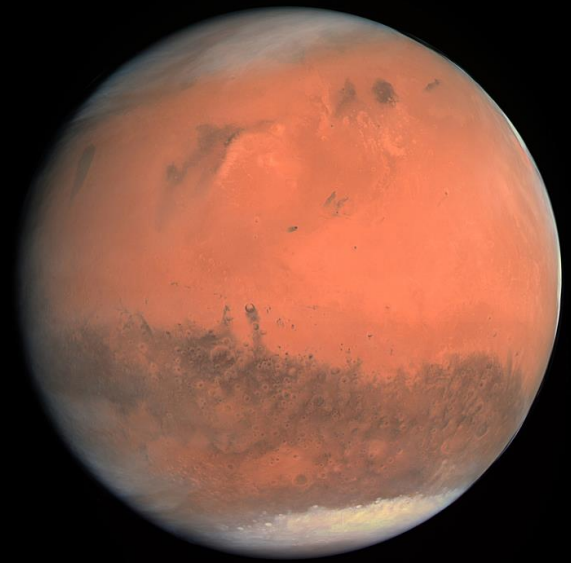

ROYAL ASTRONOMICAL SOCIETY OF CANADA
QVO DVCIT VRANIA
WINNIPEG CENTRE

BOOTS ON MARS THIS DECADE?

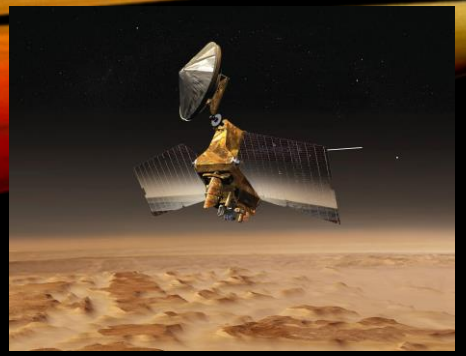
Progress towards Mars Landings this decade



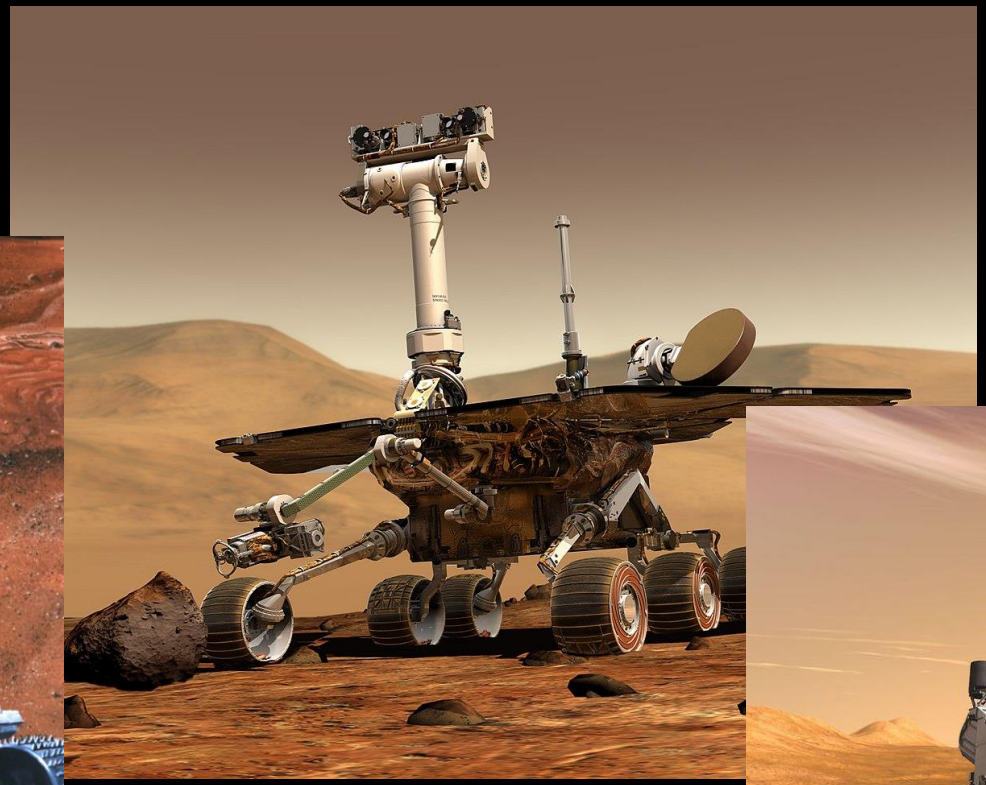
Gord Tulloch,
RASC, Winnipeg Centre

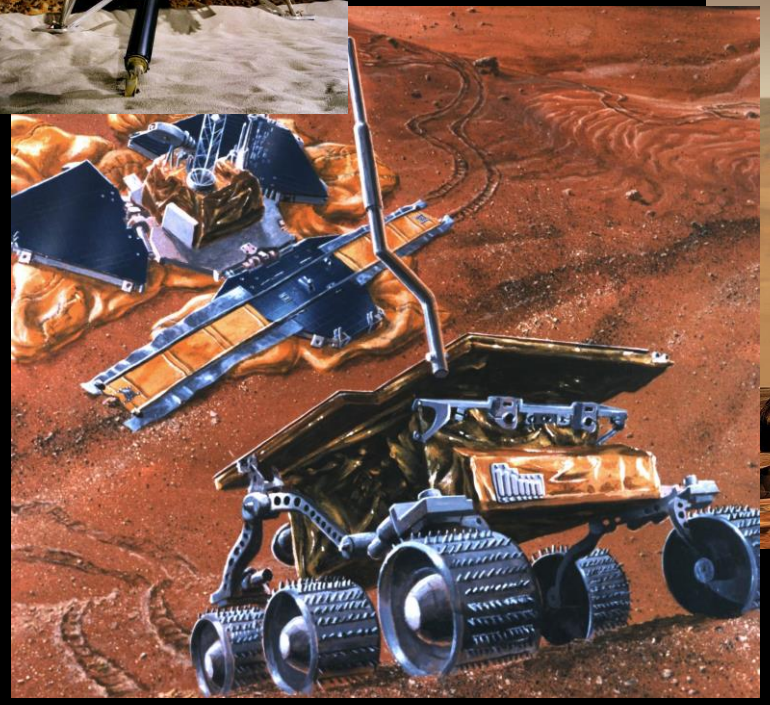
MARS MISSIONS HISTORY

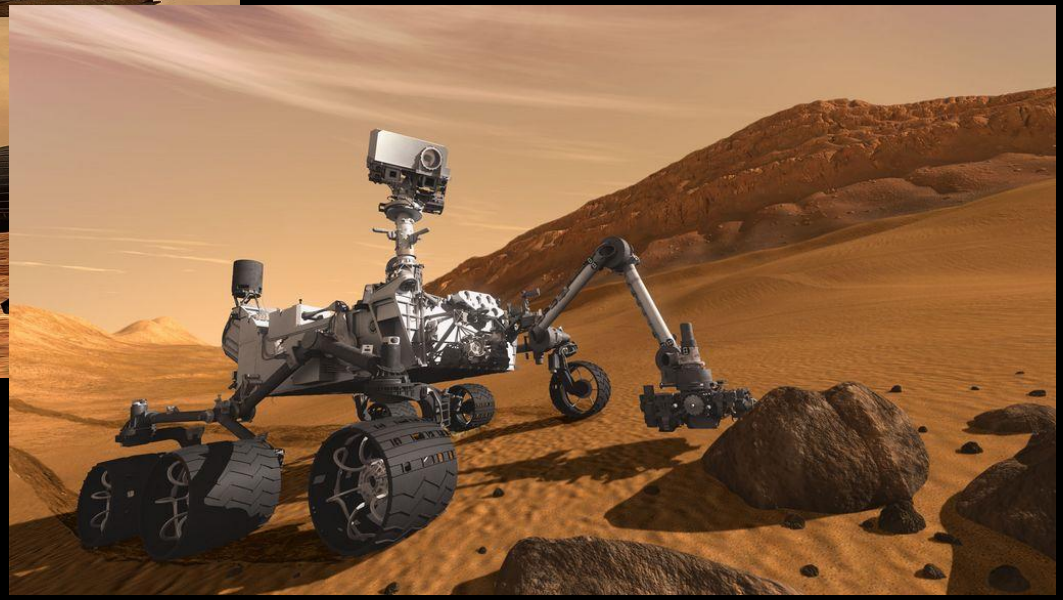
- Many people have put forward plans to land people on the Red Planet
- Werner Von Braun built a rocket capable of taking us there – the Saturn V
- Project Orion (nuclear pulse) 1957-65
- Space Exploration Initiative 1989-1993
- In 1992 Dan Golden became NASA admin and started the very successful "faster better cheaper" robotic explorations of space
- Humanity languished in LEO



