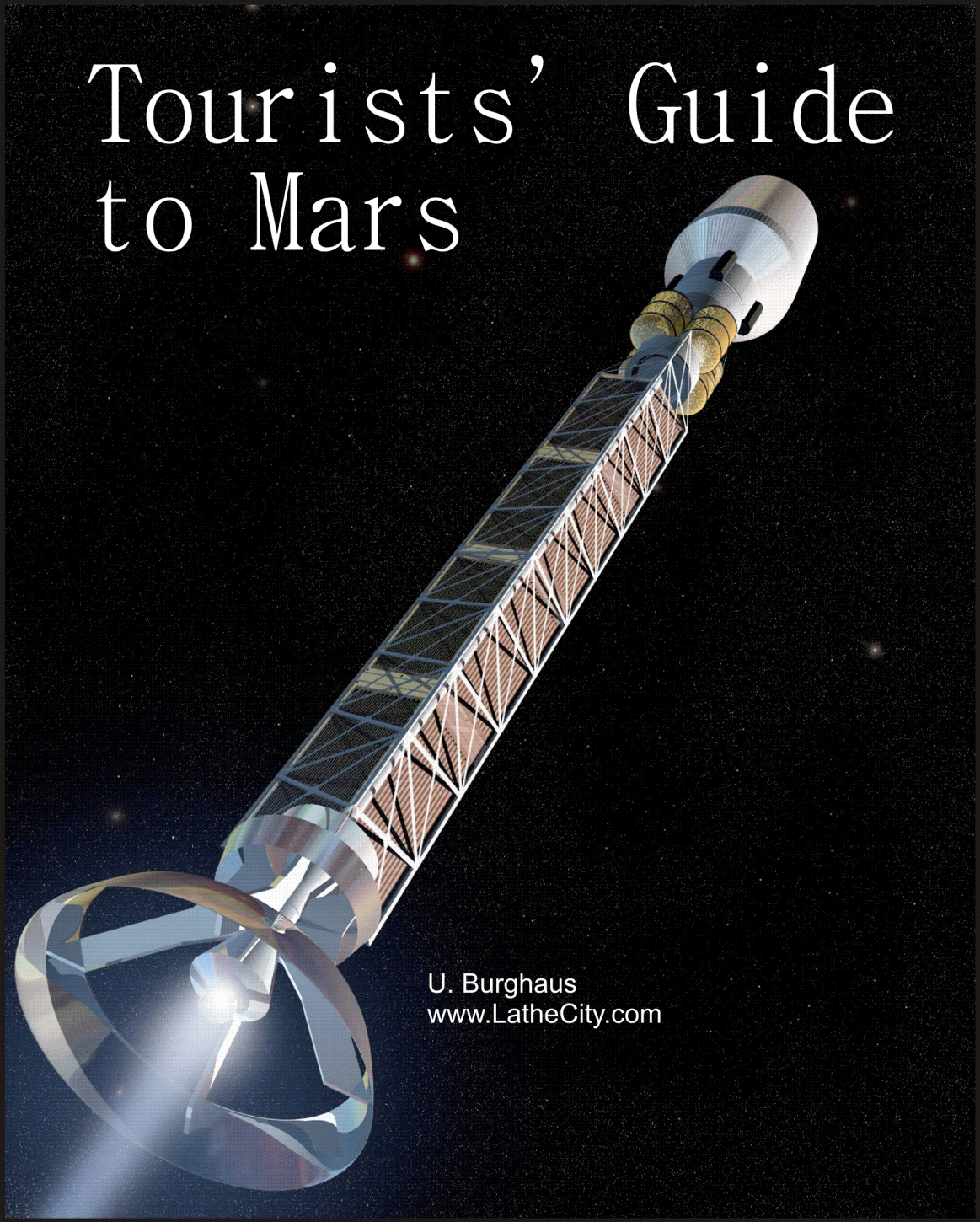
Tourists' Guide to Mars



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Tourists' Guide to Mars

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Tourists'

