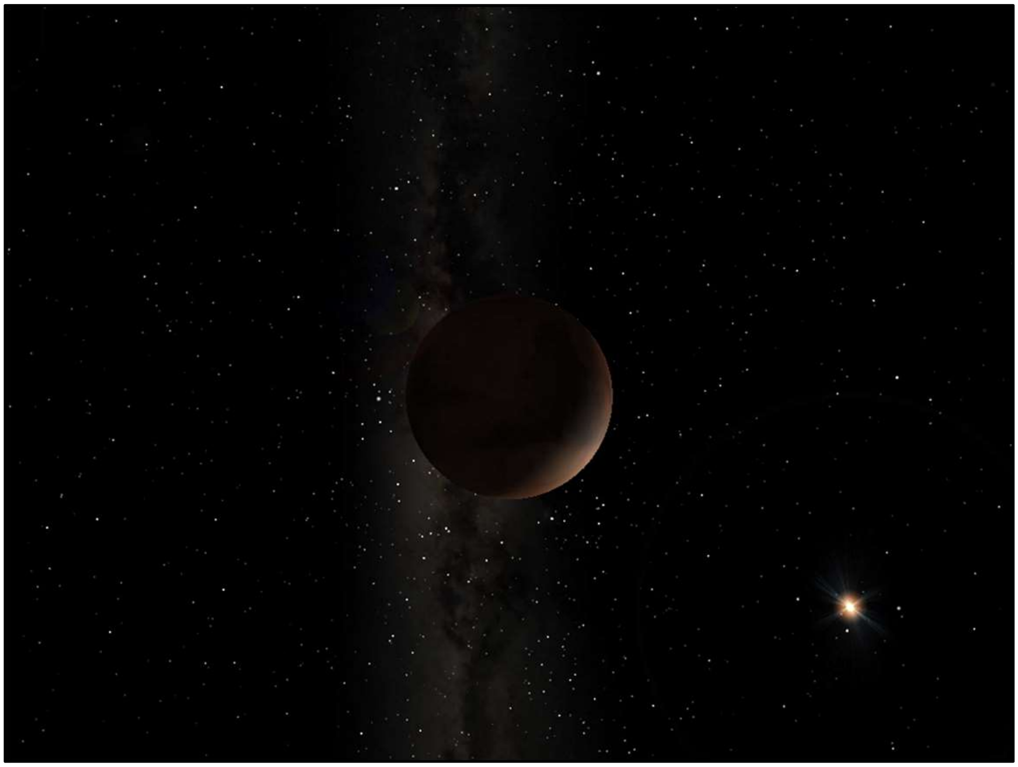
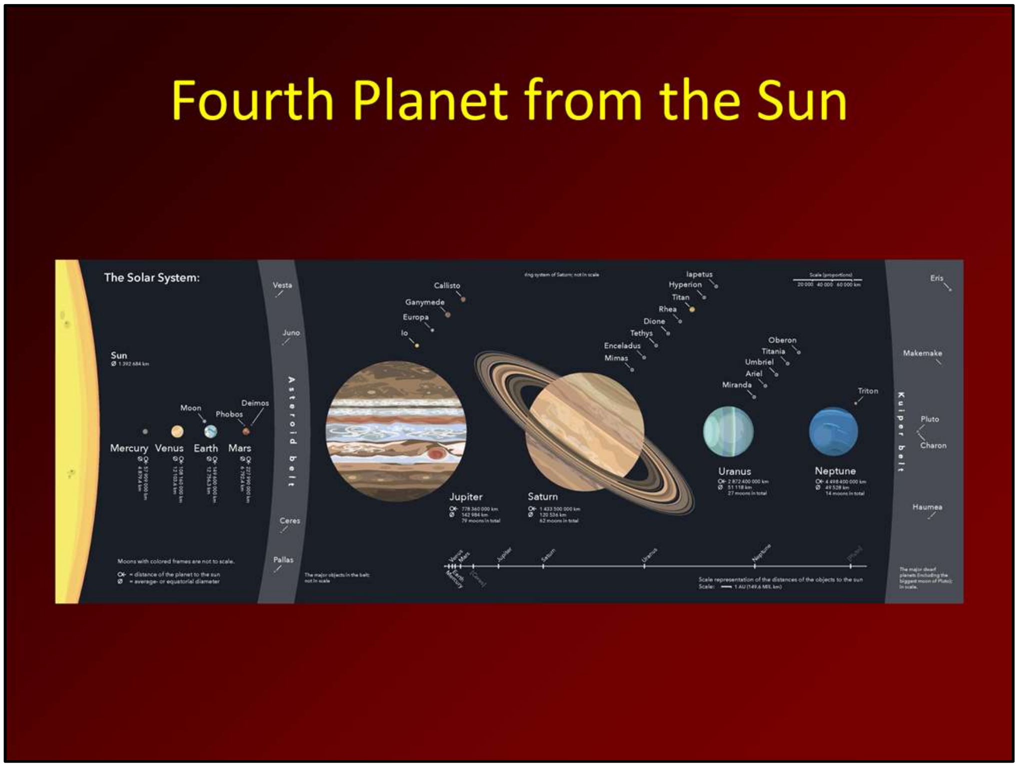


Prelude

Everybody ready? Ok hang on tight, we're going to Mars!



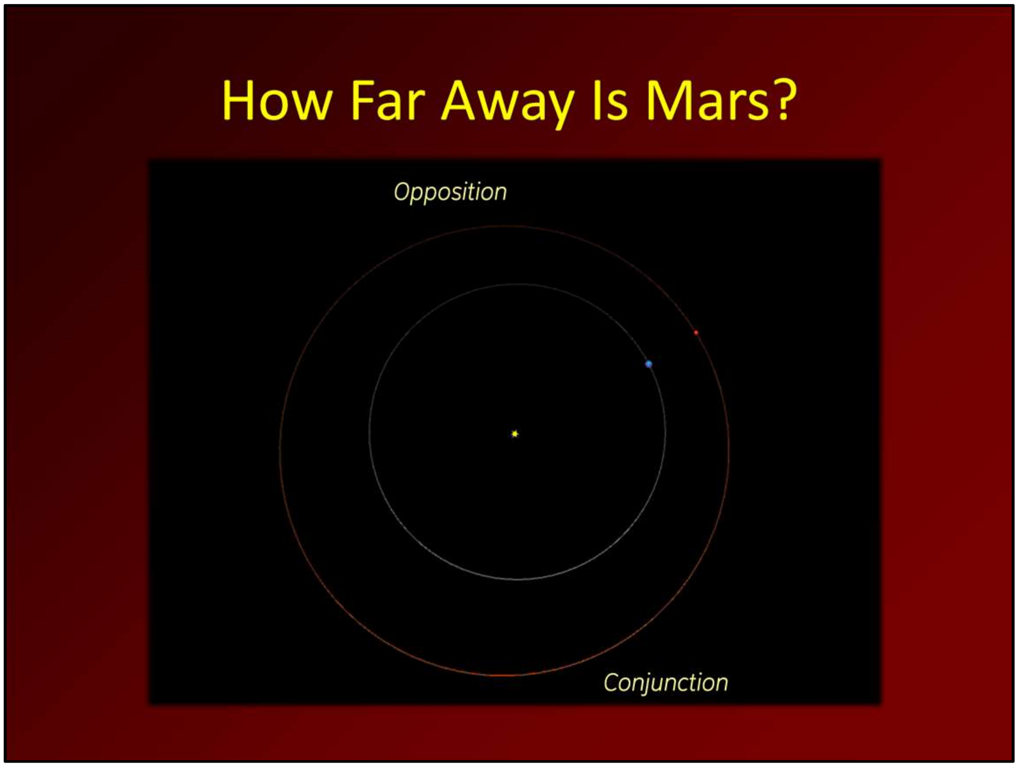
It’s the fourth planet out from the sun, of course, next one out after us.

So you’ve got Mercury, Venus, Earth – big blue marble, then <u>Mars</u>. Looks pretty small, doesn’t it?

Yeah, that’s because it is.

- Only about half the diameter of earth, and
- only about a third of the gravity.
- So walking on Mars would be kind of bouncy-floaty – not quite as bouncy-floaty as walking on the moon which is ⅙ gravity, but at ⅓ gravity, kind of close to that.

I do have a clarification to make on this picture, though. In reality, Mars is not this close.



Well, that's an important question and it really depends on when you're asking the question.

This is a diagram of the solar system showing:

- the sun at the center, with
- Earth as the blue dot here and you can see its orbit, and
- Mars as the red dot here and you can see its orbit.

Since the earth is closer to the sun

- gravity is stronger, so our orbital velocity, avg. 67000 mph, is faster than Mars, avg. 54000mph.
- Also since Mars is farther from the Sun, it has farther to go to complete an orbit
- So Mars takes about two years to complete an orbit, and it turns out we pass Mars about every two years...

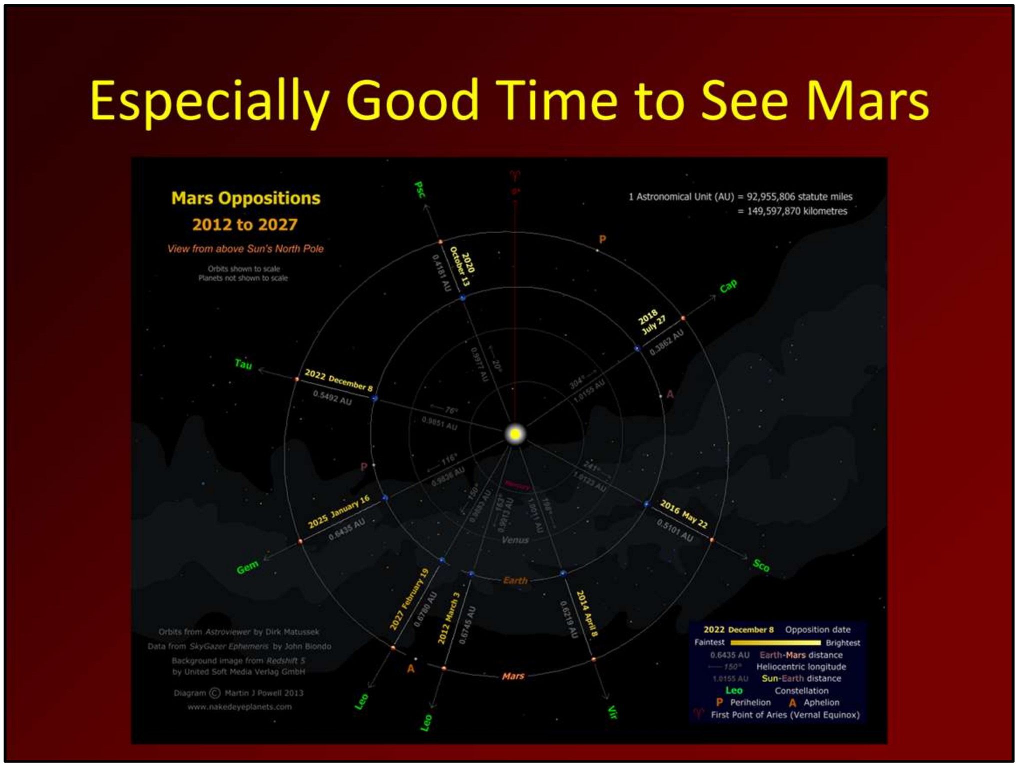
Let me show you how that works

- It starts where we were when we made our last close pass by Mars in 2018. Remember this spot.
- And let's get things moving...
    - You can see the earth is moving faster than Mars
    - So in the time it takes earth to complete an orbit, Mars is only about halfway around the sun and we're on opposite sides, this is 2019.
    - Now Mars is back to the same spot – Earth is not quite there (again) yet...
    - Because Mars' orbit is actually a hair shy of 1.9 years (687 days)
    - So now we have to catch up a bit in order to pass Mars.
- When we do, it's called opposition (because the sun and Mars are on opposite sides of

us).
- This is where we are now, October 2020
- Now let’s run it again until Earth is back in the same spot, and again, Mars is now only halfway around its orbit...
- when Mars passes behind the Sun it’s called conjunction, because the Sun and Mars appear to be together.

