684 June 17	20:05	2336297.337	040 Sagittarius 13	11:45	26756.489
1686 July 29	07:52	2337068.828	041 Makara 11	08:07	27507.338
1688 September 03	05:32	2337835.731	042 Pisces 05	17:20	28253.722
1690 October 10	12:23	2338603.016	043 Aries 28	11:29	29000.478
1692 November 21	12:34	2339376.024	044 Rishabha 27	19:17	29752.804
1695 January 17	22:09	2340163.423	045 Karka 15	03:15	30519.136
1697 March 31	01:51	2340966.577	046 Kanya 16	19:13	31300.801
1699 May 30	22:20	2341757.431	047 Vrishika 06	11:52	32070.494
1701 July 15	01:09	2342532.548	049 Capricornus 08	20:57	32824.873
1703 August 22	02:03	2343300.585	050 Kumbha 03	08:40	33572.361
1705 September 26	15:37	2344067.151	051 Mina 25	10:00	34318.416
1707 November 05	14:46	2344837.115	052 Taurus 21	18:43	35067.780
1709 December 25	03:24	2345617.642	053 Cancer 02	10:09	35827.423
1712 March 03	08:29	2346416.853	054 Simha 27	06:02	36605.251
1714 May 10	15:39	2347215.152	055 Tula 25	04:35	37382.191
1716 June 28	17:26	2347995.226	057 Dhanus 04	09:27	38141.394
1718 August 07	17:44	2348765.239	058 Makara 28	19:18	38890.804
1720 September 12	08:18	2349531.846	059 Pisces 23	21:36	39636.900
1722 October 20	08:02	2350299.835	060 Mesha 18	08:10	40384.341

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1724 December 03	13:48	2351075.075	061 Gemini 20	20:08	41138.839
1727 February 03	08:31	2351866.855	062 Leo 10	10:25	41909.434
1729 April 16	07:37	2352669.817	063 Libra 12	21:54	42690.913
1731 June 11	23:23	353456.474	064 Vrishika 25	12:32	43456.522
1733 July 23	22:06	2354229.421	066 Capricornus 25	18:54	44208.788
1735 August 30	05:18	2354996.721	067 Kumbha 20	13:24	44955.558
1737 October 05	02:06	2355763.588	068 Aries 14	21:46	45701.907
1739 November 15	14:08	2356535.089	069 Rishabha 13	18:23	46452.766
1742 January 07	16:56	2357319.206	070 Cancer 24	21:41	47215.903
1744 March 19	17:31	2358121.230	071 Virgo 25	11:15	47996.469
1746 May 23	01:22	2358915.557	072 Scorpius 17	13:02	48769.543
1748 July 08	04:53	2359692.703	074 Dhanus 21	21:31	49525.896
1750 August 16	00:11	2360461.508	075 Aquarius 18	03:08	50274.131
1752 September 20	11:44	2361227.989	076 Mina 12	02:30	51020.104
1754 October 29	10:39	2361996.944	077 Taurus 08	11:39	51768.485
1756 December 15	09:42	2362774.904	078 Mithuna 13	15:08	52525.631
1759 February 19	12:56	2363571.039	079 Simha 08	11:09	53300.464
1761 April 30	11:26	2364371.976	080 Tula 07	23:20	54079.972
1763 June 22	07:09	2365154.798	082 Sagittarius 16	20:22	54841.849
1765 August 01	11:46	2365925.990	083 Makara 15	09:46	55592.407
1767 September 07	07:33	2366692.815	084 Pisces 09	17:09	56338.715
1769 October 13	16:44	2367460.197	085 Mesha 04	13:34	57085.565
1771 November 26	02:10	2368233.590	086 Gemini 05	06:23	57838.266
1774 January 22	07:49	2369021.826	087 Karka 20	09:52	58605.411
1776 April 04	15:40	2369825.153	088 Kanya 22	05:53	59387.245
1778 June 03	16:47	2370615.199	089 Vrishika 11	03:41	60156.153
1780 July 17	07:59	2371389.833	091 Capricornus 12	01:27	60910.061
1782 August 24	04:37	2372157.692	092 Kumbha 06	09:01	61657.376
1784 September 28	19:08	2372924.297	093 Aries 01	11:16	62403.470
1786 November 08	00:39	2373694.527	094 Taurus 26	02:12	63153.091
