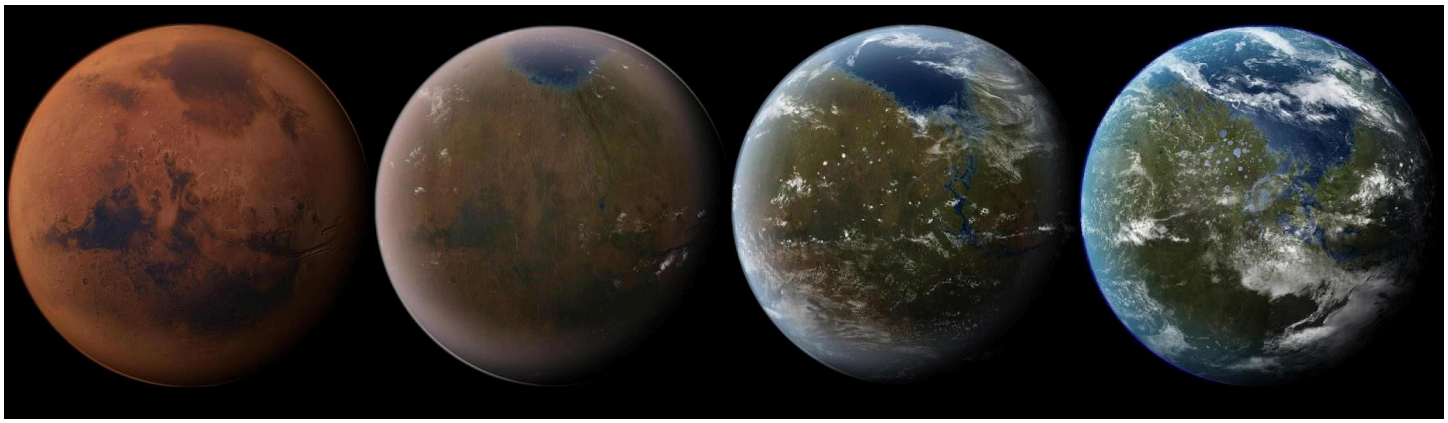


Mars Plan: Parameterization of Possibilities

Introduction

Part of what makes following Elon Musk interesting is that as you see his master plan unfold, you realize how much forethought has gone into the technology. Take rocket reusability for example: He didn't just invent a rocket, lean back in his chair, and then say "Let's make it reusable"! Rather, it would seem that part of what makes Elon different is that the sequence of technological development is strongly predicated by the master plan. The master plan reaches backward in time, carefully orchestrating how things are planned for in advance.

As we get ready for the Mars plan reveal, there's a realization that we're gearing up for perhaps the largest reveal in the Elon Musk story, and along with it, new insights into how much careful planning has been going into things. Orchestrating such a complex and difficult sequence is a delight for engineering types to gain insight into.

Although we don't know the details yet, we can of course gain some insight into the structure that Elon is working within. We can parameterize the model space, so to speak, and having done so, take even more interest in seeing how he has put these puzzle pieces together.

Below is a very rough parameterization. The idea is to map it out as much as people feel the interest to do so, adding questions and thoughts, all in anticipation of new details to emerge soon. I've shared this Google Doc, so feel free to add your own questions, bullet points, answers, etc.

https://www.reddit.com/r/spacex/comments/3oah03/mars_plan_parameterization_of_possibilities/

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Mars

1 Would the first manned SpaceX trip to Mars be using MCT?

- Is it really realistic to send 100 people on the first trip?
    - Almost certainly not -- the first colonies will be built up over time, starting with groups of 10 or fewer.
    - Even though it is the first manned trip the need for hardware will be quite high even with previous unmanned cargo hauls. So 10 people to set things up in the first group sounds realistic.

2 Launch & configuration

- What does the rocket look like that gets MCT into orbit?
- How many launches required to get an MCT ready for a voyage to Mars?
    - Depends highly on whether MCT is launched whole or constructed in orbit.
        - I can't imagine that a spacecraft large enough to hold the touted 100 colonists could possibly be launched whole.
            - Please see the following section.
    - Also depends on how many colonists and how much cargo is being transported. Anywhere between a few Falcon Heavy cargo launches and a few BFR launches.
- Projected cost of a fully reusable launch of BFR, not including the MCT components?
    - Depends on the number of launches per year.
    - Somewhat of a chicken and egg problem: You need lots of people going to Mars to get the launch rate high, and you need the launch cost low for lots of people to go. One without the other wouldn't work.
- What does the launch site look like?
    - Fully automated launch preparations.
        - wouldn't that be nice.
        - Highly unlikely though. Too many lives in the balance. That would never get approved.
            - Like self-driving cars, this will likely be the safer option eventually.
- Where will the launch sites be?
    - Probably a launch site on the eastern seaboard, and probably in the United States as that's where SpaceX is incorporated.
    - List of potential sites:
        - Cape Canaveral
        - Boca Chica/South Padre Island
    - Noise Issues?
    - Launches 24 hours a day?
    - Remote location?
- How often will BFR takeoff?
    - With the latest launch cadence, probably every other week.
        - At that rate, to achieve 1 million people as stated as the minimum self sustaining size of a colony by Elon, it would take almost 400 years to colonize Mars.
        "'Excluding organic growth, if you could take 100 people at a time, you would need 10,000 trips to get to a million people,' he said. 'But you would also need a lot of cargo to support those people. In fact, your cargo to person ratio is going to be quite high. It would probably

be 10 cargo trips for every human trip, so more like 100,000 trips. And we're talking 100,000 trips of a giant spaceship.'"
        - A launch cadence of 2 BFR per week would take about 100 years to launch a million people, which seems more what Elon has in mind. That's a little faster than it was to colonise America.
    - Every hour? Every 10 minutes?
        - We're a long way from this
    - Well they will use the trans-Mars-injection as often as possible(maybe even as a necessity) So probably bundled in a small time frame to get as many MCTs on their way to Mars as possible.
        - Based on the cadence above, MCT's would need to be able to carry ~10x as many people as BFR, and even then you'd still need 20 of them. So 20,000 ish people going every 2 years.

