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# BRINGING MARTIANS TO EARTH

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## ABSTRACT

As civilization progresses further into the 21st century, certain stresses become more apparent. Global climate change is emerging as a serious challenge to our current way of life, and while clashes between nation states seem to be on the wane, clashes between states and non-state actors (terrorist groups) seem to be on the rise. In this context it is reasonable to pose the question: why send people to Mars?

Going to Mars "to do it" rings hollow as a national justification for such an undertaking. Rather, our national goal should be to bring Martians to Earth to provide them with meaningful employment in assisting us in tackling the stresses facing our civilization. Given there are currently no known Martians, the objective backs up one step to dispatch people to Mars to become the Martians we hire to bring to Earth. Given a set of assumptions regarding establishing a stable civilization on Mars, results indicate it is possible to create a stable Martian civilization within 18 years of the first humans landing on Mars, a civilization that can grow up to be a good neighbor to our own cultural values, rich with experience in putting theory into practice in the field of optimizing Closed Environmental Life Support Systems, resource management, and technology advancement. A strawman architecture is put forward to build a sustainable Earth-Mars transportation system to support the development of Mars.

## INTRODUCTION

In the 1950s, rocket scientist Werner Von Braun laid out his vision: build a fleet of space shuttles, use them to build and maintain a space station in Low Earth Orbit (LEO), expand the station as a staging point for launching a fleet of ships on expeditions to the Moon then Mars.[1]

Space Architect Brent Sherwood notes we are following the von Braun paradigm to this day.[2] Sherwood goes on to outline four options for the focus of human spaceflight objectives over the coming years. He describes them as the Hero myth (explore Mars like Lewis and Clark), the Jet Set myth (space passenger travel like Richard Branson), the Green myth (Solar Power Satellites), and the Pioneer myth (settle the Moon like a Heinlein story). For about the same investment of resources the outcomes are vastly different. The Hero myth results in six international government employees on a distant planet. The Jet Set myth results in a thousand to tens of thousands of citizens per year visiting low Earth orbit. The Green myth results in hundreds of skilled workers on extended duty tours in high Earth orbit. The Pioneer myth results in a thousand mixed-demographic citizens offworld, some permanent and raising families. Members of the Mars Society espouse the pioneer myth with Mars as the destination.

The US space program is capable of doing more than the four options Sherwood examines. In its heyday, astronauts were viewed as national heroes[3], technology advanced in leaps and bounds[4], the nation had a sense of national purpose[5], and – at least insofar as its race to the Moon -- the U.S. seemed to be following a moral compass that kept it on the high ground.[6] "The crucible of Apollo focused goal orientated teamwork, raised abilities, ambitions and aspirations of a nation to exceed its wildest dreams. In doing so, the rich technological returns have also revealed the finest possibilities of human achievement.[7]"

Are astronauts still heroes? (See figure 1 showing adults' top 10 childhood career aspirations.) Today, children aspire to be models, sports players, or celebrities (figure 2).[8] The space wilderness cannot be opened up with these skill sets. This paper explores retooling the U.S. space program to generate the infrastructure (social, political, moral, educational) requisite to develop a sustainable spacefaring civilization.

## HUMAN CONSIDERATIONS

Why should we send humans to Mars? Why do people choose to do anything? Psychologists and business owners have studied the motivation as to why customers choose to purchase a product. Our motivation to buy something can be classified as one of two reasons: 1) we either want to get rid of a PROBLEM we have and don't want, or 2) we want a RESULT we don't currently have.[9]

By that measure, sending astronauts to explore Mars ("flags and footprints") is a result that is likely not financially sustainable beyond a few expeditions. (The Apollo program was cancelled before Apollos 18, 19, and 20 could launch.[10]) Colonizing Mars for the sake of transforming humanity into an interplanetary species is a result desirable enough to the general population that it led to the creation of the Mars Society, but it is not desirable enough to directly fund such an undertaking at this time. The same could be said regarding Elon Musk and his ambitious plan to build an Interplanetary Transport System.

I propose colonizing Mars as a tool for solving problems here on Earth, and as a tool to generate a result broadly supportable by (at the least) the tax payers (plus selected special interest groups) of the United States. The key is to go to Mars not for the sake of settling on Mars, but for our sake back here on Earth.

### Our Founding Problem

When Europeans first explored the New World, some of them thought they had entered the Garden of Eden.[11] Even so, our founders brought trouble with them into paradise. Consider the two major New World countries of Brazil and the United States. Both are rich in natural resources and together span more territory than the largest country on Earth.[12] The culture of Brazil is different from the culture of the United States. The first explorers and settlers set the tone that lasts to this day – 400 years later. Bandierantes in Brazil scoured (figure 3: Bandierante Domingos Jorge Velho[13]) the land for slaves and minerals, returning to their starting point with the loot they extracted from the interior of the continent. In contrast, American settlers brought their families with them (figure 4: "Daniel Boone escorting settlers through the Cumberland Gap[14]" by George Caleb Bingham) to homestead the land permanently.

The United States is founded on the concept that government derives its power from the consent of the people. President Roosevelt famously espoused four of our core beliefs in his State of the Union speech of 1941: freedom of speech (figure 5: "Freedom of Speech" by Norman Rockwell[15]), freedom of worship, freedom from fear, freedom from want. We in the United States value these four freedoms, and should aspire to establish a Martian culture with similar values.

It bears mentioning that a founding culture can persists for many generations. It applies to corporate cultures[16] (think of FaceBook, Microsoft, Google, …). It applies to colonizing Mars. If a football team is sent to Mars to establish the first colony, a football team culture will be the dominant Martian culture for at least the next 400 years. If a cheerleader squad is sent to Mars to establish the first colony, a cheerleader squad culture will be the dominant Martian culture for at least the next 400 years. It is worth asking: do we – as citizens of the United States – want to see our better values established as the dominant Martian culture – want it enough to aggressively pursue that outcome? – or are we content to step aside and allow some other entity (such as the Chinese government) establish the dominant Martian culture for at least the next 400 years?

If we (as citizens of the United States) choose to found the dominant Martian culture, we must first acknowledge we have some undesirable founding values (from 400 years ago) that persist to this day, values we should strive to avoid passing on to the Martians. Native Americans enjoyed the nomadic life of hunters, requiring vast amounts of land to preserve their way of life. We new Americans, convinced of our cultural and racial superiority, tragically engaged in an "irreconcilable collision of cultures and values."[17] New world colonists also enslaved millions of Africans whose labor substantially contributed to building the infrastructure of the United States.[18]

These historical attitudes have a lasting effect that lingers to this day. Examine the Oakland crime map for 2015 (figure 6)[19]. In particular, note the contrast between Piedmont and the surrounding neighborhood. As a Google satellite view will verify, the high crime neighborhoods are starkly different in appearance from the low crime rate neighborhood. Consider this as evidence of the effect of lingering racial segregation in our society.

