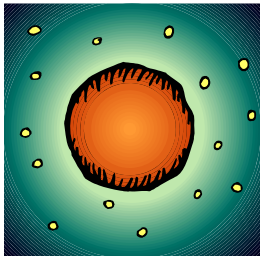
Arts & Sciences Geek Week, Spring 2016



2016 is a Leap Year … why is that so, and what is the history of the calculation?

Why are we so Earth-centric .. What if we lived on Mars, would we need leap years there? Come to the talk and find out!

Leap Year, Shmeep Year!

-- what's the big deal?

Dr. Scott Schneider

Department of Natural Sciences

Monday, March 21st, 2016, 7-9 PM
Science Building, S211

Free Walking tacos!

Can I get a copy of the talk?

Well, the talk has only **just** begun .. But, ok!

http://vnatsci.ltu.edu/s_schneider/astro/index.shtml

note the underscore:

`http://vnatsci.ltu.edu/s_schneider/astro/index.shtml`

Don’t read ahead and give away all the goodies!

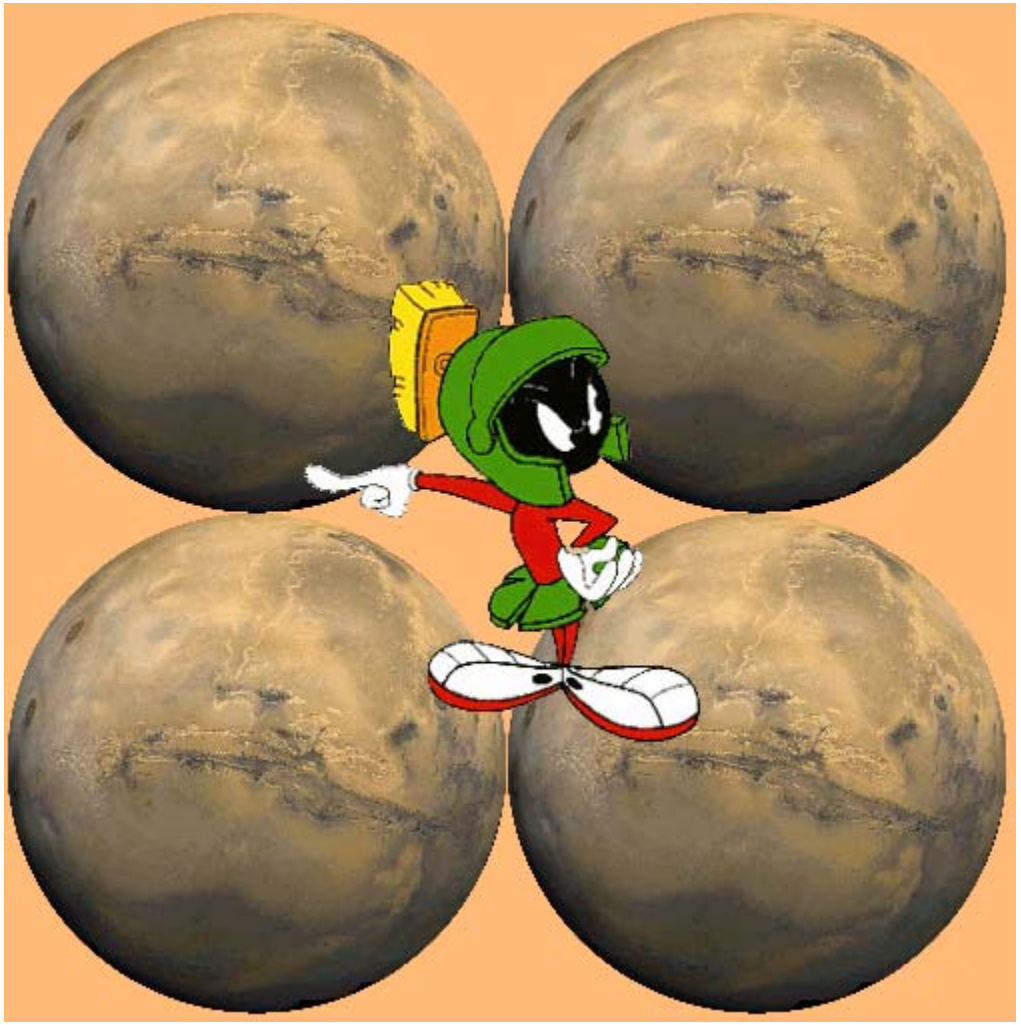
Topics covered today

- Orbit period of the Earth around the Sun
  - Compared to Earth solar day
- Corrections to the calendar to add leap days
  - Thanks Mr. Caesar!
- Weird leap day rules – Thanks, your Holiness, Pope Gregory!
  - Why/How do they work?