So the way this all works, we don’t pass Mars in exactly the same spot.
- It’s not <u>really</u> two years between passes, it’s two years plus two months <u>on average</u>, so that opposition point advances around our orbit.
- How long between opposition varies, because Mars’ orbital velocity varies, depending on its distance from the sun.
- Let’s take a look at a bunch of opposition points, past and future.

1. Bits
2. Orbital Ellipse
3. Orbital periods
4. Animation
    a. Note Speeds
    b. 1 yr. point
    c. Mars orbit cpt... 1.9 yr. point
    d. Earth catches up
    e. Opposition/Conjunction
5. Progression of opposition



So this shows you Earth/Mars oppositions from 2012 to 2027, eight oppositions in all.

- The previous opposition was July 2018, this one is October 2020, so 2 yrs, 3months between
- Then the next opposition is December 2022, so 2 yrs, 2 months between...
- Lets look at the 2025 opposition, that happens in January, then the next one is February 2027, so 2 yrs, 1 month between... why so different?

Now something you might notice,

- While Earth's orbit is quite circular,
- Mars' orbit is a bit lopsided – this is an elliptical orbit (actually all orbits are elliptical orbits, some are just more circular than others).
- Mars is closer to the sun on this side, and farther from the sun on the opposite side
- This diagram also shows the point where Mars is closest to the sun, aphelion, and where it is farthest from the sun, perihelion.
- As Mars climbs farther out from the sun, (to the aphelion point) it slows down (49kmph)
- then as it falls back in closer to the sun (perihelion), it speeds up (59 kmph).

You can see these speed differences in the gaps between oppositions

- Mars orbital period isn't <u>exactly</u> 2 yrs, it's a bit less, 1.9 yrs. So when it's completed an orbit, we're not quite there yet, we still have to catch up. Where Mars is when we are trying to catch up makes a difference.
- When we are passing near perihelion, it takes a little longer (2 yrs. + 3 mos.) between oppositions because Mars is going faster when we are approaching.
- When we are passing near aphelion, the time between oppositions is shorter (2 yrs. + 1 mo.) because Mars is going slower when we pass.

So we passed Mars July of 2018, and then again October 13th of this year – about a week ago

- Both of these oppositions are close to Mars perihelion, which means we are really close to Mars right now
- When Mars is at aphelion it will be nearly twice as far away during opposition as it is now.
- Which of course makes this a really good time to see Mars.

Ok great, but what is there to see?

- Actually quite a few features, so let's find some reference points and start to learn how to navigate our way around Mars.

Martian day is 24 hrs. and 40 min. so you never know which side of the planet you might be looking at...

- except that if you look again the same time tomorrow night you'll be looking at the same side.

Acidalia Planitia:

- dark peninsula stretching down from the north
- this is where Mark Watney in the Martian starts
- directly across from the Spikey Region sticking up from the South, Margaritafer
- not to be confused with Margaritaville, Jimmy Buffett has never been to Mars. That I know of.
- notice that dark, skinny wedge pointing off to the east... let's follow that and see where it goes

Syrtis Major

- dark peninsula sticking up from the south
- different from Acidalia because it has a huge crater behind it
- in fact, the hugest visible crater in the solar system, the Hellas Basin

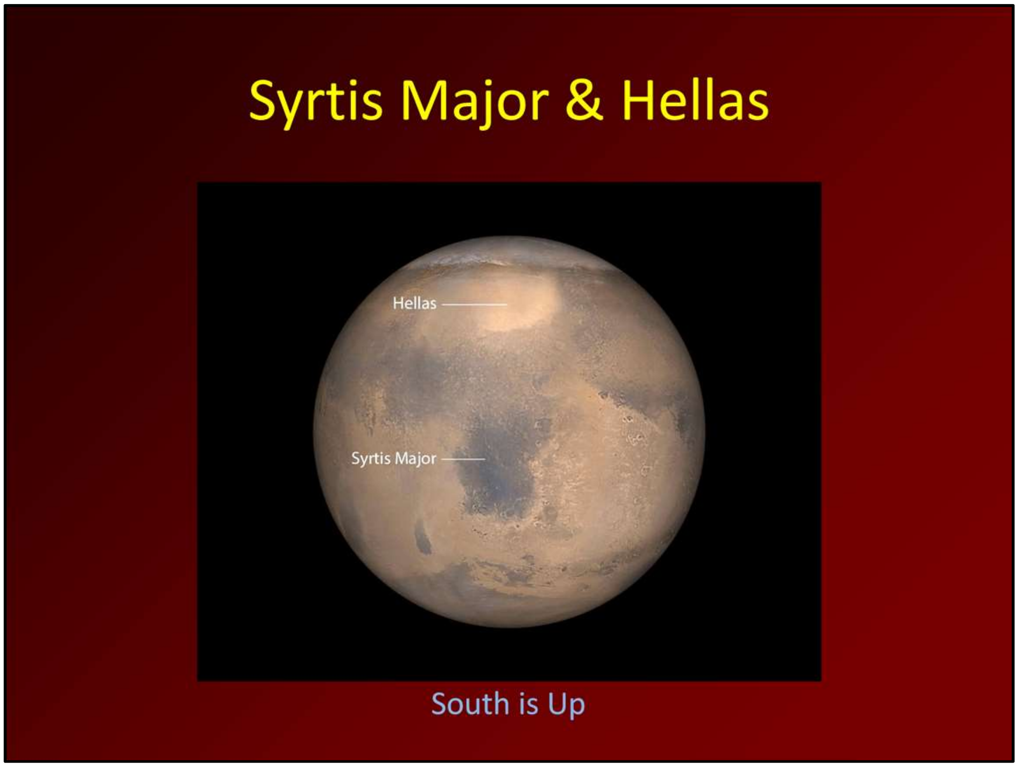
Tharsis

- the region just to the west of Acidalia
- marked by four volcanoes – the Tharsis Montes and Olympus Mons
- tough to see in the scope
- look for a lot of dark regions to the east

Elysium

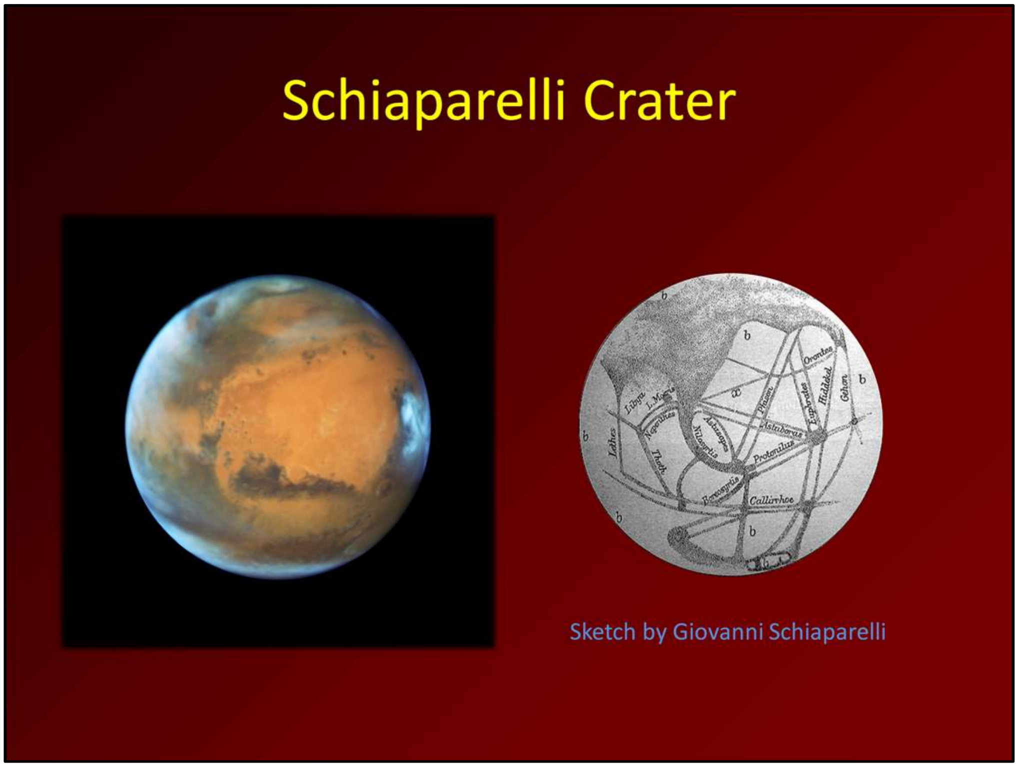
- dark terrain to the south, ramping up from east to west

- marked by the Guppy and the Slash
- look for dark terrain (Syrtis Major) to the west
- Elysium is the light plain to the south,
- Arcadia is the light plain to the northeast, pretty much between the Guppy and Olympus Mons – more about that in a minute.
- To the Northwest of Elysium is Utopia Planitia, the largest impact basin in the solar system.



A different view of Syrtis Major, giving you a better look at the Hellas crater.

- We've turned Mars upside down here so the south polar cap is up.
- The Hellas crater and Syrtis Major together form a very distinctive, planetary landmark, very easy to spot when it's there.



This shows the Skinny Wedge with the bite in it better.

- the Skinny Wedge is actually called Terra Meridiani
- The bite is the Schiaparelli Crater, named for Giovanni Schiaparelli
- He extensively identified and described markings on the surface of Mars, including linear structures he called channels or “canali”.
- This was mistranslated into English as “canals”, extrapolated into the conclusion of intelligent life on Mars, promoted strongly by Percival Lowell.
- Shiaparelli Crater is where Mark Watney launches from when he leaves Mars (sorry for the spoiler).

Up in the Northwest region you can see the Guppy and the Slash, which is the Arcadia Region... what’s so significant about that?

- It’s where SpaceX is targeting to land and set up a Mars Base and Colony
- It is believed that there is a massive sheet of water ice under this region
- The ice sheet is 130 feet deep and covers an area the size of Texas & Florida put together.
- That will be crucial for manufacturing the methane fuel needed for the return trip to Earth.

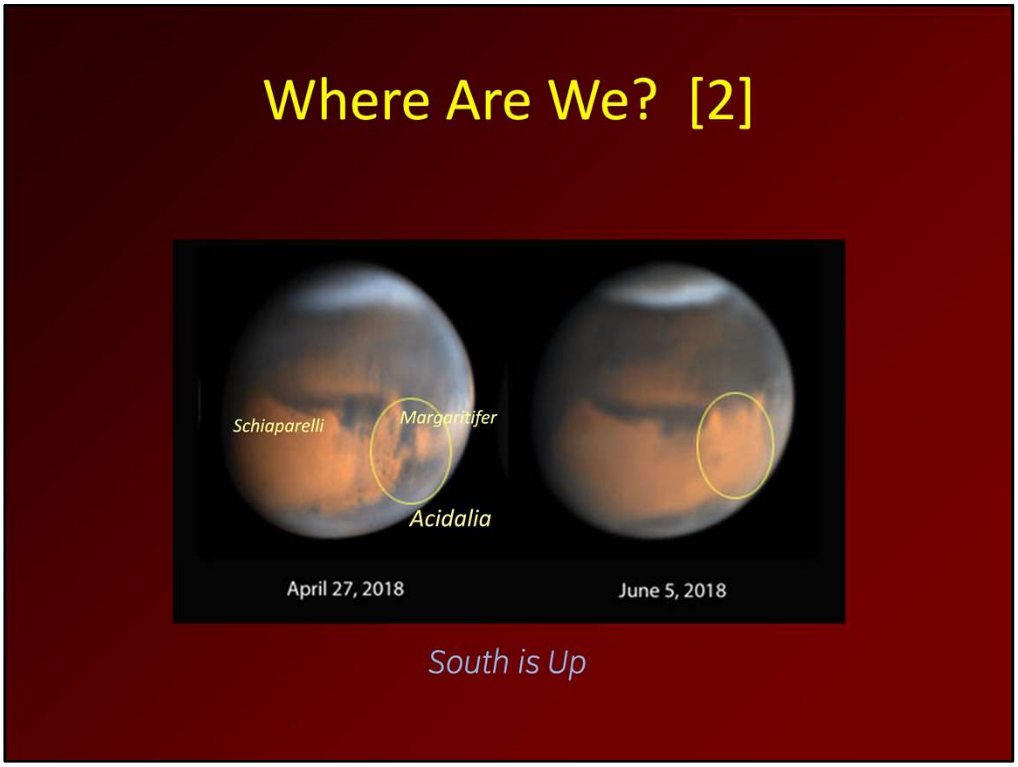
Of course there are many, many more Martian surface features that are known

- but if you can recognize any of these features in your telescope you're doing quite well,
- so now it's time for...