Guide to Mars

A Scientific Perspective in a Nutshell

- **Is there a chance for a successful crewed Mars program within the next decade?**
- **Will the technology for that ever be developed?**
- **Does that technology already exist?**
- **What about propulsion systems?**
- **Do we need warp drive for that?**
- **What about life support?**
- **How to fly without air?**
- **Orbital mechanics: What is that?**
- **Changing orbits and whatnot: How does that work?**
- **What is the current state of space flight technology?**
- **What are the strategies for a Mars trip?**
- **How long would that trip take, by the way?**
- **Costs?**
- **When do we make it to Mars?**

- **What if NASA, ESA don't ever try?**
- **Non-government space flight?**
- **Space tourism today.**
- **Artificial gravity.**
- **Making O_2 on Mars.**
- **1000 mission plans exist, no kidding.**

Guess what? Planet Mars. (Image collected in 2005 with Hubble Space Telescope). Darker regions are due to a dust storm in the equatorial region. Image credit: NASA, ref.[1]

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Part II – Mission Logistics

➔ How to really do it is described here. That's what is mostly discussed in the hobby space community, that's the stuff most Sci-Fi stories live from.

Included are: Aldrin's Unified Space Concept; NASA's Design Reference Architectures; Other, Newer NASA Plans; Mars Direct; Mars 1; Why Wait any Longer?; Non-government Missions?; Mission Risks; Timeline & Politics; Why are "We" Still on Earth?; Precursors Missions – What is Next?

Part III – Basics - How Spaceships Fly

➔ That's a little heavy on the physics end, yes, I know, but it would be good to know that stuff and it is all written for non-scientists with some memory about high school science.

Included are: Basic Newton Dynamics; Orbital Mechanics; Gravitation; Gravitational Maps; Orbits & Centrifugal Force; Orbital Paradox; Orbital Energy; Orbital Paradox II; Orbital Energy vs. Shape; Escape Speed; How to Launch in the First Place?; Elliptical Orbit vs. Hyperbolic Escape; Again, Here is Your Guide …; Sphere of Influence & Patched Conics; Why Launching at The Equator?; More Space Flight Jargon; Orbits/LEO; Geostationary; What is Δv?; Step on Gas Twice; Minimum Fuel Transfer – greetings from Hohmann; Front or Back Thrusters?; Rendezvous part I; Devil in Details; Aero-brakes, Aero-capture; Direct Entry; Flyby, Slingshot Effects, Venus swing-by, Gravity Assist; Rendezvous II – Capture Orbit; So What?; Lagrange Points; Lagrange Points Viewed Differently; Why do Astronauts Float?; Kepler's Laws

Appendix – Nitty Gritty Details

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Included are: Life Support; Closed-Loop Systems; Breathing Gas; Making Oxygen on Mars in 2020; More Chemistry on Mars; Making Water on Mars; Making Fuel on Mars; NASA's in-situ Resource Utilization; Terraforming – Settlement; Turn up the Heat; Shields up; Propulsion; Artificial Gravity; Communication & Navigation; Surface communication; In flight communication; Navigation; Costs; Why Mars?; Why should we leave?; Becoming a NASA Astronaut?; Couch Potato Astronauts

References & Notes

There is a 2nd (non-print) appendix to this travel guide available for a free download at www.LatheCity.com It includes mostly web links. Similarly, the reference list to this guide can be downloaded in different formats including clickable links. For further free resources go to http://www.lathecity.com/Books/Mars/ or http://www.lathecity.com/Books/Mars/Tourists_Guide_to_Mars.html

Foreword

"There is no manual to science," I used to say to my students in class as a "young" assistant professor. I am a physicist by training and physical chemistry professor at a US college. "Learn this properly"; no "shortcuts." Nearly two decades later, I probably still believe that this is true, but in the meantime, I am more diplomatic—my teaching evaluation scores have improved. Also, I found the manual in the meanwhile, or, simply, I sell the same old stories better: the basic concepts we use in science (laws of thermodynamics, postulates in quantum mechanics) are the manual to science, if you will. Probably **there is a guide**, **always, also for a trip to Mars.**

Why do I tell you this? Well, there is a second thought, and both will meet on Mars.

