F.5. EXTRATERRESTRIAL COLONIZATION

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F.5.a. INITIATIVES IN PART UNDERSTOOD AS ENCOURAGING OF EXTRATERRESTRAIL COLONIZATION

The several initiatives noted here are underway, will generate continued public attention, and are well-suited to be promoted and perceived as logical steps towards extraterrestrial colonization. A fair guess would be that all of these (other than #5) could be realized over the coming 30-40 years, i.e., by between 2050 and 2060. Obviously, any one of them might encounter major delays, for a variety of technical, political or other reasons, and a major catastrophic tragedy, such as the loss of an entire Mars crew, could set efforts back by decades. The point is that there is likely to be enough real on-going space exploration activity underway over the coming 40 years to provide a foundation for the continued discussion and promotion of extra-terrestrial colonization.

1. Space Tourism. Many of these efforts were initiated by and are supported by celebrity billionaires. Business plans generally call for modest first steps which, once successful, will generate the experience and capital for more ambitious efforts. Efforts underway Ocotober 2018 include:
* *Virgin Galactic* - Richard Branson - testing has resumed. $250K/person for15 min. sub-orbintal hop.
* *Blue Origin* – Jeff Bezos – 11 minute sub-orbital hop. ~ $200-300K/person.
* *Orion Space* – Orbiting space hotels – ready ~ 2022; 4 guests, 2 crew. $9.5 million/guest for 12 day stay.
* *Roscosmos* – "Luxury" hotel module attached to the ISS, ready ~ 2022. $40-$60 million/person for 2-4 weeks.
* *Axion Space* – Orbiting space hotel. Module set to visit ISS in 2022, in operation by 2024.
* *SpaceX* – Elon Musk - announced plans to fly 2 tourists around the moon; date and price unavailable.
* *Bigelow Aerospace* – expandable modular orbital hotels for space tourism.

Media attension given to Richard Branson's Virgin Galactic was lavishly doting until the first test fatality in 2014. Coverage of space tourism has been more restrained for a while but is now once more beating the drum. There is always the possibility that space tourism efforts could quickly come to be seen as billionaire vanity projects enabling egregiously flagrent displays of elite priviledge on the part of the super-wealthy, and draw social opprobrium. See F.5.c. following for more. See also Waldek (2018) and Wattles (2017).

2. Construction of a semi-permanent moon station – In December 2017 President Trump directed NASA to return to the Moon. A key objective would be establishing the **lunar orbital platform gateway (LOPG)** that would support lunar and eventually Mars operations. Plans as of 2017 call for the first modules of the LOPG to be in lunar orbit by 2022 and lunar landings sometime after that.

3. Crewed landing on Mars – As of 2018 NASA's conceptual plans called for the LOPG to be ready to support Mars missions by 2030, and the first mission of four astronauts to Mars in about 2033. Elon Musk's announced plans to build a launch and transport system capable of carrying 100-200 passengers per launch as part of an effort to build a colony of 1 million settlers between 2050 and 2100 is regarded by most serious aerospace engineers to be a PR move. See F.5.d below for more.

4. Asteroid Mining – Several serious start-ups have been established, again heavily backed by Tech billionaires. A wide range of proposed business plans have been developed, involving different sorts of asteroids, mining objectives, technologies and mission configurations. The two most commonly suggested minerals to be mined are platinum (for general use on earth) and water (for human consumption and rocket fuel on extended space missions). Skeptics doubt the ultimate feasibility or utility of asteroid mining. But it captures the imagination and

plays into a well-known Western/entrepreneurial narrative, and demonstration projects could be successful. See varying degrees of skepticism about asteroid mining here, here and here.

5. Inter-stellar space travel. Two serious efforts are undeway. ***Breakthrough Star-Shot*****,** initiatied by Russian Oligarch Yuri Milner, seeks to send very small solar sail craft to the earth-size exoplanet Proxima Centurai B. Each mission would involve ~ 1000 interstellar craft, each with a mass of about 1 gm and about 1 cubic cm large. They would be accelerated to 1/5 light speed by a large array of tightly focused earth-based lasers. Milner estimates development time of about 20 years and the flight itself another 20-30 years, putting interception with Proxima Centuri B by ~ 2060-2070. Each craft would carry a tiny camera and send back a photo. Skeptics question the feasibility of both the phased-array laser propulsion system and the ability of such a small craft to transit a photo back to earth. For more see here, here and here. The other project is the ***100-year Starship Project.*** In recognition of the magnitude of the challenge of extraterrestrial space travel, its intial mandate is the seemingly modest one of establishing the means by which the *research and planning* for possible interstellar travel might be undertaken and sustained over a period of 100 years. This approach seems likely to entail an ongoing program of building a large and deep base of public support for the presumed eventual interstellar flights themselves. 100ySP was initiated by NASA and DARPA, who funded the Dorothy Jemison Foundation for Excellence, headed by former NASA astronaut Mae Jemison, to conduct an initital planning study. See Gilster (2017) for technical details. Also see here, here, here and here for more.

