To Each According to Their Space-Need: Communes in Outer Space

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Abstract

Space settlement advocates frequently argue that we will soon be able to settle humans in space. Surviving on Mars is clearly a pre-requisite to settlement, and much work has been done examining the engineering aspects of this endeavor. Less work has been done on how to arrange a society in space. How can settlements pick members who are likely to contribute? How will they retain their most talented members, and how can social stability be attained? The literature on space settlements frequently posits that early settlements are particularly likely to be communal. This paper explores lessons from three major communal movements: The Hutterites, kibbutzim, and 60s-era communes. It evaluates the nature of social constraints and discusses how they may differ in the space environment.

Keywords

Space settlement

Mars

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Society

Kibbutz

Hutterite

1. Introduction

Are space settlements finally about to become a reality? In the US at least, interest in space settlements is increasing, and a handful of powerful stakeholders may be in a position to make settlements in space a reality. Two of the richest men in the world are dedicated to human settlements [1–4]. Elon Musk has claimed his company, SpaceX, may be able to get humans to Mars by 2029 [3], and suggested it may take only two to three decades to get a self-sustaining settlement of approximately one million people established [5]. Government officials argue that space settlement is an urgent need as well. For example, a 2022 report from the United States' Defense Innovation Unit claims a New Space Race with China has begun, and "…seeks to achieve nothing less than the permanent establishment of the first off-planet, human settlement…" [6]. Despite significant technological, biological, legal, geopolitical, and ethical hurdles that still remain [7–15], momentum toward space settlement appears to be building.

However, while the technology and capital may be moving toward readiness, attention to social systems for space settlements has lagged behind. Surviving on Mars is certainly a pre-requisite to settlement, but there are psychological and social factors that need to be considered as well. Early habitats will be cramped, settlers will be isolated from family and friends back home on Earth, uncertainty about the health risks of living in space may generate anxiety, and technological malfunctions could result in death. Reducing social stress by, for example, picking the right social model for a settlement is critical. Although much science fiction has been written about social science for space settlement, as have quite a few speculative articles, very little of

the work done by the space settlement community has been informed by models that are already well-studied by social scientists.

Communes are one social model for early settlements that is frequently proposed in the space literature. For example, a 2019 book published by The Mars Society included 22 proposals for how to start the first 1,000 person settlement on Mars, and around 25% of the proposals either called for a commune-style settlement directly or emphasized that many aspects of life would need to be communal [16]. Additionally, a questionnaire given to volunteers for a year-long Martian settlement simulation found that the values of these volunteers were more similar to scores obtained when these questions were asked to real-life communards than when the questionnaire was given to a more general population [17]. Thus, it appears that at least a subset of both the people planning early settlements and those potentially interested in populating those settlements are interested in communal living. However, we were able to find few studies that actually engaged with the social science literature on communes to extract lessons for life in space, and the studies we did find focused on a limited set of features from the kibbutzniks [18–20] and Hutterites [21].

So why communes? Communal resource usage can function as a kind of insurance policy for existence, which is especially valuable in hostile environments where the goal is more about surviving than absolute efficiency [22,23]. As long as there is enough to go around, equal sharing means everyone has the basics – food, water, shelter, and in some cases things like healthcare, childcare, and physical defense. Communes benefit from economies of scale [23] where, for example, it is cheaper (on a per-person basis) to build a big kitchen used by everyone than it is to build a separate kitchen for each person or family. Given the high cost of sending goods from Earth to space [24] and the time it will take to get on site manufacturing up and running,

efficiency and the sharing of goods will be necessary in early space settlements. Additionally, communes offer strong social ties and a common goal [23], which could be beneficial both psychologically and sociologically.

To clarify why reducing social stress will be critical in early settlements, we begin by briefly discussing some of the difficulties that will be faced by early settlers. Next, we explored the literature on communes and examined a specific set of social issues encountered on Earth which are likely applicable to communes in space. That is, how does one pick members who are likely to contribute as much or more than they take from the commune, how does one make sure everyone in the settlement continues to contribute, and what can settlement planners do to help retain their most talented members? Here, we explore what lessons, if any, can be learned regarding these questions from three large, and well-documented, communal movements: the Hutterites, kibbutzniks, and the 60s era communes.

2. A Sampling of the Many Hardships of Life in Space

The most frequently proposed locations for space settlements are the Moon, Mars, or in rotating space stations [16,25–31]. For any settlement beyond Earth's protective magnetosphere, settlers will need to protect themselves against space radiation, which differs from the kinds of radiation we typically encounter on Earth [32,33]. While we currently have a limited understanding of how these types of radiation impact the human body [34], suspected risks include increased rates of cancer and cardiovascular diseases and problems related to reproduction [35–38]. Thus, early settlers may grapple with anxiety related to health risks, while perhaps also dealing with radiation-associated debilitation or death. A common proposal for protecting settlers against space radiation is to take the regolith (i.e., a surface layer of jagged

dust and fines) found on the Moon and Mars, and place a few meters of it over the habitat to reduce the radiation that reaches the inhabitants [39–41]. Alternative proposals recommend achieving shielding from radiation by placing habitats inside of the lava tubes found on the Moon and Mars [29,42].