Your Martian Geography Quiz

Note the "N" => North, "P" means Preceding. Alternatively, "S" points to South, "F" points to Following.

Mars day is 24hrs. 40min. so what you see tonight will be pretty much the same if you look tomorrow at the same time.



This shows the effect of dust storms on Mars,

- which can obscure features that
- would otherwise be clearly visible.

Since South is up,

- The skinny wedge with a bite mark taken out of it is obvious in the middle, and
- you can clearly recognize the spiky region (Margaritafer) sticking down from the south
- which means the dark peninsula projecting up from the north is Acidalia Planitia

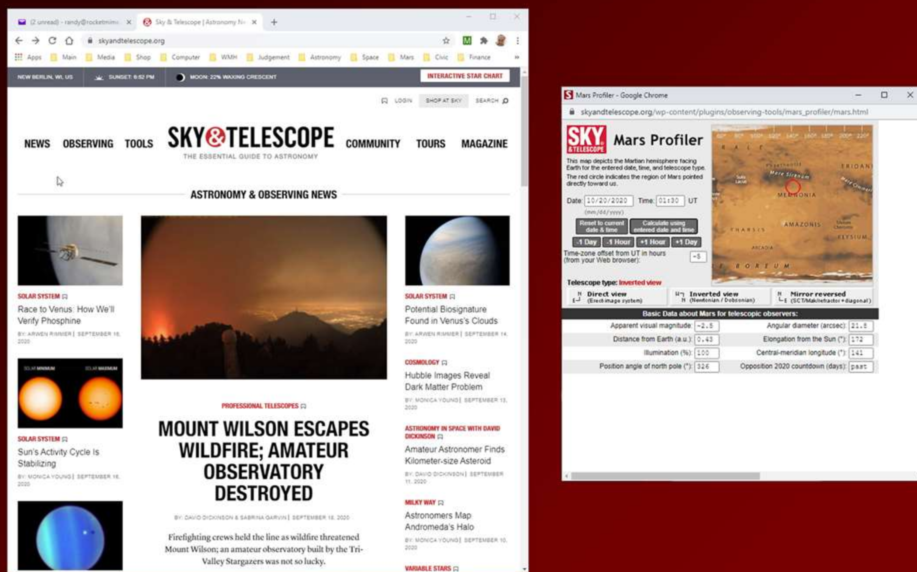
This astonishing picture shot from a ground telescope by Damian Peach

- shows why it is unlikely you can visually see the volcanoes in your telescope, but
- you may be able to recognize that you are looking at the Tharsis region.
- up and to the left is the Eye of Mars

Longtime MAS member Lee Keith has made good use of the 2020 opportunity by using the club's A-Scope at our observatory in New Berlin for all these fantastic images. That scope is a 12.5 inch f/8.71 Newtonian reflector. The dates of the images are shown.

9/1: Meridiani (Skinny Wedge) / Schiaparelli
9/3: Skinny Wedge / Syrtis Major / Hellas Crater
9/4: Syrtis Major / Hellas Crater
9/14: Elysium
9/23: Tharsis / Eye of Mars
9/29: Margaritafer / Acidalia
10/1: Margaritafer / Acidalia
10/5: Meridiani / Schiaparelli

Oh, Sure, NOW You Tell Us

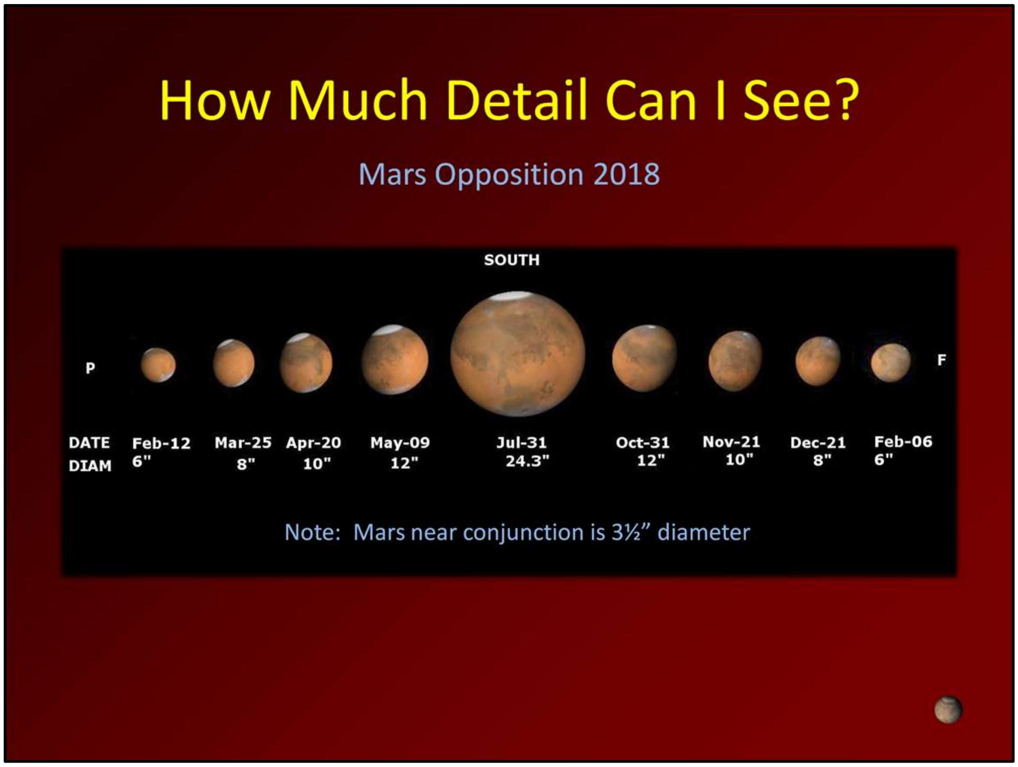


You can go to the Sky and Telescope web site,

- click on Tools,
- scroll down to Mars Profiler, bring up that page,
- then click on the link to the Mars Profiler tool.

The tool shows you what side of Mars you see now.

- enter the date and time of interest in UTC
- hit “Calculate using entered date and time”
- you can plan an observing session and know what to expect.



What does that size difference mean in terms of what we can see in the telescope?

Resolving Power of Your Scope

$$P_R = \frac{120}{D_O}$$

P_R is in arc-seconds, with D_O in mm

Telescope (inches)	Telescope (mm)	P_R (arc-sec)
4	100	1.2
6	150	0.8
10	250	0.5

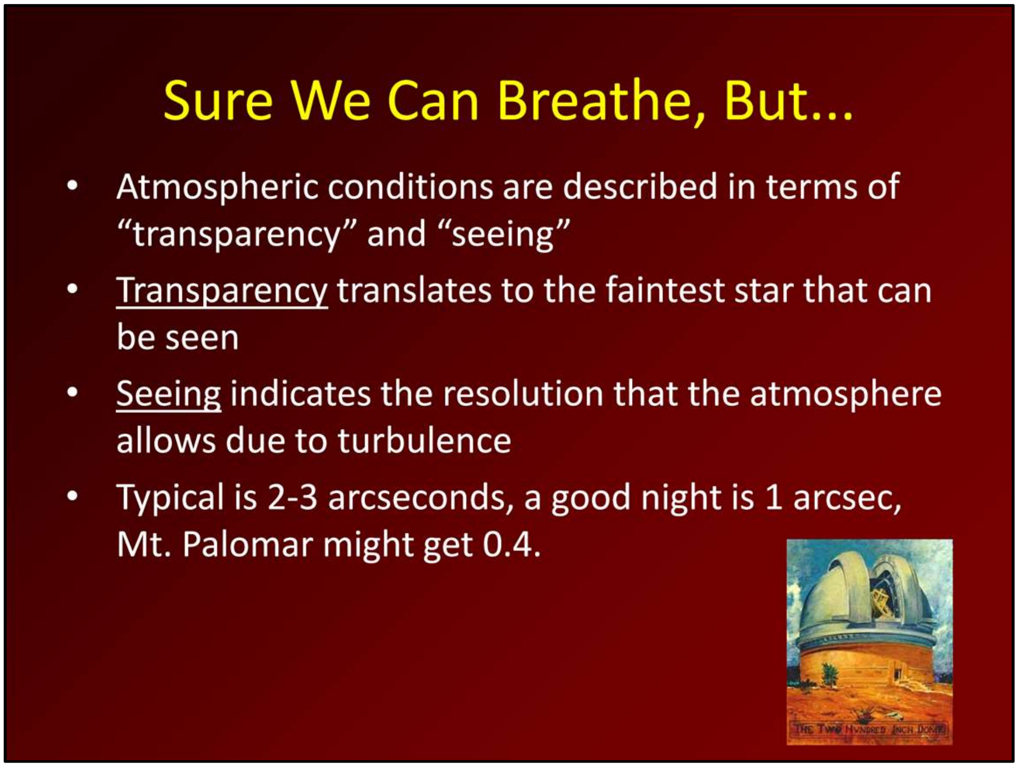
So how much detail can you see in your telescope?

- This is the formula for "resolving power", P_R,
- which depends on the diameter of your telescope, due to physics of diffraction of light
- P_R is measured in arc-seconds, and tells you the smallest feature you can see in your telescope.

So when we say you can resolve 1 arcsecond,

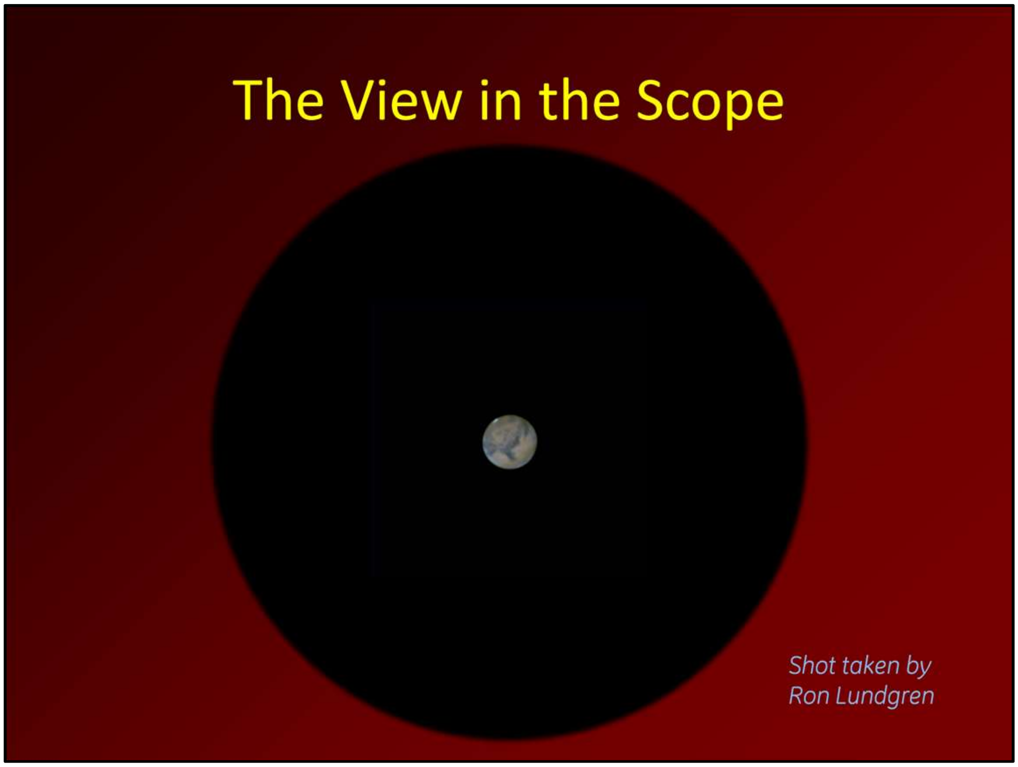
- that means the smallest feature you can see is 1 arcsecond across.
- If it gets smaller than 1 arcsecond, it still appears 1 arcsecond across but gets fainter.