3 Number of people

- Hard to imagine MCT really being 100 people. Really that high?
    - I can certainly imagine the construction of an apartment-building-sized spacecraft that can hold 100 people.
    - Is 100 people a long term goal, or from the very first transport?
        - 100 people is the long term goal, yes.
        - Earlier launches would probably be more equipment, with less people, so 100 is more likely a nice round maximum.

4 In-orbit fuel depot?

- Would an in-orbit fuel depot be used?
    - It would certainly be useful and reduce the number of launched necessary to get an MCT ready for a flight.
    - On the other hand, that requires significant orbital infrastructure that Elon Musk has said he has no intention of building up.
        - ULA has stated that this is the route they are pursuing, and I can see the two companies working towards these separate but related goals at the same time
            - I'd love to see that.
    - Refueling in orbit is actually pretty hard, afaik it has never been done before. But that would only add to the already long list of firsts.
- How many tonnes of fuel would it hold?
    - Enough to get it to Mars, land it on Mars (or its landing vehicle), get back into orbit, and back to Earth (Refuel on Mars? - I believe this is the current plan with the new raptor engines using methane and oxygen as fuel, both of which can be made on Mars). This includes all the cargo and personnel onboard. Anyone want to guess at how much dry mass the MCT would likely have? I know they want to land about 100 tonnes of cargo on Mars.
- One depot, or multiple of them?
    - Considering the current state of our space industry, I couldn't justify more than a single depot, orbiting either Earth or the Moon depending on the fuel source.
    - In the far future, we'll likely have several depots in Terran and Martian orbits.
- What rocket used to fill up the fuel depot?
    - Falcon Heavy? BFR?
        - Almost certainly BFR for the MCT itself, though Falcon Heavies and Falcon 9s could very well provide crew and cargo to it.

- What is the risk of space debris hitting the fuel depot? Could it ever explode? Or no risk of that because it's only methane without oxygen
    - The result of a space debris hit would not require explosive materials to be catastrophically destructive due to the kinetic energy of the debris involved.
- Presumably Oxygen also would be stored at the fuel depot, but a safe distance away from the Methane?
    - I should hope so -- the risk of the two coming into unwanted contact should be minimized.
        - Not an issue - you would store it like you would in any rocket booster. No structural difference between a depot and an upper stage - you just need shielding to prevent boil-off, longer term electricity, and the transfer mechanism.
            - Yes, potentially an issue. You want to make sure that if a leak occurs in one tank, it has as little possible contact with the other tank. This is infrastructure we're talking about, not a rocket. If a leak occurs in a rocket tank, the rocket fails and we launch another one. We don't want a catastrophic explosion in a fuel depot we've spent months designing, launching, assembling, and filling.
                - If you leak, it's dead anyways since you just lost all fuel for station keeping and will re-enter atmosphere. No explosion risk when you vent to vacuum. Much easier to just launch another from earth. If not convinced, read some reports on what these things would likely look like [pdf]. These would be modular, not huge sprawling permanent installations.
                    - ULA's proposed design there is a decent short-term solution, but my idea of a "fuel depot" is more like what they show in Figure 4. They are engineering challenges, sure, but something we should definitely be tackling. Ideally the depot would also host human or robotic crew performing regular maintenance and inspection to quickly find and patch leaks before they get out of hand.

5 Transit to Mars

- Length of transit to Mars
    - What proportion of that is in an accelerating spacecraft? (likely a small proportion, I'd imagine, if a chemical rocket)
        - Until in-orbit fuel is incredibly cheap, there will likely be very short amounts of acceleration, relatively speaking. Likely a burn in Earth orbit to escape, and a burn in Mars' SOI to enter orbit. Most of the journey will be in a non-accelerating craft.
    - Any chance of an Ion engine?
        - Nice idea, but not likely -- ISRU capabilities make methalox a far more appealing choice of fuel.
        - The low thrust of ion engines would probably not be feasible for such a large vehicle. Also time is of the essence, since radiation exposure is a big deal for Mars flights.
- Artificial Gravity?
    - Tether two or more MCTs together and rotate. Would provide backup if systems in one MCT failed crew could transfer to the other MCT.
        - More mass efficient to have a small counterweight on the end of a long tether.
    - Could start rotation to simulate Earth gravity and slow rotation during journey to Mars to transition passengers to Mars gravity.
    - Need passengers to be able to perform tasks shortly after landing. Reduces low gravity recovery time.

    - Considering the length of the trip (3-4 months is Elon's preferred length), artificial gravity may not be necessary. Astronauts spend about that much time on the ISS. It will require some recovery time once landed, but considering the significantly lesser gravity of Mars, perhaps less time than astronauts need to recover from their trips to the ISS.
    - If artificial gravity is used, you need an even larger vehicle. People need less space when they are floating around. So i highly doubt it.
- Number of cubic meters per passenger
- What would the sleeping quarters look like? Somewhat like the ISS?
- What would people spend their time doing on a long journey?
    - Reading
    - Virtual reality headsets
        - Getting to know their destination, including the geography, resources, current habs, and residents.
        - Team/community building activities and games with other Mars-bound passengers.
    - Running experiments
    - Pastime physical intimacy (see pregnancy)
    - Exercising (gotta stave off atrophy!)
    - What Internet bandwidth would be available?
        - As ping times increase beyond 1 minute, would existing TCP protocols work for browsing the web, or would a different communication stack need to be invented to allow Web communications.
        - Earth to LEO/GSO Laser communication with byte level WAN optimisation software (Silver Peak, Riverbed Steelhead, etc). Multiple Laser Relay Satellites around Mars GSO (4 or more). The satellites that comprise system would likely use high capacity Solid State Disks to cache byte streams.
        - Laser has over Radio waves,1,000 greater bandwidth - amount of data that can transmitted per second but the remember the transmission times will be same because both mediums propagate at the same speed.
        - There will likely be changes/ tweaks to protocols or more efficient protocols introduced to make Mars Internet access more useable.
- Presumably it wouldn't be possible to watch Earth disappear out the window over time? (given that the craft would be oriented away from Earth?)
    - Depends on the spacecraft design. I imagine that being able to watch Earth as you leave its orbit is something Musk would want for his passengers.
- What would possible "problem" scenarios be on the trip to Mars?
    - Psychological problems?
        - What happens if a crew member snaps?
    - Equipment malfunction
        - What to do if oxygen generation fails? Game over?
            - Perhaps try to make the system as easy to fix as possible.
            - Additionally, make it as foolproof as possible. This is a really, really important system!
        - What to do if water recycler fails? Game over?
            - See above.
        - How much redundancy can you afford?
        - Any way to reverse course and bee-line it back to Earth in a dire emergency?