Habitats on the Moon and rotating space stations would also be surrounded by almost pure vacuum, exposure to which would be lethal [43]. This risk would likely be on the minds of settlers, as the only people who have died while in space are Cosmonauts Viktor Patsayev, Georgiy Dobrovolskiy, and Vladislav Volkov, who likely died of massive brain hemorrhaging during the *Salyut-1* mission in 1971 when an equipment malfunction exposed them to the vacuum of space [44]. Mars is little better. The pressure from the Martian atmosphere is only one percent that of Earth [45], so decompression that could not rapidly be sealed off would be lethal there as well. In any of these off-Earth options, anyone wanting to explore outside of the habitat would need to put on a pressure suit – a time-consuming process, requiring training.

A third problem is gravity, or the lack thereof. The Moon and Mars have 17% and 38% of the gravity found on Earth, respectively [46]. On the International Space Station (ISS), where everyone is in a constant state of freefall, one study found that four months in space was associated with a loss of bone mass in the spine of one percent per month [47]. Another study found that, despite a weekly exercise regimen that included approximately five hours of aerobic exercise plus resistance exercises, calf muscles shrunk by 13% after six months in orbit [48]. How a human fetus or developing child would fare developing under these conditions is unknown. It is also unclear whether the partial gravity supplied by the Moon and Mars would eliminate this loss of bone and muscle, or if some combination of partial gravity, exercise, diet, and medication would be sufficient. If life in partial gravity does result in unavoidable losses of

bone and muscle, people residing in space for long periods of time or children born in space may not be able to live comfortably (or may not even be able to survive) under Earth gravity.

A recently developed device (that simulates gravity by rotating) flown aboard the ISS showed that mice living under simulated Earth gravity for 35 days had similar bone density and muscle weight relative to controls that remained Earth-bound [49]. Stations rotating in open space could simulate Earth gravity, or whatever gravity regime ends up being the minimum necessary to keep humans healthy [50]. If partial-Earth gravity turns out to cause serious problems for long-term survival or the survival of offspring, rotating space settlements may be the best way forward. The environment of space thus has the potential to constraint the ability of early settlers to leave, and/or the kinds of habitats in which we can safely sustain ourselves.

Even if settlers are physiologically capable of safely leaving these other worlds, they may not be able to do so at a given time, due to distance, cost, and in the case of Mars, the fact that the orbital "window" is not always open. The Moon is a relatively short trip from Earth, with Apollo missions arriving at the Moon after only about three days. The Moon is thus close enough for communication to happen in near-live time. Mars, on the other hand, is quite a bit farther and its distance from Earth is not constant. A trip to Mars is projected to take about six months, and because of orbital mechanics the window to start this journey only comes around every two years or so [51]. Communication delays from Earth to Mars will range from three to 22 minutes, depending on where Mars is in its orbit relative to Earth [52]. Trip times and communication delays in rotating space stations will depend on where the station is situated, but at least one proposal puts the station in Equatorial Low Earth Orbit where settlers could return home quickly and communication could happen in live-time [28]. However, even under favorable conditions in orbital mechanics, finance may prove difficult. The current cost to put objects into low Earth

orbit is still over a thousand dollars per kilogram aboard a Falcon Heavy [24]. Delivering mass to more distant locations is substantially more expensive. Even with large cost reductions, a return ticket to Earth is likely to remain very expensive for a very long time. Early settlers will therefore be quite isolated from the family and friends left behind on Earth, potentially raising the stakes for the social interactions happening within a settlement.

Due to the cost of shipping goods from Earth to settlements in space, it will be imperative that settlements become self-sufficient, especially with matters that pose immediate danger to survival. Settlers will need to grow their own food, leverage plants to scrub carbon dioxide from the air and generate oxygen, and recycle waste efficiently. The science for creating these closed-loop ecologies is still in its infancy, and very little is known about how to build them reliably at scale. Many very basic problems await solutions. For example, growing plants in the regolith found on Mars and the Moon will be difficult. The lunar surface lacks enough carbon, potassium, and phosphorous for agriculture [53]. Earth will have to provide supplementary minerals, which lunar settlers will then need to recycle with great care.