1788 December 28	04:03	2374475.669	095 Cancer 07	08:00	63913.333
1791 March 08	00:47	2375275.533	096 Virgo 05	19:06	64691.796
1793 May 13	15:09	2376073.131	097 Scorpius 02	01:18	65468.054
1795 July 02	03:08	2376852.631	099 Dhanus 08	16:45	66226.698
1797 August 09	21:13	2377622.384	100 Aquarius 04	20:32	66975.856
1799 September 15	09:47	2378388.908	101 Pisces 27	20:54	67721.871
1801 October 23	12:53	2379157.037	102 Mesha 22	10:45	68469.448
1803 December 08	06:24	2379932.767	103 Gemini 26	10:08	69224.423
1806 February 07	22:02	2380725.418	104 Leo 16	20:47	69995.866
1808 April 20	15:10	2381528.132	105 Libra 19	02:28	70777.103
1810 June 15	12:41	2382314.028	107 Sagittarius 03	23:20	71541.972
1812 July 27	02:18	2383086.596	108 Makara 02	20:51	72293.869
1814 September 02	07:04	2383853.794	109 Kumbha 25	12:58	73040.540
1816 October 08	05:43	2384620.738	110 Aries 19	23:08	73786.964
1818 November 19	01:14	2385392.551	111 Rishabha 18	03:03	74538.127
1821 January 11	22:23	2386177.433	112 Kanya 02	00:12	75302.008
1823 March 25	10:16	2386979.928	113 Kanya 04	00:46	76083.032
1825 May 26	22:37	2387773.442	114 Scorpius 23	07:34	76855.315
1827 July 12	13:25	2388550.059	116 Dhanus 27	03:41	77611.153
1829 August 19	03:34	2389318.649	117 Aquarius 23	04:17	78359.179
1831 September 24	14:47	2390085.116	118 Mina 17	03:20	79105.139
1833 November 01	18:54	2390854.288	119 Taurus 13	17:32	79853.730
1835 December 20	07:10	2391632.799	120 Mithuna 19	09:53	80611.412
1838 February 24	04:34	2392429.690	121 Simha 13	23:34	81386.982
1840 May 04	14:15	2393230.094	122 Tula 12	23:17	82165.970

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1842 June 25	18:41	2394012.278	124 Sagittarius 22	05:27	82927.227
1844 August 04	15:30	2394783.146	125 Makara 20	11:16	83677.469
1846 September 10	08:51	2395549.869	126 Pisces 14	16:16	84423.678
1848 October 16	20:32	2396317.356	127 Mesha 09	15:08	85170.630
1850 November 29	15:36	2397091.150	128 Gemini 10	17:19	85923.721
1853 January 26	17:59	2397880.249	129 Karka 26	16:59	86691.708
1855 April 10	03:30	2398683.646	130 Kanya 28	14:37	87473.609
1857 June 07	08:27	2399472.852	131 Vrishika 15	16:47	88241.699
1859 July 21	13:20	2400247.056	133 Capricornus 17	04:31	88995.188
1861 August 27	06:55	2401014.788	134 Kumbha 11	09:07	89742.380
1863 October 02	22:08	2401781.422	135 Aries 06	12:03	90488.502
1865 November 11	09:44	2402551.906	136 Rishabha 03	08:53	91238.370
1868 January 02	05:32	2403333.731	137 Cancer 13	06:39	91999.277
1870 March 12	18:05	2404134.253	138 Virgo 12	09:09	92778.382
1872 May 17	15:25	2404931.142	139 Scorpius 07	22:47	93553.949
1874 July 05	13:20	2405710.056	141 Dhanus 13	00:32	94312.022
1876 August 13	00:30	2406479.521	142 Aquarius 08	21:35	95060.900
1878 September 18	12:13	2407246.009	143 Mina 03	21:07	95806.880
1880 October 25	19:45	2408014.323	144 Mesha 26	15:17	96554.637
1882 December 11	00:31	2408425.522	145 Mithuna 03	01:38	97310.068
1885 February 11	11:59	2409217.999	146 Makara 28	02:36	97726.108
1887 April 24	22:11	2410386.424	147 Libra 24	06:30	98863.271
1889 June 18	02:02	2411171.585	149 Sagittarius 08	10:11	99627.424
1891 July 30	07:04	2411943.794	150 Makara 06	23:21	100378.973