When I turned 50, a routine physical triggered a cancer warning. Fortunately, it turned out to be a false alarm. Anyway, I started to realize that there is actually nothing really pressing in my life anymore that "I have to do," except for one thing: watching, at least, humans walking on Mars. That was the second thought.

How do these points now fit together and what has this to do with another book about a hypothetical Mars mission?

Although I gave up the hope that the National Aeronautics and Space Agency (NASA), European Space Agency (ESA), or whoever would come up with something

great again, I did follow more or less what space flight agencies were doing over the years, as a mental space tourist. From that perspective, it would appear that the astronauts that will walk on Mars one day haven't even been born yet. This is a scary thought and perhaps one that's not true. President Obama[2] seems to believe that he will still be around then. SpaceX announced a planned first robotic landing by 2018![3]

I don't know how much you already know about all of this. I didn't know too much myself. Therefore, I did start to look around and read stuff for days and weeks and months: **there is a lot of information out there**. In part, amazing developments are evident, which did not pop up at CNN. There are hundreds of NASA websites, press releases, e-mail lists, books from ex-astronauts, books from astrophysicists, books with mostly bogus science, books with real science, books from/about space flight entrepreneurs, biographies of famous past and future space travelers, a Mars Book[4] from 1953 written by Wernher von Braun[5] himself, recently founded private space companies,[6] Nixon[7] administration plans for Mars missions from the 1970s, a one-way-trip-to-Mars-club,[8] Mars direct,[9] Mars 1,[8] NASA design reference architectures,[10-12] a NASA 90 day study from 1989, a 2017 NASA astronaut class,[13] NASA inspector general with issues,[14] free astronomy simulation software,[15] etc.

That's a jungle of information.

/Bang for Your Buck

Most people want to have an overview about the current state of the art rather than reading all the details on 600 pages of fine print. That's how all my little stories now fit together: **a short "tourists'" guide to Mars may be interesting.** Not a bogus nonsense story, but a scientific outline for non-science

gurus; a brief summary of the various proposals that are out there today. **Can we make it?** Will we make it **within** the next **10 years?** I worked hard on keeping this well below 150 pages text of a pocket book-sized, brief travel guide to Mars.

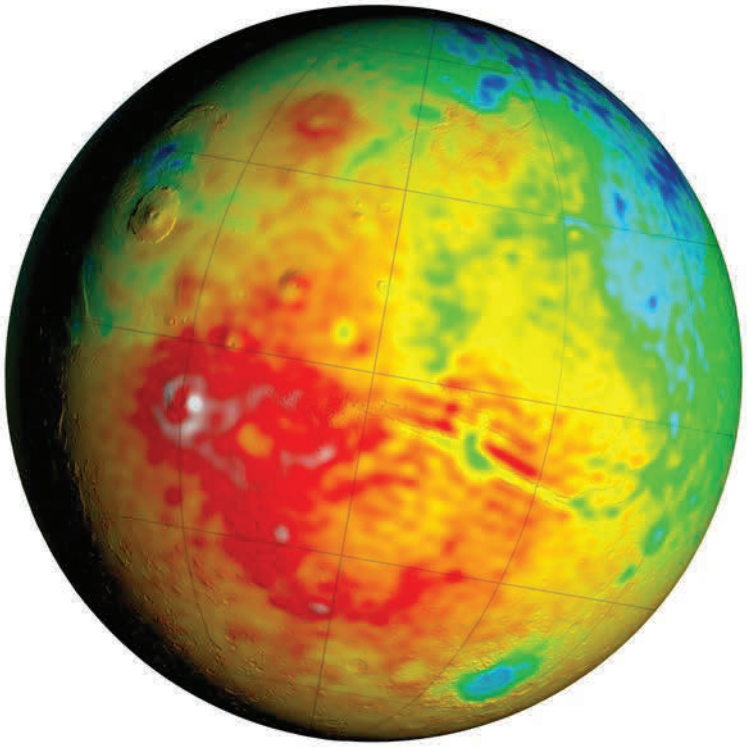
Realistically, there won't be any tourism to Mars any time soon. What I am saying is this: most of us are just observers of the unfolding scenery. We won't be able to change NASA's budget or start our own space company. What I am outlining here is the couch potato perspective of possible missions to Mars. I am not a NASA employee nor am I a (retired) astronaut. I am not promoting my own mission plan here either, i.e., my story is therefore hopefully more objective and journalistic than others.