However, simply supplementing regolith does not seem to be sufficient to make it into an ideal growth medium for plants. A 2022 study found that *Arabidopsis thaliana* planted in lunar regolith supplemented with nutrients and water grew poorly and showed signs of stress relative to plants grown in comparable Earth soil [54]. Regolith on Mars is somewhat more Earth-like, and would require less supplementation, but has the downside of containing perchlorates (a chemical that interferes with thyroid hormones) and other toxic salts [55,56]. These would have to be removed before the regolith could be used for growing food. Because of the difficulties associated with using regolith as a growth medium, hydroponic or aeroponic gardening may be preferred. Animal sources of food will also be problematic. Given the size and difficulty of

maintaining farm animals, experts suggest protein in early settlements will likely come from insects or cellular agriculture (i.e., where cells and nutrient solutions are placed in bioreactors to grow things like meat) [57].

Science currently knows very little about how to operate these closed-loop systems efficiently at large scale, though there have been several small-scale projects. For example, Japan's Closed Ecology Experimental Facilities (CEEF) was able to grow enough food for two inhabitants and their goats, but they had difficulty generating enough oxygen [58]. In China's Lunar Permanent Astrobase Life-support Artificial Closed Ecosystem (PALACE), the goal was to create a life support system that generated and recycled food, water, and breathing gases. They were able to grow 78% of the fresh weight of the crops and insects consumed by the participants [59]. In PALACE, crops were only able to scrub enough carbon dioxide and create enough oxygen after two of the men on the three-man crew were substituted for two smaller, female members [60].

We currently lack the know-how required to create the kind of self-sustaining system that would be required for a large settlement, but we can predict with a fair degree of confidence that the maintenance of such a system would be time consuming. In the USSR's BIOS-3 closed system, which did not even tackle the task of recycling waste and supplemented the crew with outside foods like meat, the crew spent 20% of their time on maintenance tasks [61]. Maintaining the system in Biosphere-2, a 3.14 acre facility in Arizona which is substantially larger and more developed than anything we can expect to build in space in the near-term, took an eight person crew eight to ten hours of work per day for five and a half days a week [62]. Despite this time investment, the crew was not able to produce enough food and lost weight [62,63]. These examples highlight the importance of selecting the right members for early settlements – as early

settlers need to be committed to putting in the long hours necessary for tasks like sustaining life support systems.

While it is clear that space settlement science has much work to do, it is on much sounder footing than space *social* science. If space settlement is imminent, as some advocates claim, then we need to begin investing in space social science now. Among some advocates for space settlement, a common view is that we should simply let the settlers work out their problems. But given the difficulty of space settlement, the long hours that will need to be spent maintaining the settlement, and the need to work together, any ability to predict sociological conditions would likely be valuable. While predicting human behavior is difficult, communes on Earth have had a surprising level of commonality through time and space, much of which has been documented and analyzed by social scientists. Communes are a model that is both proposed by space settlement advocates and well-studied by economists and sociologists. Thus, they present a rare opportunity to both provide a detailed analysis of problems that might actually arise if a particular social structure is picked for a settlement, as well as a look at solutions that have been found for these problems on Earth.

3. A Very Short History of Communes on a Planet with Air

Because the terms are sometimes confused, we note that communes are different from a communist government in that communes are small voluntary arrangements, not overarching governance structures. For the purposes of this review, we define "commune" as a social arrangement, typically oriented around a farm or factory, where everyone shares the work and shares equally in the benefits. Although communes can differ considerably in the extent to which

they allow their members to own personal property, they can be strikingly similar across contexts. Commonly, group ownership applies to many things considered private in the outside world, such as housing, cars, equipment, food, and money [64].

Many approaches to communal life have been taken, but only two large modern communal movements managed to thrive for over a century and still exist in some form – the Hutterite Anabaptists and the Israeli kibbutzniks. Here, we also consider 60s era communes, which had comparatively less success, and whose struggles are often illustrative. These communes tended to disband in short order, and those that persisted typically held onto their members for months or years, rather than generations. This makes so-called "hippie communes" an inferior model for settlements, where the eventual goal is to have *generations* born in space and residing together. However, we include these here because, as we will describe below, there is substantial overlap in the kinds of social problems encountered in all three of these movements.

2.2. The Hutterites

The Hutterites, Amish, and the Mennonites share a theological origin in a 16th century movement called "anabaptism" which gets its name from the insistence on voluntary adult baptism as opposed to child baptism [65]. Two social institutions that separate the Hutterites from other Anabaptist traditions may be especially relevant for space-communards. First, there is no direct bias against technology [65,66]. The term Hutterite actually encompasses three or four different groups who have more or less conservative traditions [67], and one way that they differ is in the extent to which they view technologies as appropriate for communal living [67,68].