ROBOTS RULE



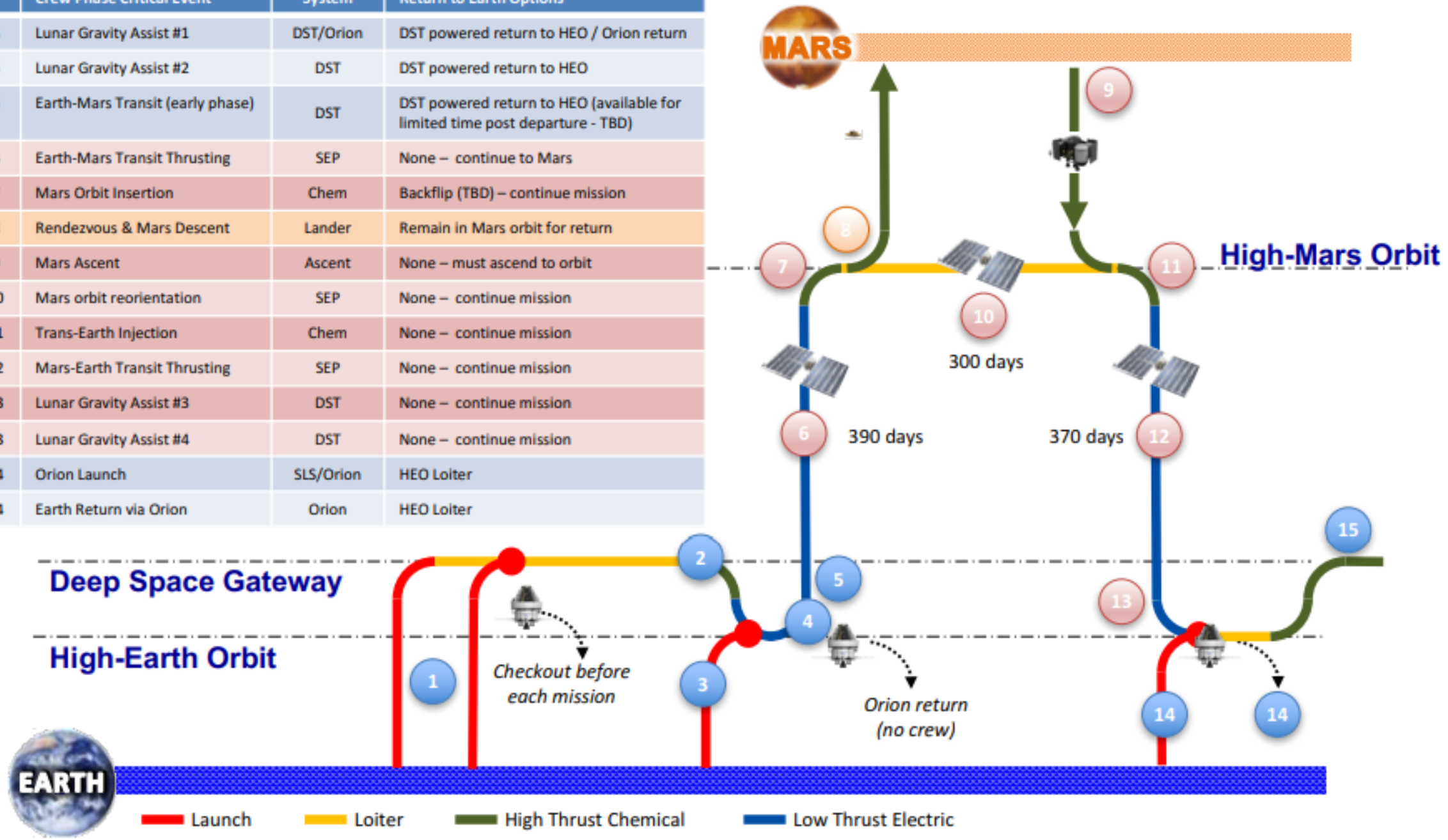




MANNED MISSIONS BEYOND LEO

- NASA Journey to Mars and the Moon
  - Current plan SLS/Orion launch Artemis 1 (2022) Artemis 2 moon orbit (2024) Artemis 3 (2025?), landing with SpaceX lander), 2030s Mars landing with some of the same hardware
- SpaceX Starship
  - Already building and testing infrastructure and vehicles for pathfinder missions to Mars in late 2023 and 2025 with crewed missions in 2027
  - Contracted to provide moon lander for Artemis Missions
- Other players (e.g. Blue Origin) on the horizon

#	Crew Phase Critical Event	System	Return to Earth Options
4	Lunar Gravity Assist #1	DST/Orion	DST powered return to HEO / Orion return
5	Lunar Gravity Assist #2	DST	DST powered return to HEO
5	Earth-Mars Transit (early phase)	DST	DST powered return to HEO (available for limited time post departure - TBD)
6	Earth-Mars Transit Thrusting	SEP	None – continue to Mars
7	Mars Orbit Insertion	Chem	Backflip (TBD) – continue mission
8	Rendezvous & Mars Descent	Lander	Remain in Mars orbit for return
9	Mars Ascent	Ascent	None – must ascend to orbit
10	Mars orbit reorientation	SEP	None – continue mission
11	Trans-Earth Injection	Chem	None – continue mission
12	Mars-Earth Transit Thrusting	SEP	None – continue mission
13	Lunar Gravity Assist #3	DST	None – continue mission
13	Lunar Gravity Assist #4	DST	None – continue mission
14	Orion Launch	SLS/Orion	HEO Loiter
14	Earth Return via Orion	Orion	HEO Loiter