                - Not likely. Changing course to re-intercept Earth isn't as easy as "undo the acceleration we applied to leave!" Earth has moved, you have moved, and you're headed well away from Earth's orbit.
            - Any way to send an emergency MCT to aid in a dire emergency?
                - Not in-transit, no.
- Radiation in transit?
    - Approximately 300 mSv. One sievert carries with it a 5.5% chance of eventually developing cancer.
    - MCT orientation maintains water tanks, propellant and engines between Sun and crew to minimise solar radiation exposure. Radiation sanctuary required in case of solar storms, supernovas etc.

6 Landing vehicle

- Heat shield? Or only propulsive deceleration?
    - Almost certainly both. The Martian atmosphere is thick enough to require a heat shield to survive contact, but thin enough to make parachutes unviable for all but the smallest payloads.
    - Primarily propulsive deceleration. Could also adapt current landing legs with heat shielding to use them as drag flaps. Could move legs/flaps to steer vehicle while landing.
- How does the crew get from the top of a tall vehicle down to the ground?
    - More than likely, the landing vehicle will be designed to have a hatch as close to the ground as possible. Otherwise, a ladder -- Martian gravity is small enough to make that more than feasible.
- Would the initial MCT landing require each passenger to don a Mars suit to venture to the habitat modules?
    - Presumably not, because you wouldn’t want to have to bring 100 suits with you. Better to have 10 suits and share them.
        - Suits tend to be individualized, not general purpose. If SpaceX could design a general-purpose space suit, though, props to them.
    - How to get from the top of a tall rocket down into the habitat module without venturing into the atmosphere?
        - After landing, the MCT could be dismantled to become the habitat. I’m envisioning six cylindrical chambers around a 7th core. Those chambers could fold down into a starlike shape after an upright landing. This would spread out the ship into a stabilized structure with increased floor space now that gravity is affecting them again. During the transition the section would be evacuated of personnel, and future expansions could be added to the ends of the 6 chambers.
- Would there be HD video on the ground able to capture it from a good angle?
        - Definitely not for the first landing, however the same could be said about Apollo 11 and their camera work wasn’t bad at all.
- How many landers per crew of 100 people? Two?
    - One for equipment, one for the people?
        - Elon mentioned ~10 cargo flights for each 1 manned flight initially
    - How do you unload heavy equipment such as vehicles from a tall rocket?
        - Equipment sent earlier that could roll up next to the rocket, secure it with more stability than the landing legs and have an industrial elevator/ crane system in the center
- What logos are on the rocket?
    - SpaceX, definitely.
    - Digital screen .gif logo (faces of passengers, flags, etc?)
        - Unlikely with current technology

            - I'm thinking a flexible digital display attached to the rocket stage with some form of epoxy and coated in a type of transparent gloss paint. It would work?
        - Some kind of international / earth logo?
        - Flags, such as the US flag? Flags of all countries represented by the mission?
            - Almost certainly the flags of the nations that helped fund the mission, or perhaps the flags of the nations that contributed crew/passengers.
- Vehicle Name
    - Something from the Culture series (books) similar to the barges?

7 Ascent vehicle

- The same thing that lands? Or only a portion of it?
    - SpaceX is aiming for reusability. They'll likely design the landing vehicle to double as the ascent vehicle.
- Possible to leave Mars in hurry if there's a need to?
    - Better be at least a way into orbit in a hurry, perhaps with the MCT waiting to pick up crew for an emergency return to Earth.
- What percentage of colonists would stay for more than two years?
    - Depends largely on conditions. What percentage wishing to go would be doing so out of a desire to move there versus vacation? Should this not be considered in selecting who goes? I would think some heavily weighted ratio (~ 9/1) should be chosen of those with initial plans to stay versus return. You need a large number committed to stay and do the hard work of building a colony, yet a few to return and tell of their first hand experiences.
        - Something more like 4/1 is probably acceptable, the MCT as Musk has said should be fully capable of returning 25% of the mass sent to earth.
- Imagine: Watching the first manned (or even unmanned) rocket launch from Mars, watching the first colonists unloading from the MCT back on Earth, watching the first hugs between loved ones that haven't seen each other in 4 years. Watching the first press interviews of people reliving their experience, conveying their emotions.
- What ground infrastructure will the ascent vehicle need other than fuel?
    - concrete landing/launch pad?
    - water suppression system?
    - refurb?
    - I would think None would be the goal.

8 How many times could an MCT be re-used?

- Presumably this would involve launch from Earth, journey to Mars, landing on Mars, 2 years on the surface, take-off from Mars, journey to Earth, landing on Earth, refurbishment, and then launch again.
    - Or would they get away with MCT not landing back on Earth to save the fuel of a launch? (seems very unlikely)
        - Were it up to me, the MCT would be an entirely in-orbit craft, with accessory vehicles to bring cargo and crew to and from the Martian Surface, and a skeleton crew in it at all times. I wouldn't have it land on Earth, Mars, or anything else.
- Imagine: Watching the first MCT perform a propulsive pin-point landing on earth, after having spent two years on Mars.