Particularly among the less conservative groups, Hutterites tend to embrace modern technology for agricultural, industrial, and domestic use, sometimes operating state-of-the-art computerized processing facilities. They are not opposed to technology in general; only to technology that facilitates the penetration of worldly values into their community. Hutterites are biased in favor of *community*, which often leads to a ban on certain devices. One story speaks of a Hutterite commune where the hogs got thermostats before humans [23]. Why? Good indoor temperatures mean fat hogs, which is good for business. But good temperatures where *humans* live may mean they are more likely to stay at home and not engage with the rest of the community.

The second distinctive Hutterite cultural institution is communalism. They have a concept they call the "community of goods" [69] which basically means they share everything and live in small communal settlements rarely numbering over 200 people at any time. For Hutterites, communal life lies at the center of their identity, more so than any other theological belief. To leave the colony is to leave the church. For example, some of the Hutterites, known as the *Prairieleut,* settled on individual farms after coming to America and did not practice community of goods. They soon lost their identity and became indistinguishable from the Mennonites amongst whom they lived [70].

The history of the Huttererian Brethren is one of success followed by persecution followed by success in seemingly endless cycles [65,71]. Persecution in Europe motivated a migration of Hutterites to North America between 1874 and 1876 [65,72,73]. They have grown in population since, albeit with legal issues from time to time (generally having to do with simple bigotry or disagreement with their pacifist refusal to join the military) [64,73]. Hutterites have grown to around 50,000 and run thriving agricultural operations in the US and Canada, making them easily the most successful still-existent communal movement [67,74]. The success of the

Hutterites is no accident either – as we will explore below, this success was accomplished with a complex set of internal rules and values that are inculcated from cradle to grave.

Is this a good model for space? One problem for many potential space settlers will be that Hutterite culture is extremely traditional, especially when it comes to gender roles [65,75]. For example, their leadership and voting rights are exclusively male [65,75]. These communities have a hierarchy composed of elected officials, with the Minister serving as the final arbiter in disputes. They are also profoundly religious in a way that the average spacefarer likely will not be. A good question to ask for space settlement is whether the deep structure here can be adapted without the patriarchal religion. It may not be able to. At the very least, as we will later argue, strict religion likely has value on communes that should not be ignored.

2.3. The kibbutzniks

Kibbutzim are Jewish communal settlements that started in the early 1900s, and grew more rapidly in the 1930s and 1940s as Jews fled persecution in Europe and Russia [23]. Although some of these settlers intended to live alongside the Palestinians, their Socialist ideology often contrasted with their Zionist mission. As with Hutterites, in discussing them we do not mean to justify any particular behavior or social norms.

Most kibbutzim were secular, but some were religious, with the major unifying features being Jewish identity, Zionism, and socialism [23,76–78]. Kibbutzniks were highly communal, initially even having communal child-rearing in most cases [76–80]. They tended to be larger than Hutterite communes – generally 100 to 1,000 people lived in each [23,78]. Like the Hutterite communes, kibbutzim have largely been agricultural in focus, though with notable

exceptions. But, while the kibbutzim retained communalism for many years, things began to change in the 1980s [22,23,81–84]. Today, the vast majority of these communities are no longer strictly communal in the sense of completely equal sharing [22,23,82]. The great socialist dining halls now scan credit cards, and employees are paid differential wages based on the work they do [22,23,82]. One author who volunteered as a young man at Kibbutz Shamir was surprised years later to find the company Shamir Optics listed on the Nasdaq [85]. But the kibbutzim had nearly a century of survival, and many of the conditions that led to decommunalization had to do with the development of an advanced local economy nearby. The present lack of such conditions in space, coupled with the potential for space settlement to develop into a proper city, may make the case of kibbutzim particularly insightful for space communities.

2.4. 60s Era Communes

The 60s era's so-called "Hippie Communes" were quite diverse - some of these communes were more urban, some were rural, some were religious, some were secular, some were utopian while others simply wanted to drop out of mainstream society [86]. Depending on how you count, there were somewhere between 500 and tens of thousands of these communes [74,84]. Although few survived to the modern day, many left commune-influenced institutions in their wake, including Habitat for Humanity, co-ops and organic farms, and what you might call 60s-influenced homeowners' associations [74,84]. In the few remaining communes from this era, members tend to come for months or years to experience a new way of living, but rarely do they and their children spend their whole lives. For example, founded in 1967, Twin Oaks is a still-existent commune in Virginia. In 1993, there were about 100 individuals living in Twin Oaks,

with around 40 members having lived there for over five years and only nine having lived there for ten years [87].