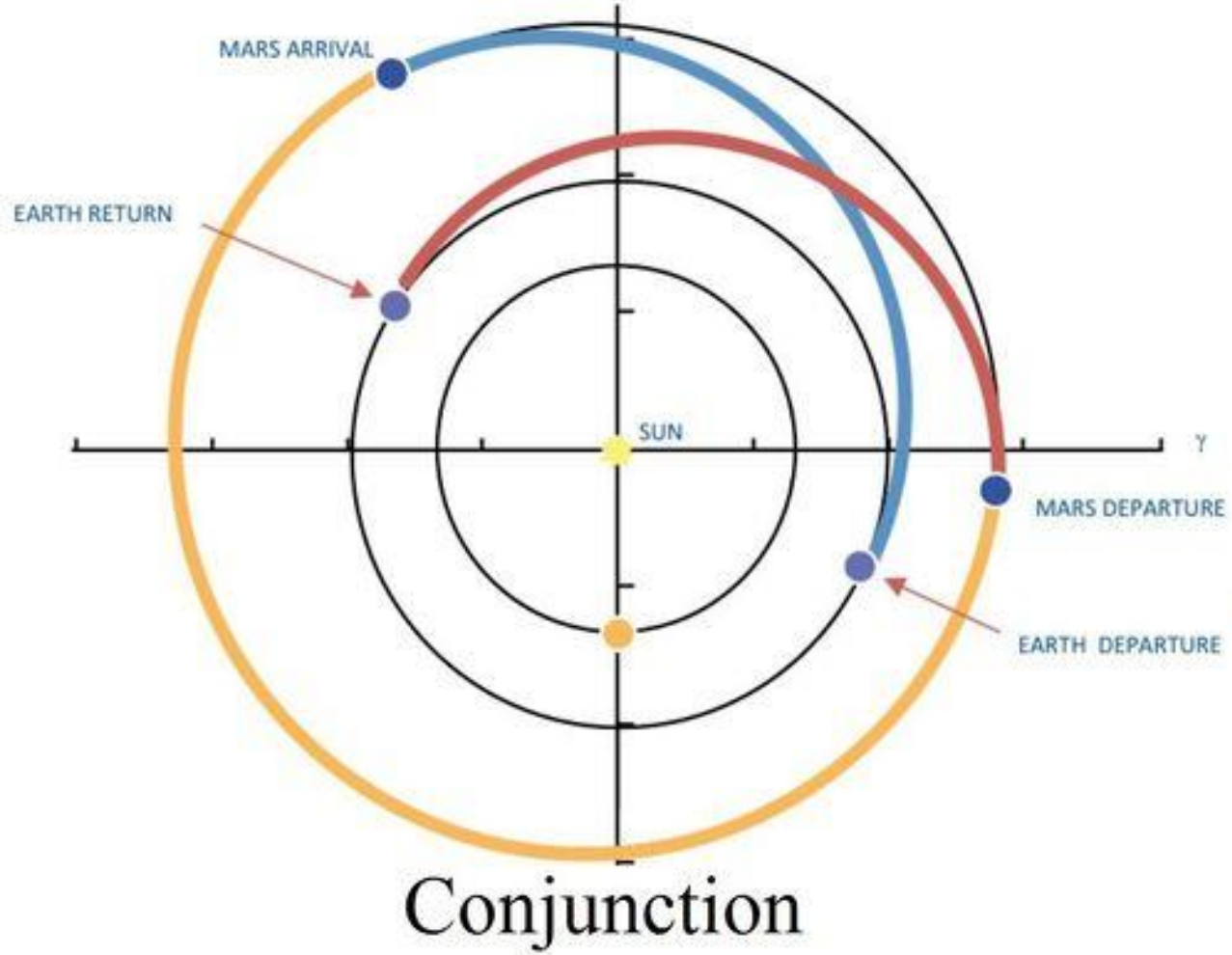


https://nvite.jsc.nasa.gov/presentations/b2/D1_Mars_Connolly.pdf

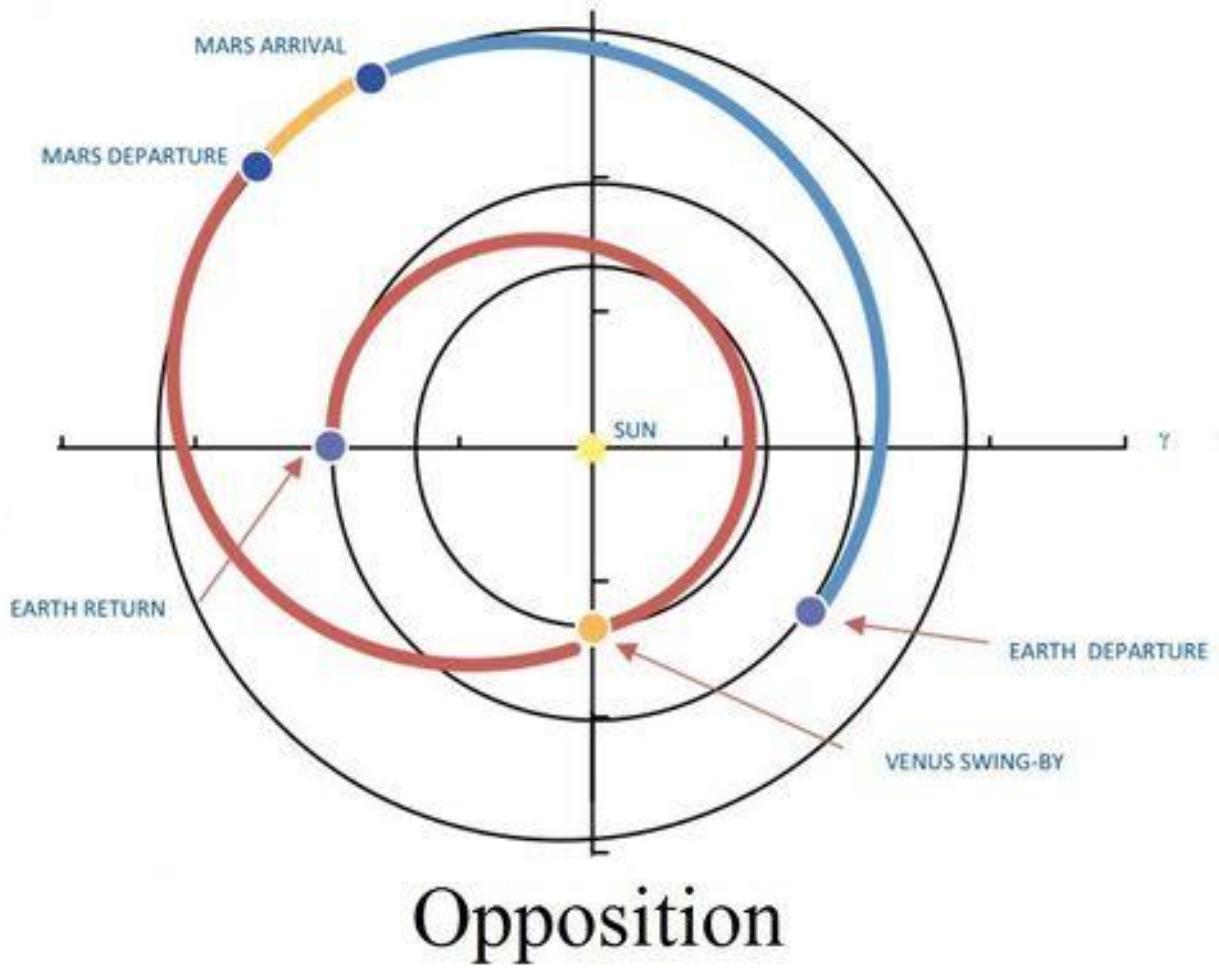
WHY IS SLS STILL A THING?

- SLS is corporate welfare for the US space industry

CONJUNCTION VS OPPOSITION



Conjunction

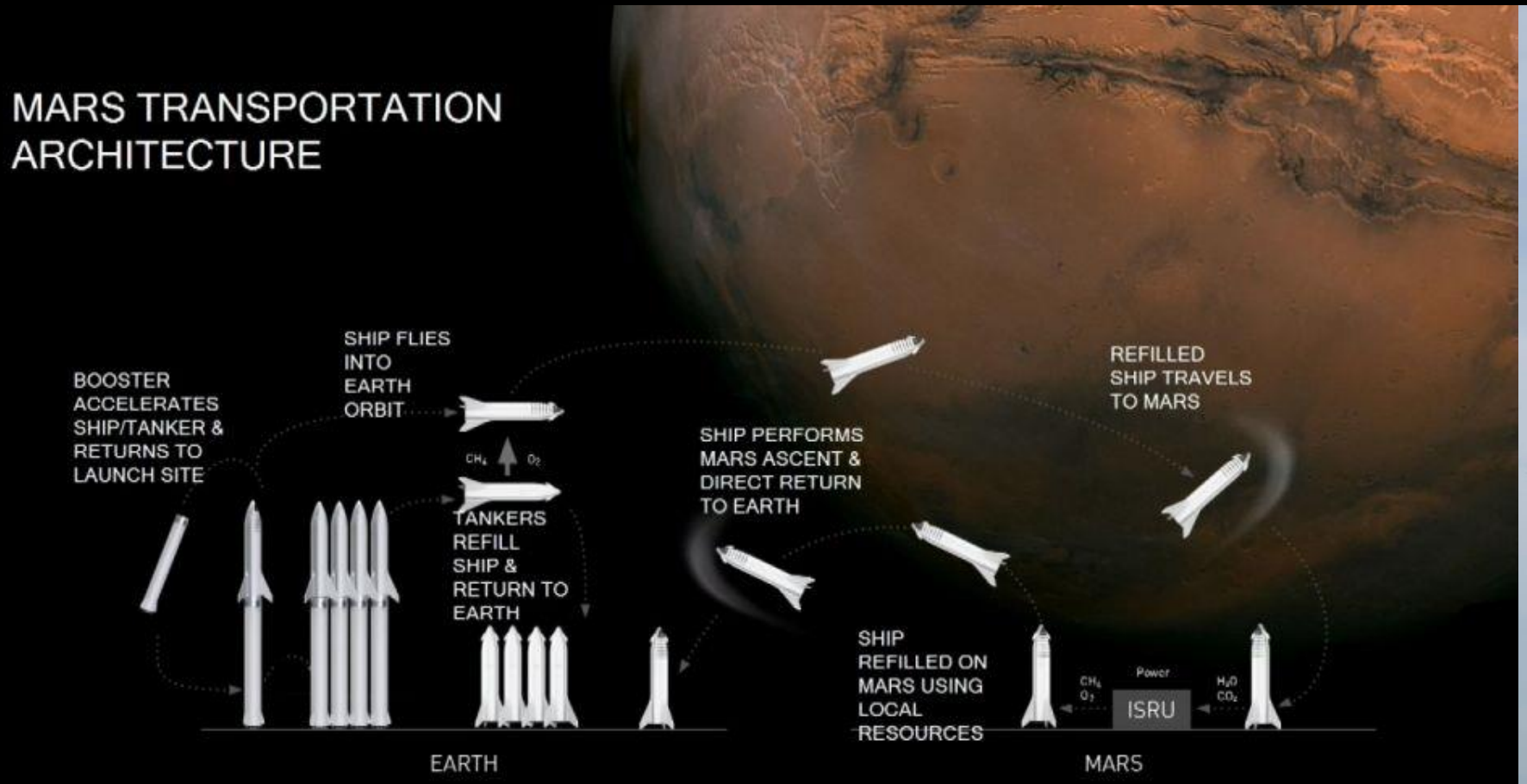


Opposition

Mission type [1]	Total mission duration, days	Earth-Mars trip, days	Time spent at destination	Mars-Earth trip, days	Total ΔV, km/s	Trans-Mars Injection, km/s	Mars Orbital Insertion, km/s	Trans-Earth Injection, km/s
Conjuction	1005	198	558	197	2.81	0.50	1.25	1.06
Opposition	560	177	40	342	5.69	0.61	1.75	3.33

https://marspedia.org/Mars_mission_duration

STARSHIP MISSION PROFILE



STARSHIP ECONOMICS

- Cost to build depends on volume
  - 2 Starship per month = $37M ea
  - 2 Starship per week = $13M ea
  - 20 SuperHeavy per year = $32M ea
  - Target is 1000 units
- Starships and SuperHeavy reused 100 times
- SpaceX wants to get per flight to orbit costs down to $2M (although independent analysis is $10M)
- 100-150 tons to orbit means about 100-200 people per flight means $20k – 10k / flight which is about cost range of business class.
- 40min flights between NY and Shanghai referred to as “Earth-to-earth” flights similar to aircraft costs
- Of course overall operations costs offset by satellite (eg Starlink 2) launches
- Colony flights to Mars like ships to North America – sell all your stuff to pay for a ticket and work off the debt

https://www.nextbigfuture.com/2020/05/mass-production-rate-and-spacex-starship-costs.html

Proudly supported by:

Marcus House,
Patreon members,
NASASpaceFlight.com.