/What You Hold in Your Hands

. . . is a brief summary of concepts for missions to Mars floating around on Earth as of today: we write in the year 2016.

You will be able to consume this on your couch in one weekend or two. That's the concept of this guide to Mars. **Get some potato chips, buckle up, and read this guide to see what is out there.**

Most of this information is in the public domain—basically the only major player in this game, NASA, is federally funded. Therefore, the information is out there for free for everyone, but it is unsorted, it is too much, and not easy to consume. This guide will help.



This Mars map shows variations in thickness of the planet's crust apparently derived from maps of gravity variations and other information. For a color version of this image and more information go to ref.[16] Image credit: NASA/GSFC/Scientific Visualization Studio[16]

Part I
FLYING TO MARS; BUT HOW?

➔ Cycler; fuzzy orbits; superhighways; quick and dirty concepts – fast pathways, slow pathways, minimum energy, long stay, short stay; opposition trips; conjunction trips; Venus flyby; Mars free return; and politics . . .

Politics Comes First?

In the planning for the manned US moon landing, different mission proposals were considered,[11] such as just shooting up a big rocket (direct ascent, vertical start, & vertical landing—apparently favored by von Braun[5, 17]), or putting a spaceship together in an Earth orbit (Earth Orbit Rendezvous), or the fancy variation finally realized: using a "Lunar Orbit Rendezvous" (apparently proposed by J. Houbolt[17, 18]).

/The 59 Ways to Mars

Regarding a Mars mission, the situation today is somewhat similar and various scenarios are still considered, some of which are publicly discussed or even advertised,[8, 9] while others are probably classified or considered proprietary information of space flight companies. Note that ref.[19] lists 59

mission plans to Mars (as of 3/17/16), starting with Wernher von Braun's book[4] (*Das Marsprojekt*, German for *The Mars Project*) from 1952 and currently apparently ending with "Marpost", a mission concept from 2000, a version from Roscosmos, the Russian space agency. Some more are even missing in that list since "Inspiration Mars" (2013), a privately funded, crewed Mars flyby plan of the multimillionaire Dennis Tito[20] is missing. In 2015 or so, D. Tito's project did run out of money for now, it would appear. This year, 2016, SpaceX circulated another plan to land on Mars by 2018.[3] A history write-up from NASA even mentions "more than 1000 piloted Mars mission studies".[11] That's why we need a guide.☺ Mars always has been fascinating and was considered the next step after the moon missions.

/Bush's vs. Obama's NASA plans

What NASA today really wants to do and how has, as of today (2016), not been released in much detail, in my opinion. However, more and more NASA texts and speeches appear stating that a crewed mission to Mars is indeed the plan for the near future: ". . . Project xyz today supports deep space exploration *and* a Mission to Mars . . ." or something like that, one can often read.