What is most interesting for our purposes is that some 60s era communes *are* still around today, and they survived without religious motivations or being a particular identity group. However, the few surviving communes from this period survived because of factors that are not typically associated with the hippie stereotype. For example, Twin Oaks has a complex governance structure, a credit system that somewhat resembles money [87], and a lengthy handbook of policies for communards [88]. It is not a utopia, nor is it the worldwide economic revolution some 60s communards envisioned, but for space settlement purposes, these communes at least provide a proof of concept for a diverse, secular communal setup.

3. Social Lessons - What Common Social Problems are Faced by Communes, and How Do They Deal With Them?

In Ran Abramitzky's 2018 book *The Mystery of the Kibbutz*, he attempts to explain the persistence of socialist Israeli communes using modern economic theory. If humans are inherently self-interested, how *do* you get them to work together and share nearly everything? And how do you use their social, non-self-interested, nature to support cooperation? In his study of Israeli kibbutzim, Abramitzky identifies three major commune struggles (adverse selection, free-riding, and brain drain), and the methods used to overcome them. Here, we examine the three communal movements described above under the lens of this framework, while keeping an eye toward how the framework may apply in a space settlement.

3.1. Problem 1 - Adverse Selection

While opening the door to space communes to anyone who is interested in joining and can afford the trip may sound desirable, it turns out that successful communes on Earth do not typically have open door policies. Sixties era communes are particularly illuminating here, as communes with lower or less stringent standards attracted runaways, criminals, and people experiencing mental health crises – which sometimes resulted in unsafe conditions for these individuals and for the rest of the community [86]. Long-standing communes have learned that there are many people who would like to benefit from communal resources, but are not planning or are unable to give back as many resources as they are likely to extract from the community. Kibbutz anecdotes include stories of people who do not want to be communards until they have five kids and find out they can get free childcare, or people who decide they are tired of capitalism and would prefer to live in a community with more sharing once they reach retirement [23].

While all communes have ways to eventually force people out, the process is especially unpleasant in the family-like environment these places engender. And as we will describe below, forcing people out of an early space settlement may not be an option, making the initial selection of settlers who are both comfortable with sharing and willing to put in long hours especially important.

Successful communes have developed ways to preferentially select new members who will contribute more than they consume. For example, for the kibbutzim, there is an application process and interviews, involving lengthy questionnaires about the applicant and why they want to join [83]. The kibbutzim also collect data on education level, occupation, and age [83], and

often require a probationary period before full membership is attained [23,83]. Appropriately enough, another solution is the same one that may have inspired the Apollo program: “costly signals” [89]. Communes tend to demand people do things that prove they are not just trying to get free stuff, but actually care about communalism [23,90,91]. For example, a commune might demand that new members instantly sign over all possessions and savings [84]. Even this is an imperfect signal because it is more or less costly depending on how rich the applicant is. The ideal sieve is some behavior that is both hard to do and hard to fake. The most famous example of a costly signal probably comes from the Shakers, a communal Christian group founded around 1750, who required celibacy [65,92]. Hutterites have many requirements that make it difficult for new members to join, including requirements to wear traditional clothes, to learn *Hutterisch* -a dialect of German, and, according to their website, to endure the loss of “a lot of free will” [93].

Applicants for early Mars settlements may be motivated by the desire for prestige or adventure. Groups starting a commune will thus need to identify commune-specific signs of dedication to ensure they find members who are also committed to sharing resources and potentially long days of work. Part of why early kibbutzim succeeded was that many of their members were committed ideologues who had already spent years in socialist youth movements back in Europe. If the goal is communal spirit, inviting pre-existing communards, or having some system of direct signaling of ongoing devotion, may be wise. Though, if the goal is settlement expansion, maybe not the signaling method the Shakers used.

One option for costly signaling is to have applicants for a Mars settlement show their commitment to communal living by actually living communally for some period of time on Earth beforehand. Pre-existing facilities such as the Mars Society’s Mars Desert Research Station (MDRS), the International MoonBase Alliance’s Hawaii Space Exploration Analog and

Simulation (HI-SEAS), China's Lunar Permanent Astrobase Life-support Artificial Closed Ecosystem (Lunar PALACE), or the experimental isolation facilities in the Russian Academy of Sciences' Institute of Biomedical Problems (IBMP) may be ideal locations for these pre-settlement trial periods to be run. These facilities also mimic some of the difficulties of life in space, and would provide some insights into the applicant's ability to handle life in isolated and confined environments.