9 ISRU

- Things needing to be generated
    - Energy

        - How much energy does each colonist need?
        - Solar?
            - Some estimate for the number of solar panels, batteries, and weight required to be sent per colonist?
                - Could these be partially or fully constructed on Mars early on? Other than expendables this could be an important asset for Mars colonists, generated by Mars colonists. Systems for automated mining, refining, and manufacture would be essential.
                    - 3D printing of carbon Solar panels along with easy access to Silicates for glass making would position an established colony to be independant in power generation.
        - Batteries needed?
            - Li deposits are ‘mined’ from salt deposits effectively, it can also be prospected in aqueous brine form as indicated in Northern Quebec and Alberta(1.7-2%). I wasn’t able to find any info on Li deposits on Mars but it is theoretically probably that there is a significant amount on ancient seabeds. (up to 7ppm has been recorded in our ocean)
            - Are there other ways of storing energy on mars than a battery? (eg. kinetic storage, low atmospheric drag could allow rotation without much degradation)
                - Kinetic Energy Storage requires too much mass, and martian dust will not play well with bearings, Potential Energy Storage could be much simpler mechanically and use rocks that are found on mars for weight.
        - Nuclear?
            - On Dec 13 2015, rumors surfaced that SpaceX is indeed considering nuclear.
                - This makes a lot of sense. I think many people would be dismissive of nuclear approaches because, as mentioned below “only if SpaceX is allowed”.
                - But if you’re going to do a Mars city “for realz”, then it only makes sense to do the most realistic thing. The difference between a nuclear approach and a solar approach may be that solar just isn’t feasible whereas nuclear is. (and perhaps just barely)
                - While solar is perhaps what a “reasonable” group of people would do when setting up a Mars base, Elon isn’t “reasonable”. (I mean that in a good way) He’s going to cut the chase and go for the thing that makes the most sense, even if it’s hard. (ex. landing rockets)
            - Only if SpaceX is allowed to launch nuclear material.
            - Controversial!
            - I can’t imagine Nuclear being used at first, but once a large enough colony, of maybe a couple thousand, is established, solar would require too many raw/rare materials to keep up with demand.
                - I agree in premise, but don’t forget that if we are able to 3D print carbon solar cells solar may be good enough. There is going to be plenty of open area to spread out.
    - Oxygen
        - Gotten by processing the atmosphere? Or from water?
            - Probably water and recycling the exhaled air from crew.
            - Some will be made by plants grown for food.

        - After accounting for recycling, how much new oxygen does each person need per day? 100 people? At 2% water by weight, how much regolith do you have to cook each day to provide enough oxygen for 100 people?
            - Where are you getting 2% water? (Mars Odyssey has is 20+ quite accessible)
    - Rocket Fuel
        - Methane
        - What raw ingredients are used to produce the fuel?
            - CO_2 and H_2O, most likely.
                - Using the sabatier process presumably
            - $CO_2 + 2\ H_2O \rightarrow CH_4 + 2\ O_2$
    - Water
        - How does this affect where the Mars base is?
            - Probably want to locate in an area that has abundant water accessible, 50°-60° (N or S) has 20%+ water in the surface regolith (The Mars Odyssey- Gamma Ray Spectrometer surveyed for this)
            - There are treaty obligations that may prevent the use of in-situ water resources. The outer space treaty of 1967 says that if liquid water is found off earth that anything that goes near it must be sterilized. Seems unlikely to be possible in a colony environment. Ice-mining may be ok.
        - What "construction equipment" might be used? How do you "get at" the water?
            - If you use a vehicle with a "skirt" and microwave the ground you can extract the water (as vapour) much more energy efficiently.
            - Dig, melt, filter.
                - Mining also creates usable space underground to expand the colony.
                - What are the other useful materials/elements that can be found in the regolith?
        - After accounting for recycling, how much <u>new</u> water does each person need per day? 100 people? At 2% water by weight, how much regolith do you have to cook each day to provide enough water for 100 people? How much energy does it take to cook this much regolith each day? How many solar panels need to be dedicated to just this? What do the panels weigh? How much of a 100 tonne cargo launch is this many solar panels?
            - The ISS's current water reclamation system is ~93% efficient. Given that an adult human's daily water requirement is ~7.5 litres you need to add 7% of that per capita per day, or .5 liters per capita per day, or 50 liters total every day, just for human consumption, not taking into account any hygienic needs.
                - So 50 litres = 50kg. At 2% water, we will need to process 2500kg of martian regolith each and every day. Damn.
                    - If you establish your base in the non-equatorial latitudes you can get closer to 20-30% water content. 60° N still gets plenty of sun for a predominantly solar power base (GRS aboard Mars Odyssey)
    - Nutrients
        - What are the best plants to grow for food? What are their NPK requirements? What about micronutrients? What should be shipped in and what can be found in the regolith?
- Would such ISRU details be part of what is revealed soon? Or would they part of a phase-2 or phase-3 reveal in the future?

