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There is a lot of discussion about humans returning to the Moon.

- **What would that return look like?**
- **Who would go, and what would they do?**
- **What equipment would they need?**
- **What would they be able to do?**
- **What would this crew look like?**
- **Who is absolutely necessary?**
- **What skills are critical, and which are nice to have?**

Our Return to the Moon: Initial Considerations

George Zamka

Former NASA astronaut

- STS - 120
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Return to the Moon

Excitement is building about the prospect of human return to the Moon. We have images and broad concepts of what a Moon village may look like, but how well any concept works over time will depend greatly on how well humans are set up to succeed. Any operation on the Moon would necessarily be complex. As system complexity increases, risk of failure increases. The presence of humans will increase the probability of success of the mission, as humans provide flexibility and adaptability to combat failures in complex hardware and failures of imagination. An example is the contingency repair made to a damaged solar array on the International Space Station. The failure mode was unanticipated; a tear in the array caused by a frayed guide wire during extension of the array. Ground and Flight teams developed a repair concept, manufactured "cufflinks" to span across the torn portions of the array, and conducted a contingency repair, restoring structural integrity to the array and full electrical power to the ISS. Without the crew, the array would have been left in its partially deployed state, yielding reduced power and adding structural concerns that would lead to other degradations. An operation on the surface of the Moon will require systems of systems with many failure modes. Some of these will be anticipated, others not, and a human crew improves the chances for mission success.

Our Mission on the Moon

The first flight back to the Moon is likely to have a primary mission of establishing a presence to

which others could return. A secondary mission would likely be a demonstration of the capability or process that future Moon visitors will likely perform for economic or non-economic purposes. This would test concepts and equipment, help discover unforeseen challenges, and generate sponsor or investor confidence. Examples of this may be Extra Vehicular Activities to construct, explore, or harvest resources and robotic activities to do the same. Robotic operations are highly beneficial and carry less safety risk, but also have less flexibility to perform unanticipated tasks.

The Mission Crew

What kind of people would make up this crew? Generally, you need people who are adaptable, take the initiative, and are resilient. Adaptability allows the crewmember to live, work, and support others under suboptimal conditions. Routine tasks are more complex in less than 1 g, while others are simpler. Adaptable people take what the environment gives to them, and adjust their habits to the rest. Initiative is required to foresee all the needs of the mission, the crew, and the individual crewmember. Lethargy or indifference can be fatal. Initiative brings readiness, preparation, and efficiency, while lack of initiative amplifies hazards and risks. Initiative results in having the right response, with the right people and the right equipment, at the right time. No matter the depths of preparation preformed by the ground crew and managers, no amount of foresight will account for every contingency. A crew with good observation skills and initiative will prepare for all the hazards that become evident only *in situ*. Resilience is critical. Set backs will happen, mistakes will be made, malfunctions will occur. The crew must be able to emotionally detach from the upsets and optimistically orient themselves to new situations so that they can function optimally and not further degrade the situation.

Critical Skillsets

What general and specific skills would the crew require? A crew's highest priority is survival. If the crew dies, the mission dies. Critical skills, therefore, are those needed for survival. These include daily routine skills such as food preparation, hygiene, and waste management. Longer-term skills include facility and vehicle maintenance, and stores and supplies management. Another critical skill is the ability to diligently respond to emergencies like fire, loss of pressure, and toxic release. Emergency medical response is also a critical task. If we assume that every crewmember is critical, then the loss of any one individual is a critical failure likely increasing the risk of a mission abort. Additional mission skills would be associated with the experiments and processes ongoing during the mission. Much of the equipment would be relatively new and subject to failure. A properly trained and equipped crew can repair equipment and restore or repair broken equipment. Redundant skills spread among a crew

Our Return to the Moon . . . (cont.)

with diverse talents make for a resilient human complement to a Moon mission.

Why Return to the Moon?

The Moon is the ideal near-Earth celestial body for development of deep space operations. It takes days, not months, to return from the Moon, which enhances safety as compared to Mars. At one-sixth the gravity of Earth, it requires less energy to land on and launch from than Mars. The Moon is extensively mapped and has areas of water ice that can me used to make fuel. The Moon is, logically, the first celestial body that will have a permanent human outpost, whether it's a civil government mission or a private venture. In either case, issues affecting the crew, their interface with machinery, and their roles in the mission should be thought out well in advance. We should think about that now as fervently as we think about policies and concepts.