- Mars orbit period vs the solar day?
- Possible calendar system for Mars
  - Need leap days also?

First, a “greeting” from Mars …

If you do not recognize that this is the 21st Sol of the month Mesha in the Martian year of 216, I will be very, very angry!



Orbit period of the Earth

- Orbit period of the Earth around the Sun = 365 days, right?
- Actually, ***365.24219*** solar days
  - Oh, that pesky 0.24219 – arrgh!

- Can't have a calendar with a fixed number of days

- *When was this problem noticed?*

Brief History of Leap Time

- Early calendars allowed rulers to hold festivals to honor the “gods”
- Months added/removed at the whim of rulers
  - calendars drifted relative to Sun/Moon cycles
- “Intercalation” – adding a day to bring months “in synch” with seasons
- Skip over early calendars – jump to Julius Caesar (~45 BC)
- Julius Caesar had a leap year calendar created = +Y/4
  - Not permanent solution (and 3-year confusion!)
  - SEP? (Someone Else’s Problem)

Brief History of Leap Time - continued

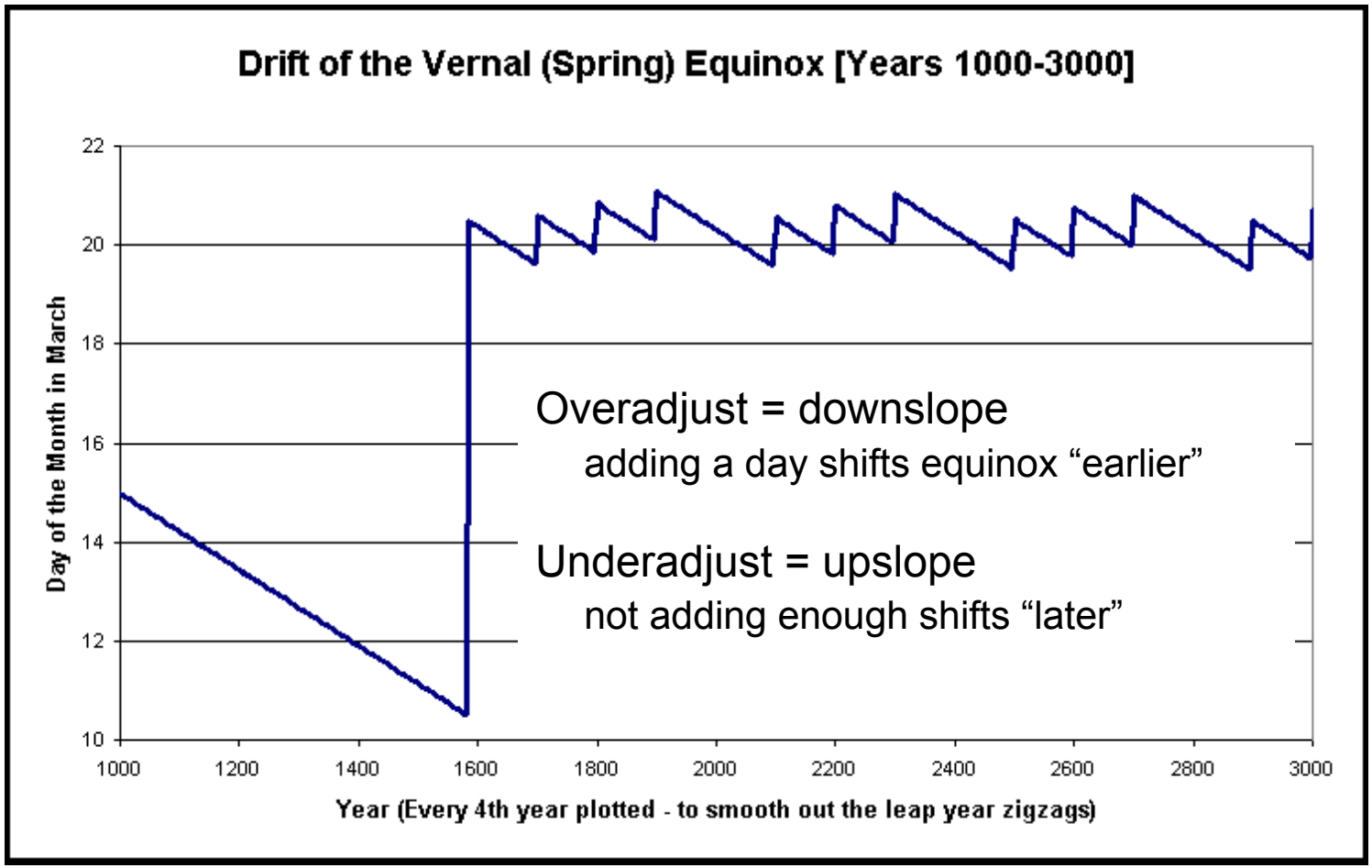
- By 1400's, Popes frustrated - Easter kept shifting
  - Also, Vernal (Spring) Equinox kept drifting earlier
- Pope Gregory finally commissioned current rules
  - *Successful, but a Y5K problem looms!*
- Gregorian Reformation – October, 1582
  - Needed to eliminate some days - Oct 4th then Oct 15th
- Add if /4 years, not if /100, add if /400