10 Food

- On Dec 13 2015 some rumors surfaced about MCT which included talk about “algae tubes”.
    - I think this is a good example of “bottom up thinking”. When people think about where to get food, they think of animals, they think of plants/crops, etc., which is a kind of top-down approach.
    - But if you are living on Mars, the constraints you’re dealing with, when considered in a bottom-up fashion, may lead one to conclude that the best source of calories/protein/vitamins could be wildly different than on earth.
    - Algae as a primary food source seems like a good example of a “wildly different” approach.
- What percentage of food consumed would be grown on Mars vs brought from Earth?
    - How do you avoid the inevitable process whereby plants grown using martian soil concentrate the naturally occurring perchlorates in the soil? Even at a few parts per billion it will cause hormonal problems. Martian soil contains up to about half of 1% perchlorates by weight.
- Is it realistic that the first years on Mars could count on producing food?
    - If so, what plants would be grown on Mars?
        - Plants that maximize calories?
            - Potatoes!!
            - Don’t forget ketchup and vicodin when the ketchup runs out.
            - Strawberries also transform the vast majority of their growth into fruit production.
        - Plants that maximize protein?
            - Soybeans
        - Plants that maximize vitamins?
          Watercress, Chinese cabbage, Chard, Beet greens, Spinach, Chicory, Leaf lettuce, Parsley, Romaine lettuce, Collard green, Turnip green, Mustard green, Endive, Chive, Kale
        - Plants that are ideally suited to the conditions?
            - Unfortunately, most of the plants with high nutrient levels are also high in water consumption, so GMO vegetables might be necessary.
                - The water isn’t being consumed, just repurposed temporarily. Diets would be oversaw so the above concern shouldn’t be a problem.
    - If not, what is the dehydrated mass of 4 years of food supplies for a person?
        - 300 lbs per person per year (Source)
        - ~125kg for 1 year supply of Soylent (Source) (275lbs)
- Would unmanned missions need to first prove the ability to grow food?
    - Using all Earth resources? Or utilizing as much Mars-sourced resources as possible?
        - Using Earth resources seem easy. Utilizing Mars is harder, but mostly the resource selection and gathering portion.
    - Elon’s greenhouse mission!
        - I still think “The money shot” isn’t a bad idea.
- Would livestock be a good idea? What animals would be the easiest to maintain on Mars, while providing good nutritional value?
    - This seems 0.001% likely, at least for the first decades.
    - Lab grown meat and meat-replacements!
        - TRL? (can’t even do it reliable on earth, and it’s very energy intensive)
    - goats and chickens are not difficult to care for, both have the added benefit of either milk(and cheese) and eggs.

    - The first animals brought for nutritional value could be insects. May sound gross, yes, but the input/output ratio is higher compared to bigger animals and they are of course easier on the launch weight limit. (Wikipedia article)
        - In all likelihood, protein is mostly going to come from dehydrated eggs initially and insects once things get going.
            - Or from GM yeast engineered to produce the needed protein.
- How can we prepare for digestive problems that occur in space and cause humans to only be able to eat goop?
- A way for colonists to have control over their food needs to be established, I imagine some sort of cultural dishes will arise from the nutrient dense foods available and that freedom to experiment add much needed morale support.
- Could new, genetically engineered crops be tested on Mars for the first time? Maybe crops especially designed for Mars soil /sunlight/other conditions ?
    - Sounds like a great thing for the first Martians to work on after their initial settlement is stable.
        - Perfect for iGem even before then!

11 Building design

- Shielding
    - Will definitely be necessary. Mars has no magnetic field and the atmosphere does not protect from cosmic rays. For a long duration stay most living quarters will need to be underground.
    - Medium-term solution could come from more research into powered electromagnetic shielding of colonies.
        - Would this accommodate for the lack of a magnetic field?
            - That's the idea, but it is still an open area of research. There are many articles mentioning it, but I am unsure of where the research is currently at. (http://physicsworld.com/cws/article/news/2008/nov/06/magnetic-shield-could-protect-spacecraft http://space.stackexchange.com/questions/3772/how-much-power-would-a-spacecrafts-magnetic-shield-require http://www.popularmechanics.com/space/moon-mars/a16757/cern-spaceship-shields/)
    - Underground?
        - Use leftover regolith mined for water and other usable materials as shielding, and live in the holes you dig.
        - Partially underground? (such as sleeping quarters)
- What would the normal Pressure be?
    - For the Mars Hab
        - The minimum partial pressure of oxygen required to support human physiology is 16 kPa. This is known to be safe.
        - The upper limit of oxygen concentration with regard to fire safety is not clearly defined, but 30% is considered reasonable.
        - If the O2 partial pressure is 16 kPa, the minimum total atmospheric pressure must therefore be 53.33 kPa
        - NASA specifies a maximum CO2 concentration in spacecraft atmospheres of 0.7%. A typical concentration in normal spacecraft operations is 0.5%
        - NASA specifies a Relative Humidity of 30-70% for spacecraft atmospheres; i.e. an average of about 50%.
        - The Martian atmosphere is 1.9% N2 and 2.1% Ar
        -

        - (All in kPa)
        - O2- 16
        - Co2- 0.27
        - Water Vapour- 1.31
        - Buffer (Ar+N2)- 35.75
    - 14.7 psi (1 bar). Normal earth pressure that is also used on the ISS. O2 would be around 21%. EVAs would take longer because of the pressure changes (EVA's are at about 5 psi)
    - 4.5-5 psi (0.33 bar). This was the pressure used in the Skylab, Mercury and Apollo missions, as well as nearly all EVS on the Space Shuttle and ISS. O2 levels are about 70%, providing the same O2 pressure levels as 21% at 14.7 psi (1 bar).
        - This provides much quicker and easier set up for EVAs, because there are no pressure changes.
        - Because the O2 partial pressures are comparable between 14.7 psi/21% and 5 psi/70%, the risk of fire and explosion is essentially the same.
        - The lower pressure make structural requirements much easier to engineer and maintain.
- Any natural light in the base?
    - This will depend on shielding requirements. If impossible, potentially digital "windows" to the outside?
    - The greenhouses would have natural light + green growth. Would be a good place to hang out in for a bit every day.
        - Probably more efficient to use LED for plant growth, Plants wouldn't grow properly in only martian light.
- Visuals
    - Words and specs are great, but there's nothing like some breathtaking visuals/renders of the buildings inside and out.
    - What's the chance that SpaceX would release detailed visuals, even if they're really just mock-ups?
        - Seems somewhat likely. What better way than to fuel the imagination and get people excited?
    - Will the visuals make people giddy with excitement? Will they be suave like the Crew Dragon internals, etc?
        - Seems likely that they'll be very impressive.
- How many cubic meters of building space per colonist on Mars?

12 Mars suits

- How bulky?
    - I can't imagine they'll be very bulky. If the space suits are going to be stylish, there's no reason the Mars suits can't be as well.
        - There is however still the possibility that stylish suits aren't possible to create - unlikely though since Musk has been talking about them for a while.
            - Something like this would be ideal, and isn't much more constricting than a thick wetsuit. Plus, it's much easier to make breeches self-sealing in a skintight suit.

