

# The Martian Clock: A novel 24-hour clock motion for Mars and Earth, using standard seconds only.

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## ABSTRACT

A novel 24-hour clock, suitable for both Mars and Earth solar days, is presented in digital and analog forms. The digital clock features hours, hundredths-of-hours, and standard seconds per hundredth-of-hour, that being 37 seconds for Mars and 36 seconds for Earth, which is the only difference between the two clocks. The equivalent analog clock has a novel hand motion which strikes the hour when all 3 hands converge on that hour; it can be mechanically constructed and is dubbed the “Martian Clock” as something which Martians might have devised, had they existed. Also a functional 20-hour clock is shown. A desktop Martian Clock is available for download, in a variety of clockfaces and sizes.

**Key words:** clock — Mars

## 1 INTRODUCTION

While there is no formal agreed system of daily timekeeping for Mars, the usual method for landed spacecraft is to stretch the hours-minutes-seconds of the 24 hour Earth clock to fit the slightly longer Mars solar day of 24 hours, 39 minutes, and 35.244 seconds (in Earth time). Thus those Mars time-seconds have 1.0274912517 times the duration of the standard Earth seconds. This eases the adaptation of existing software programmed in Earth time units to use Mars time units instead. This method is used by the NASA GISS Mars24 Sunclock<sup>1</sup> which is based on the comprehensive analysis of Mars motion given by Allison & McEwen (2000).

Mechanical analog Mars clocks usually adhere to that schema as well, starting with the earliest version of Levitt (1954) which was powered by a “laboratory-type heavy-duty” motor, forward to the Mars-time wristwatches provided to the JPL team supporting the Mars Exploration Rover<sup>2</sup> in 2004.

The notable disadvantage of that method is that the standard time-second, used in all our science and technology, is lost. This may not be a hardship today, but in a possible future era of human-occupied cities on Mars, the people will probably not want to contend with two competing values of the “second”. Also it would ease communications between Earth and Mars if the time-second retains its undisputed definition as that of the standard Earth second.

Of course, the standard time-second does not fit Mars’s solar day exactly, so to incorporate it would entail use of leap-seconds or leap-hours at regular intervals, as well as the question of how to structure the hours-minutes-seconds. One method on a long-standing web-

site<sup>3</sup> from China is to add a 25th hour consisting only of 39 minutes and 35 seconds. But that creates computational difficulties of its own. The general sense is that humans on Mars will prefer to keep the familiar 24 hours per solar day.

So to summarize, what’s needed is a simple clock for Mars which uses 24 hours per solar day and uses the standard second. A bonus would be if that clock works for Earth as well, for simulation and conversion purposes. A “clock” is here taken to be an analog-capable device, i.e., constructible as a clockface with moving hands. This paper proposes such a clock with a simple digital display and an analog display having an unexpected yet elegant mechanical hand movement. The exact description follows.

## 2 THE 24-HOUR MARTIAN CLOCK

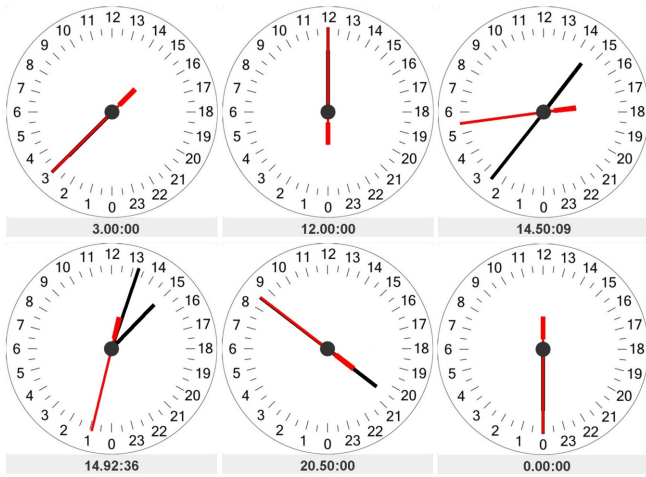
Simplicity is an obvious virtue, and the following digital Earth-Mars clock is very simple indeed. The key is to discount minutes, and build the clock only out of hours and the immutable standard second. The standard Earth second is of course contoured to Earth’s rotation, so it’s no surprise to find that an Earth day can be written as 24.00 hours where each hundredth-of-an-hour has exactly 36 seconds; thus,  $24 \times 100 \times 36 = 86400$  seconds per day. This can be written as hh.dc:ss, or, re-defining the “minute” as a hundredth-of-an-hour, as hh.mm:ss. Note that the seconds are just the remainder of the hundredths-of-hours, so the clock can be thought of as showing primarily the hours written as *nn.nn*, and then appending the leftover seconds written as *:nn*. Thus, e.g., 12.24:34 on this clock equates to 12:14:58 on the standard clock – both showing a time 2 seconds before a quarter-past-12.