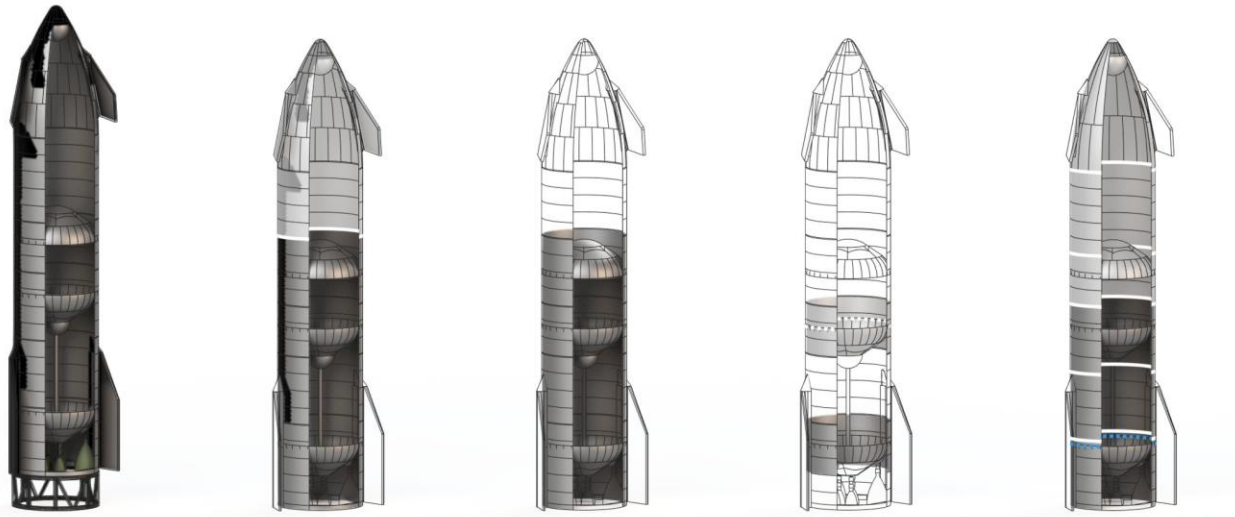
STARBASE, TEXAS

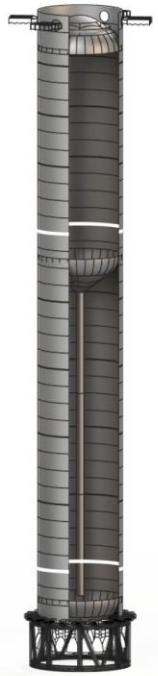
SPACEX STARSHIP BUILD DIAGRAM

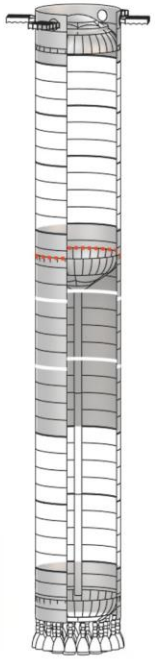
February 8th 2022

By Brendan Lewis
@_Brendan_Lewis

Cryo Proof | Static Fire | Flight | Landing | RUD | RVac Installed | RC/RB Installed | Newly Spotted Sections | Newly Mated Sections | Unconfirmed S/B#







S20
Launch Site

S21
Build Site

S22
Midbay

S23
Build Site

S24
Build Site

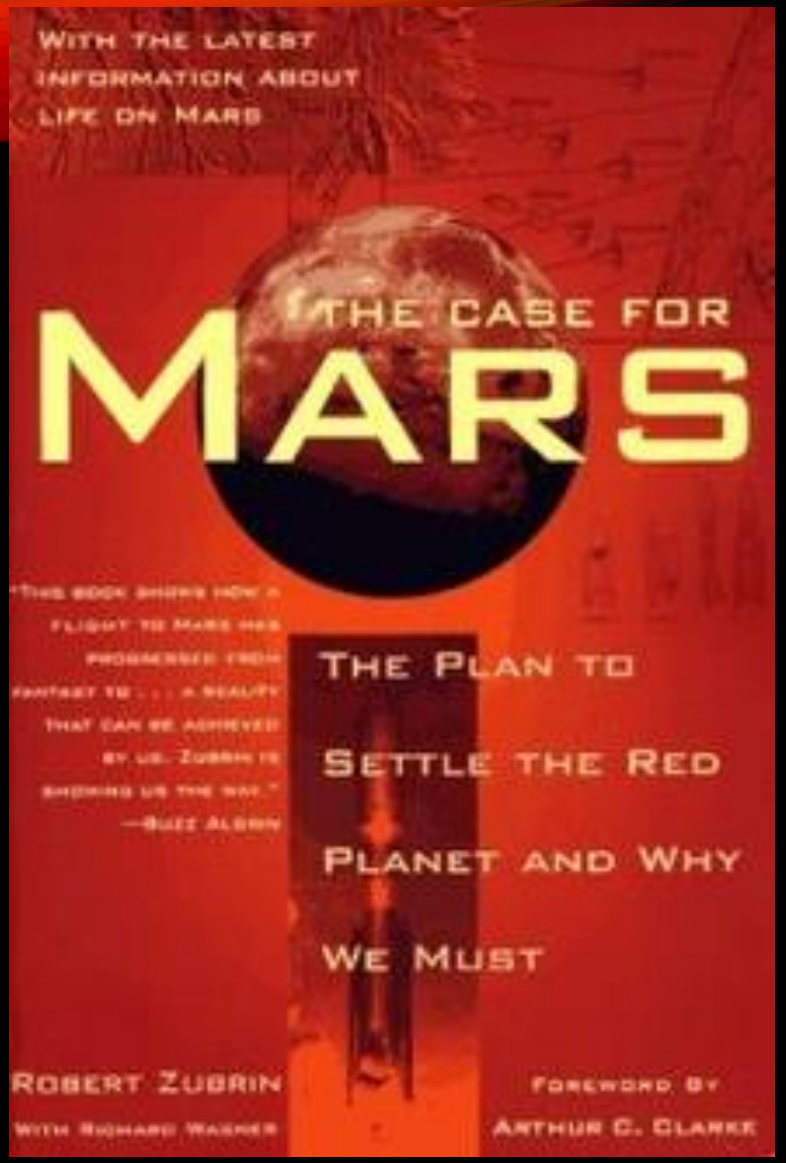
B4
Orbital Launch Mount

B7
Highbay

B8
Build Site

STARSHIP VARIANTS

Starship variants (Credit: Everyday Astronaut / Caspar Stanley)



MARS DIRECT

- ***The Case for Mars: The Plan to Settle the Red Planet and Why We Must*** by Robert Zubrin in 1996 revised 2011
- Plan for Mars mission that reduced costs from $500B to $20-$30B
- Single throw vehicles to Mars rather than fleets of "Battlestar Galactica" motherships
- 2 Year stays instead of 30 days
- In-situ resource utilization
- Initiated the Mars Society in 1998 to continue to develop the plan

MARS SOCIETY

- Further Development of plans to take humans to Mars
- Mars Analog Research Station Program
- Mars VR
- University Rover Challenge
- Annual Mars Society Conference
- Latest conference in October very well attended
- Canadian Society active in University circles, discussing resurrecting Winnipeg branch

https://www.marssociety.org
https://www.marssociety.ca

Mars Direct 3

by Miguel Gurrea

Based on work by SpaceX and Dr. Robert Zubrin

SpaceX architecture

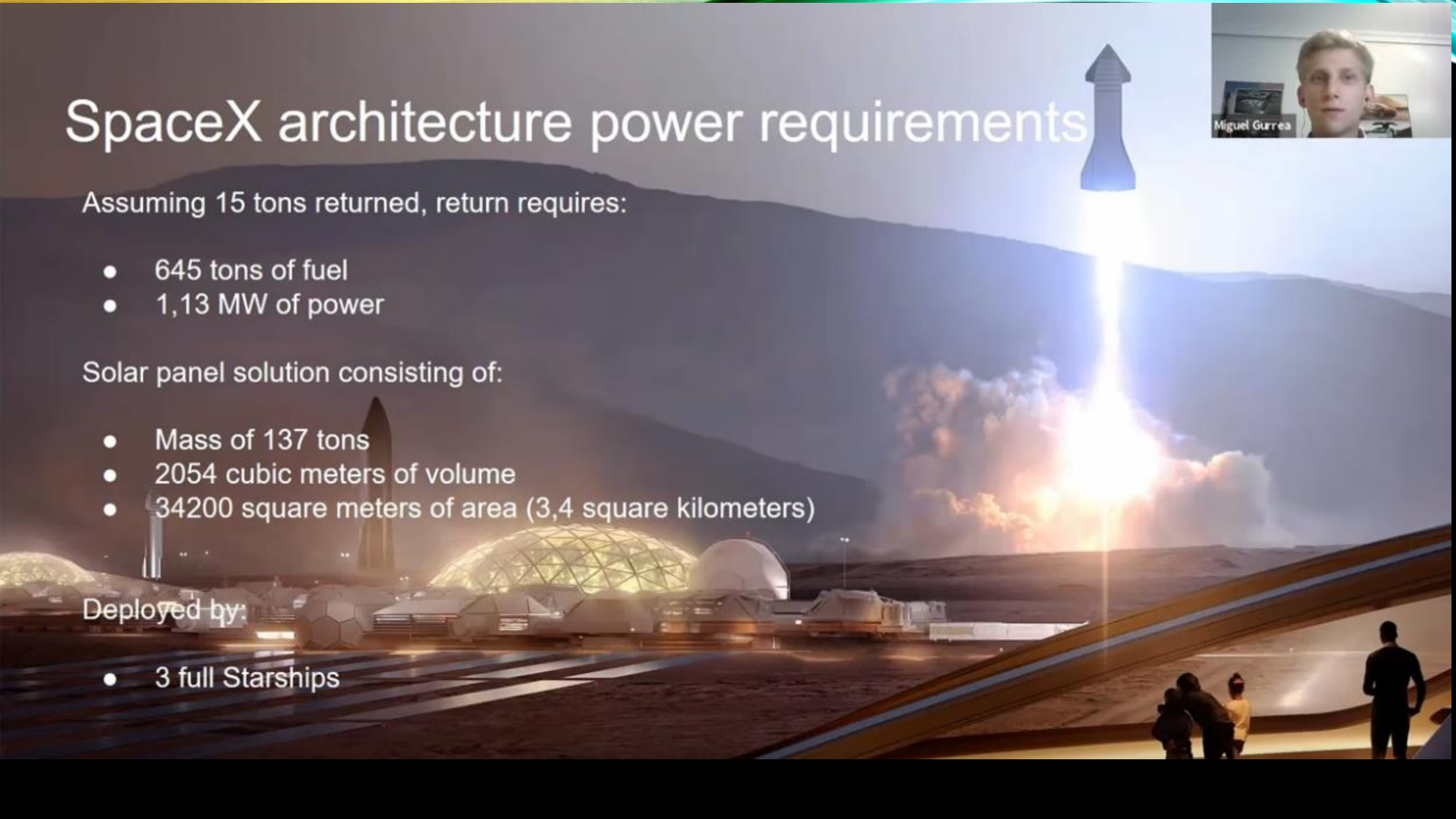
- Land on Mars with Starships
- Refuel them via water electrolysis Sabatier reaction