One undesirable outcome is the effect inequality has on our children. A recent NOVA television episode ("School of the Future", first aired on Sept 14, 2016[20]) examined the state of the educational system in the United States. Statement from the episode include: "Inequality in the U.S. is our Achilles heel." "The U.S. poverty rate is nearly double other developed countries." "Poverty invokes stresses preventing students from being ready to learn." "One third of low income students never finish high school." "If you don't envision your future, you're not going to work for it."

Stresses on students inhibit the creation of the highly skilled technical workforce required to successfully carry out a campaign to colonize Mars. Crafting a Mars colonization program that tackles these stresses is smart. A well-designed and executed Mars program can do more than address the stresses found in our educational system. It can inspire and uplift significant segments of the world's human population.

We have the opportunity to create the Martians to our better ideals. Therefore, desirable Martian characteristics are: their best representatives (such as Martian teachers) be free from major prejudices based on ethnicity, gender, age, nationality, religion, political affiliation, or sexual preferences. With that, it is time to make some estimates of what it would take to create a stable Martian culture.

**Establishing a Stable Martian Culture**

How many people does it take to establish and maintain a culture? Based on anecdotal evidence (the teachers at Whitney High School seemed to maintain their school's culture), the answer is: 50. What is the maximum fraction of newcomers allowable into a stable culture? Based on anecdotal evidence (a single class at Whitney's 7 – 12 grade school does not seem to have significantly disrupted their school's culture, whereas a single class at Cerritos High School's 9 – 12 grade school seemed to successfully disrupt their school's culture), let's say the answer is: 1/5. How many people travel on a ship linking Earth with Mars? For colonizing Mars, let's say at least six people are on a single ship, but perhaps only five disembark. (If Elon Musk is successful in deploying a ship capable of carrying 100 people at a time, it would alter the minimum time scale to establish a stable Martian colony.)

How long does it take for a newcomer to assimilate into an established culture? Earth-Mars transfers occur every 26 months. Let's say that is enough time for newcomers to assimilate. What type of transfer orbits should be employed linking Earth with Mars? To maximize the reuse of hardware, as well as maximize the safety and comfort of the passengers, use cycler orbits.

Based on these assumptions, and employing two ships per planetary launch window, the Martian population builds up as follows. On the first 26 month transfer cycle, two ships transport 12 people to Mars. Nine disembark while three remain onboard to maintain the ships back to Earth. During cycle 2, two additional ships transport 12 people to Mars. Some of the three people onboard these ships after encountering Mars could be returning from Mars from a previous transfer cycle. During cycle 3, the Martian population grows to 27. During cycle 4, three

Martians come to Earth (as opposed to astronauts returning from Mars, the difference is due to the cultural values the Martians have acquired during their longer dwell time with a community on Mars) while nine emigrants go to Mars. The Martian population grows to 33 people. The elapsed time is nine years after the first colonists have landed on Mars. With more Martians gradually coming to Earth, the population of Mars might look something like this: cycle 5 yields 39 Martians, cycle 6 yields 45 Martians, cycle 7 yields 49 Martians, cycle 8 yields 53 Martians, and cycle 9 maintains 53 Martians. Thus, after about 18 years (8 cycles) a stable Martian population of just over 50 people is established. If the infrastructure were in place to support a larger population, and if Elon Musk's Interplanetary Transport System were available, then the limiting factor would be fraction of the total population consisting of newcomers, as opposed to the minimum number of colonists being at least 50 people. As a result, a stable Martian culture could be established in as little as six cycles – about 13 years.

**The Purpose For Establishing a Stable Martian Culture**

It is not enough to establish a Martian culture for the sake of colonizing Mars. There has to be a direct benefit to the stakeholders on Earth to justify such a program, or it will not be supported to completion. Accordingly, I propose a three phase program using the colonizing of Mars as a tool for implementing improvements here on Earth. In the first phase, individuals and teams of students document their exploration of Earth – not only physically, but culturally as well. This establishes a baseline so we may know well the (eventual) Martians who come to Earth, and know their specific experiences and perceptions while they were young adults here.

The youngest participants (grades K – 3) might explore their own neighborhood; students in grades 4 – 7 might explore their county; participants in grades 8 – 10 should roam their state; students in grades 11 -12 should explore the country. Once they are beyond high school, they should explore the world. (Figure 7 shows USGS geologist N. King Huber [facing away in hat] explaining the "Devil's Postpile" as science teachers take notes during a geology field trip in 1993.) Gaining experience at one of the Mars Society's simulated Mars bases should be considered a plus.

Students earning a Master's degree should be offered the opportunity to take a Preliminary Candidacy Exam (or battery of exams). The top scorers should be offered scholarships to earn two additional Master's degrees in two additional fields (as it is desirable to have Martians who are "jacks of all trades"), while those who score reasonably well should be rewarded with something tangible – such as two years of employment at the organization (decidedly not NASA) orchestrating the program.

In phase 2, the best individuals and teams are sent to Mars. It is expected they will meet all of NASA's requirements to become astronauts, as well as additional requirements suitable for this program. The objective during this phase is to expend our best effort at establishing a stable Martian culture that we can connect with and relate to, building a Martian civilization even better than the one that is founding the Martian civilization. The crucible of Mars should extinguish some prejudices, if we select the right people for the job.

Phase 3 is the most important part of the program. Here, mentors and teachers from the new Martian culture come to Earth. Unlike the returning Apollo 11 astronauts who were doomed to retirement from further space flight once they walked on the Moon, a useful career in public service is planned for the mentors coming from Mars.

The first Martians to come to Earth may reach a status above rock stars, similar to that attained by the returning Apollo 11 crew. (See figure 8, the Apollo 11 astronauts on parade.[21]) These first Martians are to be primed to exert their influence to nurture change for the better within our own society. They can become our heroes. At the very least, they will likely be experts in fields such as closed loop Environmental Control and Life Support Systems (ECLSS). It is expected they will also be deeply ingrained with the "overview effect" experienced by astronauts who have spent significant time away from Earth – a world view that we are one humanity.[22]

What will the first Martians see when they come to Earth? (Figure 9, a visitor to a landscape unlike anything on Mars.[23]) Earth is still a potential paradise for arriving Martians. What if pollution gets away from us? (Figure 10 shows Los Angeles smog is among the worst in the United States.[24]) How would we feel if we sensed the Martians – our heroes – perceived that we failed our planet?

When the first astronauts returned from the surface of the Moon, they were quarantined until our fear subsided that they were contaminated by an unknown Moon bug.[25] It is likely the first Martians coming to Earth will face similar fears. To strike a balance between the desire to keep the Martians initially quarantined and the desire to quickly reintroduce them to our "purple mountains' majesty, our amber waves of grain," I propose we provide the first Martians with a customized railroad car that allows them to meet both requirements simultaneously.