You can see how the larger the telescope diameter gets, the tinier the features you can see in that telescope... except for one other thing...



...it comes at a cost.

- Transparency is a function of background sky glow, which is a function of light pollution and haze from smoke and humidity.
- You can gauge transparency by noting the faintest stars you can see by eye.
- Seeing is the blurring from air turbulence, like the shimmer off of hot pavement. Twinkling of stars gives you an index of how bad the seeing is.
- Getting below 1 arc second means especially dark, clear skies, which is to say, not New Berlin.
- Photography can get you better resolution by selection and stacking of only the best images (taking the motion artifacts out).

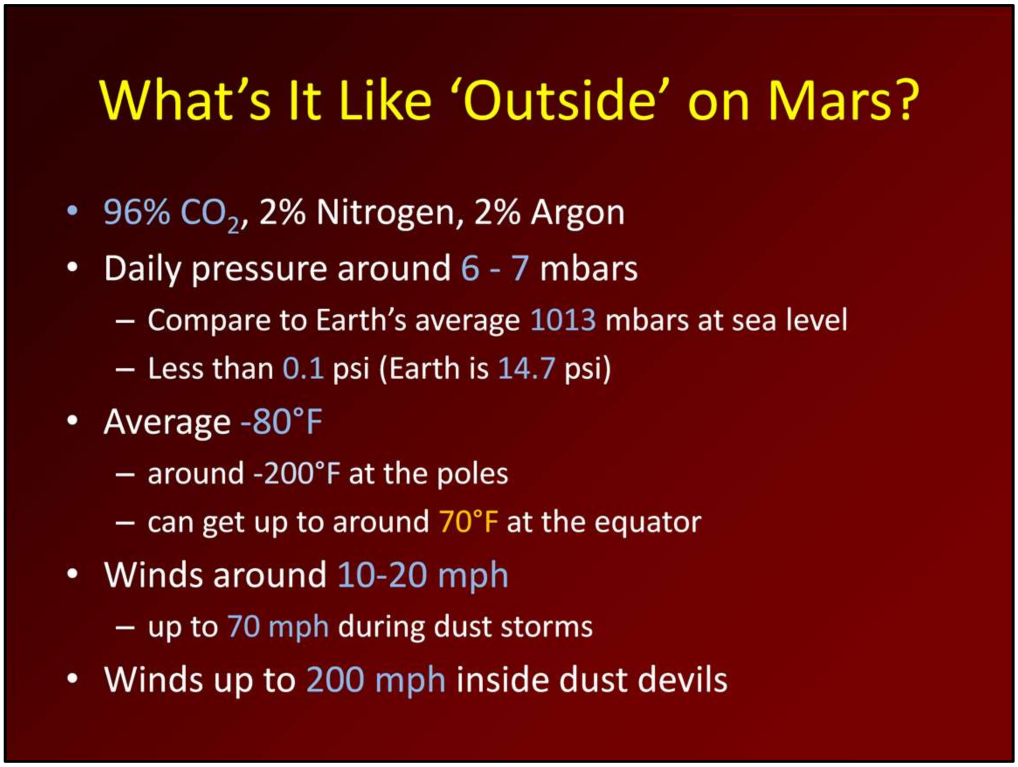


Shot using his 35 year-old Celestron C8 with a 2x Barlow, and the camera is the Celestron NexImage 5. Very similar to the image I get with my 8” f/5 Newtonian.

You not only need to worry about clouds, transparency and especially seeing on our planet,

- but there’s also those accursed dust storms on Mars.
- Like this global dust storm that lasted from June to September 2018.
- It’s helpful to check what others are currently reporting about visibility of features.

Images showing the advancing, global dust storm, taken by Curiosity's Mast Camera between Sol 2075 and Sol 2170 on Mars, which would've fallen between June 8, 2018, and Sept. 13, 2018, on Earth.
Credits: NASA/JPL-Caltech/York University

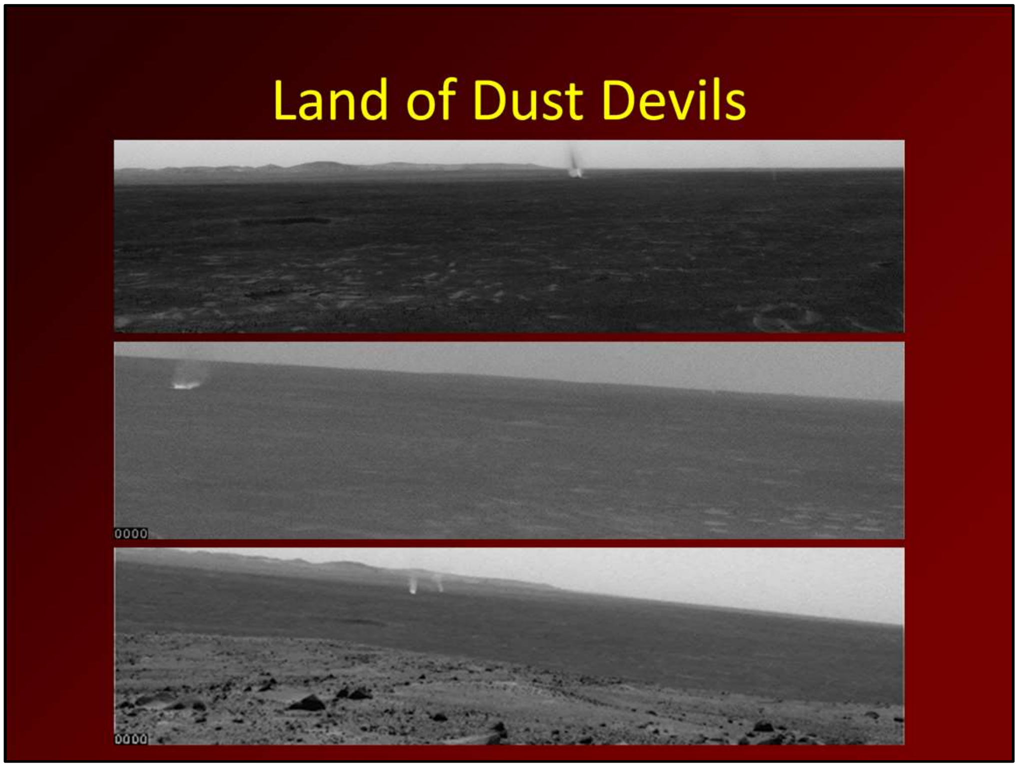


Pressure at Mars' surface is less than 1% that of Earth's atmosphere at sea level.

- So that 60-70mph wind would feel like a 6-7mph breeze, and if you're still alive which means you're wearing your pressure suit you probably can't even feel it...
- but visibility goes to nothing and
- that dust gets in everything (and sticks, because it's electrostatic).

There is a case where the wind speed gets even higher and that's in...

- dust devils, where it can get up to 200mph
- still not going to knock you on your butt, but... you might feel it, even in your pressure suit.
- Actually are nice for the rovers because they see a boost in the power from their solar panels when the dust devils hit them, cleaning off the dust.
- ...and the rovers do get to see dust devils



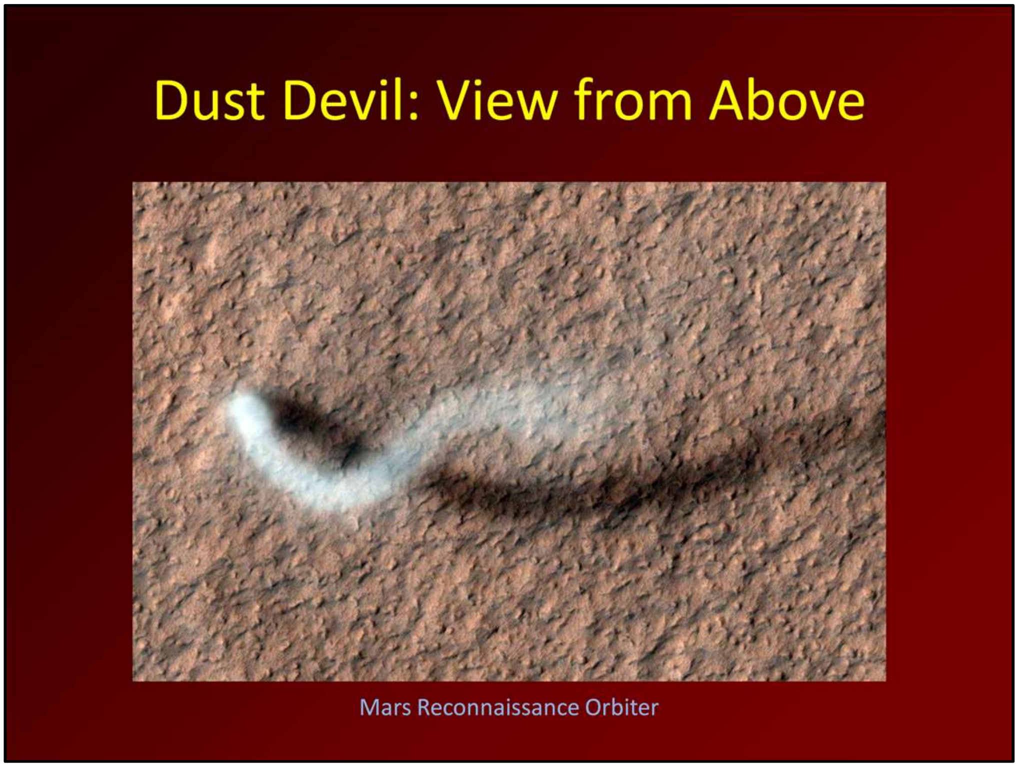
These are common on Mars, on calm days with lots of surface heating to cause rising thermals.

They can go as much as 5 miles high. Images from the Spirit rover.

If you look carefully at that center one you can see that it's leaving a trail.

In fact the surface of Mars is scored with lots of trails from dust devils, some places more than others.

- First image from Mars Global Surveyor,
- Second from Mars Reconnaissance Orbiter

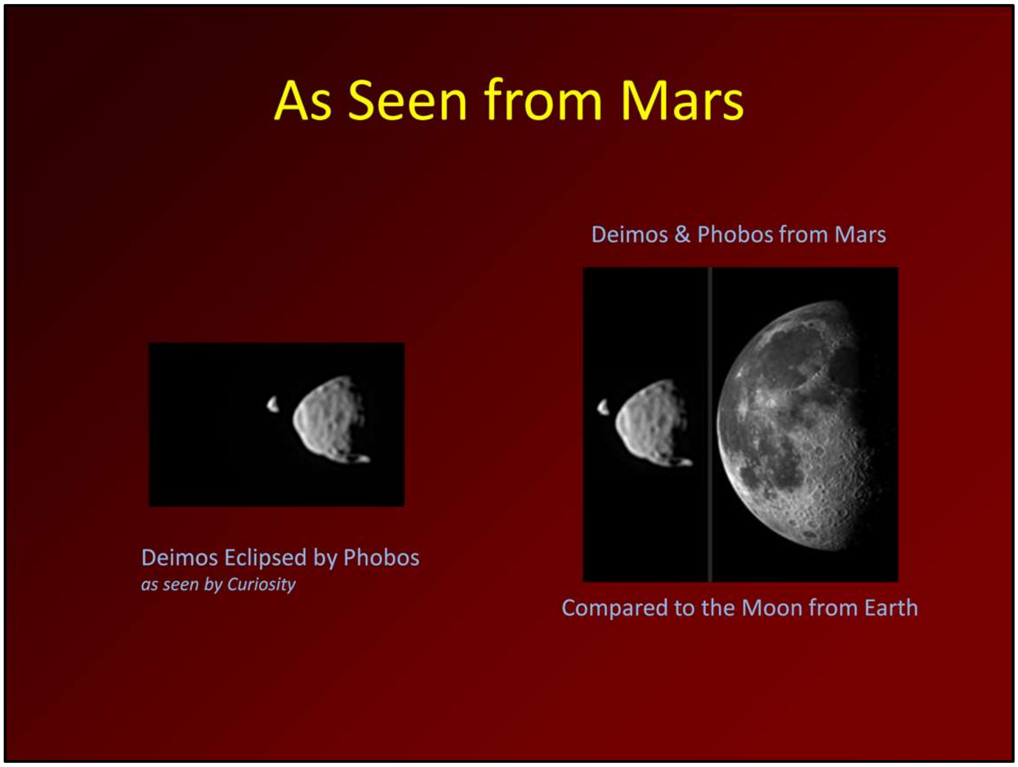


- This view covers an area a little under a half-mile across.
- That’s its shadow, the length of which indicates that the dust plume reaches more than half a mile (800 meters) in height.
- The plume is about 100 feet across
- this image acquired by NASA's Mars Reconnaissance Orbiter,
- one of fourteen known man-made satellites in orbit around Mars, six of which are active (including MRO) – 3 NASA, 2 ESA, 1 ISRO
- And man-made are not the only satellites orbiting Mars...