Relies on:

- Martian ice extraction and processing for ISRU
- Solar power

No plan B in case of ISRU failure (DANGER)

SpaceX architecture power requirements



Assuming 15 tons returned, return requires:

- 645 tons of fuel
- 1,13 MW of power

Solar panel solution consisting of:

- Mass of 137 tons
- 2054 cubic meters of volume
- 34200 square meters of area (3,4 square kilometers)

Deployed by:

- 3 full Starships

Why not use both?

-Best of both worlds

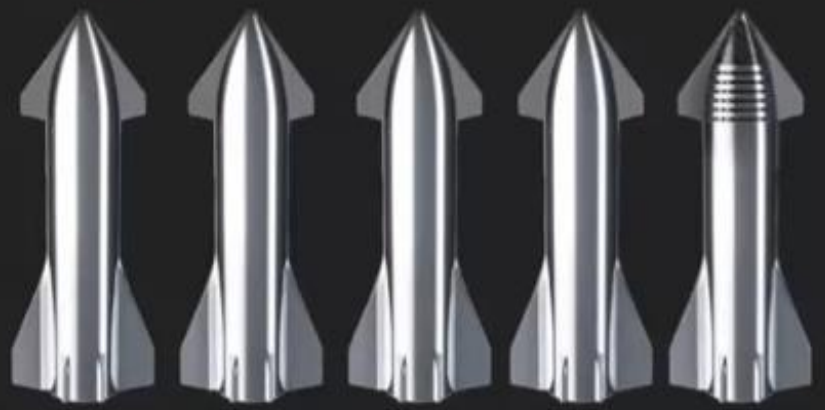
- 110t cargo capacity
- 645t methalox requirement (503t of oxygen)

- 32t cargo capacity
- 148t fuel requirement (115,5t of oxygen)