A railroad car implies Amtrak, and Amtrak implies the U.S. Congress. This becomes an excellent way for Congress to involve itself in a productive manner. Consider figure 11, showing the Amtrak national route map current in 2012.[26] I propose the first Martians travel along a train route passing through Iowa, and ending at Union Station in Washington, DC. Congress is to select the details of the route taken by the first Martians to come to Earth.

It is well known the U.S. is a representative democracy, with Congress elected to represent the will of the people[27]. The train routes debated and voted upon by Congress ultimately represents our form of government, with representatives from various districts and states competing, negotiating, compromising, and allying to generate the routes taken by the first Martians coming to Earth. It is an expression of how our government works for all the world to see.

Figure 12 is a sketch showing the first Martians upon their arrival in Washington, DC. They have finally exited from quarantine and have walked from Union station (past House and Senate office buildings, past the Supreme Court, and just up to the Capitol building) to submit their journals to the Library of Congress.

It is important to establish a role for the Martians from the beginning of the program. The Apollo moonwalkers had such a high when they completed their mission, only to be followed by a sense of drift. While the parade –like celebration of the first Martians to come to Earth will likely fade extremely quickly, knowing that a meaningful career in public service – mentoring and teaching – awaits the succession of Martians coming to Earth is a fundamental characteristic of this long term program.

**TECHNOLOGY CONSIDERATIONS**

The delta vee to travel between Mars has long been studied. It is well known Mars and Earth pass each other every 26 months in their respective orbits around the Sun, that due to the greater eccentricity of the orbit of Mars the delta vee varies from opportunity to opportunity, and that the entire cycle repeats approximately every 15 years. Figure 13 graphically indicates the delta vee for a typical Earth-Mars encounter.

I point out the time interval between Trans Mars Injection (TMI) and Mars Orbit Insertion (MOI). With conventional chemical propulsion, it is a minimum time interval of three months, and a typical transit time of six months. For initial exploration missions to Mars, it is common practice to provide all the essential life support equipment on board the spaceship carrying the crew between Earth and Mars. The focus of the program proposed in this paper is to establish and maintain a long term Earth—Mars exchange program; therefore, a strawman architecture is put forth to establish and maintain a long term sustainable Earth-Mars transportation system.

A logical choice is to employ the S1L1 ballistic cycler described in detail in McConaghy et al.[28] A cycler orbit is an orbit that repeatedly passes by Earth and Mars. It usually requires some significant expenditure of propellant to maintain a spacecraft on a cycler orbit. A ballistic cycler is a type of cycler orbit that requires a relatively small amount of propellant for a spacecraft to maintain its orbit. This is highly desirable in terms of logistics: for a relatively small expenditure of propellant over the course of each cycle, a relatively large and comfortable "oasis in space" can be maintained. The designation "S1L1" refers to this particular cycler's characteristic of 1) passing near Earth, 2) a Short 1-1/2 to 2 years later passing by Earth a second time, then 3) a Long time span of 2 to 2-1/2 years passing by Mars (typically in less than six months) and eventually coming back to Earth to repeat the pattern. The entire pattern repeats approximately every 4-2/7 years.

While employing the S1L1 ballistic cycler trajectory is not particularly desirable for a Mars Direct type of Mars exploration mission, it is an excellent selection for establishing and maintaining a permanent Earth-Mars transportation system. As with all trajectory decisions, this one trades competing features to attain a desirable balance point. In this case, reusability comes at the expense of time of flight from Mars back to Earth. To address this characteristic, three separate ballistic cyclers are recommended in McConaghy's paper; two are used to provide rapid one-way travel from Earth to Mars (one spacecraft used on each 26 month Earth-Mars encounter), and a third spacecraft used to provide rapid one-way travel from Mars to Earth.

When people discuss manned trips to Mars, one of the first concerns raised regards radiation shielding. Outer space contains two forms of radiation (electromagnetic radiation and ionizing radiation[29]); both are potentially harmful to humans. While the surface of the Earth is shielded from radiation by Earth's magnetic field and Earth's atmosphere, no such protection is available in interplanetary space. Conventional radiation shielding in space consists of high mass components (such as solar flare and storm shelters) to protect just the crew against large outbursts of solar flare protons, coupled with a strong preference in mission design to sprint through interplanetary space in the least possible time to minimize the total accumulated radiation dose.

Spacecraft occupying the S1L1 trajectory should be designed to conquer the long term challenges of living in space. NASA's Innovative Advanced Concepts (NIAC) program has funded the investigation of using electrostatic shielding to deflect ionizing radiation before it penetrates the walls of a spacecraft.[30] This concept shows great potential for dramatically reducing the system mass required to provide significant shielding from ionizing radiation. Importantly, the size of the shielded safe zone can be scaled up to proportions large enough to encompass -- not just a cramped solar storm shelter – but an entire space station rotating to generate artificial gravity.[31]

We know a little about food production in space, but not nearly enough to sustain a human population on Mars or anywhere else off Earth. It is impractical (or at least, highly unappetizing) to supply humans on Mars with food stores from Earth that last for years. We have scant data for the viability of plants and animals in anything other than an Earth gravity environment. Instead, we need to deeply study the challenge of producing fresh food far from Earth. This means creating a variable gravity research farm in space.

Eckart recommends an area of operation from 0.2 g to 1.0 g using no greater than 4 rpm of rotation to generate artificial gravity. This corresponds to a radius of 56 m (the same as a diameter of 366 feet) for a rotating structure. Figure 14 shows the dimensions of the International Space Station. At 357 feet from tip to tip, it is quite similar in scale to this proposed fixed radius variable spin rate artificial gravity research farm.

This proposed farm should not be an expansion of the existing ISS. Rather, it should be placed onto the S1L1 ballistic cycler orbit.

Before Biosphere 2 was constructed, a Test Module was built to test the viability of creating a closed biologically based life support system. One person lived in the Test Module for 21 days, setting a record at that time for sustaining a human in a completely closed life support system.[32] As figure 15 shows, the Biosphere 2 Test Module had a volume of 10,974 cubic feet (excluding its tunnel and variable volume lung); this is equivalent to a volume of 311 cubic meters. This closely matches the available volume (330 cubic meters) of a Bigelow BA330 habitat module. Although the BA330 modules would have to be modified to serve as a research farm, they appear to be the correct sized structure to employ in the proposed investigation.