- Weight
    - The lower gravity of Mars is actually a huge help here. Imagine a planet with a toxic atmosphere requiring a suit, but the same gravity of Earth.
        - This is a good point, couldn't you just make your suit 2.6x heavier so that you get the same amount of exercise as you would on earth to help prevent atrophy.

- How many minutes per week would the average colonist spend outside?
    - With a suit designed in every way to minimize radiation, it could feasibly be a lot.
- How far from the base could/would they journey?
    - At the beginning there would probably be similar rules as on the Moon. Even with vehicles they would be permitted to go only that far so they can walk back (in case of vehicle failure).
- What would the “air lock” look like?
- Imagine: The first images of people walking on Mars, with impressive habitat modules and the lander in the background. What emotion would you feel seeing the images?
- What happens when someone outgrows their suit?
    - I can’t imagine we are sending people of an age that this could be an issue.
        - You don’t expect anyone to put on weight or have their dimensions change over multiple years living with a possibly varying diet and under different gravity? Particularly with talk of “skintight” suits, it seems quite likely people will go up or down a few sizes. They do on earth.
    - Any children born on Mars will face this issue constantly however.

13 Vehicles

- Would the base include a vehicle for making further treks?
    - I would expect the base to be stocked with adequate transportation before the crew even left Earth, are we really going to expect people to walk a couple hundred meters after a 3-6month trek in 0g?
    - Maybe not the first base, but certainly that would be a top priority. Hell, we put a “golf cart” on the moon and we don’t even keep astronauts there for longer than a couple days.
- Would the colony have “drones” for flying around the area?
    - Not likely, but possible. The Martian atmosphere is incredibly thin.
    - JPL has discussed the idea for the upcoming 2020 rover, but the thin atmosphere makes it difficult, but they have a working prototype!.
- Would Tesla in any way be involved in the creation of the first Mars EV?
    - The battery technology, at least
    - Using a methane combustion engine would increase part commonality and reliability. Assuming ISRU
    - Maybe a variation of Tesla’s electric drivetrain?
    - Imagine: Tesla branded rovers.
- Will SpaceX also create general purpose building bots or rover transportation vehicles for Mars?
- Would the first Mars vehicle be most autonomous, or human-driven?
    - Human driven, for simplicity.
        - Humans will likely be able to drive from inside the vehicle’s cabin and remotely from base
- How many decades until local Mars industry can produce its own vehicles?
    - Much faster than we think, I would expect <5y after permanent non-science personnel. between 3D printing and the ability to create varied petrochemicals using modified sabatier processes plastics would be relatively easy to manufacture.
    - Several. It will probably be at least 20-30 years before permanent Mars bases can begin producing even small parts on their own, let alone entire vehicles. You have to set up facilities for:
        - Mining regolith
        - Refining ore into metal and other materials
        - Smelting and shaping metal into parts

14 AI

- Can we remove this section? This is moving way away from MCT/Mars speculation and into completely unrelated fields.
    - I think it is important due to its soon-coming massive involvement in the daily lives of all humanity. Surely it will be hugely relevant to all Mars missions and future settlements, whether it is planned for ahead of time or not.
        - It might be important, but not really relevant.
- Majority of Mars plan will include automation in 10 years. Automation should be considered narrow AI.
    - Launch preparation/launch sequence will be fully automated to insure efficiency and safety.
    - Resource collection on Mars will be automated to produce greater volumes of materials.
- While AI has grown very slowly over the last 50 years, it has started to make faster progress in the last 10 years.
- If a first mission to Mars launched between 2030 and 2035, would the state of AI meaningful change in any ways how we imagine life on Mars?
    - Is there any chance that by 2040 or 2045 that we'd have AIs that are close to human intelligence?
    - How would that change the game?
        - Better AI means more complicated tasks can be automated. This means there is less demand for humans and bigger projects can be attempted
- Would SpaceX possibly go the route of sending moderately autonomous robots/vehicles to Mars first, and operate them there for a few years to prepare the way for people?
    - Set up food production
    - Prove ISRU systems
        - Agreed. SpaceX will want to confirm they can get people back, so they will want to return a rocket to Earth using locally produced fuel before they send people.
    - Use autonomous systems for routine maintenance of outside assets?
        - ex. Clearing dust off of solar panels
        - Moving soil around
        - De-clogging / cleaning air intake filters
        - Or is it better to leave physical jobs for the crew so that they don't go stir-crazy and suffer from boredom spending so much time inside of a small living environment?
- Imagine: SpaceX pivoting 10 years from now to a more AI-centric approach to lower the astronomical costs of Mars development. Start by sending robots, vehicles, and modules, and follow 10 years later with people. Need your robots to be smarter? Just upload newer software in a couple years once the tech improves here on earth.

15 Mars adventure

- How much adventure would the people on Mars participate in?
    - As little as possible. People are trying to live here ideally, not have "adventures". Adventures typically means something has gone tits up.
        - From a less cynical POV, exploration would be a big part of colonists' lives once things have gotten established, and knowing every time you surmount another ridge that you're the first to ever be there seems to be a fairly adventurous endeavour.
- When would the first trips up Olympus Mons be?
    - Imagine: A new wave of exploration, some time in the late 21st/early 22nd century. The first humans to summit Olympus Mons, the first to climb Valles Marineris, etc.
- Would people spend significant amounts of time exploring and doing science?