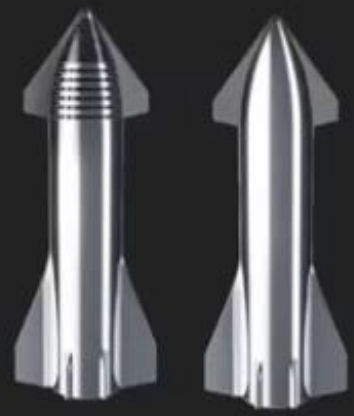
The Ships in Mars Direct 3

Requires 5 tankers
Requires 3 tankers

First launch window



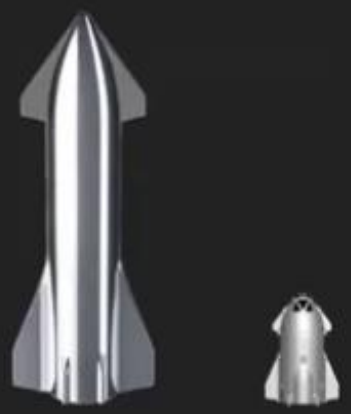
Second launch window



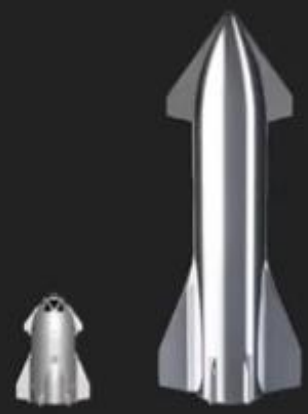
Starship-only variant

42 launches

Caravel & Starship variant



23 launches

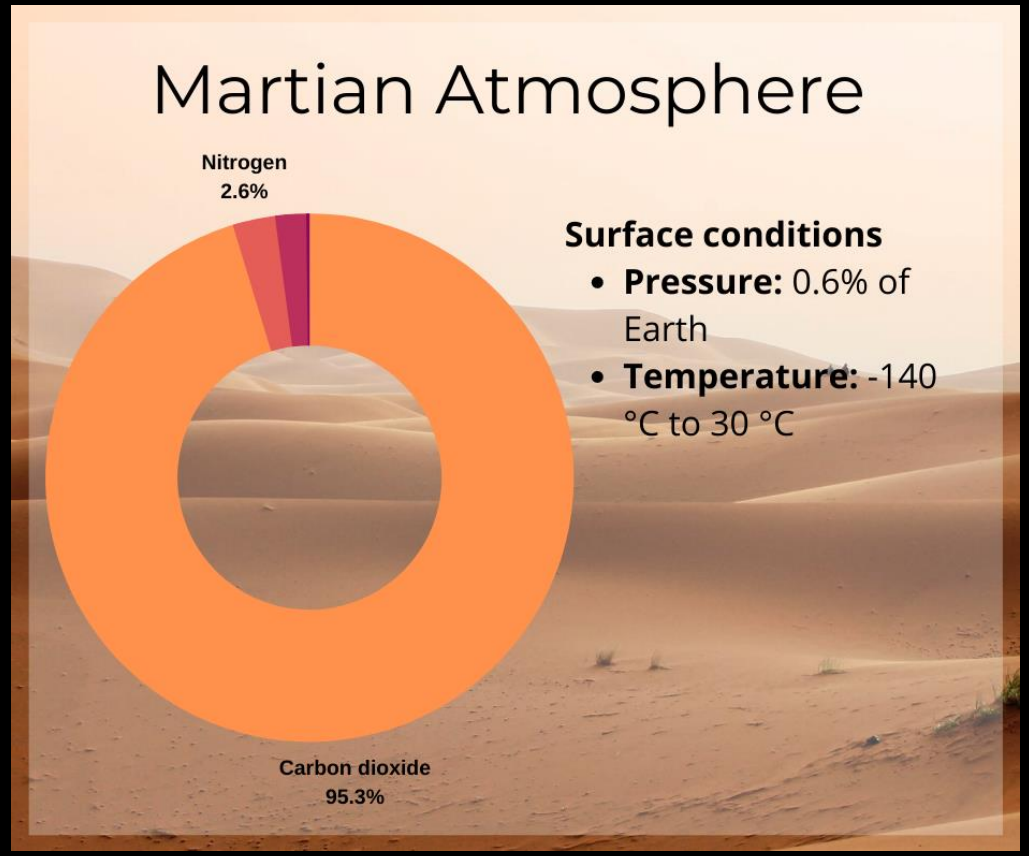


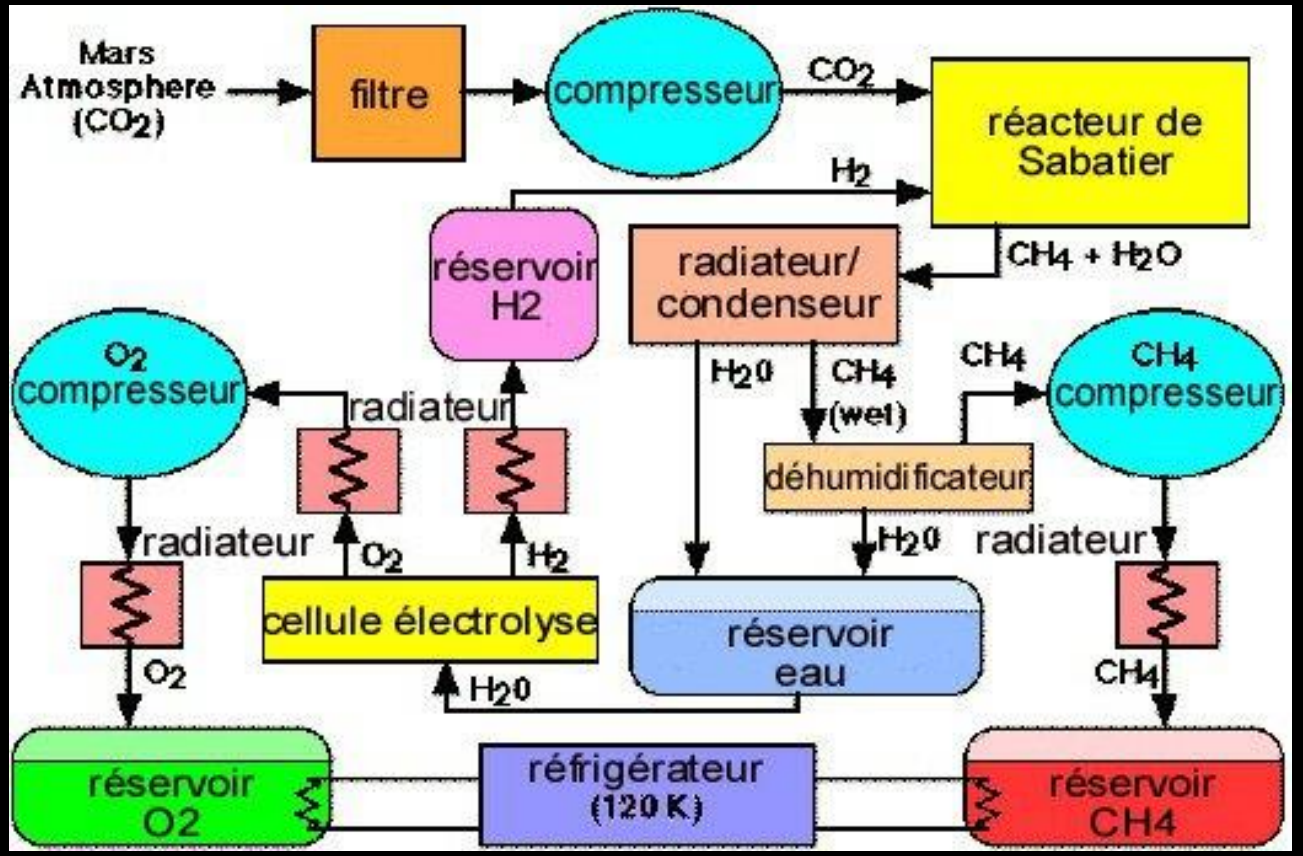
Victoria Pinta

(Added 1 extra for Earth landing)

Niña | Santa María

IN-SITU RESOURCE UTILIZATION



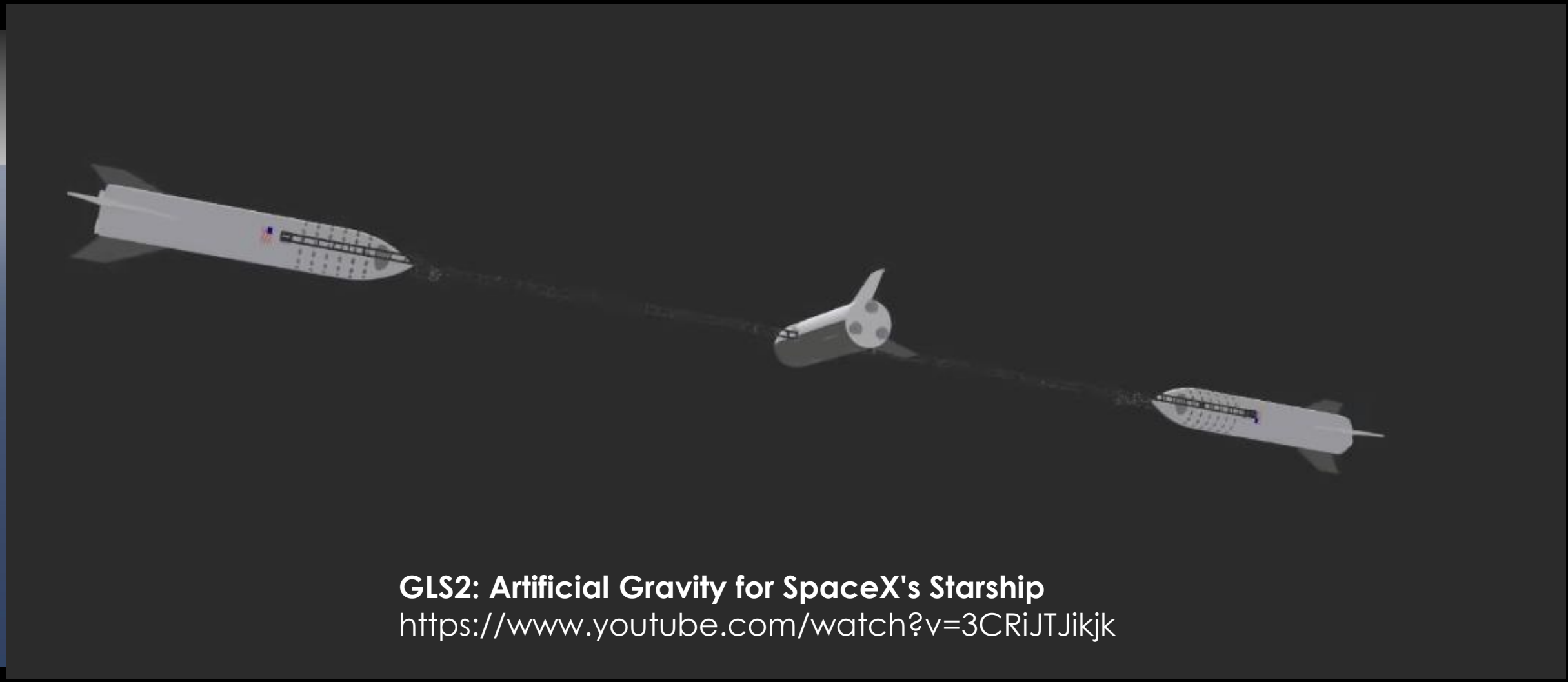


Jin Sing Sia, Mars Society Canada

MARS DIRECT PROBABLE

- Every two years there's a window at Conjunction best
- Window 0 (2022-2023)
  - LEO starship, lunar flights, on orbit refueling, additional launch capacity
  - Possible Orbital / Re-entry / landing tests on Mars if all goes well
- Window 1 (2025) – multiples of:
  - Cargo Starships – Solar Arrays / Nuclear Reactors for ISRU Power
  - Cargo Starships – Hydrogen feed stock for in-Situ CH4 and O2
  - Crew Starship (uncrewed) – Earth Return vehicles (refuel via ISRU)
- Window 2 (2027)
  - Crew Starships – crews for first mission, rovers
  - Crew Starships – uncrewed spares, rovers, earth return vehicles for next window
  - Cargo Starships – Truss Assemblies for spin gravity (refuel in orbit)
  - Cargo Starships – Power generation, ice mining supplies, in-situ fuel, rovers
- Rinse and repeat (2029 and beyond)

ARTIFICIAL GRAVITY



GLS2: Artificial Gravity for SpaceX's Starship
https://www.youtube.com/watch?v=3CRiJTJikjk

TAKING FLIGHT

OCTOBER 14-17 - 2021

THE 24TH ANNUAL INTERNATIONAL MARS SOCIETY CONVENTION

AN ONLINE VIRTUAL EVENT POWERED BY ATTENDIFY

www.MarsSociety.org

Plenary Session

Space Nuclear Power

Dr. David Poston
CTO
Space Nuclear Power Corporation

AKA "SpaceNukes"

A power-rich architecture is needed for Human exploration and habitation of Mars

- **Electricity (and heat) is needed...**
  - To create oxygen
  - To create a source of water
  - To power habitats and rovers
  - Drilling, melting, heating, refrigeration, sample collection, material processing, manufacturing, video, radar, telecomm, etc.
  - We (human civilization) have developed an infrastructure that uses electricity as the energy “middleman” for almost everything

International Mars Research Station – Shaun Moss

NASA artwork

- **Abundant electricity is also needed to make propellants**
  - Liquid Oxygen
  - Methane
- **In-situ propellant production is what makes near-term transportation to/from Mars efficient and affordable**

Why Nuclear for Mars Surface?

- **Solar power on Mars surface presents major challenges**
  - ~1/2 solar insolation of Earth
  - Long-term dust storms (months to years in length)
    - Huge increase in optical depth has been experienced many times in the "short" time we've had a presence on Mars
    - Note: diffuse light helps keep output above zero, but diminishes output to a relatively small fraction of the full power level.
  - Much colder (and slightly longer) nights than Earth
    - Which complicates batteries or other storage techniques, in addition some of the stored energy might have to be used to prevent things from getting too cold
  - Highly dependent on latitude and season
    - The "easy" water is at high latitudes, with low sun angle, long winter nights
  - Craters/gullies/cliffs/etc. can block/diminish sunlight
    - This might also be where the easy water will tend to be
    - Also, many locations might not have a large "flat" area for deployment
  - Deployment of huge arrays, and ability to deploy and keep them clean.
- **The Moon can be as (or more) challenging**
  - 14 days of darkness, the storage system itself might be more difficult than a reactor, and heavier
  - Huge temperature swings, from warm to extremely cold temperatures
  - Power needed in permanently shaded craters to extract water ice.