1893 September 04	09:00	2412710.875	151 Pisces 01	12:42	101125.530
1895 October 11	08:38	2413477.860	152 Aries 22	23:50	101871.993
1897 November 21	12:11	2414250.008	153 Rishabha 22	11:33	102623.482
1900 January 16	04:49	2415035.701	154 Karka 07	03:40	103388.153
1902 March 30	00:47	2415828.533	155 Virgo 27	18:32	104159.772
1904 May 30	17:06	2416631.213	156 Scorpius 27	23:25	104940.976
1906 July 15	19:57	2417407.331	158 Capricornus 03	07:53	105696.329
1908 August 22	05:24	2418175.725	159 Aquarius 27	03:56	106444.164
1910 September 27	17:00	2418942.208	160 Mina 21	03:20	107190.139
1912 November 05	02:17	2419711.595	161 Taurus 16	22:34	107938.940
1914 December 24	04:19	2420490.680	162 Mithuna 23	04:20	108697.180
1917 February 28	21:09	2421288.259	163 Simha 19	10:04	109473.420
1919 May 09	18:13	2422088.259	164 Tula 18	00:22	110252.015
1921 June 29	06:26	2422869.768	166 Sagittarius 26	14:44	111012.614
1923 August 08	19:35	2423640.316	167 Makara 24	13:05	111762.546
1925 September 13	11:31	2424406.980	168 Pisces 18	16:43	112508.697
1927 October 21	02:09	2425174.590	169 Mesha 13	18:27	113255.769
1929 December 03	07:11	2425948.799	170 Gemini 15	06:20	114009.264
1932 February 01	05:31	2426738.730	171 Leo 03	01:25	114778.059
1934 April 14	13:54	2427542.079	172 Libra 04	21:57	115559.914
1936 June 11	00:01	2428331.079	173 Vrishika 20	19:18	116327.804
1938 July 24	19:08	2429104.297	175 Capricornus 21	08:01	117080.334
1940 August 30	08:30	2429871.854	176 Kumbha 15	08:31	117827.355
1942 October 06	00:06	2430638.504	177 Aries 10	11:49	118573.492
1944 November 14	18:28	2431409.269	178 Rishabha 07	15:15	119323.635
1947 January 06	07:15	2432191.802	179 Cancer 18	05:32	120085.231
1949 March 17	10:14	2432992.926	180 Virgo 17	22:05	120864.920
1951 May 22	13:22	2433789.057	181 Scorpius 11	18:00	121639.750
1953 July 08	21:00	2434567.375	183 Dhanus 17	05:51	122397.243
1955 August 17	02:46	2435336.615	184 Aquarius 12	21:39	123145.902
1957 September 21	14:29	2436103.103	185 Mina 07	21:11	123891.882

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
1959 October 30	01:46	2436871.574	186 Taurus 02	19:00	124639.792
1961 December 14	18:29	2437648.270	187 Mithuna 07	16:58	125395.707
1964 February 17	02:57	2438442.623	188 Leo 27	19:21	126168.806
1966 April 29	05:29	2439244.741	189 Tula 01	11:07	126949.463
1968 June 21	15:47	2440029.158	191 Sagittarius 11	21:25	127712.892
1970 August 02	12:01	2440801.001	192 Makara 10	02:01	128464.084
1972 September 07	10:57	2441567.956	193 Pisces 05	12:28	129210.519
1974 October 14	12:56	442335.039	194 Aries 27	01:52	129957.078
1976 November 25	01:20	2443107.556	195 Rishabha 26	22;13	130708.926
1979 January 20	12:18	2443894.012	196 Karka 12	08:10	131474.340
1981 April 02	14:13	2444697.092	197 Kanya 14	22:24	132255.933
1983 June 03	11:21	2445488.973	198 Vrishika 04	15:02	133026.626
1985 July 18	02:41	2446264.612	200 Capricornus 07	12:18	133781.512
1987 August 25	07:32	2447032.814	201 Kumbha 03	03:52	134529.161
1989 September 29	19:00	2447799.292	202 Mina 25	03:09	135275.131
1991 November 08	09:16	2448568.886	203 Taurus 22	03:13	136024.134
1993 December 27	02:28	2449348.603	204 Mithuna 28	23:44	136782.989
1996 March 04	14:02	2450147.085	205 Simha 26	02:34	137560.107