    - Would it be better to leave the science data collection to rovers?
        - Commanding rovers from Mars would have the advantage of reduced latency.
- Photography: Imagine photos coming back from colonists posting their photos and videos on Facebook of their Mars adventures.
- Will there be a place for commercial adventurers? If prices to Mars are only a few million per person, companies such as Red Bull might consider sending a team of people to do and film some crazy stunts, since they spend hundreds of millions on things such as F1. Will colonists accept sharing supplies with commercial adventurers?
    - This is how I imagine Mars One getting to Mars, buying a seat or two on an MCT

16 Construction vehicles and equipment

- Will any construction equipment be necessary for an initial colony? Any need to move soil around?
- Person sitting in the cockpit?
- Remote controlled from Mars base?
    - Semi-automated?
        - Pathfinding: Tell a rover to drive from point A to point B
        - Tell it to excavate X kgs of soil from point A and dump it at point B
        - Tell it to survey land for resources
- Automation with command from earth?
    - Early preparation work done years ahead of first manned landings?
- Creating a flat area for buildings?
- Mounding up dirt to block high winds?
    - Or is the thinness of atmosphere such that wind isn't any issue?
        - WInd isn't an issue at all. Wind could only affect parachutes, and possibly kick dust up onto solar panels
- Hollowing out a tunnel or cave for protection from cosmic radiation?
    - Or a lava tube?
        - Either/both will absolutely be necessary for any long term settlement.

17 Governance

- Would the initial group of 100 people form their own "government", with a leader(s)?
    - More likely to become an issue later on, so probably not the first group.
- Or would they simply be like any 100 people, such as the folks at the South Pole?
- Who would "own" all of the equipment on Mars? SpaceX? The colonists?
- If difficult decisions needed to be made, life and death decisions, how much say would the colonists have? How much say would SpaceX have?
    - SpaceX owns the MCT, and that's a billion dollar asset, presumably. Does that muddy the waters?
- If/when other countries like China, Russia, or maybe India reach Mars, how will they divide up the surface area? Will any of the 190+ other countries on Earth get a share of the Martian land?
    - Quoting the Outer Space Treaty: "*Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.*" In other words, no nation is allowed to claim a piece of extraterrestrial land for themselves (no comment on whether anyone is actually going to conform to this).

18 Satellites

- Types of satellites required (long term) for Mars:
    - Internet/Communications
        - Communication with Earth: In Mars orbit Laser / Optical communication relay satellites.

        - Intra-Mars communication: MarsNet - relay signals between different Mars Locations.
    - GPS
    - Weather monitoring
    - High resolution imaging
    - Any other satellite capabilities similar to what Earth has?
- Would each MCT launch include a satellite that would journey to Mars but stay in orbit, increasing the coverage of MarsNet?
    - This would be a good way to seed relay satellites a between earth and Mars and in Mars Orbit.
- How many satellites would be required to provide 10 Gbps between Earth and Mars?
    - EU Sentinel-1A in 2014 can offer speeds up to 7.2 Gbit/s in LEO, with well placed relay Satellites between Earth and Mars plus further improvements, 10 Gbps between Earth and Mars could be achieved with handful of satellites.
    - Is the limiting factor the bandwidth between Earth and Mars? Or from the Mars colony to the satellite?
        - The limiting factor for any communication is the transmission medium, hence optical communication (fiber or Laser) has a higher throughput and latency than radio.
    - What limits that mostly? Electrical energy available to satellite? Distance between the planets?
- Any reason to have a decent transmitter on the surface that could communicate with Earth? Or are satellites a far better option?
    - As a backup or emergency transmitter, this would be required

19 Revenue generation

- Would SpaceX be so bold as to release some kind of figure, such as $500,000 per ticket, with their Mars plans?
    - Is $500k a long term plan when Mars can supply most supplies locally, or will it be this cheap initially?
        - 100 people at $0.5 million each is $50million for a launch of BFR. Since we know that there will be some in orbit refuelling, it is actually 2 launches, which equals $25million per BFR launch. For such a large rocket, surely this is the long term goal when most cargo can be sourced locally on Mars. There is no way $500k includes the huge amount of cargo that would be required from Earth for each and every person in the early decades.
            - Agreed. Once Mars is providing most of its own food and water and other supplies, the cost just to transport you and your luggage (and food for the trip) will likely be in the 500k range, but no way the early trips will be like this.
    - Musk's use of this number in the past was just a sketch, but if they're going to release a real "plan", attaching numbers like this would seem to be incredibly risky / speculative.
- Earth-based revenue generation to support Mars colony
- Satellite Internet
- Autonomous Tesla Taxis
    - Tesla consumes so much R&D though that it's hard to imagine it becoming a cash cow.
- Tesla battery sales (if the market for this kind of thing exploded)
    - What cars are people gonna drive on Mars? /s
- Hyperloop?
    - Let the existing two companies prove the technology, and once it looks promising, perhaps Elon would launch a competing entry into this space and "make it happen".
- Vertical take-off electric jet

20 Space suits

- We already know they're working on this
- Will the MCT have an airlock?
    - External system failures can and will happen at any time during the month-long trip (especially if the MCT actually lands and takes off), so space walks will need to be possible for repairs.

21 What year?

- Even though a first launch would be a long time from now, would SpaceX release a timeline of some kind along with their Mars plan?
- Elon has said "hopefully within about 10 years" even recently, so perhaps that's a hint.
- Mars launch windows occur every ~2 years with 2018/2020 and 2033/2035 as particularly close https://upload.wikimedia.org/wikipedia/commons/9/9d/Mars_close_appr.png

22 Medical treatment

- As soon as you sent 100 people to another planet, you need to have a reasonable medical treatment facility.
- But what you can afford to send would presumably be somewhat limited. For example, if somewhat gets cancer, are you really going to be administering chemotherapy, targeted radiation, etc? Or does life on Mars mean a lower bar for what diseases mean "sorry, you're out of luck".
    - A serious disease might, at least after the first couple hundred colonists, get you a ticket back to Earth
- Would SpaceX be brave enough to detail anything like this with their Mars plan? I somehow have a hard time imagining that level of detail. And getting into details like this is bound to make people realize just how risky an endeavour like this is.
- Is it possible to quarantine people before a launch, so they don't carry any diseases with them and we create a colony with basically no sickness?