What might be a reasonable estimate for a complete research farm? Eckart provides estimates (pp. 402-405) from a Lockheed study for creating a closed life support system on the Moon for a nominal crew of 30 people – but able to accommodate from 4 to 100 people. The characteristics listed are: a system mass of 222,700 kg (equivalent to 11 BA330s), a system volume of 2,320 $m^3$ (equivalent to seven BA330s), a system power requirement of 595 kW (five times the power output of the ISS arrays). Note that if placed onto the S1L1 cycler orbit, the solar arrays would have to be increased by a factor of 2.7 to provide 595 kW of power when the research farm is at apohelion – 1.6369 A.U. from the Sun. The research farm might begin with a crew of four, but eventually evolve to take on the rough scale of the ISS: perhaps seven BA330s for food production, plus five BA330s for living and working quarters for a crew of 30. With proper forethought, what begins as a research farm should evolve into an oasis in space to sustain crews transiting between Earth and Mars.

Ideally, three such oases should occupy S1L1 cycler orbits: two serving outbound humans from Earth to Mars plus one serving inbound humans from Mars to Earth. Each oasis would also have a permanent crew – essentially farmers or food engineers. To provision humans on the surface of Mars, a similar station should be deployed to one or both of the Martian moons, with the moons taking on the role of way stations for interplanetary travelers arriving at and departing from Mars.

Developing the Martian moons as support bases – even before the first humans walk on Mars – is consistent with the objective of creating a permanent, sustainable Earth-Mars transportation architecture. Members of NASA's Future In-Space Operations working group also advocate such an approach to Mars exploration.[33]

In the future, the Martian moons may evolve to extract kinetic energy from arriving spacecraft, and impart kinetic energy to departing spacecraft. The theoretical device orchestrating the exchanges of kinetic energy and momentum between spacecraft is called an Impulse Engine.[34] The combination of ballistic cyclers, space taxis (fueled by Martian resources) optimized for shuttling crews between the surface of Mars and the Martian moons, and Impulse Engines orbiting Mars (and potentially even surface based, such as near the summit of Olympus Mons) enables a sustainable, affordable, permanent Earth-Mars transportation architecture.

It is difficult to envision a Phobos Impulse Engine (PIE) that becomes reduced to practice without a tremendous leap of financial faith. The first challenge is orbital mechanics. Examining NASA's Design Reference Mission 5.0 Addendum #2, table 3-1, the maximum V infinite for a spacecraft entering or departing a High Mars Orbit is 4.22 km/s.[35] In comparison, examining

McConaghy's table 2 lists a maximum V infinite at Mars of 7.86 km/s. This higher encounter velocity at Mars becomes a penalty in increased mass (as propulsion and/or as heat shield) for spacecraft transferring between a S1L1 ballistic cycler trajectory and the orbit of Phobos. The advantages in using a cycler trajectory include the use of taxis – smaller mass spacecraft to shuttle crew and cargo between Earth orbit and a passing cycler, or between Mars orbit and a passing cycler. If an Impulse Engine were placed on Phobos, the maximum engagement speed of a spacecraft using NASA's trajectories could reach 3.8 km/s at Phobos. A space taxi on the S1L1 cycler trajectory could engage an Impulse Engine at Phobos at a speed of 7.7 km/s.

A second challenge centers on materials. If engagement accelerations were limited to 3.0 gees (29 $m/s^2$), and carbon nanotube-based tethers were employed for transmitting engagement forces between Phobos and spacecraft, engagement distances of 174 km (NASA trajectories) to 930 km (S1L1 trajectories) would be employed. Currently, the record length for a carbon nanotube is half a meter.[36]

Despite these challenges, Impulse Engines remain a theoretical possibility for reducing the delta vee required for arriving at and later departing from Mars orbit by at least 2.3 km/s (in terms of propellant calculations) for NASA type trajectories, with an even greater advantage for S1L1 type trajectories. That would be useful.

**GOING FORWARD**

The first Martians are already in our educational system. Most students aspiring to go to Mars are unaware of the best way to prepare themselves for the path to Mars. Along with gaining skills in Science Technology Engineering Art and Math (STEAM) it is desirable for students to become capable of growing and harvesting their own food supply, including raising and butchering chickens. Learning how to maintain bonsai trees would be potentially therapeutic and useful. Figure 16 shows a bonsai tree with a full sized apple. Knowing they have a future role as an educator or mentor coming to Earth from Mars would avoid the sense of loss that sometimes plagues astronauts who have competed their space missions. Toward this end, we are exploring the concept of conducting an exchange program of physics students with schools outside of our region, particularly locations where participating students can gain some farm experience. We may try to do this through the American Association of Physics Teachers.

Currently the Bigelow Expandable Activity Module (BEAM) is attached to the ISS. At the completion of its current mission, it is scheduled for deorbiting. It would be useful if it could be repurposed as a test satellite to dispatch onto the S1L1 trajectory at the upcoming opportunity on February 4, 2019. The BEAM could be equipped with radiation monitors to characterize the environment along the S1L1 trajectory.

In my capacity as Aerospace Engineering instructor at Cerritos High School, I plan to task my students with assessing the architecture outlined in this paper during the current school year. We will also include Elon Musk's ITS as well as Dr. Zubrin's analysis[37] of the ITS in our considerations, always with an eye toward establishing the most sustainable, affordable Earth Mars transportation system based on these various concepts.

## CONCLUSION

We are capable of building a Martian community that can serve as a moral compass for our society. A properly managed program to bring Martian teachers to the U.S. can draw together stakeholders (such as Congress, environmentalists, and students) to establish the social and technological infrastructure required to sustain the program.