1998 May 12	19:47	2450946.324	206 Tula 23	23:06	138337.962
2000 July 01	15:50	2451727.160	208 Dhanus 03	21:48	139097.906
2002 August 10	22:17	2452497.012	209 Aquarius 01	03:51	139847.160
2004 September 15	12:55	2453264.038	210 Pisces 23	15:57	140593.664
2006 October 23	06:46	2454031.782	211 Meshaha 17	20:48	141340.867
2008 December 05	22:04	2454806.419	212 Gemini 19	18:40	142094.778
2011 February 04	16:40	2455597.194	213 Leo 09	09:29	142864.395
2013 April 18	00:20	2456400.514	214 Libra 11	05:19	143646.221
2015 June 14	15:56	2457188.164	215 Vrishika 25	19:08	144412.797
2017 July 27	00:57	2457961.540	217 Capricornus 26	11:32	145165.481
2019 September 02	10:42	2458728.946	218 Kumbha 20	08:30	145912.355
2021 October 08	04:01	2459495.667	219 Aries 15	13:29	146658.562
2023 November 18	05:41	2460266.737	220 Rishabha 13	00:01	147409.001
2026 January 09	11:41	2461049.987	221 Cancer 23	07:04	148171.294
2028 March 21	02:35	2461851.608	222 Virgo 23	11:13	148951.467
2030 May 25	10:50	2462646.951	223 Scorpius 17	12:45	149725.531
2032 July 11	05:16	2463424.719	225 Dhanus 22	11:45	150482.489
2034 August 19	05:22	2464193.724	226 Aquarius 17	22:02	151230.918
2036 September 23	15:44	2464960.156	227 Mina 12	20:15	151976.844
2038 November 01	07:00	2465728.792	228 Taurus 7	21:57	152724.915
2040 December 17	12:49	2466506.034	229 Mithuna 13	08:40	153481.361
2043 February 20	17:46	2467301.240	230 Simha 06	06:59	154255.291
2045 May 02	10:42	2468102.946	231 Tula 06	13:07	155035.547
2047 June 25	02:56	2468886.622	233 Sagittarius 17	06:07	155798.255
2049 August 04	15:15	2469658.135	234 Makara 15	03:01	156549.126
2051 September 10	12:23	2470425.016	235 Pisces 10	11:43	157295.488
2053 October 16	16:58	2471192.207	236 Mesha 04	03:39	158042.152
2055 November 28	13:51	2471965.077	237 Gemini 05	08:15	158794.344
2058 January 23	20:22	2472752.349	238 Karka 18	13:14	159560.551
2060 April 06	03:54	2473555.663	239 Kanya 21	08:56	160342.372
2062 June 06	06:04	2474346.753	240 Vrishika 10	07:06	161112.296
2064 July 20	10:02	2475121.918	242 Capricornus 11	17:19	161866.721
2066 August 27	09:57	2475889.915	243 Kumbha 07	04:04	162614.169
2068 October 01	21:50	2476656.410	244 Aries 01	03:45	163360.156
2070 November 10	18:25	2477426.267	245 Taurus 26	09:59	164109.416
2072 December 30	02:53	2478206.620	246 Cancer 05	21:21	164868.890
2075 March 09	06:50	2479005.785	247 Virgo 04	16:08	165646.672

Gregorian Date	UTC	Julian Day	Darian Date	AMT	Julian Sol
2077 May 15	20:34	2479804.357	248 Tula 28	21:05	166423.878
2079 July 05	01:18	2480584.554	250 Dhanus 08	04:49	167183.201
2081 August 13	01:25	2481354.559	251 Aquarius 04	14:29	167932.604
2083 September 18	14:20	2482121.097	252 Pisces 26	15:11	168678.632
2085 October 25	11:03	2482888.960	253 Mesha 21	22:29	169425.951
2087 December 09	13:22	2483664.057	254 Gemini 24	07:25	170180.309
2090 February 08	05:27	2484455.727	255 Leo 14	19:09	170950.798
2092 April 21	09:35	2485258.899	256 Libra 16	11:32	171732.480
2094 June 17	05:44	2486045.739	258 Sagittarius 03	06:25	172498.268
2096 July 29	05:26	2486818.726	259 Makara 02	13:45	173250.573
2098 September 04	12:02	2487586.001	260 Kumbha 24	07:40	173997.319