Deimos = about 8 miles across
Phobos = about 14 miles across
Earth's moon = about 2,000 miles across.
So Phobos and Deimos are more like 'moon chips'.

Technically, the moons are bright enough to be seen in a 4” telescope

Because of the glare from Mars, it takes more like a 10” telescope to see the moons.

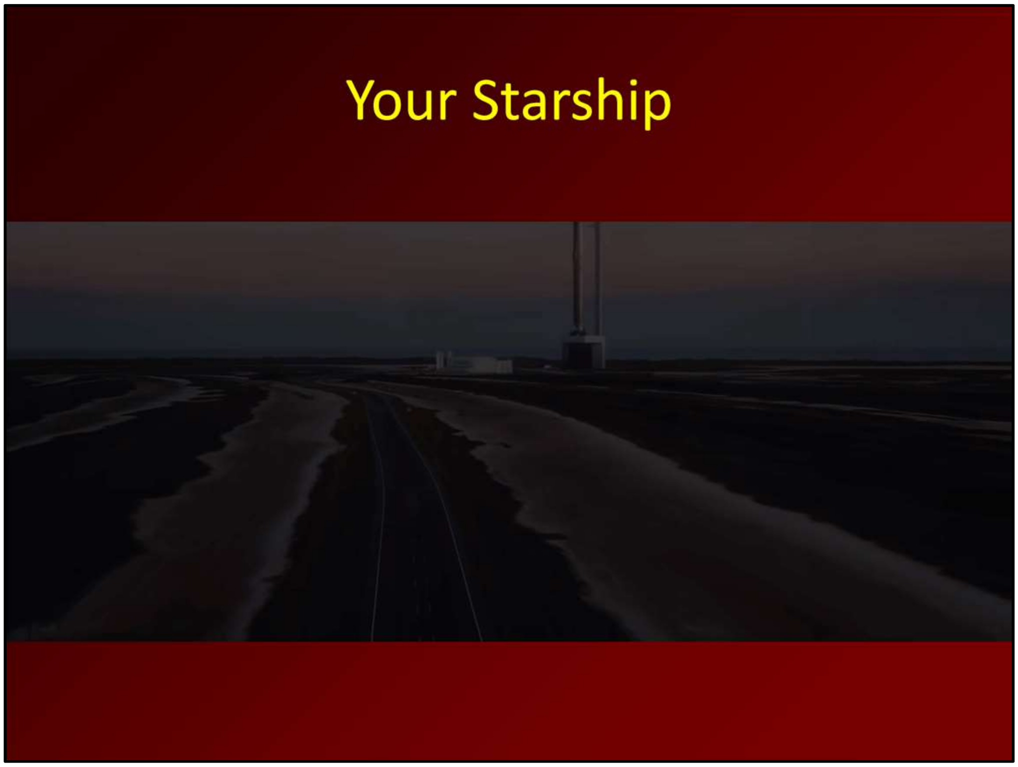


Earth’s moon is 250,000 miles from Earth, whereas
Deimos is only 25,000 miles from Mars, or ten times closer, and
Phobose is less than half that, at only 9,000 miles from Mars.

Well, getting to Mars is a non-trivial proposition.

When a reporter asked Elon Musk whether "a Mars voyage could be an escape hatch for the rich". He said no.

Everybody ready? Let's go!



If you’re looking to get your ticket to Mars your best bet is SpaceX Starship
This rocket and spaceship are planned to be the first completely reusable spacecraft flown.

- a single rocket will make three launches *per day*
- the space shuttle at best made three launches per year.

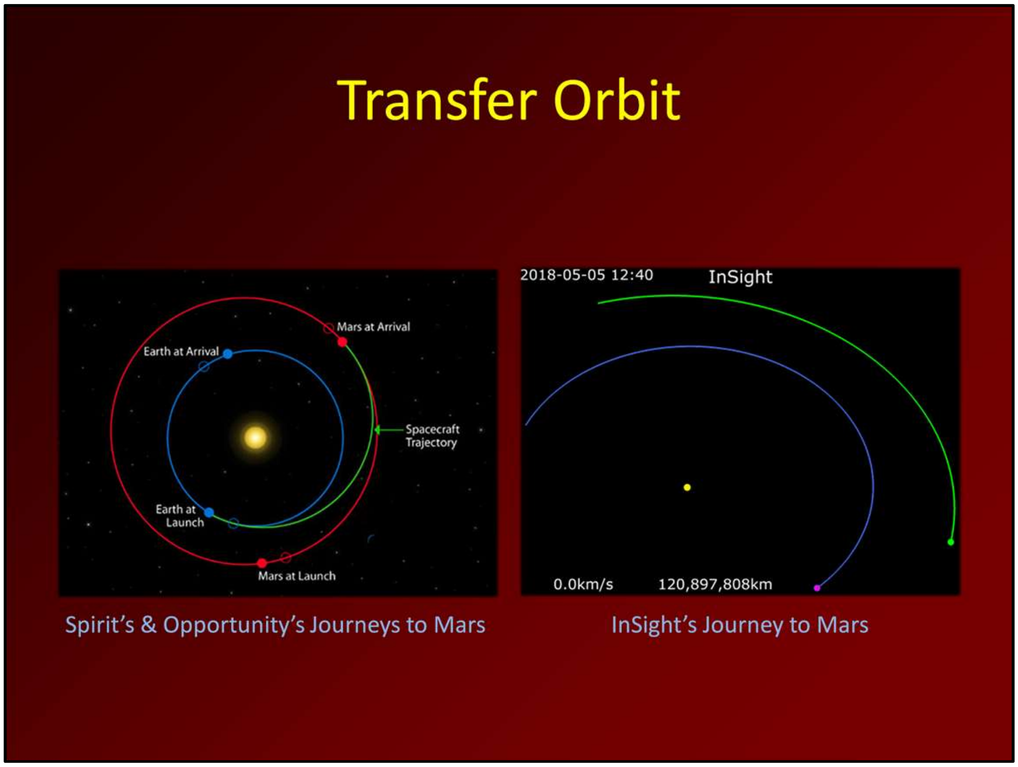
SpaceX (founded in 2002) first successful launch in 2008

- first landing and re-use of orbital-class rockets (now routine)
- first full flow staged combustion cycle engine
- first methane-burning engine
- first fully reusable orbital space vehicle (capable of three launches *per day* – space shuttle capable of three launches *per year*)

Comparison to Saturn V

The booster will have a total of 16 million pounds of thrust
- the Saturn V, the most powerful rocket ever launched, was 7.5 million pounds of thrust
- for routine daily launches, the Starship/Super Heavy rocket will be launched from a platform at sea due to the extreme noise

The 28 Raptor engines are the first full-flow staged combustion cycle engine ever flown
- this is the rocket on which SpaceX is currently running test flights
- they will be launching Starship to 9 miles to test its landing capability, possibly before the month is out.



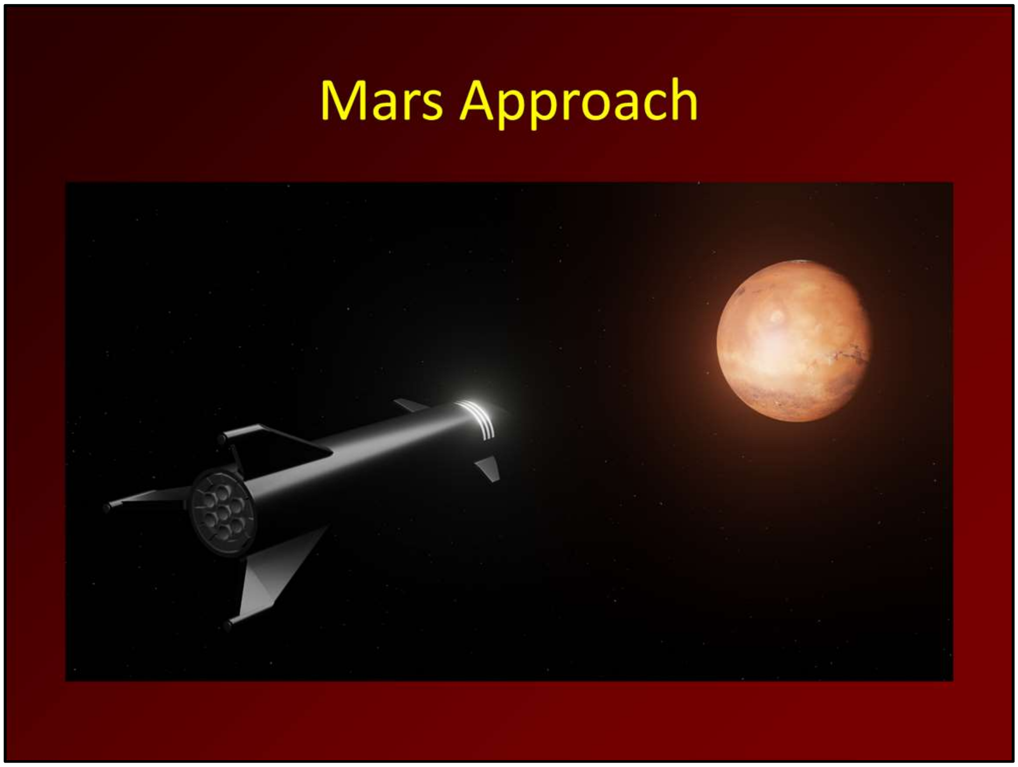
You can't just point to Mars and go there

- Step One: escape Earth's gravity
- Step Two: do so with enough speed for an elliptical orbit (of the sun) that touches or intersects Mars' orbit
- Step Three: time it so you arrive at Mars' orbit when Mars is actually there

If you just barely touch (Hohmann Transfer Orbit), you arrive on the other side of the sun, 9 months later

- taking less time means bigger ellipse, using more fuel.
- SpaceX (meaning Elon Musk) is planning for a six month trip,
- hoping to get it down to four months.
- Six months is very do-able, if you're a tiny probe and not a huge spacecraft carrying a dozen or so people.

Typical ISS stay is six months...



So approaching Mars' orbit a little ahead of the planet so it is catching up with us.

This close and we are already in Mars' "sphere of influence" –

- our motion is dominated by the force of Mars' gravity
- we are now falling into Mars
- course adjusted so we can make a direct entry into Mars' atmosphere.

SpaceX’s Starship uses a “bellyflop” maneuver to enter the atmosphere and aerobrake.