Viking Optical Depth Data

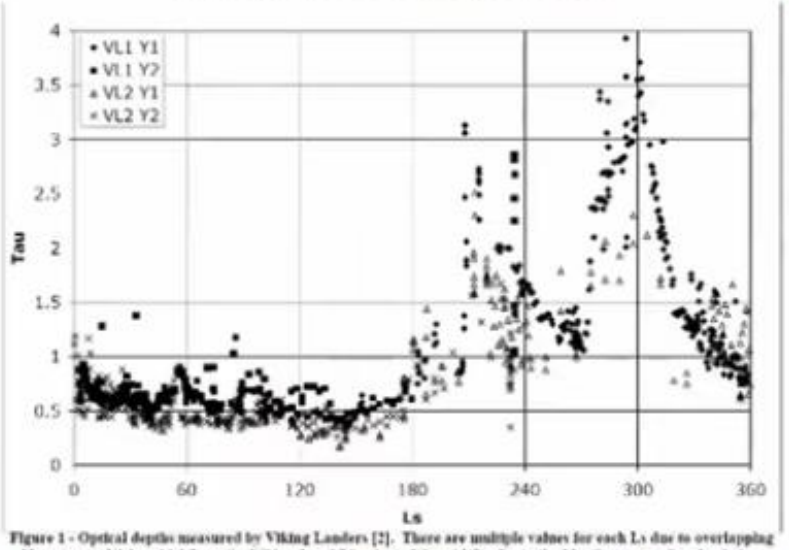
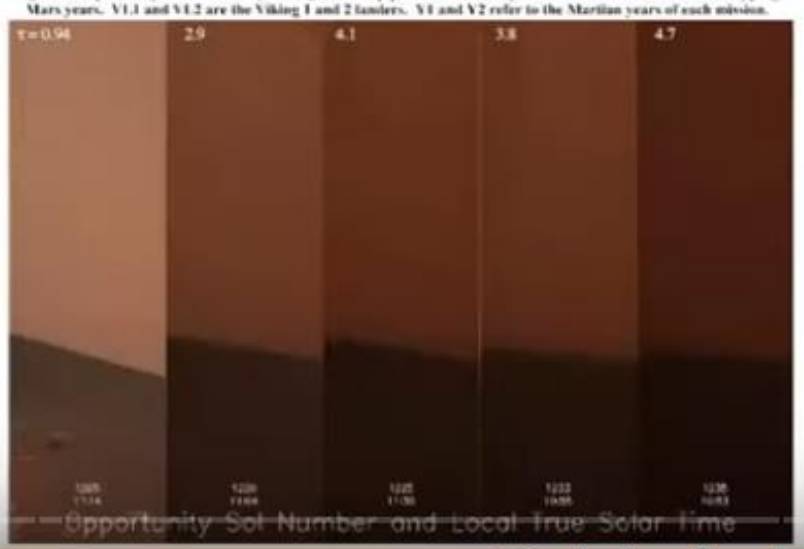


Figure 1 - Optical depths measured by Viking Landers [2]. There are multiple values for each Ls due to overlapping Mars years. VL1 and VL2 are the Viking 1 and 2 landers. Y1 and Y2 refer to the Martian years of each mission.



How much energy potential does uranium have?

One KRUSTY Piece = 10.7 kg U8Mo
This piece = ~8.1e8 MJ if all U atoms are burned

the hard part of fission is
not creating the energy,
it is utilizing the energy.

= 121 X

1 piece of KRUSTY fuel contains the energy equivalent of 121 fully-fueled Falcon Heavies

One fully-fueled Falcon Heavy (both stages)
~156 mT RP-1, ~43 MJ/kg = ~6.7e6 MJ

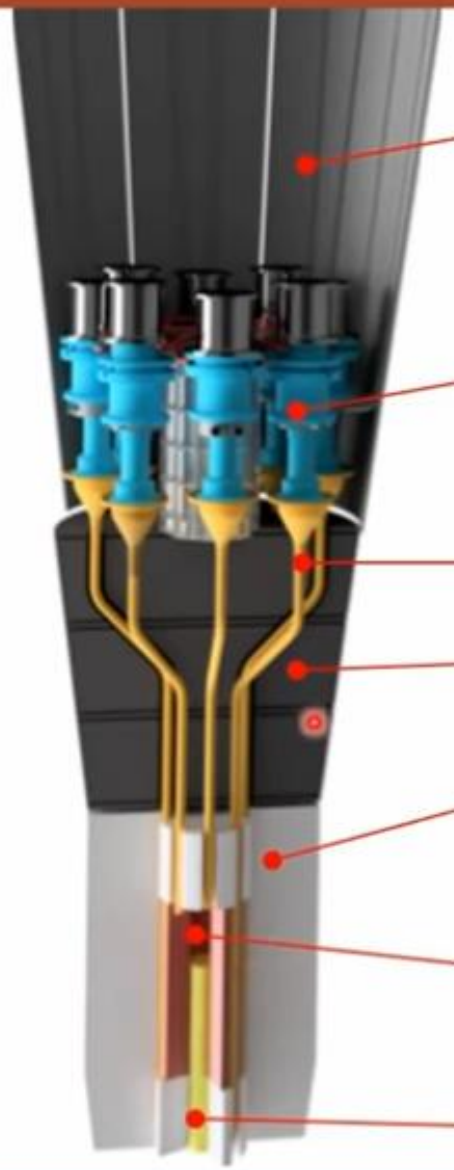
Kilopower Reactors offer the best chance to finally get something flown.

- Reactor concepts produce from 1 to 10 kWe at low mass, or up to 25 kWe for an LEU system.
- Reactor easily adapted to operate in space or on surface, and for robotic or human missions – power system accommodates modular shielding blocks
- The reactor technology/approach evolves up to > 1 MWe without significant change/risk from a nuclear perspective.

10 kWe, 1500 kg concept

NASA artwork

Kilopower Reactor Using Stirling TechnologY (KRUSTY)



Titanium Heat Pipe Radiator

Stirling Power Conversion System

Sodium Heat Pipes

Lithium Hydride, Tungsten Shielding

Beryllium Oxide Neutron Reflector

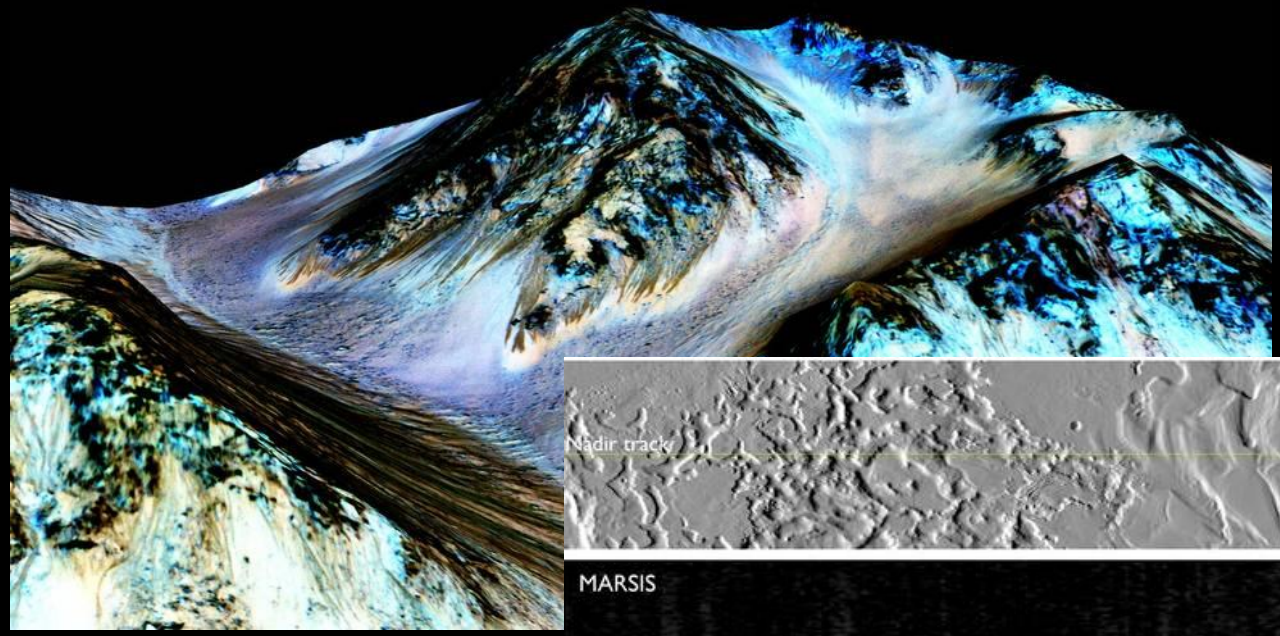
HEU U-Mo Cast Metal Fuel

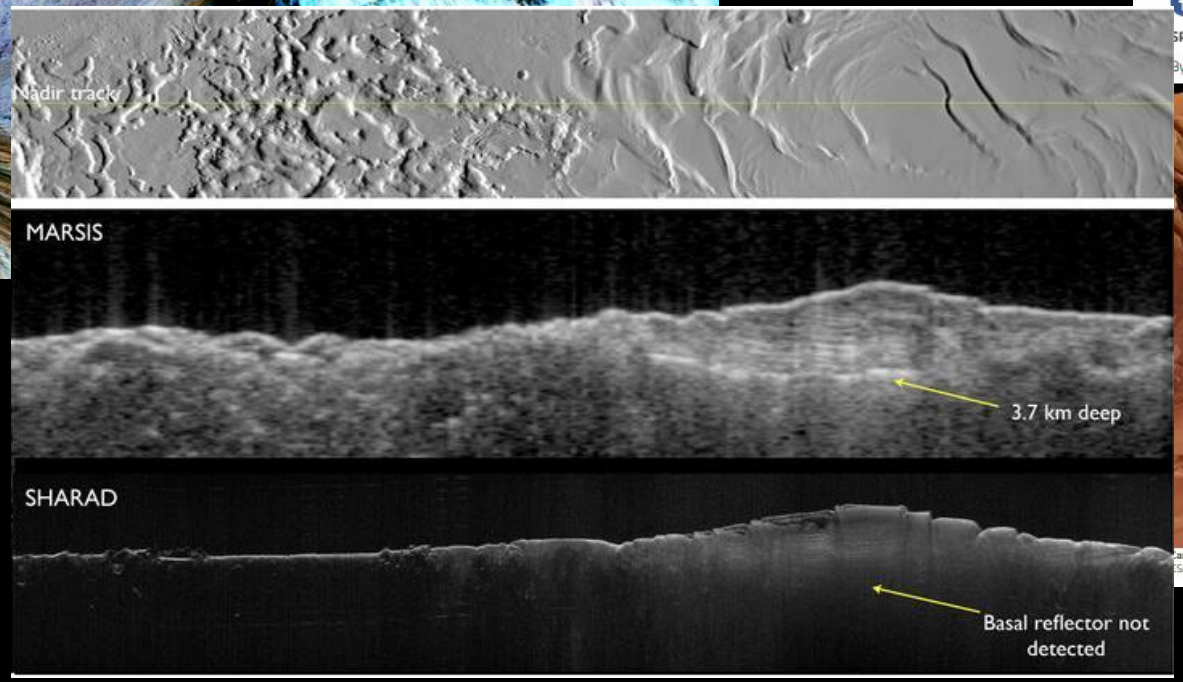
B_4C Neutron Absorber Rod

System enclosed in vacuum

photos courtesy LANL and NASA GRC

WHAT ABOUT WATER?