The older NASA concepts one can find[21] in public sound like a re-make of the Apollo program from the 1960s: probably some kind of Mars orbit rendezvous where, however, cargo is landed in separate missions first.[10-12] Similar to the Gemini program, as of 2016, training trips to the moon orbit and beyond (e.g., to asteroids) would precede the Mars mission.[22] Presently,[22] NASA directly mirrors here what President Obama[2] announced in 2010; they have to, I

guess. Now, I write this in 2016—who knows if the next president will cancel all of this again. President Bush's constellation space program ("back to the moon,"[23, 24]) was basically canceled by President Obama and never really got off the ground due to Bush(es)[24] not providing the required budgets anyway. (Interested in the history of NASA/US space politics? See ref.[25] and appendix to ref.[17])

Cygnus spacecraft from NASA's commercial provider, Orbital ATK, is inside of this payload. It is moved to the launch site, Cape Canaveral, where a United Launch Alliance Atlas V rocket will carry the ~7,500 lb. (3.4 t) supplies to the international space station. (3/17/16, MEDIA ADVISORY M16-030; Photo Credits: NASA/D. Gerondidakis)

/Did Nixon Wreck NASA Crewed Flights?

NASA ref.[11] describes that plans to reach Mars had apparently priority over the moon landing until Kennedy's space speech. NASA's earliest Mars mission plans date back to the 1960s.

Although Nixon[7] ended the Apollo program, burring with it crewed space flights and almost canceled the last two flights to the moon, NASA plans to reach Mars were made again by the President Nixon administration.[17]

Brute force (more or less) concepts such as minimum energy path, slower transit, Venus swing-by, or even more futuristic travel plans (cycler), have actually been known for decades. Most of this would apparently be doable with today's propulsion systems and budgets.[26] Wernher von Braun did write (the 1st edition of) his Mars book[4] in 1948, no kidding.

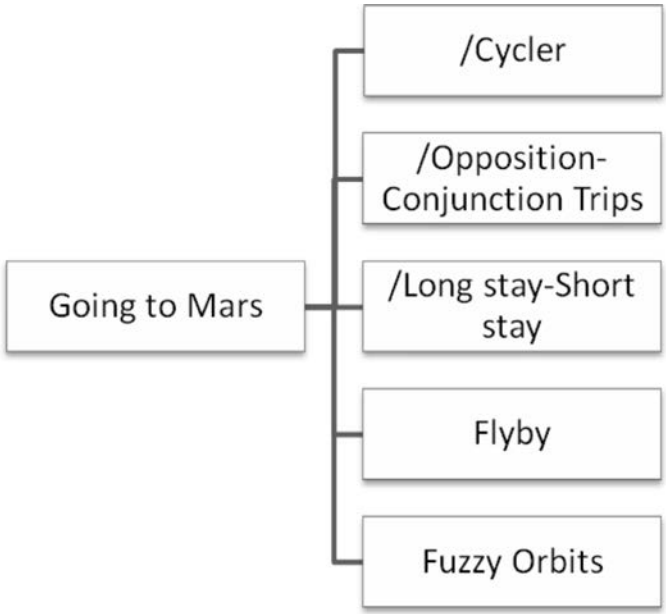
/Private Sector

Since non-government endeavors appear to be taking over from government, more and more (see e.g., D. Tito,[20] E. Musk,[27] R. Bigelow,[28] etc.), politics may become less dominating for the challenge to reach and stay on Mars. A list of aerospace companies (with Mars ambitions) is in the Appendix; I come back to this in more detail in Part II.

/Mars Plans Today

As of today, 4/16, five satellites orbit Mars (MAVEN, Mars Odyssey, Mars Reconnaissance Orbiter, all NASA as well as India's Mars Orbiter & Mars Express from ESA)[29] and two NASA rovers (out of seven) are still operational. Seven landings on Mars; ~39 missions to Mars.[30] What is next? NASA is working on the Orion capsule[31] (first launch planned for 2018, type EM-1 at www.NASA.gov) and a new heavy lift hardware, the Space Launch System (SLS). A car-sized rover with in-situ resource utilization (see /*Making O_2 on Mars*) is planned to be sent to

Mars in 2020.[32] ESA[33] just recently shot a robot to Mars.[34] Interestingly, a European–Russian Mars collaboration[35] is on



Graphical table of contents for this section. (I did not number images since this is not a college physics book. The images and text can pretty much be used on their own. I would probably recommend skimming over the figures first.)

