Chapter 19
CALENDARS AND TIMEKEEPING

Break-out sessions went on for hours.

. . . And continued outside after the conference ended.

1020

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THE DARIAN CALENDAR

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The Darian calendar is a complete timekeeping system for the 24-hour, 39-minute, 35.244-second sol and the 668.5921-sol year. 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.

• 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 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.

• An intercalation formula keeps the calendar synchronized with the vernal equinox for up to 10,000 Martian years.

• A defined epoch allows the Darian date and local time on Mars to be calibrated with the Gregorian date and local time on Earth.

• A distinctive nomenclature for months and sols eliminates any possibility of confusion with Gregorian dates.

• A special calendar format provides an easily understandable visual display of both Darian date and Gregorian date.

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 day — 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, have proposed Martian "metric" clocks based on powers of ten.

Days and Years on Earth and Mars

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.

Information on many of the other Martian calendars is available on the Martian Time Web Site.

2.0 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! The correct figure to use in expressing Martian time in consistently Martian units is 668.5921 sols per 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. Of course, since the fractional amount of sols in a Martian tropical solar year of 668.5921 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 tropical solar years there are 6,685.921 sols, the difference thus being -0.079 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 66,859.21 sols in 100 tropical solar years. Finally, by making every year divisible by 500 a leap year, there are 334,296 sols in 500 calendar years, and the remaining error is only 0.05 sols. Theoretically, this error amounts to only one sol in 10,000 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.

1022

To summarize, the intercalation formula is (Y-1)\2 + Y\10 - Y\100 + Y\500, where the backslash indicates integer division.

3.0 MONTHS AND SEASONS

The Stretched Gregorian Calendar

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 than represent 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 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 equal divisions of the tropical solar year to be far more useful than a system in which the longest month is nearly 50 percent longer than the shortest month. The stretched Gregorian calendar is a typical example of these wildly changing months. Imagine the difficulty of working out monthly budgets in such a variable system, or trying to remember how many sols each month contains. A mnemonic poem would be of epic length!

1023

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 668.5921 by 24 results in an mean month of 27.8580 sols, or 28.6238 Earth days, so the difference between the mean Martian month and the mean Earth month would be only 6 percent. 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 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 for 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 difficult to remember, and to make it even worse, I recently 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 which 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.

1024

The Darian Months

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 (13 Kumbha). In accordance with Kepler's laws of orbital motion, Mars is at that time travelling 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 before the summer solstice, summer is the second longest season. 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 (13 Simha). 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 28th of Pisces. 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 10th sol of Mithuna, the Sanskrit name of that same constellation. After 142 sols winter begins on 13 Virgo 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, 1 Sagittarius marks the beginning of autumn, which lasts 194 sols, and so on.

1025

4.0 WEEKS

Sols of the Week

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.)

1026

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.

The table shows the layout of the calendar for the entire Martian year.

5.0 THE STARTING DATE OF THE DARIAN CALENDAR

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. Accordingly, the Darian year 0 began with the Martian vernal equinox on Thursday 18 December according to the Gregorian calendar, when midnight on the prime meridian of Mars occurred at 22:52:51 Universal Coordinated Time. (**NOTE**: this is a correction to earlier papers, and is based on Mars Pathfinder mission data and information supplied by Michael D. Allison.) According to this epoch, the current Darian year 12 began on

14 July 1998.

1027

However, while the idea of beginning the Darian calendar with the first remote presence on Mars is a straightforward one, it has recently been called to my attention that this choice may have nationalistic overtones which some might find objectionable. An alternative would be to adopt Robert Zubrin's idea of beginning the Martian epoch with the most recent Martian vernal equinox which occurred at the beginning of a Gregorian year. This occurred on 1 January 1707, which would make the current Darian year 155.

6.0 AN EARTH-ORIENTED DARIAN CALENDAR DISPLAY

1028

Despite our enthusiasm, for the next few decades, users of the Darian calendar will all be here on Earth. The terrestrial version of the Darian calendar must therefore be a dual-calibrated display. It must relate the local date and time on the Martian prime meridian to Universal Coordinated Time. The calendar display for the current month of Dhanus is an example. For each Martian sol, mean midnight on the Martian prime meridian is expressed in terms of Gregorian date and Universal Coordinated Time. Note that terrestrial days of the week appear in their normal positions only occasionally on this hybrid calendar, so in order to readily orient the earthbound 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 (Tuesday, 1 September 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.

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 at 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 was done during the Viking and Pathfinder/Sojourner missions. This second example of a Darian calendar display takes us back to July 1997, or the Darian month of Taurus in the year 11. It expresses chronological information pertinent to the Mars Pathfinder/Sojourner mission in the format of the Darian calendar. For each Martian sol, local mean Martian midnight at the Carl Sagan Memorial 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.

An additional display that is available on the Martian Time Web Site is a real-time clock showing the date and time on both Earth and Mars. I thank Alan Hensel for cleaning up the Java code to make the clock run more efficiently.

7.0 CONCLUSION

The Darian calendar combines the advantages of the two major proposals for calendar reform here on Earth in the 20th century, the World calendar and the 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 Sol Solis, the first sol of the week (International Fixed calendar).

- The leap sol occurs at the end of the year (International Fixed calendar).

While I have emphasized the utility of the Darian calendar on Mars at this convention, the Darian calendar is not restricted to Mars. I have also developed the Darian system to include the four Galilean moons of Jupiter: Io, Europa, Ganymede, and Callisto. The Darian system is an integrated timekeeping system for five worlds, not an isolated system for just one planet.

For information on the Galilean variants of the Darian calendar, see my article on "The Calendars of Jupiter" on the Martian Time Web Site.

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 adopt a 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.