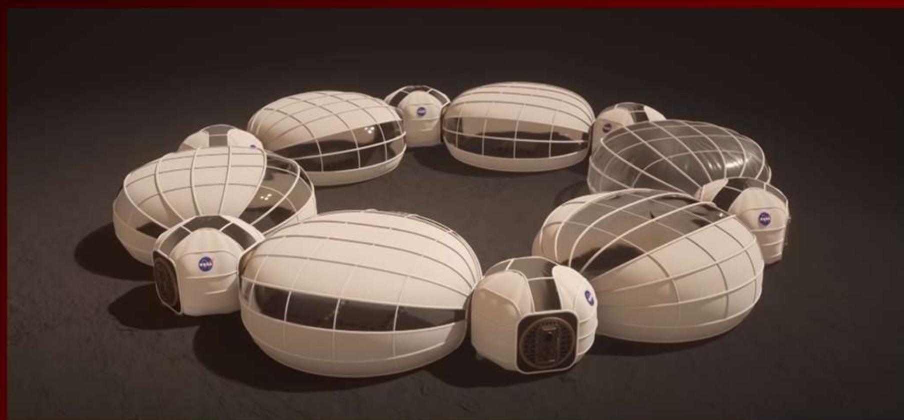
A couple supply ships land on Mars ~2022.
The objectives for the first mission will be to

- confirm water resources,
- identify hazards, and
- put in place initial power, mining, and life support infrastructure, including 3D printing of shelters... want to see that?

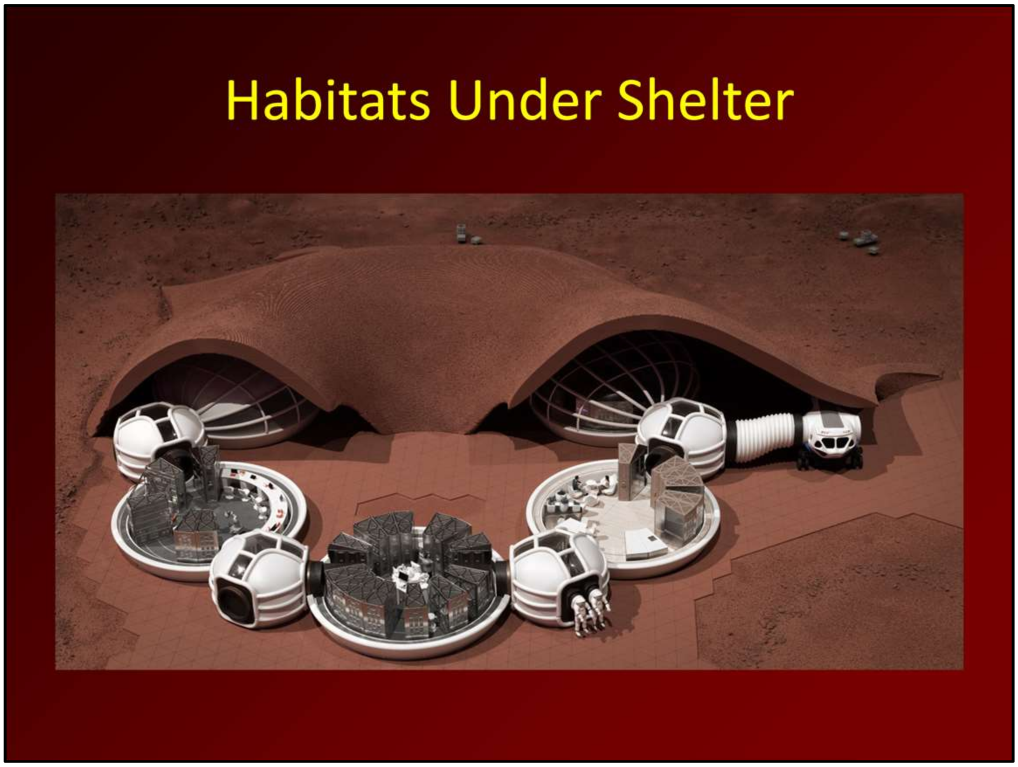
Building shelters out of Martian regolith using construction bots

- This shows them heating it up (to melting?) and pouring,
- A recent competition (NASA’s 3D Printed Habitat Challenge) was won using crushed rock mixed with a polymer binder creating high-tech concrete
- The rock used was Hawaiian basalt, considered to be equivalent to Martian rock.

Pressurized Habitat

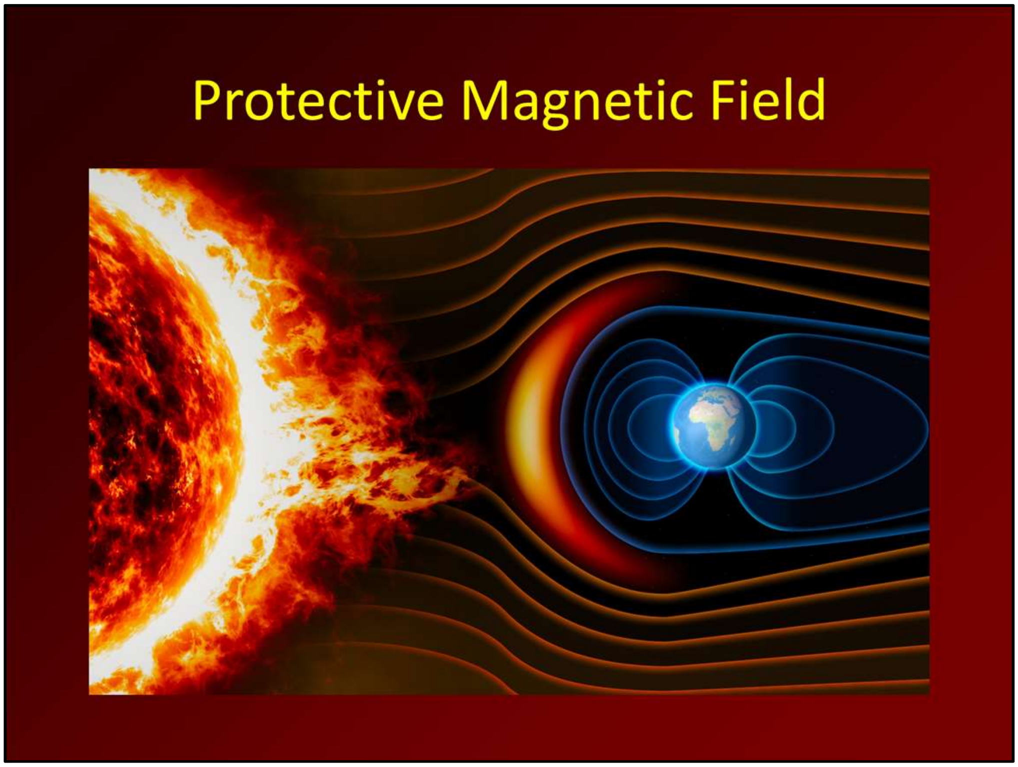


With the shelters up, the actual habitat modules would then be inflated (again using robots) inside the shelter.



This shows a cutaway of the shelter and of some of the modules

- showing racks being used for storage areas, work areas and living quarters.
- Note the suits which stay outside, as part of regolith dust management.
- Why are these habitats kept under a shelter though? Because it's a radiation bunker.



Earth has a magnetic field which deflects the solar wind and cosmic radiation

- This, along with 3 times the gravity, has helped earth to keep its atmosphere
- This also protects us from the extreme radiation conditions of space
- Mars doesn't have a (significant) magnetic field, or atmosphere, so protection is required.

Completed Mars Residence

So then this would be a completed Mars residence, with radiation shelter and pressurized habitat modules.

Establishing a Mars Base

The first manned mission follows in 2024. Mars base established by 2025.
A second mission, with both cargo and crew, is targeted for 2024, with primary objectives of

- building a propellant depot and
- preparing for future crew flights.

The ships from these initial missions will also serve as the beginnings of the first Mars base, from which we can build a thriving city and eventually a self-sustaining civilization on Mars.

The idea is to start with a base, build up to a village, continuing to build into a city, eventually multiple cities on Mars. Elon Musk believes we could end up with a population of one million by 2050.

Initially the colony would be funded by selling property –

- if moving to Mars could be done for around $200,000, with the promise of
- good-paying jobs in a labor-short economy,
- escape from tradition, freedom under a young, pioneering political system
- ability to participate in building a new civilization in an untamed and undefined world.

Of course, the question "what's the point" would be obviated in the event of a catastrophe like

- collision with a near-Earth asteroid: Apophis passes within 22,000 miles of Earth in 2029 (inside the orbit of a geosynchronous satellite)

So yeah. If you're interested, save up some money, give Elon a call, maybe you can get a deal on an early one-way ticket.

You could be the first on your block to move to Mars.

APPENDIX

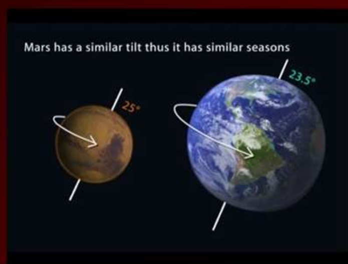
MARSHA Design Habitat

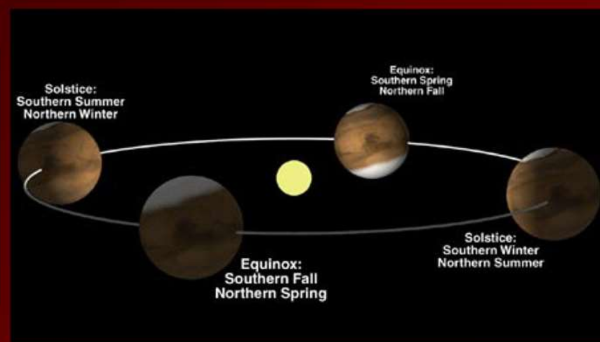
Tera

Syrtis Major on 30 September

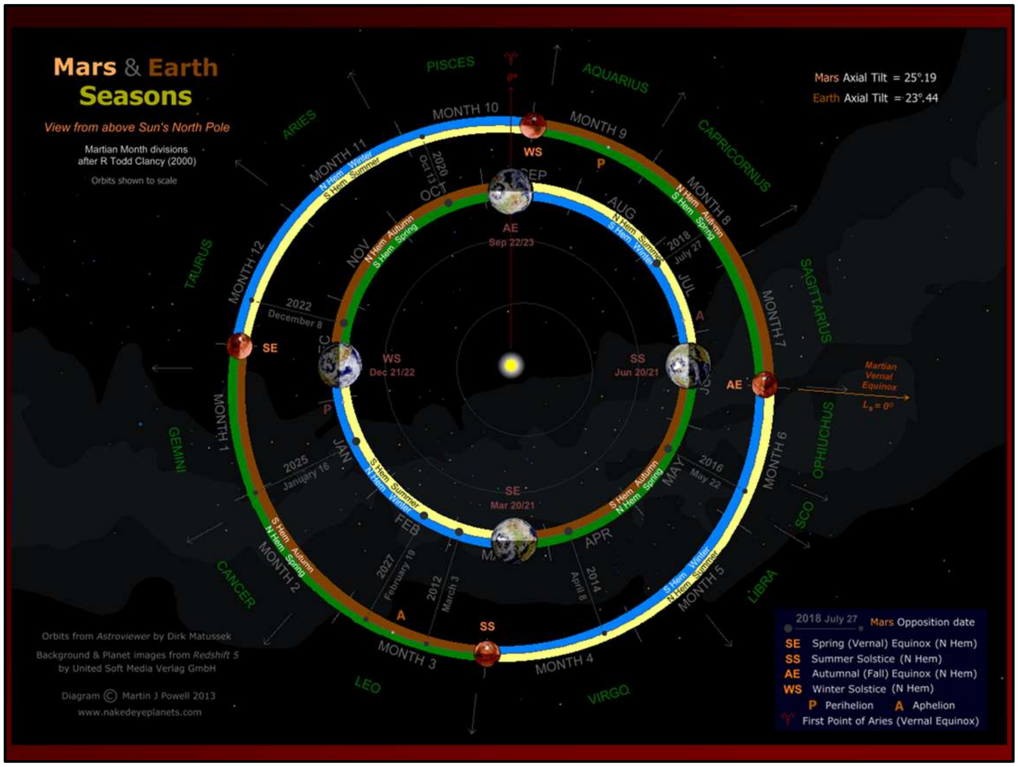
Polar ice caps are made of water and carbon dioxide ice.