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**FIGURES**

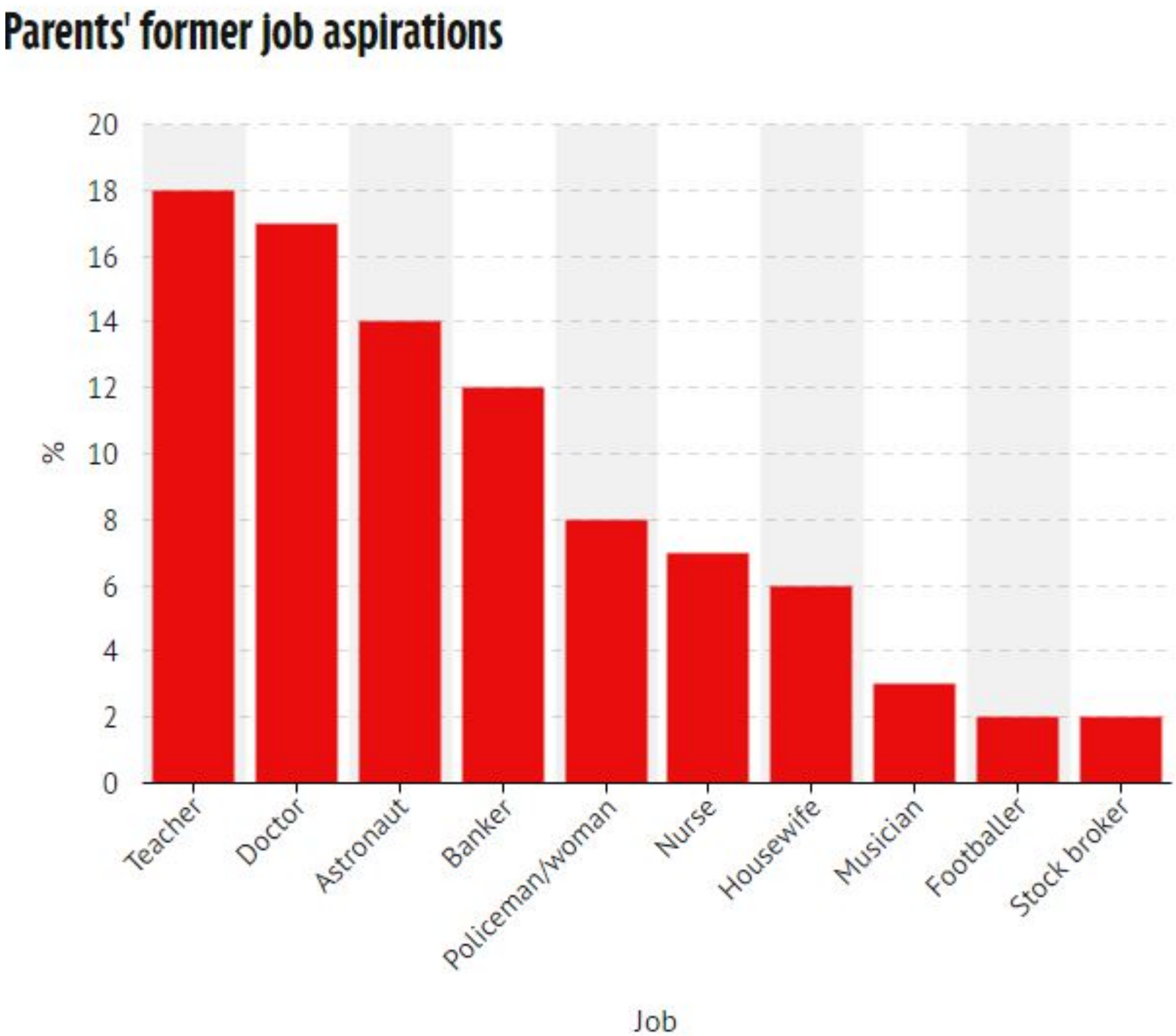


**Figure 1 Adults aspired to become teachers, doctors, astronauts.**

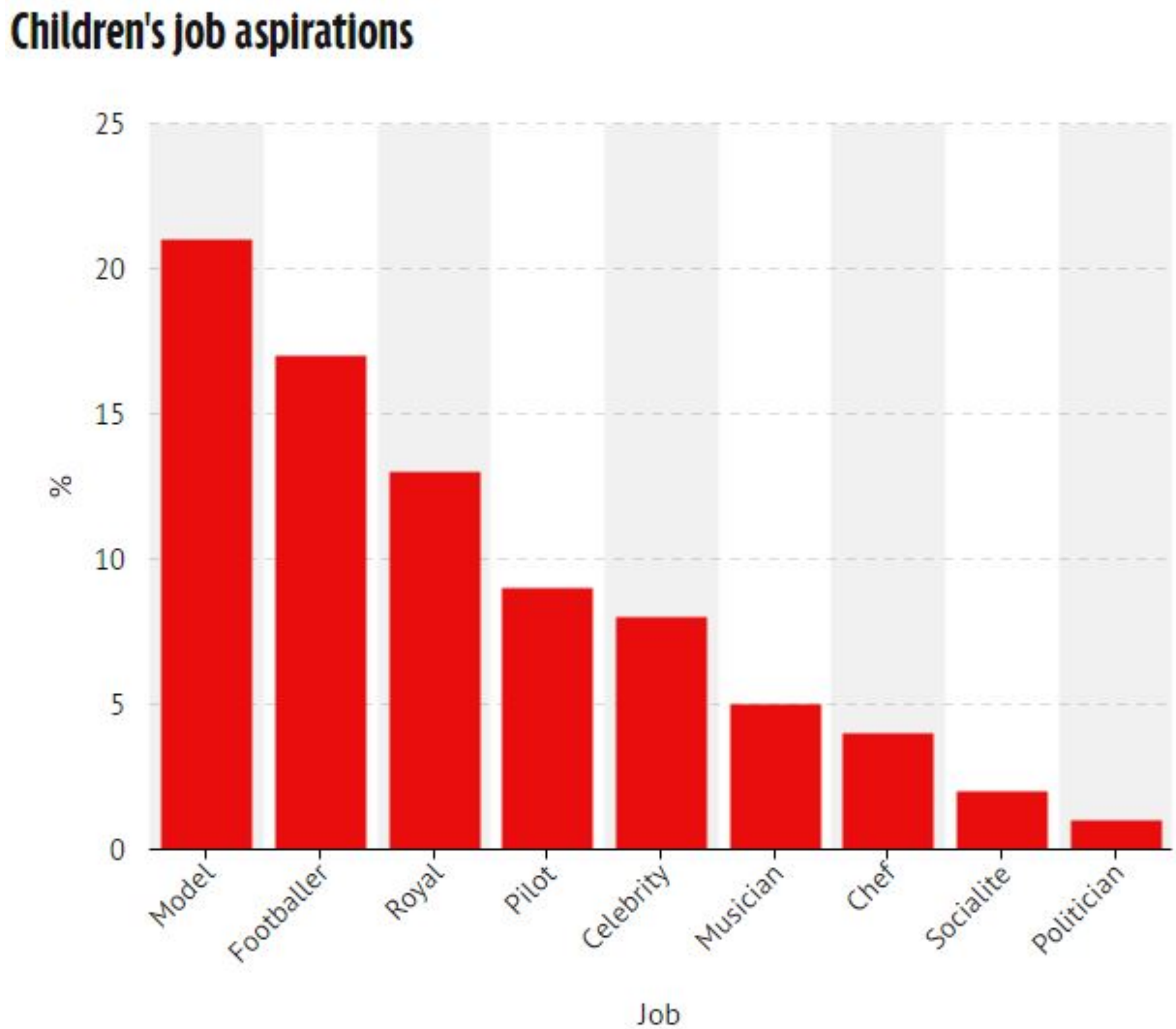


**Figure 2 Today's children to not aspire to support a spacefaring infrastructure.**

**Figure 3 "Domingos Jorge Velho" by Benedito Calixto.**

**Figure 4 Daniel Boone escorting settlers through the Cumberland gap.**

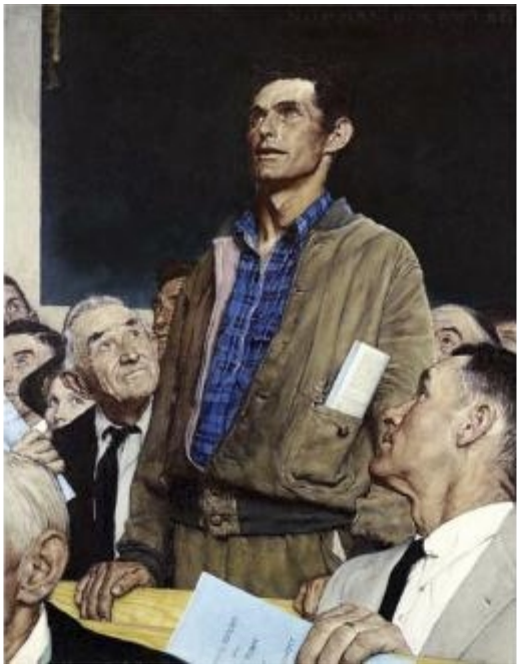