Leap Formula = +Y/4 -Y/100 +Y/400

"integer divisions"

Follow Spring Equinox Date

- **Spike before 1600? – Gregorian Reformation!**



Why does the 4-year rule work?

- Let's round *365.24219* to 365.25 = *365 + ¼*
- Each 365 days, Earth doesn't quite make it around
  - Takes ¼ day more
  - Would mean the "seasons" would eventually drift
  - 365 **undercounts** the number of days of orbit
- Solution - every 4 years .. Add one day
  - Chosen to be **Blair and Nell's** wedding anniversary day
    - Happy 6th anniversary … seems more like 24 years, go figure!
  - (Also known as February 29th – Leap Year Day)
    - Some see it as a "free" day to do something different

- *So, that solves the problem right?*

Why is the 4-year rule not enough?

- 365.25 > *365.24219*
  - check my math please?
- We **over-adjust** with the 4-year rule
  - Extra time each year = 0.25-0.24219=+0.00781 days
    - 11 minutes a year extra
- Every 128 years, would add up to an extra day
  - Seasons would start shifting again – sheesh!

- So – we have a century correction
  - If Year divisible by 100, don't add Leap Year Day
  - Even though it must also be divisible by 4!
- 1700, 1800, 1900 not leap years
  - *1600 was .. What about 2000?*

Why is the 100-year rule not enough?

- If use 4 year and skip 100 year – 365.24
  - *365.24219* > 365.24 (= 365 + 1/4 - 1/100)
- We under-adjust with the 100-year rule
  - Missing time each year = 0.24291-0.24=0.00219 days
    - 3 minutes a year too few
- Every 450 years, would end up losing a day

- So – we have a 400-year correction
  - If Year also divisible by 400, add Leap Year Day
- 1600, 2000 = leap year – as will be 2400

- *Ok … but we are done with changes now, right?*

"Y5K" problem

- Using +Y/4-Y/100+Y/400 = 365.2425 > *365.24219*
- We over-adjust with the current rules *(see previous graph)*
  - Extra = 0.24291-0.2425=0.00031 days
    - 26 seconds each year too much
- ~Year 4900 (round to 5K) – extra day accumulated

- One solution: Could skip every 3600 years
  - Needs adjustment in 31,000 years
- Another solution: Could skip every 4000 years
  - Adjust in 17,000 years
- Another solution: Could skip every 3000 years
  - Adjust in 42,000 years

- SEP! *(But, that's it .. Right?)*

“Y5B” problem yet looms …

http://www.y5b.com/

Benefit to the 400 year rule…?

- Since 2000 was divisible by 400, can have a 28 year calendar
- Each 4 years, we add a day – after 7 of those …
- Calendars from 1901 can be used in 1929
  - 1902 same day for date as 1930, etc.
- 2081 will be “last 28 year calendar”

- So, dust off those 1988 calendars, still relevant!
  - *First Internet Virus (1988 Internet Worm)*
  - *Comic strip Foxtrot first appeared*
  - *Microsoft Windows 2.1 !!!*
  - *Skrillex and Michael Cera born*

Bonus slide: “Leap Second”?

