Leaving Home: Opportunities and Challenges for Human Exploration of the Solar System and the Milky Way Galaxy

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The late Dr. Carl Sagan, a hero of mine, once said "The sky calls to us. If we do not destroy ourselves, we will one day venture to the stars." And many people – space enthusiasts especially – hope that Dr. Sagan will be proven right. After all, beyond the mere thrill of exploring new stars and new planets, are existential reasons why we should – and eventually *must* – leave Earth. From natural forces such as massive super volcanic eruptions, catastrophic asteroid collisions, and searing solar flares, to self-induced threats such as nuclear annihilation, we have known that our survival dangles precariously at the end of a string propped up by happy coincidences and a fair amount of luck.

Even so, we know that our luck will eventually run out. And if we are not destroyed by any such cataclysmic events, the Sun will one day grow to exponential proportions during its "red giant" life phase, engulfing the Earth in its fiery outer corona, and we will have to go. Granted, this isn't expected to happen for another 4-5 billion years. But notwithstanding, if we are to continue on indefinitely, departing from Earth will at some point be inevitable. But leaving is not as easy as it sounds. It goes without saying that we should not wait until we face imminent extinction to figure out how to do it (Freedman, 2018).

Space is hard. We've known this since the earliest days of human spaceflight, and on through the present era. In 1967, we lost three astronauts during Apollo 1 mission testing right here on Earth – before the lunar rocket program even left the ground. Then, just under two decades later in 1986, we lost STS Challenger and its entire crew on ascent when one of the side rocket boosters burned a hole in the main tank and detonated the fuel "bomb" to which the shuttle was strapped. Not quite two decades after that in 2003, we lost STS Columbia and *its* entire crew when it broke up on re-entry due to hull damage caused from ice buildup before launch. And barely ten years after that in 2014, the burgeoning private space sector mourned its first human casualties, as two astronauts for Virgin Galactic were killed during flight testing.

Yet – for all our struggle and loss in space exploration to date, we haven't gone awfully far either. 95% of all astronauts who have ever been to space have only ever been to low-Earth orbit – a few hundred miles above the Earth's surface at most. The other 5% have gone as far as the Moon, which, to be fair, is several orders of magnitude fur-

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ther than low-Earth orbit. But it's still a pitifully short trip in comparison to the distance to other planets, to say nothing of other stars.

A lightyear is the amount of distance that light – traveling at lightspeed or 186,000 miles per second – travels in one year. When you do the math, it turns out that a lightyear is equivalent to roughly 5,880,000,000,000 miles. Now, the Milky Way galaxy (of which we are a part) is estimated to be about 100,000 lightyears across. It comprises roughly 100 billion stars, and the nearest star to our own is that of Proxima Centauri at 4.25 lightyears (or roughly 24 trillion miles) away. So, we can ask the question: How long would it take us to get to Proxima Centauri using today's spacecraft abilities?

We could begin by looking at an astronaut-carrying vehicle like the Space Shuttle. To be clear, the Shuttle was never intended to leave low-Earth orbit, but we can still do the calculation. The Space Shuttle orbits the Earth at approximately 17,500 mph, so if we took the Space Shuttle (at that speed) to Proxima Centauri, it would take us approximately 38,000 years to get there.

But what about other, *faster* spacecraft? Well, the fastest spacecraft we've ever built is called the Parker Solar Probe – a robotic space probe that orbits the Sun, collecting data as it moves at a blistering 364,000 mph. The Parker Solar Probe is *not* built to carry any astronauts, but we can nonetheless do the math again here. At 364,000 mph, it would take the Parker Solar Probe more than 1,800 years to reach Proxima Centauri.

And remember, these calculations are just to our *closest* neighboring star. What about the lengths of time required to cross the Milky Way? It turns out that the Parker Solar Probe could make it to the other side of the galaxy in about 50 million years, while the Space Shuttle would take closer to a billion years. I don't know about you, but I don't have that much time to spare. We need to develop a better way to travel if we're ever going to become an interstellar space faring species (Heyl, 2005).