**Figure 5 Freedom of Speech by Norman Rockwell.**

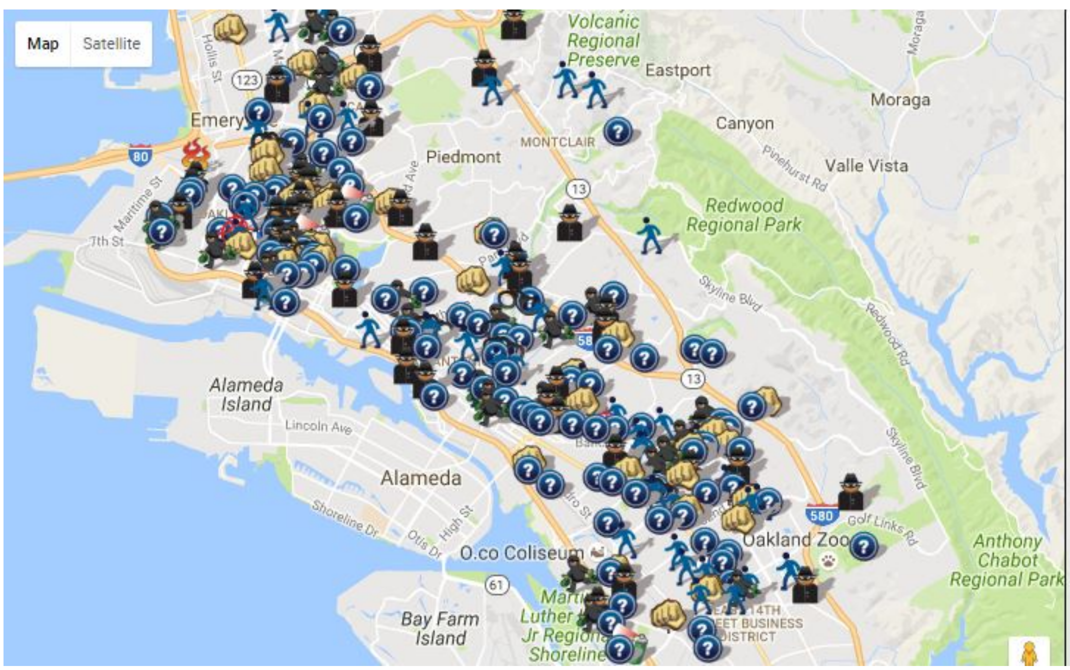


**Figure 6 Oakland crime map for 2015. Note the contrast regarding Piedmont.**

**Figure 7 N. King Huber explains geology as students take notes.**


**Figure 8 Apollo 11 astronauts receive a ticker tape in NYC. Image courtesy NASA.**

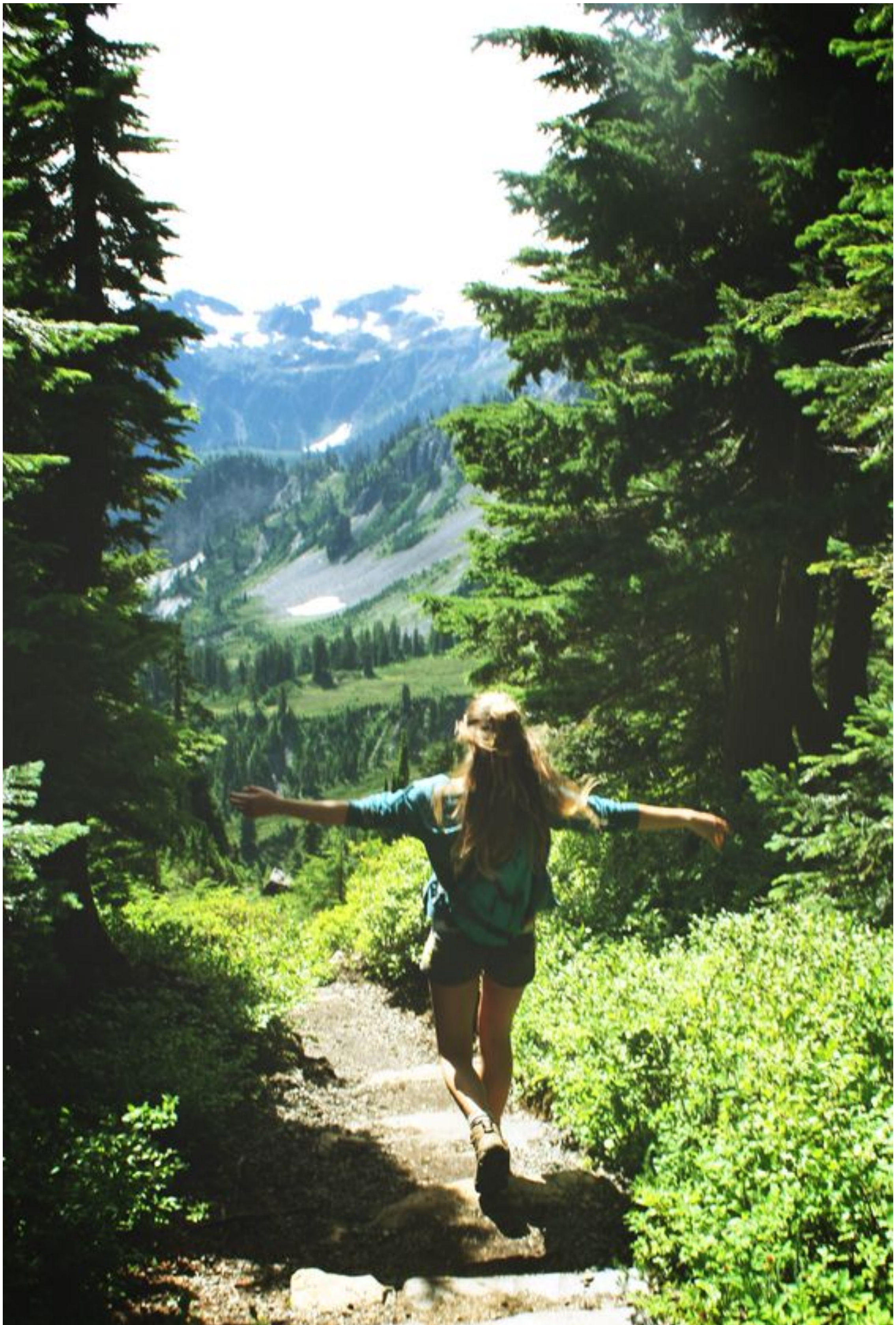

Figure 9 A Martian explores Earth.