F.5.b. SPACE TOURISM: STATUS, SAFETY CONCERNS AND SOCIETAL CONCERNS

1. In October 2014 **Virgin Galactic's SpaceShip Two** (the "VSS Enterprise") **exploded and crashed** on its fourth powered test flight, killing the co-pilot and seriously injuring the pilot. In the wake of the crash many criticisms of the project that had been voiced earlier, but were largely ignored by the scientific, aerospace and popular press, now attracted much attention. Criticisms had been made of the flight testing plans, the safety certification process, the design of the spacecraft and of its engines, the exuberant promotion of the enterprise by Virgin Galactic founder Richard Branson and others, the fawning complicity in this promotion by local and national media, and the foolishness and foolhardiness of space tourism in general. For examples and discussion of pre-crash critique see Mendick et al. (2014), Fernholz (2014), Associated Press (2014) and Bland (2012).

2. A September 2016 **pre-launch explosion destroyed a SpaceX Falcon 9 rocket** and the Israeli communications satellite, partly owned by Facebook, that it was to place into orbit. Such accidents are expected in the course of developing rocket systems but this failure was significant because the Falcon 9 was set to begin ferrying human crews to the International Space Station in 2017. The explosion appears to have occurred when supercooled liquid oxygen being loaded into the rocket unexpectedly solidified and reacted with the carbon fiber composit surface of adjacent fuel tanks. As of November 2016 the cause of this cooling/phase change anomaly was yet to be determined. See Fecht (2016).

3. The safety of human spaceflight can be expected to improve, but it is very unlikely to ever be as safe as, say, airline travel. The amount of power generated by a Boeing 747 flying ~ 400 passengers round-trip between New York and Paris is roughly the same as the amount of power generated by a Saturn V rocket putting an equal mass into low earth orbit. But the 747 burns its fuel over the course of 14 hours, while the Saturn V does so in *12 minutes.* Such intense release of energy is inherently unstable, and glitches that can be safely compensated for during an airline flight would be catastrophic in a rocket launch. See Lopata (2015).

4. Critics of space tourism suggest that the proposed suborbital trips will be only marginally more interesting than presently available zero-G flights (the "vomit comet"), and fifty times more expensive ($250K vs $5K); the potentially more interesting orbital trips will be too expensive and dangerous to ever begin; space tourism may be targeted as an egregiously offensive display of wealth, priviledge and frivolity in a time of growing economic inequality; and for all these reasons may never get off the ground. See e.g. Stromberg (2015).

F.5.c. IS EXTRATERRESTRIAL SPACE COLONIZATION POSSIBLE AND DESIRABLE?

This section is in preparation. I believe the weight of evidence strongly suggests that extraterrestrial colonization is simply not possible, under any other than non-credible scenarios (e.g. the Singularity, which makes everything and anything credible.) However, I haven't seen this argument made in a manner thorough and rigorous enough to persuade the current enthusiasts to forego their cause.

If extraterrestrial colonization *were* possible, I (provisionally) believe that a case *might* be made that it *might* be desirable, or at least not necessarily undesirable. However, the successful establishment of extraterrestrial colonies would have little direct bearing on the many questions we will need to address in any event to ensure a very long future for human life here on earth.

Assuming that extraterrestrial colonization is *not* possible, is widespread and enthusiasm for it a problem? Those who say *no* argue that it's impossiblitiy will become evident in due time, that in the meantime the enthusiasm for colonization simply helps build support for the many socially and scientifically beneficial space programs. Those who say *yes* argue that space colonization is a foundational element in the growing techno-utopian ideology that is in fact *antithetical* to a world of economic justice, ecological integrity and technological responsibility, and that anything that can be done to bring this constituency back to earth would be importantly desirable.

As one more instance of how the space colonization mentality shapes thinking, consider that while most colonization advocates prioritize Mars, **Jeff Bezos** appears to argue that the major site of space colonization will be free solar orbiting civilizations, eventually capable of supporing a population **of 1 trillion humans throughout the solar system**. See David (2017).