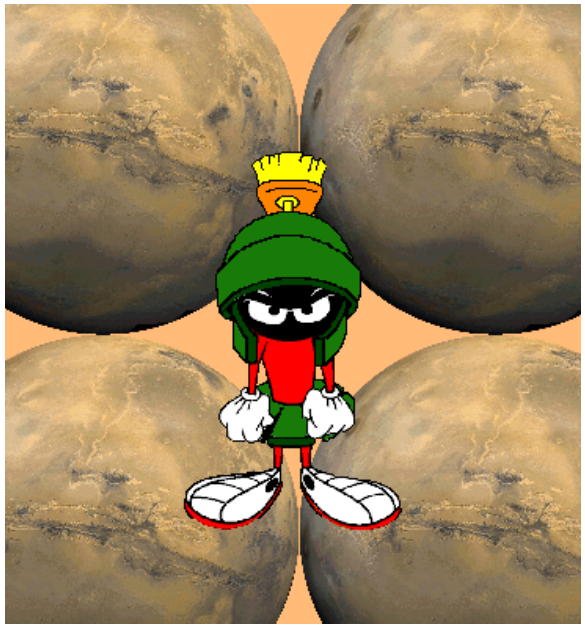
- Rotation of Earth on axis not regular
- Can be adjusted by weather events
  - Tsunami a few years ago – physically moved mass around – changed rotation period
- Tidal bulge from Moon – dragged “forward”
- Moon “speeds up” slightly – Earth slows
- Need to add ‘leap second’ occasionally
  - *26 corrections in last 34 years*
- Recent Lunar Eclipse – treasure them!
  - As time passes – more rare!

Second bonus slide: “Leap Birthday?”

- Let’s see 365*4 + 1 leap day (every 4 years) = 1461 … so, 1/1461 chance of being born on a leap day = **0.068%** .. we can round that to 0.07!
  - But, by “only” including the “every 4 year” rule .. this percentage is good for the years 1901-2099 (so, easily “now/current” percentage).
- But, if we include the 100 year rule .. then we would not have 25 leap days in 100*365 days .. we skip on the 100s, so …
  - just as we counted when we only cared about 4 .. the fewer number of leap days in the necessary years .. 1/4*365 .. we do the same now, but now in 100 years, we’ll have 25 normal leap days .. but that last one would be too many (skip the 100th year one) .. so 24 leap days in a 100 year span .. so 24/(365*100) = **0.0657%** (dropping slightly)
- if we go with the 400 year rule, we add it back .. so .. not 24 * 4 in 100*4 years .. 24*4+1 in 100*4 years .. so 97 leap days in 146000 years .. or **0.0664%** (so, slightly better than the 100 year rule, but still worse than 4 year rule) ..
  - whatever the next rule would be .. would make it “slightly” worse than that last one … but, can still round it to 0.07% !!!

Pretty Earth-centric – what of Mars?

- So far, we are the only inhabited planet ..
- Suppose Mars had denizens … calendar?
- Mars has seasons not unlike us ..
  - Calendar would drift without corrections
- Problem with terms “day” and “year”
- There are several proposed calendars
  - Try putting “mars calendar” into Google!
  - http://pweb.jps.net/~gangale4/chronium/compare4.htm



“Adirondack” Rock !!

Darian system

http://ops-alaska.com/time/gangale_converter/calendar_clock.htm

- Symmetric Vernal Equinox Martian Calendar
  - 24 roughly equal months (28 or 27 days)
  - Seven-day week
  - Begin year on Vernal Equinox
  - Leap “sols” (days) at end of the year (mYear)
  - (Can even extend system to Jupiter’s Moons!)

- *Problem with terms “day” and “year”*

“Day” and “Year” on Mars?

- Solar day on mars – call it “sol”
- Earth= 24hrs - Mars=24 hrs 39 min 35.2 secs
  - Probably just “expand” Earth clocks by 2.7%
  - Keeps the 24 “hours” / sol
- Orbit around Sun = 668.5921 “sols”
  - That darn extra 0.5921 !!
- Need leap sols more often than Earth
  - Basically every other mYear = Mars Leap Year!

Mars Leap Year Rules

Formula = +(Y-1)/2 +Y/10 –Y/100 + Y/500

Magic number = 668.5921 sols

- Even years = 668 sols, odd = 669 *(668.5)*
  - Undercounting – 1 sol extra in 10 years
- If divisible by 10 then 669 *(668.6)*
  - Overcounting – 1 sol missing in 128 years
- If divisible by 100 then 668 *(668.59)*
  - Undercounting – 1 sol extra in 476 years
- If divisible by 500 then 669 *(668.592)*
  - Undercounting – 1 sol extra in 10,000 years!

Months and Calendar

- 24 months – most 28 sols, some 27
  - If 27 sols – the last sol would be
- 7 days a week – add ‘sol’ to name
  - solSolis, solLunae, solMartis, solMercurii, solJovis, solVeneris, solSaturni
  - Avoids confusion with Earth days (won’t line up that often)
- 4 quarters – 27 sol month end of quarter
  - Leap sol added at the end of the last month
- Use Zodiac names for month names
  - Mars has same zodiac constellations (2% tilt)
  - Latin first (Sagitarius, Scorpius, Libra …)
  - Sanskrit next (Virishika, Tula, Kanya ...)
    - Mixture of East and West in names

Months and Calendar

The Darian Calendar (perpetual)

	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	

	So	Lu	Ma	Me	Jo	Ve	Sa
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
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	

	So	Lu	Ma	Me	Jo	Ve	Sa
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
Leo	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
Simha	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	

	So	Lu	Ma	Me	Jo	Ve	Sa
Virgo	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
Kanya	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
Libra	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
Tula	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
Scorpius	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
Vrishika	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**

Key to Equinoxes, Solstices, Apsides, and Leap Sols in the Calendar Tables

1	Vernal Equinox
13	Aphelion
28	Summer Solstice
10	Autumnal Equinox
13	Perihelion
13	Winter Solstice
28	Leap Sol

Q: Longer day vs occasional shorter weeks?