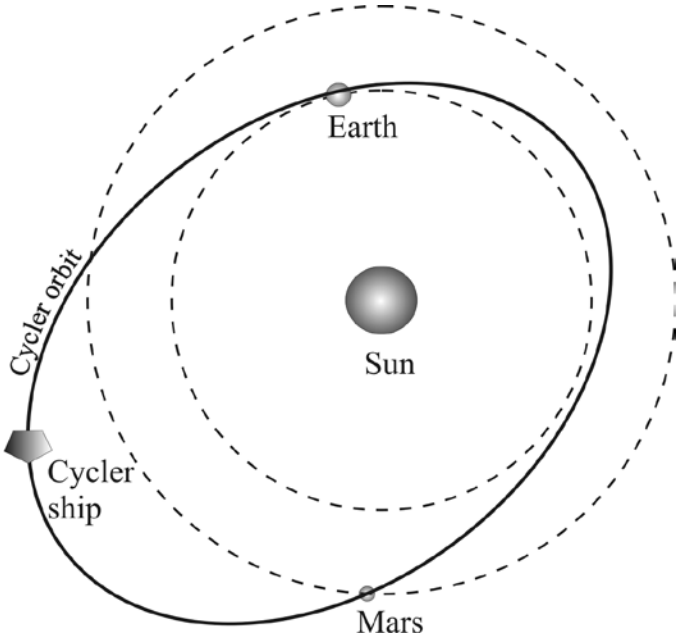
the way, with another launch planned in 2018. US–India apparently also have plans together.[30] A list of past/current Mars missions would be here: ref.[30]

Before we dive deeper into mission logistics (see Part II), the most pressing question is perhaps: **How to make it to Mars in the first place?** What concept could be used? What concepts are known? Do we need a warp drive[36] for this? **What trajectories bring us to Mars?** What options do we have? I will focus in this section on the very basic ideas of these questions.

I did add another chapter about basic orbital mechanics (astrodynamics, celestial mechanics, Newton dynamics—all the same thing) to this guide, which was originally my "Chapter One," but at some point I became afraid that too much physics in the very beginning would scare off some readers. Therefore, my "Basics" chapter is now the last part of this guide; see "III. Basics – How Spaceships Fly." In addition, many more technical concerns are in the "Appendix"; see "Nitty Gritty Details." That's not the most systematic structure for a book, but perhaps it leads to the easiest to read travel guide to Mars. (Add-on sections, as this one, are set in a smaller text fond. Your guide would easily fit in a spacesuit!)

The Many Ways to Mars

➔ What trajectories bring us to Mars? What options do we have? (See also the "Basics" section at the end of this guide.)



Basic idea of a cycler orbit. This orbit intercepts with both Earth and Mars orbits.

/Cycler

➔ Fancy option, won't be realized any time soon; anyway, let's start with that idea; the concept is simple.[37-40]

The trajectories of satellites looping around Earth, or the path of our moon are usually referred to as orbits. Yes, we all know that (details are in the "Basics" section). However, it is important to recognize again that there are no rockets connected to the satellites or the moon for steering them about Earth, i.e., their journey is determined by gravity, only: greetings from Newton[41] and Kepler.[42] A balance of centrifugal and centripetal forces, respectively, defines the orbit. Because a warp drive[36] has not quite been invented, yet, it is not feasible to fly to Mars on a straight line using an active propulsion system all the way. All realistic flight paths (/trajectories) will be determined by gravity.

Of course, a starship has usually to be kicked into the chosen trajectory—that requires quite significant energy. And, if Earth is the start, large rockets are required to escape Earth gravity in the first place. Finally, often a capture into an orbit is used before the landing on a planet.