Figure 10 Los Angeles smog is among the worst in the U.S. What will the first Martians see?

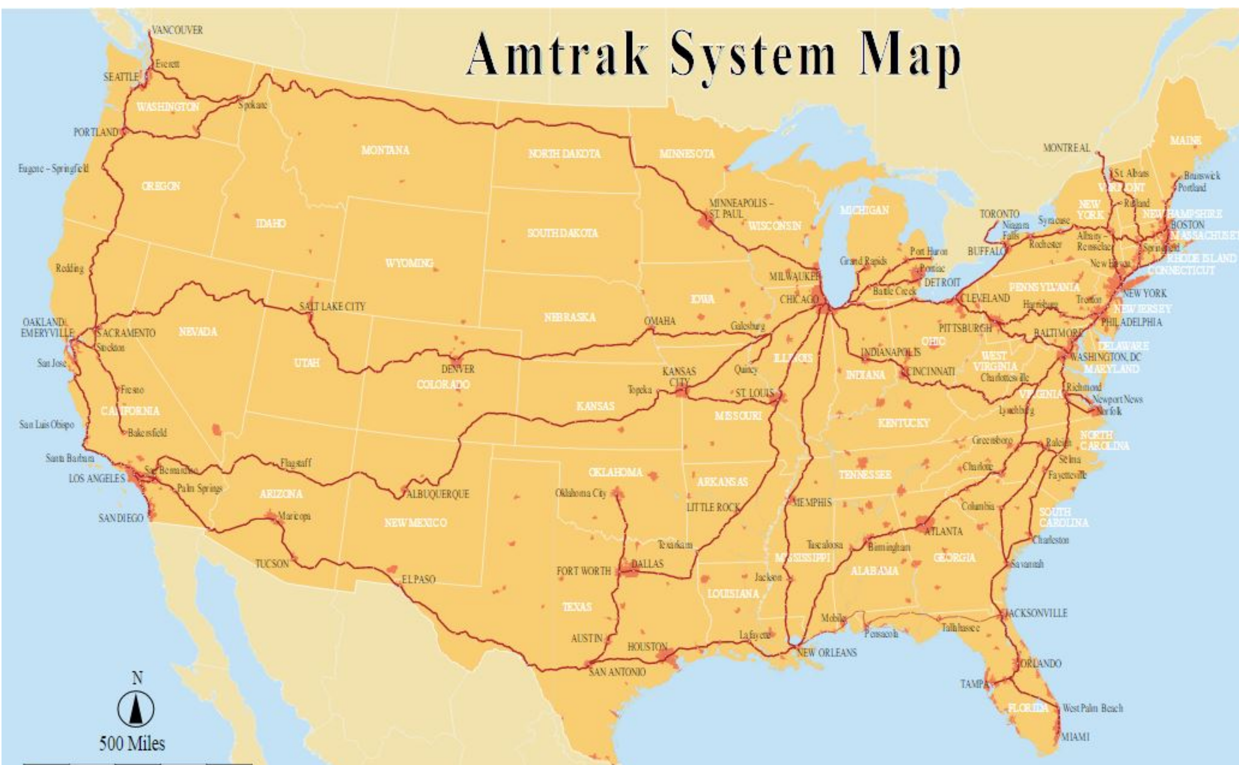


Figure 11 The Amtrak system touches most states.

Figure 12 Martians submit their journals to the Library of Congress.

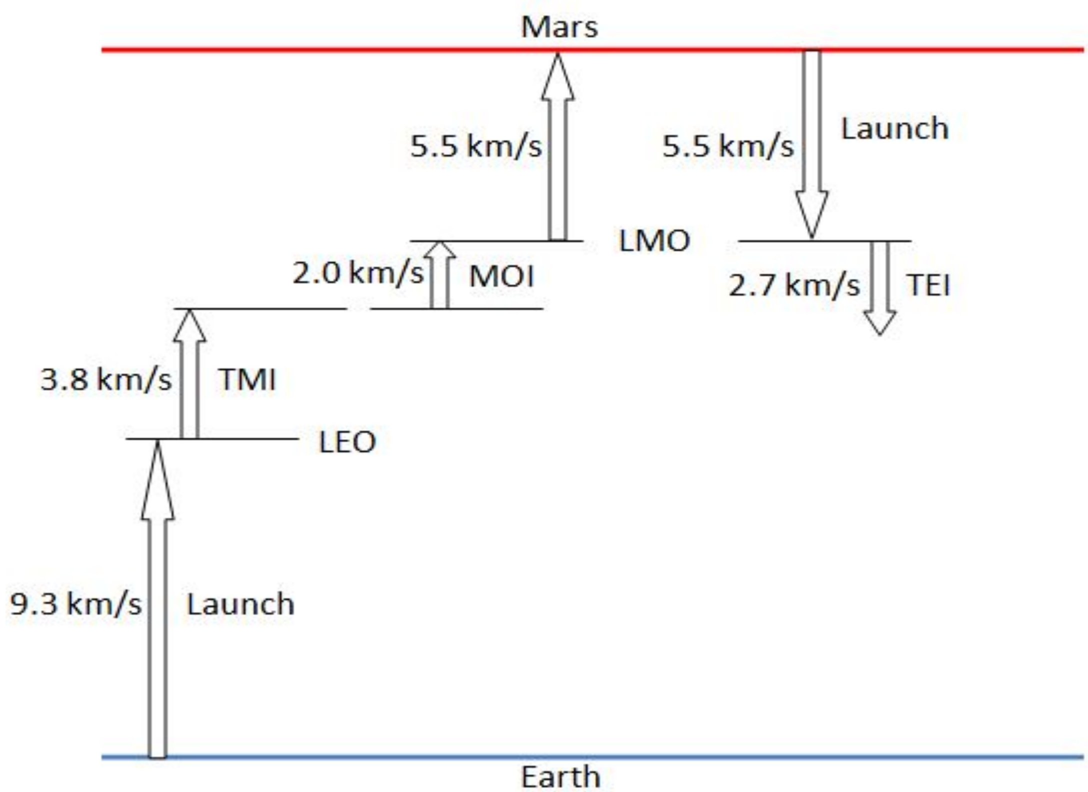


Figure 13 Delta vee for a typical Earth-Mars encounter. LEO is Low Earth Orbit, TMI is Trans Mars Injection, MOI is Mars Orbit Insertion, LMO is Low Mars Orbit, TEI is Trans Earth Injection.