Mars Seasons



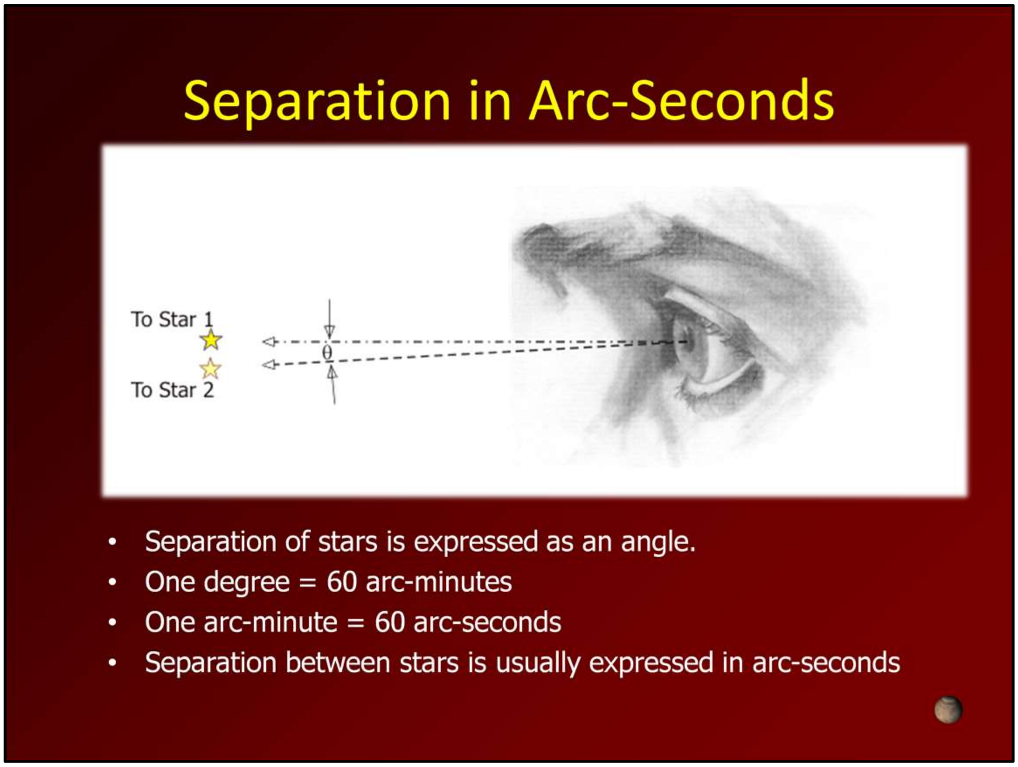


Northern summer is close to aphelion
- (farthest from the sun)
- Northern winter, southern summer, is close to perihelion
- since we are very close to Mars (perihelion), we’re at southern summer – the ice cap you see is the South Polar cap.

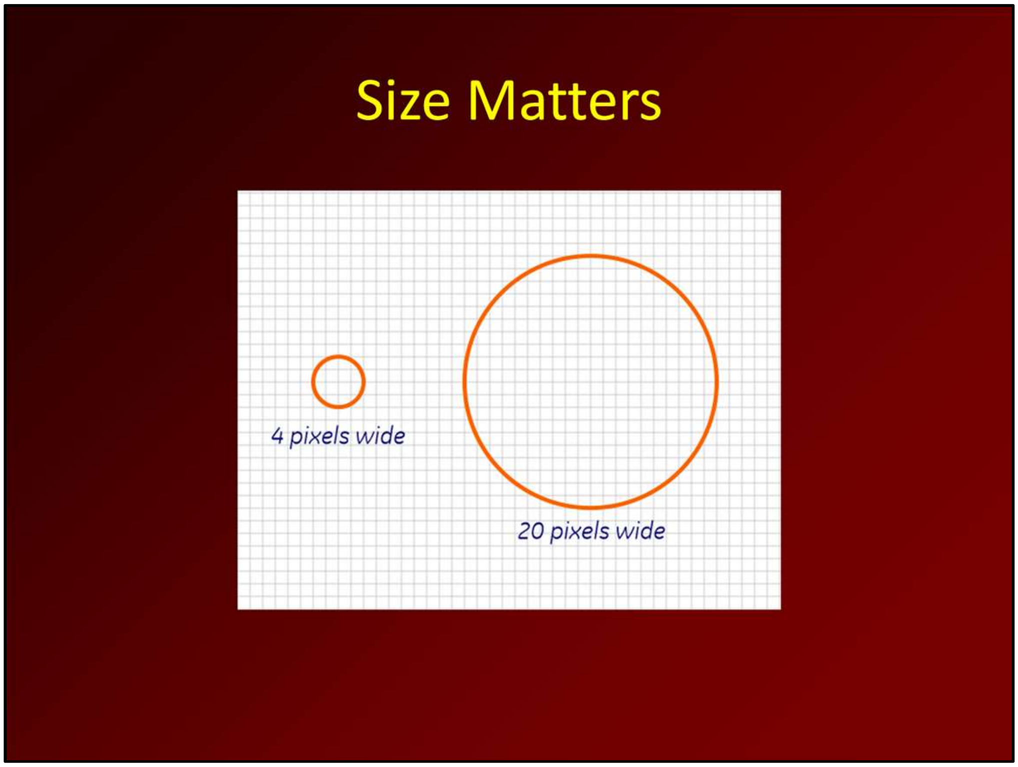


Note that Mars North Polar Cap points toward the top of the screen, Earth's North Polar Cap points to the left

- When Mars is at the bottom of the screen, its North Pole is pointing toward the Sun: Northern Summer Solstice
- When Earth is at the bottom of the screen, we are at Spring Equinox.
- So when the two planets are at the same point in their orbits (Mars Opposition), Mars is one full season ahead of Earth
- In our current opposition, Earth is one month past Fall Equinox, so Mars is 30° into Northern Winter (Southern Summer)



1. Everything in the night sky is so far away that it's not the actual distances between things that we see, it's the differences in the angle from our vantage point.
2. For that reason we measure distances and sizes in the scope image in terms of angles – degrees and fractions of degrees.
3. The actual system is not degrees and decimal degrees, but instead it's degrees, arc-minutes, and arc-seconds, which works just like hours, minutes & seconds
4. When stars are very close, then we are measuring their separation in terms of arc-seconds, which is one 3600^{th} of a degree.

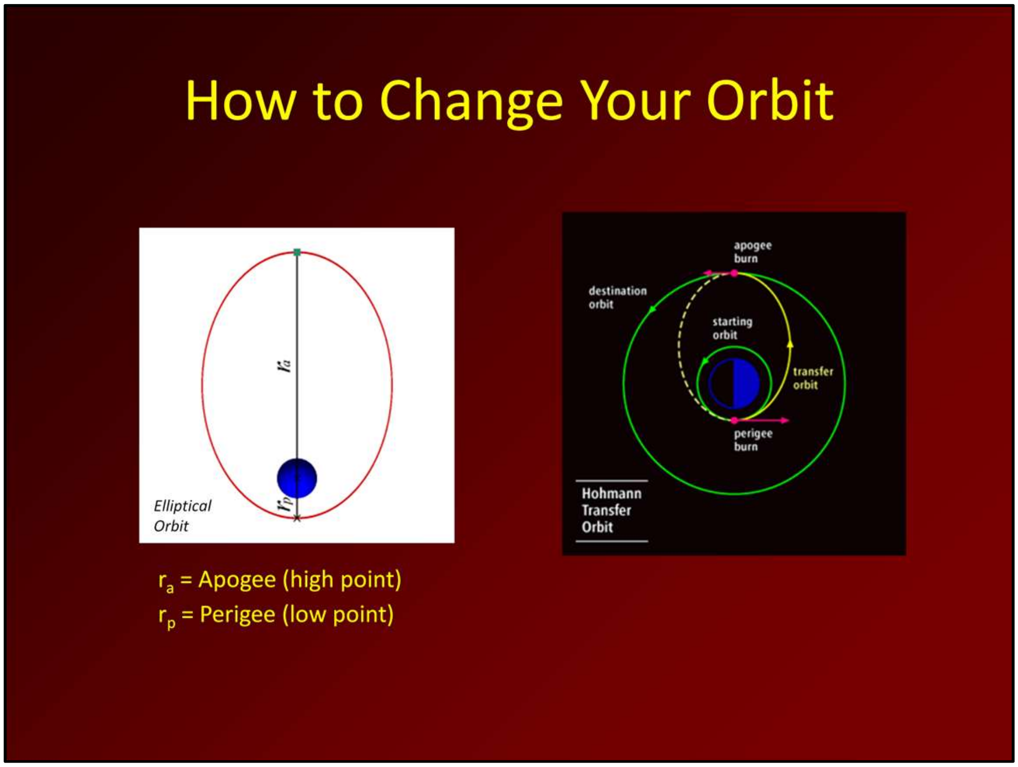


Remember when we say you can resolve 1 arcsecond,

- that means the smallest feature you can see is 1 arcsecond across.
- That means the resolution element is a bit like pixels on a computer image.

Then if Mars is in conjunction,

- It's only 3 or 4 pixels wide. Can't construct a lot of detail with four pixels. You'd be lucky to see the polar caps.
- Conversely with Mars now in opposition at 23 pixels wide, clearly much more detail about the surface can be seen.
- This is the significance of Mars in opposition.

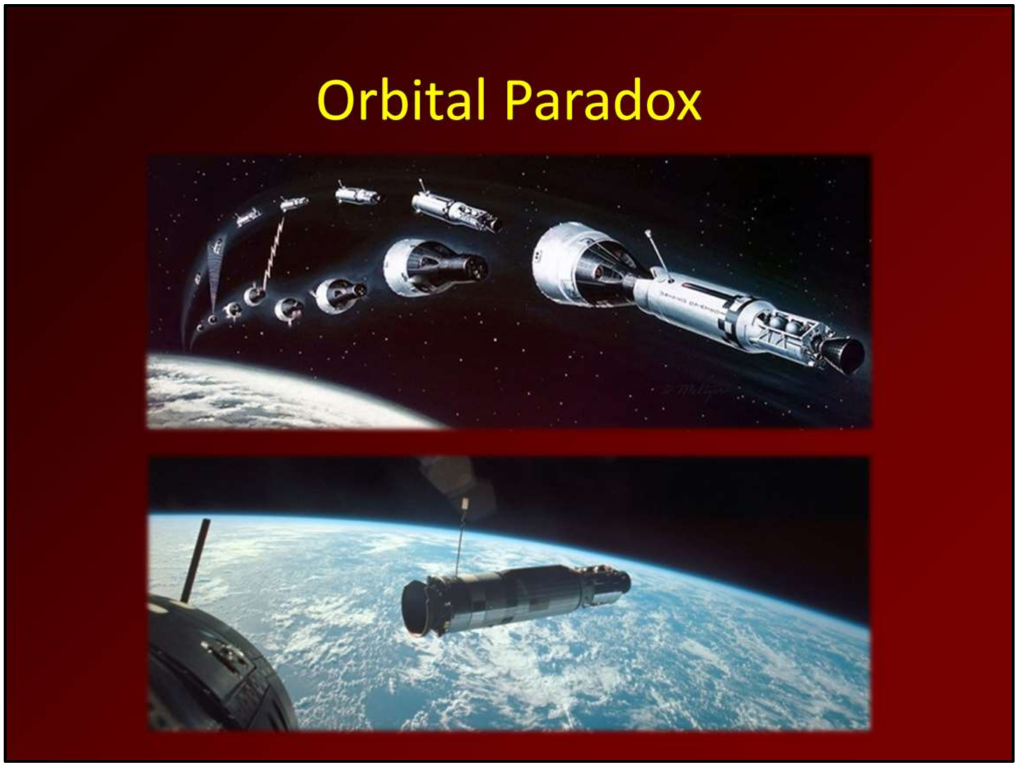


To get to Mars, we have to get from Earth's orbit to Mars' orbit, which is non-trivial