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<sup>1</sup> <https://www.giss.nasa.gov/tools/mars24/>

<sup>2</sup> [https://mars.nasa.gov/mer/spotlight/spirit/a3\\_20040108.html](https://mars.nasa.gov/mer/spotlight/spirit/a3_20040108.html)

<sup>3</sup> <http://interimm.org/mars-clock/en/timing-doc.html>



**Figure 1.** The “relaxed” Martian analog clock; a selection of times shown, with digital time beneath. Top left: 3 o’clock: all 3 hands point to the ‘3’, etc.

## 2.1 The Digital Martian Clock

The magic of the above schema happens when Mars’s rotation is considered, where a Martian solar day of 88775.244 standard Earth seconds is written as 24.00 hours. Each of those hours is comprised of 3698.9685 standard seconds, suitably close to 3700 seconds which we now adopt, accepting the need for leap-seconds or leap-hours later. Thus, 3700 standard seconds per hour yields 37 standard seconds per hundredth-of-an-hour; thus,  $24 \times 100 \times 37 = 88800$  seconds per day, which can be taken as a “practical” value for Mars timekeeping, with leap-hours used to reset the clock periodically as described below. This Martian time can be written in the same notation as the Earth version above, and actually it is seen that the only difference between the two is that the Earth version has 36 standard seconds per “minute” whereas the Mars version has 37 standard seconds per “minute”, just one second more. And that is the only difference, so the overall schema is very simple while still adhering to the solar days of both planets.

The leap-seconds needed to keep this Martian clock aligned with Mars’s rotation comes to 24.756 seconds per Martian solar day, which can be performed as 4 or 5 leap-hours per Martian year, a frequency not far ( $\approx 19\%$  more often) from that of daylight savings hour shifts on Earth.

## 2.2 The Analog Martian Clock

The corresponding analog clock needs to mark 100 “minutes” onto a 24-hour dial. This is done with 3 marks between successive hours, thus 96 total marks on the dial, plus the hour hand moves 4 more marks as the hour passes – thus the minute hand must be made to catch up to the hour hand to traverse 4 more marks to make an even 100. Thus, on this clock, the hour is struck when the minute hand catches up to and passes over the hour hand. Similarly, the second hand catches up to and passes over the minute hand at the stroke of each minute, including that minute which coincides with the stroke of the hour. Therefore at the stroke of each hour, all three hands meet at that hour mark on the dial. This is achieved with the following configuration of the clock hands:

For each solar day:

- The hour hand performs one sweep of the dial.

- The minute hand performs 25 sweeps of the dial.
- The second hand performs 2425 sweeps of the dial for the “exact” clock, or 1225 sweeps for the “relaxed” clock explained below.

One such second hand sweep of the dial of the “exact” clock, if timed as consecutive crossings over the minute hand, takes 37 seconds for the Mars clock and 36 seconds for the Earth clock; the second hand does not follow any marks on the dial, but ticks the seconds of its own accord. However, such a rapid sweep of the second hand would not have eye appeal to most people. A “relaxed” version allows the second hand to sweep once per 2 “minutes” (i.e.,  $1/50^{\text{th}}$  hour), thus needing only 48 total marks on the dial to service the minute hand; for this movement, the second hand sweep takes 74 seconds for the Mars clock and 72 seconds for the Earth clock, when timed as consecutive crossings over the minute hand. Figure 1 shows six times-of-day depicted on the relaxed analog clock, starting with 3 o’clock where all 3 hands point to the ‘3’; the dial shows the midnight hour at bottom and 12-noon at top, so that the hour hand follows the Sun.