23 Death on Mars

- What percentage of crew will survive the 2 year stay?Unlikely. Minor accidents can be fatal when there's no hospital to check you out.
    - So many colonists died on trips to the North America or in wagons crossing the continent. I think Mars colonists will have to be ready to accept that they are accepting a risk of death much higher than the average person. If 5/100 people dying in 2 years is the price of a foothold on Mars I'm sure plenty of people are willing to take that risk.
- What would human life expectancy be long term on Mars?
    - Can't find it now, but I've seen an estimate of maybe 15 or so year less than on Earth
- Imagine the news of the first death(s) from Mars.
- Imagine the first burials under the red soil.
- Will corpses need to be incinerated due to no natural decay on Mars?
    - Incineration wouldn't be as "easy" as it is on Earth - there would probably have to be special equipment for it, which of course adds mass to the MCT.
    - Recycle bio-mass from the deceased to support colonist needs.
        - Crop growth, fuel, etc.
    - Ok, just dump them at least 4km from base camp then /s
        - Nice :)

24 Pregnancy

- What do you do about this?
    - Vasectomy all the men, it's even mostly reversible nowadays.
    - Perhaps you just deal with it as well as you can, and they come home on the next flight, which is <= 2 years.
    - The first real colonists will be preceded by a lot of astronaut-engineers that build large enough structures for children to be raised?
    - Alternatively, pack a lot of condoms.
    - Male & Female Birth Control.
    - Allow colonists to choose to attempt pregnancy at their own risk once basic necessary facilities are available, with the understanding that the availability of medical services and lack of understanding of risk has been made well known.

25 Utilization of Mars moons

- Phobos and Deimos
    - Part of the plan?
    - Making a base on them would be much easier to do as it would require much less Delta V and less complex engineering for landing.
    - L1 point for Phobos-Mars system is about a kilometer above Phobos's surface, potential for a station?
    - Orbital hub for refueling, etc?

26 Utilization of near-Mars asteroids

- Amor asteroids
    - Useful as non-gravity well sources of fuel and materials, and due to their orbits.

27 Non-SpaceX Research needed for a Mars Colony

- https://www.reddit.com/r/spacex/wiki/colony
- Bigelow inflatable habs
- Definitely NASA research

28 Terraforming Plans

- Will any terraforming plans be revealed?
    - Likely nothing more than "someone should do it soon-ish"
- Would "nuking Mars" actually be part of the plan?
    - Highly unlikely, since this would not be accepted broadly by the community (and getting access to nukes, well…)
    - Not only is broad acceptance unlikely, it is also likely to spread radioactive waste and debris all over Martian orbit, if not Martian soil. This is not particularly conducive to making Mars habitable.
        - The amount of harsh radiation that hits the surface of Mars every year would be a large multiple of the radiation deposited from a nuclear blast, and presumably the radiation deposited from a nuke would decay over time.
    - Elon said that the nuking would happen the atmosphere so there would be minimal fallout. The heat still reaches Mars. Also, if it happens on spot away from all colonies and rovers etc, I don't think the radiation would really affect anyone. Think of all the nuclear tests that happened as close as 100 Km from Las Vegas on Earth! (wow)

        - Despite the above point, using nukes on Mars has the risk (however slight) of killing (or at least affecting) martian bacteria. That would be disastrous.
            - Then again, introducing change above in the environment in any way is almost guaranteed to affect whatever bacteria may or may not inhabit Mars natively. It's an unfortunate side effect of terraforming, but unavoidable for a permanent settlement.
- If the colonists eventually decide to create oceans to on Ma rem o' tears, where would they put the sea level/how will they decide which lands and potentially other countries' colonies get to stay above "Martian sea level"?
    - Mars is going to decide that, pretty much. It'll be the first time humanity has ever intentionally terraformed anything at this scale, it's unlikely that we'll have much precise control over it.
    - Is there even enough water on Mars to create large oceans? Or would they only be a couple meters deep?

29 Colonist mental health

- What about any mental health issues that will most probably arise with 100 people living in a closed space so far away from Earth?
- Mental health specialists will be a must, but they might suffer from the same issues.
    - E.g. social people (as well as psychologists of course)
    - Mental health AI?
- What special activities and pastimes will be a part of the colonists' lives to battle any feelings of claustrophobia, anxiety, etc? Relevant scientific research should be carried out on Earth.
    - Music, cooking, art, and sports
    - Developing a culture and a sense of camaraderie between the colonists is a must
    - Virtual Reality
    - Construction of biosphere-domes that mimic earth-like outdoors
    - Really any sort of work which makes you feel like you've accomplished something can help stave off dementia
    - Recreational EVAs on top of strictly professional ones
- Reminder that any communication with Earth happens with a 30 minute delay between sending a message and receiving a reply. Therefore live consultations with "unaffected" Earth based psychologists would not be feasible.
- How do colors/the desolate environment affect long-term human stay?
    - How could a central growing center within the habitat mitigate some of this

30 Inspirational Imagery

- Imagine:
    - Standing under a clear sky in a geographically serendipitous spot, at an orbitally serendipitous time, watching the stars. The ISS blinks out of the shadow of the Earth and crosses the starscape as a bright dot… followed by another, brighter dot, and another, and another. A cluster of dots, trailing the ISS. Suddenly, each dot blossoms with a propellant bloom, like the membrane of a deep-sea jellyfish expanding without resistance in the vacuum… the fleet's synchronised TMI burn. As they sink towards the far horizon, the blooms interfere and resemble a flower, and the dots dim imperceptibly as they begin their journey to Mars.
    - Waking up and peering out of your sleeping area through the zipper, as light streams in and the smell of people preparing breakfast wafts through the cabin.
    - The sense of community on the trip to Mars. People floating together for a "campfire" after supper, telling stories and jokes, sharing fears and dreams.

- Watching the first HD video of the first MCT landing on Mars. Like the barge landings, only 100x more nerve-racking.
- The first photos of the martian sunrise/sunset. Photos of martian weather phenomena.
- Videos of stunts only doable in martian gravity