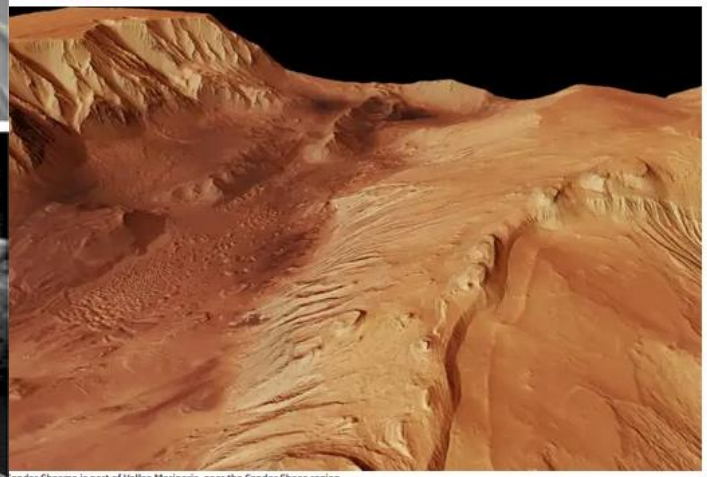


Large deposits of water found on Mars below the surface at the equator

Previous discoveries of water on Mars were limited to the poles or deep underground, but water deposits spotted near the surface at the equator could be easily accessed by future astronauts

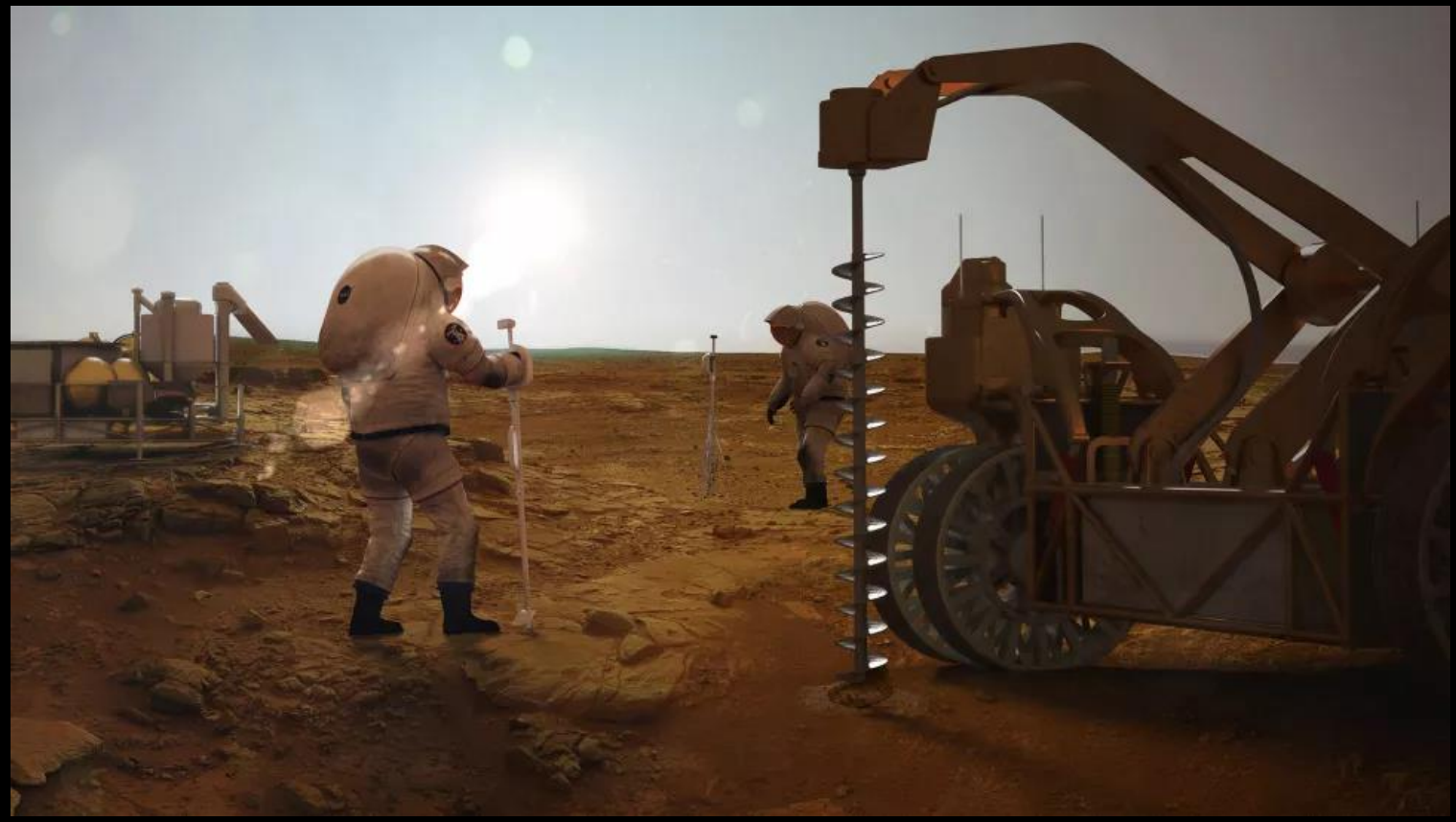
SPACE 16 December 2021

By Alex Wilkins



Candor Chasma is part of Valles Marineris, near the Candor Chaos region
ESA/DLR/FU Berlin (G. Neukum), CC BY-SA 3.0 IGO

MINING WATER



An artist's illustration of astronauts mining water on Mars. (Image credit: NASA Langley Advanced Concepts Lab/Analytical Mechanics Associates)

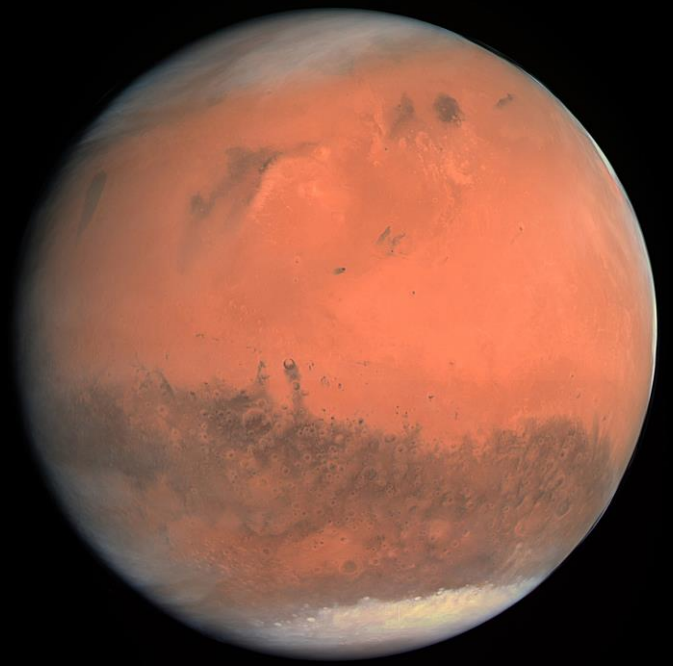
WHEN CAN I GO?

- Starship environmental approval now delayed to Feb 28 2022
- Next conjunction window late 2023
- Every 2 years after that

I want to die on Mars. Just not on impact.
Elon Musk

WHY BOTHER?

- "Why bother going to Mars when we have some many problems here?"
  - For a fraction of the cost of a military program (or even NASA's budget), it makes sense to make humans a multiplanetary species
  - Facilitate resource exploitation off-world Develop new technologies
  - Create space tourism
  - Advance science – boots on ground beat robots every time
  - Create new frontiers for humanity
  - Beat the Chinese*



* I didn't say they had to all be **good** reasons

BUT (INSERT COMPANY NAME HERE) SUCKS!

- I urge you to take the long view – this is humanity evolving. Evolution can have it's inconveniences.
- Starlink satellites – several versions have been developed to address astronomy concerns. No one is going to forego ubiquitous internet for astronomers so we need to adapt. Starlink funds Starship.
- Kessler cascade – The only solution is either do not operate in orbit (not likely) or clean it up. Cheap, efficient cleanup is key.

We don't get to *Star Trek*
without something like Starship

MARS SOCIETY OF CANADA

Winnipeg Chapter may be restarting, contact Gord if you're interested

QUESTIONS?

- www.marssociety.org
- www.marssociety.ca
- gord.tulloch@gmail.com