Note that the 12<sup>th</sup> hour on the Martian dial is just one of the 24 hours, with no positional significance as it has on standard clocks where it serves as the anchor for the minute and second hands. On a standard clock the three hands move independently of each other, but on the Martian clock the three hands move interconnectedly, with their relative positions showing the time. To tell the Martian time at a glance, just note the hour and the orientation of the minute hand to the hour hand, which matches the orientation of the minute hand to the ‘12’ on the standard 12-hour clock. Thus, at the half-hour the minute hand points directly away from the hour hand, just as it points away from the ‘12’ on the standard clock. The second hand is similarly oriented to the minute hand, pointing directly away from it at the half-minute.

No 12-hour AM-PM analog Martian clock is available because the clock marks cannot fit both hour hand and minute hand for a 12-hour clock. The digital clock is not hindered by that, so a 12-hour AM-PM digital display is trivially makeable for the Martian clock.

A desktop Martian Clock is available for download<sup>4</sup>; its initial display shows a joint analog-digital Earth clock, in local time, using the relaxed Martian hand movement. Other movements and clock-faces are available, including whether the clock is to be for Mars or Earth; in total 32 variants are selectable, with many more available to those wishing to tweak the “settings” file. The downloadable zip file includes a ReadMe which explains the optional settings in detail. A Java 7 (or better) runtime environment is required to run the clock. Example desktop clockfaces are shown in Figure 2. An improved-quality display is a work in progress – we are not professional Java programmers.

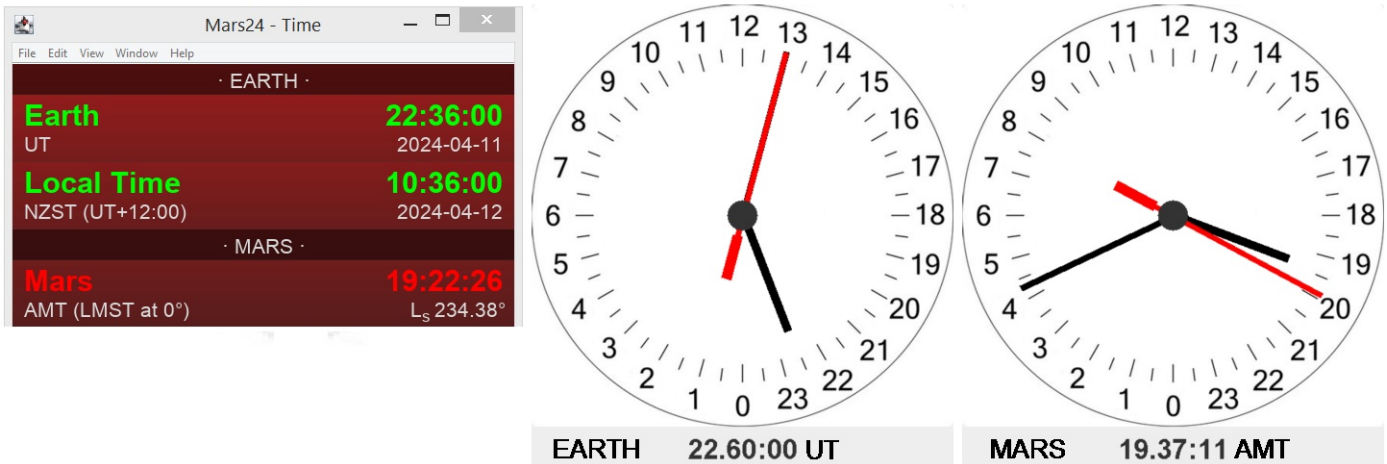
This analog clock was originally developed in 2015 and put online<sup>5</sup> as a “space clock” in 2019. Its serendipitous suitability to the Martian solar day has prompted us to re-brand it as the “Martian clock” as a plausible venue for its use. Still, its elegant analog hand motion can be seen as a competitor to the standard hand motion of today; it may have been a chance of history as to which design was first developed, thus obviating the other. Perhaps elsewhere it may have gone the other way, such as on Mars, had there been Martians to develop their own clock. Thus the “Martian clock” evokes not just a new clock design, but choices made and what might have been.

<sup>4</sup> <https://quasars.org> displays a paragraph on the Martian Clock which provides a download link (at <https://quasars.org/Martian-Clock.zip>)

<sup>5</sup> now at <https://quasars.org/clock/marsclock-for-earth.htm>



**Figure 2.** Three desktop clockfaces. Left: the “exact” Martian clock, the second hand sweeps once per each “minute” (hundredth-of-an-hour); Middle: the “relaxed” Martian clock, the second hand sweeps once per two “minutes”; Right: the Space Clock, for free-floating crew.