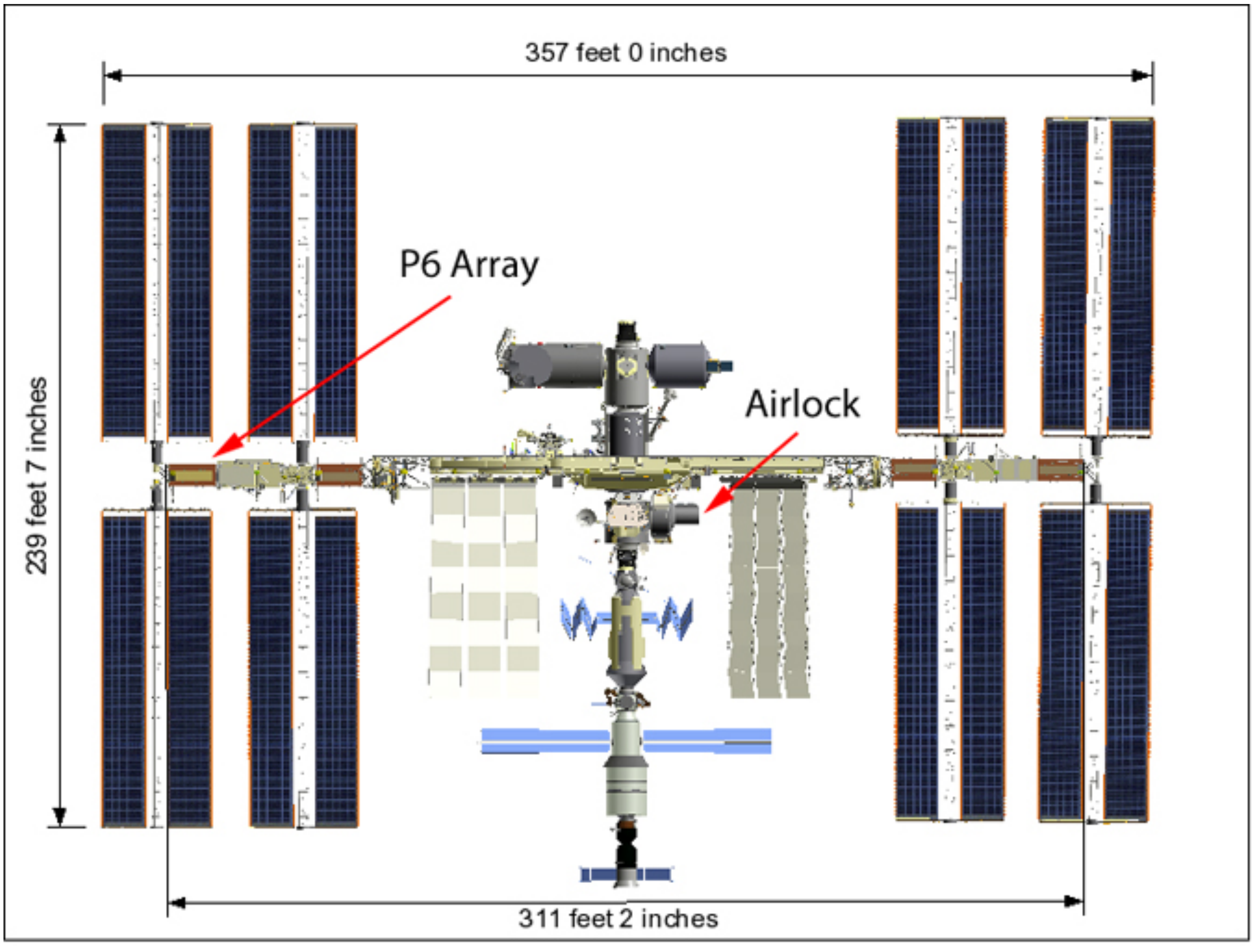


Figure 14 ISS dimensions. Image courtesy NASA.

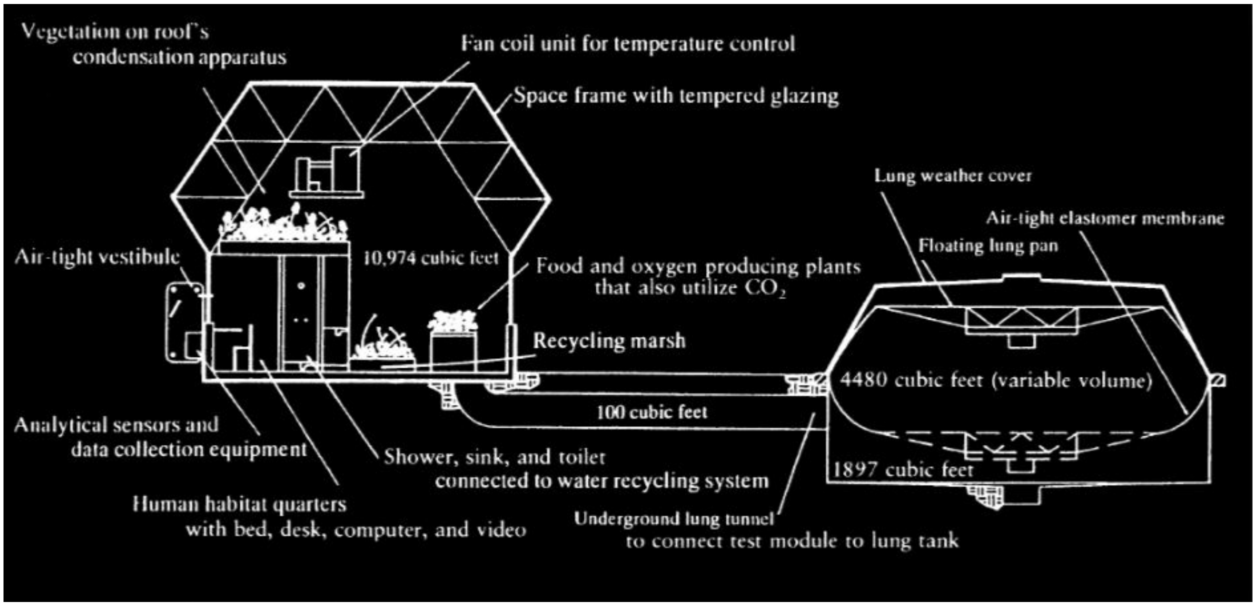


**Figure 15 With a volume of 311 cubic meters, the Biosphere 2 Test Module is roughly the volume of a Bigelow BA330 habitat module. Image source: naturedocumentaries.org. Ref: http://naturedocumentaries.org/5352/landscape-evolution-observatory-leo-biosphere-2/**

**Figure 16 Full sized apple on a bonsai tree. This activity could be both therapeutic and useful in space.**

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## REFERENCES