For arguments pro and con extraterrestrial colonization see Kriss (2017), Torres (2018) and the Space Future Forum on space colonization.

BOX F.5-1 below offers a condensed outline of questions and responses regarding human extraterrestrial colonization.

F.5.d. THE ABIDING ALURE OF MARS

Elon Musk's Advocacy of Mars Colonisation

1. In September 2016 SpaceX CEO Elon Musk unveiled plans to enable perhaps **1 million people to settle on Mars** between 2050 and 2100 in a permanent self-sustaining colony. Uncrewed cargo missions to establish supply, heavy equipment and infrastructure depots could begin as early as 2020. Crewed missions would begin in 2024 and continue indefinitely after that. Early flights would carry perhaps a dozen crew tasked with constructing habitats, power plants, food and water production, mining operations, propellant fuel manufacturing facilities (to convert water from sub-surface ice and CO2 from the atmosphere into methane and O2 for rocket fuel), and other necessary systems. By 2050 spacecraft able to transport 100-200 passengers per flight would be in operation. Musk estimates that each human trip would require 10 cargo trips, in which case 1000-2000 flights annually for 50 years would enable 1 million humans to settle on Mars by 2100. Musk estimates costs of the initiative would run between $200-500,000 (US$) per settler. SpaceX has committed to fund and develop the Interplanetary Transport System (ITS), i.e. the primary rockets and launch systems, the cargo and crew modules, and the Mars-based propellant production and storage systems. Musk acknowledges that other parties – either firms, governments, NGOs or individuals – will need to commit funds for the many other aspects of establishing and sustaining a human colony on Mars. He believes that interest in doing so will be forthcoming as SpaceX continues to make progress in developing the critically important ITS. See Musk (2017) for a full account. See also Wall (2017, 2016) and Gebhardt (2017).

2. How do members of the planetary astronautics community **evaluate SpaceX's proposal for Mars** colonization? Many are unreservedly enthusiastic. Others say that the present plan is unrealistic regarding scale, cost and

timeline, but see no reason that it shouldn't work if scaled down and stretched out. Still others think this particular plan is fundamentally flawed but don't directly question the objective of a permanent, large, self-sustaining human population on Mars. Some argue that humans should forego Mars colonization because intelligent nanobots will soon be able to do this more quickly and cheaply, and they deserve the opportunity. Only a few argue that we should leave Mars as it is, except for continued robotic exploration and perhaps some limited human scientific forays. It may be that many technically competent observers refrain from denouncing proposals like Musk's because they understand that the vision is objectively preposterous and that the Mars enthusiasts will come up against reality soon enough on their own. It's possible that even Musk and other Mars advocates are playing a strategic game: they have no idea if colonization will ever be practical, but to find out we first need routine NASA-style exploration, and the best way to generate support for *that* is to build a large, clamoring, popular base, and the best way to do *that* is with the most grandiose yet arguably credible vision possible. For a sharp critique of Musk, his Mars plans and the utopian Silicon Valley mentality see Russel and Vincel (2017). For a range of views on Musk's proposal see Howell (2017), Grush (2016), Zubin (2016), Quinn (2016), Cofield (2016), Teller and Teller (2015), and Regis (2015).

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BOX F.5-1: HUMAN EXTRATERRETRICAL COLONIZATION – KEY QUESTIONS AND RESPONSES

A. Why should we want to establish human colonies beyond Earth?

1. To allow humanity to survive
    a) a non-avoidable catastrophic natural disaster (e.g. monster asteroid, existential-scale pandemic, death of the sun)
    b) if we are unable to prevent humanity from making earth unlivable
        i) by precipitating some sort of terminal ecological collapse
        ii) as a result of some deliberate or accidental technologically-driven catastrophe
        iii) through warfare or other massive and terminally lethal conflict
2. To allow humanity to continue to grow economically indefinitely
3. To allow humanity to realize its innate imperative for exploration and discovery
4. To allow humanity to contribute to the greater universal good

B. Options for human extraterrestrial colonization

I. Colonize Mars and the habitable rocky moons and asteroids
2. Build very large sun-orbiting habitable structures, using asteroids as raw material
3. Build Dyson spheres or comparable structures enclosing the sun
4. Colonize extra-stellar solar systems, using any of the approaches 1-3
5. Colonize using any of the approaches 1-4 as nanoscale superintelligent AIs rather than as current humans

C. The range of assessments of the possibility and desirability of extraterrestrial colonization

Within the Solar System:

1. It can likely be possible and is a worthy or even imperative goal
2. It can likely be possible but the costs outweigh the benefits and is thus not worth striving for
3. It is unlikely to be possible but it is still useful, worthy or imperative to set and pursue it as a goal
4. It is unlikely to be possible and won't make a big difference either way if humanity sets it as a goal or not
5. It is unlikely to be possible and it is undesirable or even dangerous for humanity to set it as a goal

Beyond the Solar System:

1-5. All the same assessments, with the caveat that we can likely demonstrate objective impossibility

Beyond the Galaxy:

1-5. All the same assessments, with the caveat that we can very likely demonstrate objective impossibility

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F.5.e. HUMAN GENETIC MODIFICATION FOR EXTRATERRESTRIAL TRAVEL AND COLONIZATION

I. Varied Proposals: Scientists interested in long duration human space travel, typically considered in the context of extraterrestrial colonization, know that all known natural extraterrestrial environments are lethal to humans and that the creation of mechanical sustaining environments is a daunting challenge. Several have suggested that humans might be genetically modified to make extraterrestrial survival less difficult, and human genetics scientists have been more than happy to collaborate in thinking through the possibilities and to begin conducting some preliminary studies. Suggested human genetic modifications for extraterrestrial travel and living include:

* Make human cells resistant to pervasive radiation with extra copies of gene TP53, which helps prevent cancer.
* Add the EPAS1 gene, common among Tibetans, to allow astronauts to get by on less oxygen.
* Add the LRP5 gene associated with increased bone density to counter long term bone loss from micro-gravity.
* Add the muscle-mass enhancing MSTN gene, to counter atrophy from extended periods of low gravitation.
* Add the MO53 variant that has anti-inflammatory effects in radiation-induced pneumonias.
* Add genes associated with low anxiety, such as PDE4B.
* Add the DEC2 gene which is associated with high performance under conditions of little sleep.
* Add genes associated with problem-solving skills and other cognitive traits, e.g., APOE, TERT and APP.
* Add genes known to relieve increased intracranial pressure (ICP) on eyesight and performance.
* Genes associated with very small stature, which would decrease many costs of extraterrestrial habitation.
* Modify the genes of the microbiome that coats our skin, to povide radiation protection.
* 250 Genes that would enable humans to live off of sugar water, as "autotrophs," synthesize vitamins, amino acids and other life-critical nutrients we currently get from eating plants and animals.
* Genes to allow astronauts to perform their own photosynthesis and turn light, water and CO2 into food.

Sources: Regalado (2017), SpaceGene.com (2018), Achenbach (2016), Mason (2016), Veritas Genetics.

II. Christopher Mason: *500 Year Plan* for human genetic modification to allow extra-terrestrial colonization.
Dr. Christopher Mason, Professor of Physiology and Biophysics, Weill Cornell Medicine, and members of his lab have prepared a **500 year plan** for ensuring human survival and beneficial role in the universe by colonizing many habitable planets with human beings genetically modified to thrive under a range of conditions. His proposal is summaried here:

A. Proposed long-term goals of the human species:

- Establish colonies in multiple star systems, to avoid extinction due to a cataclysmic event in 1 solar system.
- Improve the ability of humans and other species to survive in spaced-based environments or other planets.
- Compile a "do-not disturb" list for the human genome; regions that cannot or should not be altered.
- Engineer mammalian insulators that can carry genetic payload safely.
- Establish long-term safety, efficacy, and functional characterization of engineered genomes.
- Improved DNA damage detection and repair (via *Deinococcus radiodurans*).
- Protective technology (e.g. Nano-fabrication of radiation absorbers).

B. Proposed timeline for adapting humans to extraterrtrial environments:

Phase 1: 2010-2020 - Basic genetic research, focused on space habitation-relevent genes.
Phase 2: 2021-2040 - Gene sequencing is cheap, accurate. First efforts to change mammals for space habitation.
Phase 3: 2041-2050 - Begin long-term human trials of genome engineering.
Phase 4: 2051-2060 - Test protected human genomes in space environments.
Phase 6: 2060-2100 - Begin settlement of other planets and genesis of synthetic genomes.
Phase 7: 2101-2150 - Expand new genomes to tolerate extremely cold/hot and acidic/basic environments
Phase 8: 2151-2300 - Send new genomes (panspermia) to begin seeding of Earth-like planets
Phase 9: 2301-2400 - Begin shipment of humans to these new worlds
Phase 10: 2401-2500 - Human settlement of a new solar system, used as a model for future systems
Phase N (End of universe) Determine if we should prevent the implosions/entropy death of the universe, or allow self-destruction in the expectation that life will arise again.