3.2. Problem 2 - Free-Riding

A free-rider is someone who takes out more than they put in. The best such example we found was from a 60s era commune:

"…Bill… lived in a hole in the ground at Morning Star [East Commune]… He ate nothing but pancake mix with syrup but he didn't cook pancakes, he ate handfuls of it. He would basically disappear in this hole for months and then he would come out. He never took a shower, he never bathed, he never did anything. When it snowed up there, they would lose track where Bill was because all he had was a trap door going into his hole, until one day the snow would move and Bill would come out of his hole."[86]

Bill, whose tale was surely embellished over time, is nevertheless what one might call the mathematically ideal free-rider. Bill contributes nothing while extracting calories from the commune in the form of handfuls of pancake mix. Although not all free-riders are bad people – children are free-riders, and aging members may be too - in general free-riders are a pernicious

problem on a commune. In addition to extracting resources, free-riders can reduce the morale of hard-working members, perhaps creating new free riders out of resentment. Communes are well aware of this, and they use three main approaches to reduce free-riding: surveillance, culture, and punishment.

3.2.1. Surveillance

Communes tend to be small communities. Twin Oaks has historically hovered around 100 [74,87]. Hutterite communes are small by insistence: They have a unique process, almost like cell division, where they split off a new community whenever a colony reaches 150 people [67,94]. One benefit of small communities is that regular face-to-face interactions can happen between most members, allowing a lot of surveillance to be done simply though gossip [95,96].

In addition to keeping the community small, familiarity with the various jobs done on a commune also facilitates surveillance. Many communes insist that people do tasks together. Working together may increase efficiency or provide amusement, but it is also an opportunity for direct surveillance. Finally, some communes have job rotations (Abramitzky 2018), which should give all communards a sense for how long it takes to do each job well. Early space communes may have difficulty cross-training their settlers in the same way as agricultural communes. Given the technical difficulty of space settlement, communards may need to specialize on particular tasks. That said, cross-training for redundancy of knowledge may be beneficial, both as a safety feature in case a settler with highly specialized knowledge passes away, and because it would help identify free-riding.

While cross-training may be difficult in space, surveillance is likely to be quite a bit easier. In fact, some argue that the harsh environment of space - where one bad actor could sabotage the habitat and kill everyone – may be particularly susceptible to over-surveillance [97]. This is generally considered a negative, but for the narrow case of detecting free-riders it will likely be useful.

3.2.2. Culture

Both Hutterites and kibbutzniks instill hard work as a value, starting from a very young age. Hutterites in particular drill into their kids that their personal desires need to be subordinated to the success of the group [67,98]. This is rigorously enforced, and as one book put it, "punishment is physical, arbitrary and inconsistent" [65]. Hutterites keep everyone busy and fear unemployment because, as a Hutterite proverb goes "When a man doesn't work, Satan works" [67]. This emphasis on work continues throughout a person's life, with people switching to less physically demanding jobs as they age. Another benefit of creating a new community whenever the population hits around 150 people is that it creates new jobs and opportunities, ensuring that all members of the community are always kept busy with meaningful and purposeful work. Hutterite behavioral norms are very strict, in a way that would be unusual for people likely to be early space settlers. However, space is an extremely hostile environment, where controlling deviant behavior may take on special importance [99,100]. Space settlers will have to think carefully about how to encourage cooperative behavior and team spirit while avoiding cruel and harmful measures.

3.2.3. Punishment

Even with selection and surveillance and culture, you still get a Pancake Bill from time to time. The almost universal solution is what is often called "shunning," in which members are socially ostracized on the commune. In the tight-knit communal world, where members are often friends or lovers or relatives, this can be quite traumatic. Hutterites impose what could be seen as an active process of humiliation. They might require a public confession, or there may be a demotion to a work position in the colony that is held in lower esteem. They might make a delinquent colony member stand conspicuously during worship. One book spoke of making adults sleep in the area normally reserved for children to make them "humble like a child" [65]. Twin Oaks has similar, if less harsh, policies. When members do not make their labor quota, they go in the "Labor Hole" [87]. For communards in the Labor Hole, there may be a public announcement, or they may be obligated to make a public explanation. And, although communards are given time to fix their debts, they can eventually be given probationary status and ultimately be expelled [88].

One thing that makes shunning especially effective is the promise of affection once the shunned person is brought to heel. Kat Kinkade, who helped found Twin Oaks commune in the 1960s and then left only to return again with a less utopian perspective, wrote about once being in conflict with fellow communards for bringing in a microwave without getting group consensus [87]. Following a vitriolic public meeting, Kinkade removed the microwave. Suddenly, she was greeted with overwhelming group kindness; as she wrote "I went around in a euphoric daze for weeks" [87].

We do not know how this sort of thing will play out in space, but it is important to note that physically leaving a space settlement will be wildly harder than leaving a commune on Earth. We also suspect shunning will feel especially personal and especially cruel in an isolated space settlement. Communes might need to have punishments to function, but adult communards on Earth are always, at least in a broad sense, there because they have chosen not to leave. This will not always be true of a space settlement until a lot of development has been completed. In the case of people born in space, who for example may have bodies not acclimated to full-Earth gravity, there might even be physiological constraints on their ability to leave. A shunned communard who is unable to leave may also pose a risk to the morale, or perhaps even the safety, of the rest of the community. Exactly how to enforce good behavior without being psychological torture or inciting retribution could be a difficult problem.