- So let's take a look at how orbits work so we can figure this out
- As we saw with Earth's and Mars' orbits, the general case is an elliptical orbit
- Notice how at perigee, you're going too fast for a circular orbit, so you climb,
- And at apogee, you're going too slow for a circular orbit, so you fall

Many ways to get to Mars

- Hohmann Transfer orbit is lowest-energy means
- It's still a lot of energy, barely attainable with current technology
- So it's usually the way this is done
- While in a circular orbit, deliberately create an elliptical orbit by speeding up – perigee burn
- At apogee, instead of falling back down, speed up again to the correct speed for a circular orbit – apogee burn



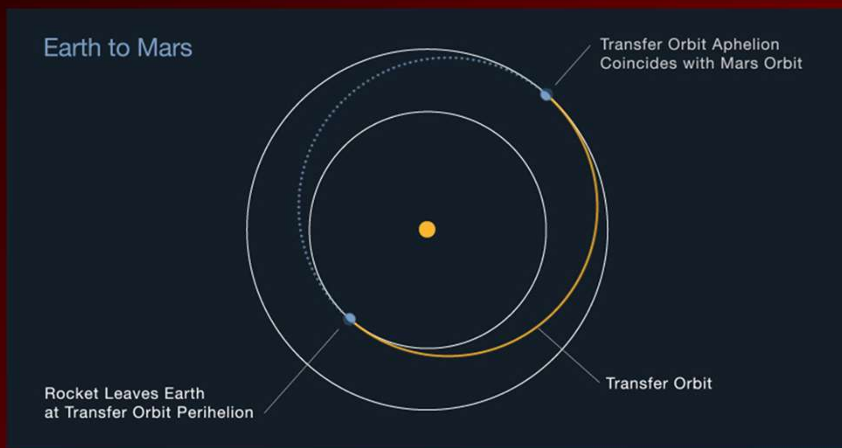
The first attempt at rendezvous failed during Gemini 4 due to a lack of understanding of orbital mechanics.

Starship on the Launch Pad

Here's your spaceship ready on the launch pad: SpaceX's Starship with its Super Heavy booster.

Starship Launch

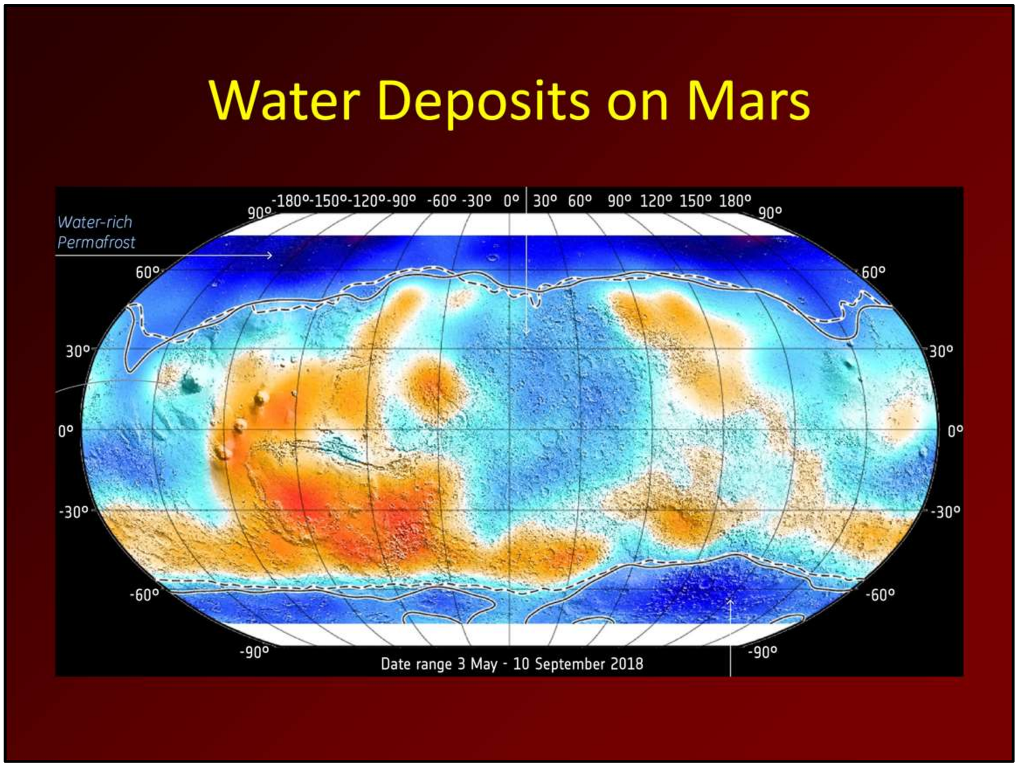
Mars Transfer Orbit



Nine-Month Trip – One Way

You remember I pointed out water deposits up by the Guppy and the Slash,

- this maps it out and shows the area they'll be aiming for.
- They will also be trying to get as close to the equator as possible to get as much sunlight as possible
- So close to the bottom of that region



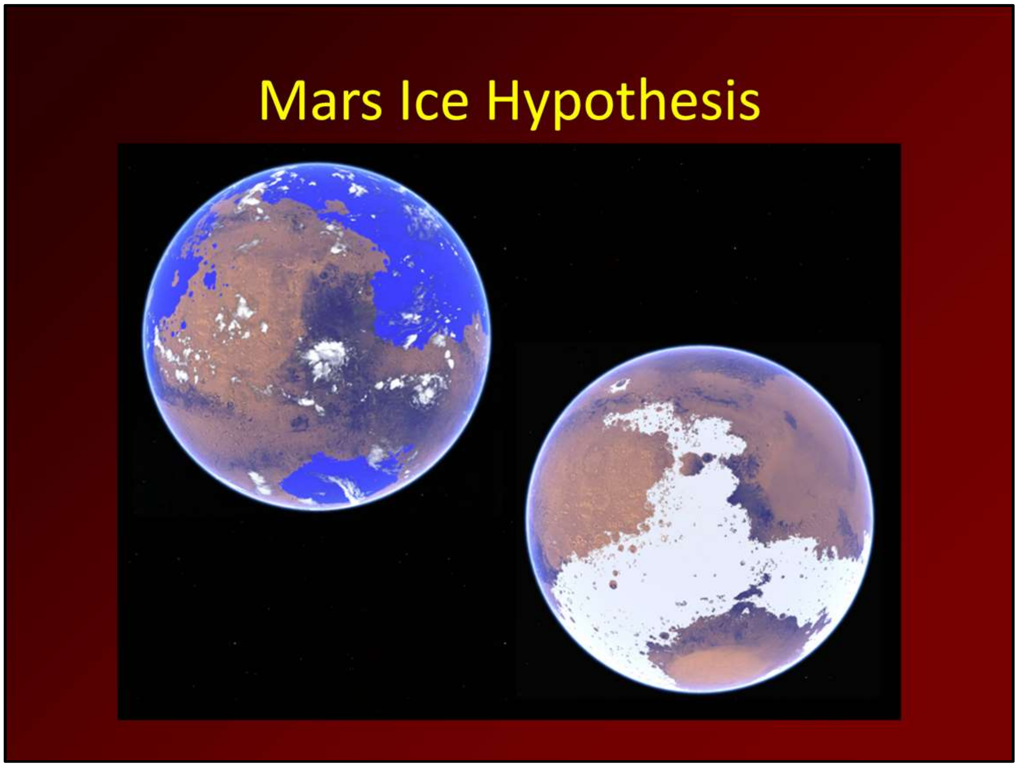
This is another look at the subterranean water deposits, with the target area at the upper left.

There are some pretty grand ideas for greenhouses for a sustainable closed environment,

- however the plants will also need to have radiation shielding,
- so the most likely the initial greenhouses will be under shelter with artificial light or light piped in

Terraforming Mars

Mars Ocean Hypothesis



Scientists compared the Martian valleys to the subglacial channels in the Canadian Arctic Archipelago and uncovered striking similarities.

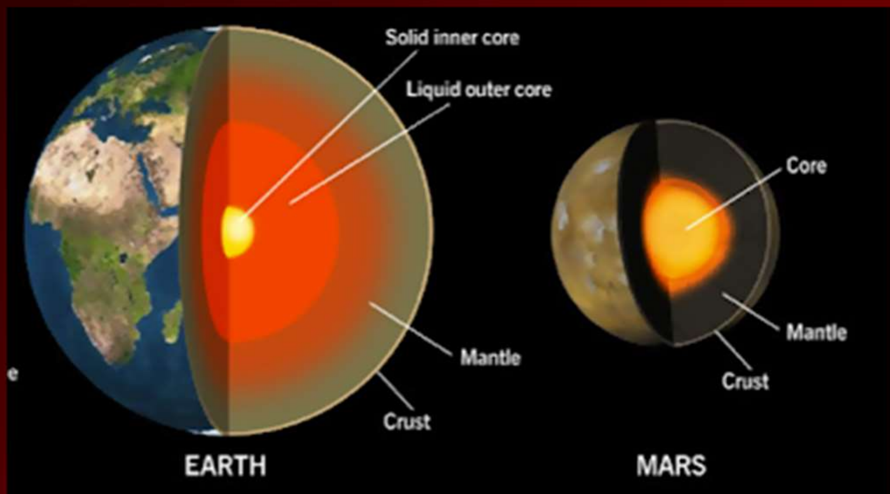
Devon Island in the Canadian Arctic motivated the authors to conduct their comparative study. "Devon Island is one of the best analogues we have for Mars here on Earth -- it is a cold, dry, polar desert, and the glaciation is largely cold-based,"

"The findings demonstrate that only a fraction of valley networks match patterns typical of surface water erosion, which is in marked contrast to the conventional view. Using the geomorphology of Mars' surface to rigorously reconstruct the character and evolution of the planet in a statistically meaningful way is, frankly, revolutionary.“

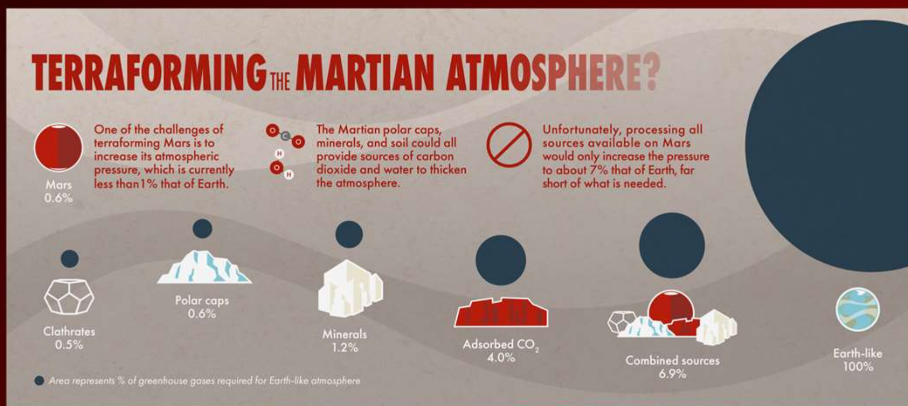
Grau Galofre's theory also helps explain how the valleys would have formed 3.8 billion years ago on a planet that is further away from the sun than Earth, during a time when the sun was less intense. "Climate modelling predicts that Mars' ancient climate was much cooler during the time of valley network formation," says Grau Galofre, currently a SESE Exploration Post-doctoral Fellow at Arizona State University. "We tried to put everything together and bring up a hypothesis that hadn't really been considered: that channels and valleys networks can form under ice sheets, as part of the drainage system that forms naturally under an ice sheet when there's water accumulated at the base."

Devon Island, Mars on Earth

Planetary Structure



Resource Limitations



Hazards of a Mars Mission

- Long-term exposure to zero/⅓G gravity
- Radiation (Solar & Cosmic)
- Landing (~50% historical success rate)
- Low atmospheric pressure/lack of O_2
- Dust: contamination, adhesion & toxicity
- Excursions over treacherous terrain
- Isolation & duration: crew dynamics & sanity