Now, the moon loops around Earth in repeated cycles. We know that, yes, but importantly, similar orbits also exist between planets such as Earth and Mars, or between planets and moons such as Earth and our moon. Again, these are gravity-driven trajectories. Meaning, once an artificial object is set on this kind of orbit it would loop around Mars and Earth forever and for free! A propulsion system is in principle not required to stay on the orbit. Therefore, one could use a spaceship on this orbit as a taxi to move cargo and people over basically infinite distances without a warp drive—similar to weather satellites cycling around Earth, but on a really wide orbit. That idea or a very similar one dates back to the 1960s

positions on Earth and astronomical reference points.[195] The angular accuracy amounts apparently to 10 nanoradian.[194] In addition, images sent back by the spacecraft are used to determine its position. To figure an orbit, not only the position, but also the direction of the speed is needed. That is apparently done simply by tracing the position for a few days. As discussed, one better direct the thrusters in the correct direction. For that, apparently, Sun trackers are used. Software for all of this was developed over decades by the jet propulsion lab. Most orbital mechanics books include long chapters about orbit determination—Kepler was one of the first to work on this.

Costs

Briefly, as this is a short travel guide for space tourists (who cares about money anyway):

- NASA's budget after the Apollo program dropped from 4% to 0.5%—1.0% of the federal US budget.[196]
- However, in adjusted dollars, NASA's budget during the Apollo program was about the same as it is today![26] Larger budgets help, but it's apparently not the budget alone that holds back NASA's crewed (as they call it) flight program. That's one of the saddest conclusions one is forced to draw.
- NASA's budget today is $18 billion (in 2015); ESA $5.5 billion (in 2012), which is about the same as the Russian space agency's budget.
- NASA's Apollo program did cost $25 billion total at that time, which would be $100 billion today.[17]
- Cost estimates for manned Mars missions are hard to find and are probably mostly bogus anyway; one estimate is

$4–6 billion[8] for the first crew drop off at Mars following a quick and dirty mission concept. Zubrin/Wagner[26] estimate $20–30 billion development costs and $3 billion per trip. That is in the same ballpark as the Apollo moon program. They predict a development time of 10 years and another 10 years for the first set of missions.[26] That timeframe would cut the costs down further, i.e., given today's budgets, current robotic NASA programs would not need to be dropped to advance the Mars exploration. Zubrin/Wagners'[26] plan dates back to the 1990s. The resistance inside NASA to restart crewed flights may to a large extent be related to internal budget battels.

- By the way, on the SpaceX website, under "Capabilities and Services," one can find also the price for a trip to Mars:[197] with the Falcone Heavy (does not quite exist yet as far as I know, 4/30/16), a 13.6 ton payload to Mars would cost $90 mil—standard payment plan (whatever that is), earliest launch in 2018. The former PayPal co-owner did not add a PayPal payment button to his website, yet. (I love this company. ☺) In comparison, NASA pays apparently $80 mil/seat to ISS (!) with the Russian space taxi.

- The international space station did apparently cost something such as $100 billion,[17] which would be a starting point for a cost estimate to build a cycler spaceship, I guess.
- The Iraq war has cost the US $800 billion so far.[198] The Apollo program and more so plans for a manned post-Apollo program (e.g., Mars flyby) were overshadowed by the costs of the Vietnam war.[11] Similarly, the Iraq war

was probably more important for the Presidents Bush than their Constellation program ("Back to the Moon").[72]

- For my taste, all the Mars program budgets are basically peanuts. Total US federal budget is in the three $trillion range ($3,000 billion/year). NASA budget: 1%.
- Nearly every country has a space agency, at least on paper. However, only three space agencies currently have human spaceflight capability (USA, China, Russia). It's about time to come up with a "Star Fleet Academy" and join resources.
- Most people believe that Mars could be colonized if just the costs would be lower. Therefore, build really cheap disposable rockets,[80] or build reusable rockets.[197] In any case, "live off the land." What do you think?