3.3. Problem 3 - Brain Drain

Brain drain is a sort of mirror to adverse selection. It is the selective loss of the most productive members to outside opportunity.

Suppose a commune offers housing, food, utilities, and so on, worth about $50,000 a year. This would be good pay for a low-skill worker, but bad pay for a high-skill worker. Consider a 13-year-old computer whiz born and raised on a kibbutz. At a young age, she is already a huge asset to the operation. But while the commune is only offering the equivalent of $50k for her services, she could make ten times as much at a tech firm. Effectively, she is getting a bad deal. Meanwhile, imagine there is another young person who is clearly not fit for any work

on or off the farm. Maybe, for instance, he likes to live down a hole eating pancake mix. For him, being on the farm is a fantastic deal.

Such a setup does not absolutely guarantee that all computer geeks will leave or all pancake-mix enthusiasts will stay. The computer whiz might like socialist culture. Also, according to an oral history, Bill was a particle physicist working on teleportation, so it is possible he could have dematerialize at any moment. People are complicated and communities provide intangible value of a sort that is hard to measure with dollars or shekels. For example, Abramitzky's grandmother was a kibbutznik, and he notes that, "Though she'd worked all her life as a simple seamstress, my grandmother died with round-the-clock nursing care delivered with the kind of compassion money can't buy." [23]

However, intangibles have limits, and there is a statistical tendency for more productive people to be more likely to leave, especially when they can get more money elsewhere. During 1983-1995, as the Israeli tech sector took off, 20% of kibbutzniks left, among them the most highly skilled and educated [23,83]. Tellingly, the richer the kibbutz, the more able they were to hold their membership [23,82]. That is, they retained skilled people not by socialism or familial bonds, but by being able to afford to provide a nicer bundle of amenities. Things were similar during the Alberta oil boom in the first decades of the present century when it was easy for Hutterite men to get jobs on oil rigs and for women to find employment as domestic workers or cooks in oil-workers' camps [101].

The good news for communes in space is that the usual tactic for member retention is one that Mars provides automatically: make it really tough to leave. This is hard to analyze because on Earth, communes tend to restrict their members' ability to leave via social mechanisms, not a 55 million kilometer vacuum. For example, Hutterites traditionally limit kids in the community

to the equivalent of an eighth grade education [67] (though this has changed in some more liberal Hutterite communities lately) [102]. Kibbutzim took a similar, albeit much more liberal approach, often refusing to pay for higher education unless it provided skills that would be useful back on the farm [23]. In both cases, the strategy is to increase someone's human capital without improving their ability to leave.

While the governments of communist countries have restricted the movements of their citizens [23], no commune that we are aware of creates a space-like physical barrier to exit. And this will create problems. Ideally, multiple kinds of settlements nearby and the option to return to Earth would give settlers who no longer want to be communards some choices. However, for the first settlers, this will not be the case. And, we do not yet know if babies born in space will be able to withstand the trip back to Earth and survive in Earth gravity. So the question then is whether the 13-year-old computer whiz of Mars simply recognizes the rational economic choice and stays put, or whether she comes to feel resentment at being forced to stay.

4. Religion to the Rescue?

Religion may be a solution to many of the above social problems. All things considered, religious kibbutzim tended to do better than purely socialist ones [23,91,103–105]. It is not clear why this is, but it may be that religions have natural means of dealing with commune issues.

Costly signals of socialism for instance may just be easier to fake. Socialism is a profound personal ideology, but socialists are not obligated to arise in the wee hours to pray to Karl Marx. In the context of voluntary communalism, socialism does not necessarily require one to dress a certain way or read only from certain books or limit education on certain topics.

Engaging in a religion requires a large commitment of time and effort and opportunity – something a person is far more apt to give if they actually believe in it. On the other hand, profound mission goals for early settlements – such as making humans an interplanetary species – may to some extent fill the role played by religion.

Religion can also help lower the risk of free-riding. For a Hutterite, getting expelled from the commune would mean loss of family, loss of friends, and would have potential implications for the afterlife. Religion also likely helps with brain drain because people find religion instrumentally valuable. Religion makes the overall bundle of goods on a commune more desirable in a way socialist philosophy may not. This may help retain a few more of those computer geniuses, all things considered.

Religion-based communes are certainly not without problems. Like economic entities, religions compete for members. A major modern problem among Hutterites is not the intrusion of technology, but losing members to evangelical Christianity [66,67]. In any case, even if a settlement planner thinks religion is good, they can not just go to a group of space settlers and say "for the sake of cohesion, you are all now Hutterites." But if communes are a good survival mode in space, and among them religious ones are more likely to survive, their disproportionate success would affect off-world culture over the long-term.