**Figure 3.** NASA Mars24 time compared with Martian clock times. Earth UT of 22:36 is expressed by the Martian clock (Earth variant) as 22.6 hours, with the second hand passing over the minute hand at the stroke of that minute. Mars24 AMT of 19:22:26 is expressed by the Martian clock as 19.37 hours and 11 seconds, 3 seconds offset from the Mars24 time as discussed in the text.

### 3 COMPARISON OF THE MARTIAN CLOCK TO THE NASA MARS24 CLOCK

The NASA Mars24 clock<sup>6</sup> presents the Mars timekeeping system used by most Mars landers; its daily clock consists of a variant of Earthtime with hours, minutes, and seconds all “stretched” by a multiplier of 1.02749125 to fit the Martian solar day which is longer than the Earth day by that ratio. In so doing it loses the standard second, of course, which is what the Martian clock, presented in this paper, is designed to remedy. So it would be beneficial to reconcile these two timekeeping systems to verify that the Martian clock is keeping Mars time accurately, i.e., in accordance to current benchmarks.

As both systems use 24 hours for the Mars day, those hours should be aligned across the two clocks. Figure 3 shows a photograph in time (given by the Mars24 Earth UT) of the Mars24 display alongside working Martian clocks for Earth and Mars – these two Martian

clocks running from Java code authored by one of us (RS). The caption of Fig. 3 details the matches, but in brief the Earth times match exactly (as they trivially should), and the Mars times are offset by 3 seconds at that point in the day. That offset is explained next.

The Mars solar day is 88775.244 standard seconds long, which is exactly fitted by the Mars24 stretched hours-minutes-seconds. The Martian clock adopts a working Mars day length of 88800 seconds (to divide it into 24 hours of 3700 standard seconds each) which is thus 24.756 seconds longer than the actual day length. In production, this overlap would be reconciled to the Mars solar day by use of a “leap hour” scheduled 4 or 5 times per Mars year. But for this demonstration model, we re-initialize the Martian clock after 88775.244 seconds to keep its days aligned with Mars24. Therefore there is a “drift” of 24.75 seconds across the two models per each day before re-initialization.

<sup>6</sup> available at <https://www.giss.nasa.gov/tools/mars24/>

In practice, this demonstration Martian clock re-initializes about

16 seconds before the Mars24 new day<sup>7</sup>, so is 16 seconds ahead at the start. As the day progresses, the “drift” causes the Martian clock to lose about 1 second per hour, so that by end of the day, the Martian clock is 8 seconds behind Mars24; then the Martian clock re-initializes and the cycle begins anew. Due to this slippage, at the 19<sup>th</sup> hour of the day the Martian clock runs about 3 seconds in arrears of the Mars24 clock, as shown on Figure 3. The calculation is: the Mars24 clock shows 1346 “stretched” seconds after the 19<sup>th</sup> hour, converted to  $1346 \times 1.0274912517 \Rightarrow 1383$  standard seconds; the Martian clock shows 0.37 hr + 11 sec after the 19<sup>th</sup> hour, thus  $0.37 \text{ hr} \times 3700 \text{ sec/hr} = 1369 \text{ sec}$ , plus 11 sec = 1380 standard seconds. Thus the Martian clock is 3 seconds behind the Mars24 clock just after the 19<sup>th</sup> hour, and is correctly keeping Mars time as per the schedule set for it.

Also, the Mars24 clock shows the Earth & Mars clocks ticking off the seconds at arbitrary offsets to each other, which of course happens because those seconds are of different durations. By contrast, because the Martian clock uses standard seconds, it is of course set to tick simultaneously with Earth’s ticks, as seen by an observation point equidistant from Mars and Earth.

The Earth version of the Martian Clock can be seen keeping your local time at <https://quasars.org/clock/marsclock-for-earth.htm>. We plan to make that page (or pages) more comprehensive, as our Javascript develops.