On that point, there are essentially three different approaches we might take to viable interstellar space travel. And the first is obvious: We could build spaceships that go a lot, LOT faster. If we could do this – and develop propulsion technologies that would allow us to travel at significant fractions of lightspeed, we could potentially cut down the trip to a neighboring star such as Proxima Centauri to timescales that are within the scope of a present-day human lifespace. For example, if we could invent a spaceship engine that supported velocities near 25% of lightspeed, then a trip to Proxima Centauri might take just 20 years or so. Granted, that is still a very long time to be stuck on an interstellar road trip (Are we there yet?!). But it could conceivably be done (Lubin, 2016).

However, it's not without its serious challenges. In addition to the complications of inventing the technology for the propulsion itself, spaceships moving at such extreme speeds would also need some kind of shielding to avoid being shredded to pieces by every mote of dust that it might encounter along its path of travel in space. Also, it's worth noting that traveling at such extreme speeds brings into play some very weird phenomena that results from Einstein's general and special relativity theories – including time dilation. The details of time dilation are beyond the scope of this brief review (Deel, 2019), but it suffices to say that such speeds create time travel implications that could have untenable implications for those who might otherwise wish to go.

A second approach to interstellar travel is to meddle with human biomedical engineering in such a way that we massively extend human longevity. If we could tweak our genetics and other health variables in such a way that humans could be capable of living significantly longer than we are now, and perhaps even bypassing death altogether, then long trips wouldn't necessarily be an obstacle to our travel objectives, even at current spacecraft speeds. For example, a trip of a thousand years wouldn't necessarily be a dealbreaker if humans could routinely live to be thousands of years old. Granted, this approach wouldn't make such long trips any *less long*. But it could potentially enable us to survive long enough to reach our destinations.

Finally, a third approach is simply to design our interstellar spaceships and crew in such a way that we plan for multigenerational space missions. That is to say, if we aren't able to make our ships go faster or our passengers live longer, then we could still set out on hundred- or thousand- of million-year trips to different stars in our galaxy – but we would have to accept that those who make the first steps of such trips will not be alive to see the last steps.

For example, if we wanted to venture to Proxima Centauri at Parker Solar Probe speeds and we knew that such a trip would take us roughly 1,800 years, we could design a spacecraft with a robust crew, with sustainable food and water and recycling programs, and with full facilities to support life – and we could set off on such a mission with the understanding that it would take 20 or more generations of passengers to eventually reach the endpoint. It isn't necessarily romantic to think that the embarking voyagers will have to bear children and die, and then their children will have to do the same, and their children's children, and so on, all the while living their entire lives onboard the spacecraft – and that only their great great great …. great great great grandchildren might someday enjoy the bounty of all their sacrifices. But it is nonetheless at least theoretically doable.

Aside from all the factors discussed herein already, there are also many other challenges to human space travel to overcome before any of these strategies are even possible. As examples, space is too cold for human comfort outside of sunlight, but also too hot in close sun exposure (especially with no efficient means of heat transfer), so insulation and climate control are a critical challenge. Also, space offers no air, no gravity, no water, no food, and nothing else particularly helpful to human survival. On the other hand, space *does* offer lethal radiation, high speed particles, and other significant threats to astronaut health. Yet more significant obstacles that must be overcome if we are to journey to the stars (Crawford, 2010).

Still, in closing, I'm reminded of another quote from Dr. Sagan, wherein he offered his thoughts upon the extent to which conquering these challenges should perhaps be more of a priority for us than it currently seems to be: "Just now, there are a great many matters that are pressing in on us that compete for the money it takes to send people to other worlds. Should we solve those problems first, or are they a reason for going? Our planet and our solar system are surrounded by a New World ocean: the depths of space. It is no more impassable than the last."

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