5. Discussion

In this review we have explored only one facet of communal living that may be relevant to early space settlements. We suspect that those interested in planning for early space settlements could fruitfully explore the literature on communes for additional lessons as well. For example,

communes on Earth frequently interface with the world outside the commune. Sixties-era communes have generated funds by doing things like selling soy products, taking jobs outside the commune, setting up a publishing house, selling hammocks to Pier One, and when times got tough could often rely on welfare [84,86]. The Hutterites have sold their goods to Costco and other retail stores [67]. The cost of communal living in space, where equipment is needed just to generate clear air to breathe, will be much higher than the cost of communal living on Earth. We suspect a Hutterite community on the Moon will not be price competitive if they need to ship their goods through the void of space to get them to Earth's market. This suggests that communes may only be viable if, for example, they are established after other communities are established first (e.g., a research station to which produce can be sold), are able to engage in remote work, or can generate intellectual goods. Twin Oaks offers book indexing services, for example, which could be accomplished in space as well. Exploring the dynamics of communes that produce goods which could be viable to support a space settlement may be a worthwhile research direction.

Another problem is what will happen to people who want to leave the commune. Hippie communes experience particularly high turnover [86], and Kinkade described years where a full 25% of all members left [87]. She did not think it was entirely a bad thing either – mass exodus often occurred after large difficult decisions, and the loss of angry members functioned as a sort of pressure valve [87]. People leave Hutterite and kibbutz communities as well, with Hutterite attrition rates hovering around 15% in recent years [67,73]. And sometimes fervor for the cause lessens across generations. As one man who grew up on a kibbutz recalled: "My father was prepared to work without personal incentives. I needed the motivation of interesting work. My children quite simply don't see why they should support others." [23] Leaving space to return to

Earth would be a quite costly endeavor, and if the settlement is on Mars, would-be emigrants may be stranded for months or years depending on when the next appropriate launch window will occur. If they were born in non-Earth gravity, it may even be physiological impossible for them to go to Earth. Ideally, there will be other options, such as other settlements nearby to which the disillusioned communard could migrate. If no options exist, resentment could cause problems both for the individual who wants to leave and the community as a whole.

If the population size and/or immigration between communities remains low for generations, then small, isolated communities in space may need to confront the genetic perils of inbreeding. This has been a problem for the Hutterites, and has resulted in the keeping of a genealogical record to enable them to monitor and control relationships. Marriage between cousins is forbidden and marriage between second cousins is discouraged [67]. Similar mechanisms may be necessary in space, with genetic diversity a key requirement for would-be space settlers.

But it should be noted that communes can sometimes evolve to create their own alternatives. Consider "Damanhur", a movement founded in 1975 by followers of Italian mystic Oberto Airaudi [84]. A Google search of "Damanhur" will repay you with images of gorgeously painted rooms, decorative columns, and high ceilings. What is not immediately obvious is that all of this is underground, constructed in secret over more than a decade, only revealed to the public in 1992 during a spat between members [84]. According to one author, the original communal structure might have been the only way to accomplish the goal, which required the purchasing of a large piece of land and paying for a complex and artistic construction project – a massive outlay of time and money that none of the individuals could have achieved alone [84]. But, having completed their goal, they transitioned to a less communal system. Today,

Damanhur is privatized, and runs on sales from agricultural products and art [84]. Similarly, kibbutzim started as communal farms, with equal sharing of resources and communal ownership of property, but over the years they adopted to changes in their external environment, including transitioning to industry, shifting away from full equal sharing, becoming less communal, and recently even discussing private ownership of property [22,23,106,107]. Perhaps space communes will make similar transitions, taking advantage of the way communes help pool and distribute resources early on, then becoming more typical market-based entities when resources are more plentiful.

People who are interested in communes, like people interested in space settlement, often come to the table with ambition to change the world, by setting an example or becoming a new branch of human society. The dream does not always come to fruition in the exact way it was imagined, but even when they fail, these experiments in communal living have sometimes left behind institutions that would have made their founders smile: surprisingly egalitarian communities or especially ecologically-minded villages. Often, the legacy of time spent on a commune is an expanded view of human possibilities. And perhaps that should be enough. If you believe the human future lies in space, the institutions created early on may shape that future, even if they ultimately change or fall away. As commune scholar and lifelong communard Yaakov Oved once wrote, looking back over two centuries of commune history, “Even if the communes have not succeeded in realizing utopia, some of them have served as workshops that have prepared their members for the possibilities of alternative ways of life.” [84]

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