#### 4 ANOTHER MARS CLOCK CANDIDATE

For completeness, a search was done for other Mars-suitable analog clocks using standard seconds and having user-friendly attributes. Only one other was found, a 20-hour clock which uses standard (not “Martian”) hand motions and has 4440 seconds/hour. Those seconds/hour are not divisible by 100 but are divisible by 60, thus it uses 60 minutes/hour and 74 seconds/minute for Mars time, as  $20 \times 60 \times 74 = 88800$  seconds per practical Mars solar day. Its attractions are its standard hand motion and the familiar 60 minutes/hour; the chief drawbacks are the unfamiliar 20-hour day and that leap-hours would be a larger adjustment to the day, being 4440 seconds. However, this 20h/60m/74s schema would also allow for a 10-hour AM & PM analog clock, should that be popular. Figure 4 shows the two clockfaces with an example time.

The 20-hour clock also works for Earth with 72 seconds/minute, but realistically would have no actual use except perhaps as an aid to converting the 20-hour Mars time to the 24-hour Earth time.

#### 5 CLOCKS WHICH ARE NOT GOOD ENOUGH

Another functional Mars clock has 25 hours/day and 50 minutes/hour and 71 standard seconds/minute, thus 3550 seconds/hour and 88750 seconds/day – slightly short of the 88775.244 standard seconds in the Mars solar day, whereas the above clocks slightly overlap it. This schema marks the analog clock dial easily into 50 partitions servicing both hours and minutes. However, the 3550 sec/hr has few divisors (being  $2 \times 5^2 \times 71$ ), the 71 sec/min is a large prime number not divisible and thus unfriendly for public use, and the clock has no Earth equivalent, so it is not considered further.

<sup>7</sup> because we take Earth-UT and Mars-AMT as exactly aligned on 06-Jan-2000-00:00:00 whereas Mars24 treats those as 10 seconds offset then, and 6 subsequent Earth leap seconds are included by Mars24 but not by us. These 16 seconds are submerged by the daily slippage of 24.75 seconds.

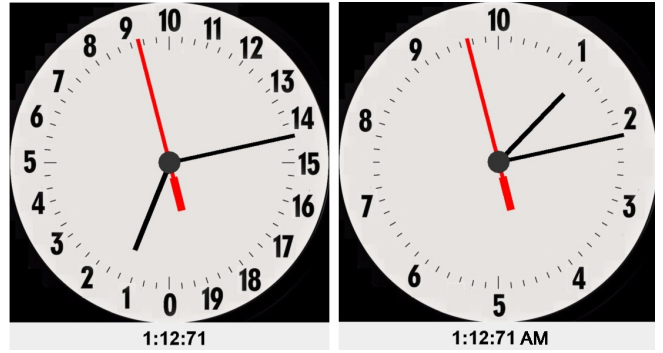


Figure 4. The 20-hour Mars analog clock, with AM-PM variant.

Another 25-hour clock has 48 min/hr and 74 sec/min for Mars ( $25 \times 48 \times 74 = 88800$ ) and 72 sec/min for Earth ( $25 \times 48 \times 72 = 86400$ ). But the corresponding analog clockface cannot fit 25 hour marks with 48 minute marks, and nobody wants 48 min/hr anyway.

Yet another Mars-eligible clock homes right in to the Mars solar day, clocking in at 88775 standard seconds per day. This is obtained by simply factoring 88775 into  $5^2 \times 53 \times 67$  – thus 25 hours of 53 min/hr and 67 sec/min. The accuracy is excellent in that a leap-hour would not be needed for decades, but in spite of that, the prime numbers of minutes and seconds are unwieldy, no acceptable analog clock face can be drawn, and there is no equivalent Earth clock. This schema may be practical for scientific use, but is simply too ugly for public use.

All these unacceptable clocks illustrate that a functional clock also needs elegance and ease of use to be adopted. The 24-hour Martian clock has that, although there is no 12-hour analog clockface for it. The 20-hour clock has the 10-hour analog clockface, but the long 4440 sec/hr would likely be unpopular. Thus the 24-hour Martian clock with its simple digital display of *hh.mm:ss* and its elegant analog hand motion is presented as the best clock to keep daily Mars time with standard seconds, and its digital counterpart can trivially display a 12-hour AM-PM format if desired.

#### 6 CONCLUSION

The “Martian clock” with its simple digital display of *hh.mm:ss* with “minutes” re-defined as hundredths-of-an-hour, and its unique elegant analog hand motion, is presented as the best clock to keep daily Mars time using 24 hours/day and standard Earth seconds.

#### ACKNOWLEDGEMENTS

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#### REFERENCES

- Allison, Michael & McEwen, Megan, 2000, P&SS, 48, 215  
Levitt, I.M., 1954, S&T, 13, 216

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