Why Mars?

➔ Most Earth-like planet, rather close, full of resources.

The four inner planets—Mercury (no atmosphere, -70–400C), Venus (92 bar, 460C), Earth (1atm, -90–57C) and Mars (0.006 atm, -140–35C) are considered Earth-like.[199] However, Mars is probably the only realistic target. All other planets have environmental conditions that make them hopeless destinations for any human settlement and/or the distance is too far. Mars is the most Earth-like planet in reach with plenty of water and an atmosphere that offers possibilities for terraforming. And is life out there already? Was life out there? Our moon may have water bound in the soil, but based on today's knowledge, close to nothing is up there that could easily be used, no atmosphere, and temperature swings significantly larger than on Mars. That's just my opinion.

Why should we leave?

➔ Search for life, science/cultural development, security, leadership, foster collaborations, overpopulation.

"Should we stay or should we go?" It appears illogical placing this at the end, but for me it is obvious that we should go on crewed missions beyond the moon ASAP, i.e., now. How to do this and if US politicians will ever be willing to finance such an enterprise are more urgent questions. Therefore, I have just added a brief note at the end about the "why." It is also largely a political topic; I try to focus rather on science-and-engineering in this guide.

- There is still a pretty good chance for finding past life of some sort on Mars. So what? Well, I am not an astrobiologist, but finding some fossils (or microbes) in/on Mars would strongly suggest that the development of life is not unique. Thus, we would for certain not be alone in the universe. Would that knowledge be worth some investment? Germans like sarcasm.
- "The search for life . . . great intellectual enterprises of our species," citing P. Boston who recently became director of NASA's Astrobiology Institute.[200] I mention this here because she appears to be associated with the *Mars Society*—one of the Mars clubs.[200]
- The diversity of life found on another planet may open new insights in medical advancement, biotechnology, etc. (That's more than a long shot, but, also that sounds like the movie *Alien*—unfortunately, NASA is basically a military operation as of today, recruiting military jet pilots as astronauts—aren't they?)
- One of the theories states that 4 billion years ago Mars's climate was quite similar to today's Earth climate including liquid surface water. For unknown reasons, the climate changed dramatically at some point, but residuals of subsurface life may still be present. There is still some discussion about early results from the Viking space probes, which may actually indicate past life on Mars. In

start of it as of the mid-2030s. The only hope is probably SpaceX; their estimate for a first test landing on Mars: 2018.[3]

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The reference and notes list can be downloaded for free at www.LatheCity.com. It is available in various formates, larger text fond, and with clickable links. Most web links were accessed early in 2016.

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About the Author

The author is a physical chemist, a surface chemist, and since 2003 a faculty member at a US college. Born in West-Berlin, he got most of his education in Physics in Germany. After many years of postdoc positions (Italy, USA, Italy, Germany) and a habilitation in Germany (German tenure), he found a faculty position in the US where he obtained tenure in 2009. Although this book project has nothing to do with the university he is employed, more one could find here www.uweburghaus.us He has written several books, (most of these about practical engineering topics), and sells most of those books in the meanwhile by myself, i.e., he owns a part time small business. Details are here: www.LatheCity.com. LatheCity is actually specialized in manufacturing tools for benchtop metal work systems.

Did you ever consider a trip to Mars? It does become cheaper year after year, though. If you do, we recommend this brief guide that covers everything from the launch, over a smooth cruise, to the soft landing and, of course, growing potatoes (”in-situ resource utilization”) in just ~150 pages. All that you need to know for your trip—all inclusive. This is the real deal, however, a serious guide: the physics of interplanetary travel, rendezvous maneuvers, transfer orbits, and why astronauts float are explained by a college professor, in plain English. All the nitty gritty details are included, too. How to make O_2 and fuel on Mars? Life-support systems, communication, and navigation—how does that work? Why should we go there in the first place, and who will likely be first? Buckle up and join the ride.