A: 1% more

When to start calendar?

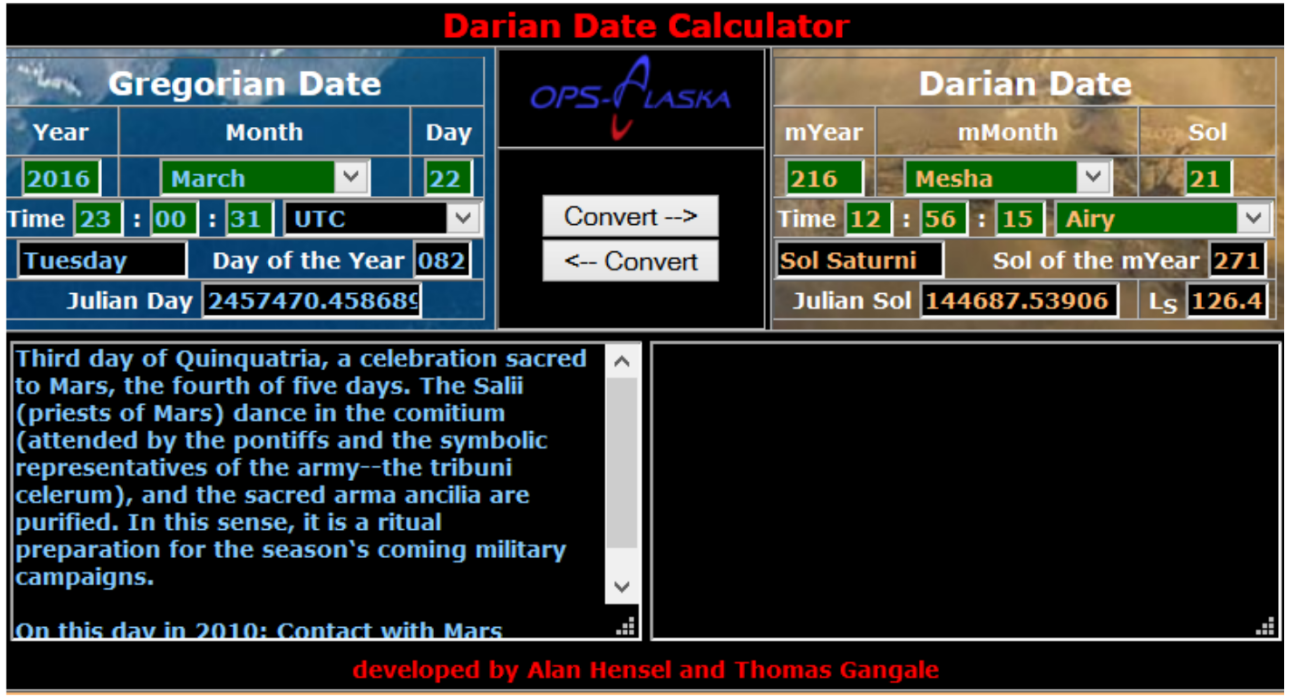
- We landed on Mars in 1976 ….
  - But have observed for centuries

- 1609/1610 year chosen
  - Kepler/Newton – overturning of “circles”
  - “Telescopic era” for Mars
  - Any telescopic events can be calibrated

What day is it on Mars?

- Conversion webpage (Marvin “callback”)

`http://ops-alaska.com/time/gangale_converter/calendar_clock.htm`



Today – 7:00 PM local time = 21nd sol of the Month Mesha in the mYear 216

2nd Sol of Rishabha in the mYear 188 … a very good day … IMO

Acknowledgments

- Calculations from **Astronomy Morsels III** by **Jean Meeus**
    - If you want to do astronomy calculations – he is THE source of information!
- Graphs courtesy of Microsoft Excel
- Presentation by … um, oh yeah, Powerpoint
- Websites, as linked in this talk
- “Mapping Time: The Calendar and its History” – E.G. Richards
    - ISBN 0 19 850413 6 - Excellent reference!