Kathleen D. Toerpe, PhD

Editor

Astrosociological Insights

In this Issue

George Zamka has aptly set the stage for this issue of *Astrosociological Insights:* the challenges of creating off-world human settlements - experimental, temporary, or permanent - on the Moon, Mars, space stations, or eventually, extra-solar planets. These challenges - and the questions they elicit - are many, are intertwined, and are far reaching.

- What assumptions, justifications, or rationalizations are being made about the need for human off-world settlements?

- Should terrestrial social institutions (family, government, religion, etc.) be adapted for off-world settlements? If so, how and in what form? Should this process be planned or allowed to occur organically?

- How will economic factors (supply/demand, competition, profit motives, etc.) affect if, where, and when off-world settlements are created?

- What role does nationalism and politics – both domestic and global – have in the creation, success, or failure of human settlements in space?

- How can both historical lessons and contemporary research analogs be used to predict and address the social and cultural challenges of creating off-world settlements?

In This Issue . . . (cont.)

- How can science fiction, gaming, and the performing arts help us to visualize, model, and mediate these challenges?

- What are the foreseeable human physiological and psychological changes that will ensue from humans living in space settlements?

- What laws – both domestic and international – already exist or are needed to promote equal access, to mediate property rights, nationalist claims, etc.?

- How do issues of inequality and privilege affect who is chosen, where settlements are established, and what groups or individuals lead the process of settlement?

- What have we learned from nearly twenty years on the International Space Station that can guide us in creating successful off-world human settlements?

These are just our *initial* questions about human space settlement, borrowing from the historical analogs of human settlements on Earth. Precursor or alternative missions employing robotic or AI crews will be likely, while more fanciful scenarios such as devising long-term cryogenic travel or intergenerational worldships pique our individual and collective imaginations. The sky is, literally, the limit.

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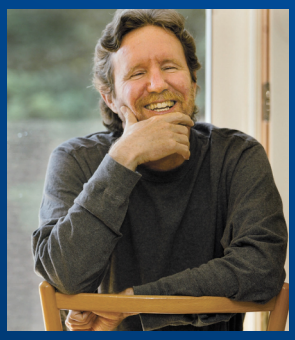
What is the Minimum Size of an Early Space Settlement?



Al Globus

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A pair of NASA Ames/Stanford studies [1] [2] in the 1970s suggested that it was possible to build cities in space – spacecraft big enough for 10,000 people to live in. These settlements would rotate to provide 1g of pseudo-gravity to the inhabitants. Space settlements like these have never been built, in part because they have a mass of millions of tons – mostly radiation shielding - and are located at lunar distances from Earth. The smaller and closer the first orbital space settlements are, the easier they will be to build. However, how small is too small?

Since the NASA Ames/Stanford studies the minimum size has been driven by the need for 1g of pseudo gravity created by rotation. It was believed that rotation rates greater than 1 or 2 rpm are the most that could be tolerated by settlers. These rates correspond to a 1,790 m (1 rpm) or 450 m (2 rpm) diameter. There is some concern that this is a very small place to live, particularly when taking a trip elsewhere is expensive.

When exposed to rates much greater than one in a rotating room, many people do get sick. However, the rotation literature clearly indicates that people habituate fairly quickly, usually within a few days. Based on a literature survey [3], modern recommendations for settlement rotation rate are as follows:

- Up to 2 rpm should be no problem and require little adaptation.
- Up to 4 rpm should be no problem but will require some training and/or a few hours to perhaps a day of adaptation.
- Up to 6 rpm is unlikely to be a problem but may require extensive training and/or adaptation (multiple days). Some particularly susceptible individuals may have a great deal of difficulty.
- Up to 10 rpm adaptation has been achieved with specific training. However, the radius of a settlement at these rotation rates is so small (under ~40 m for 7 rpm) it's hard to imagine anyone wanting to live there permanently, much less raise children.

This places the lower bound on the diameter of a settlement at 112 m (4 rpm) or even 50 m (6 rpm). First, this means that concerns regarding the livability of small settlements are even more acute. Second, it means that rotation rate may not be the limiting factor on settlement size. For our purposes here, we assume, without proof, that social and psychological factors, not rotation rate, will limit the minimum size of early space settlements.

The isolation effect of small community size can be reduced by good communications with the

What is the Minimum Size of an Early Space Settlement? (cont.)

rest of humanity, including phone calls, real time interactive video links, etc. Thus, close proximity to Earth would be valuable. Fortunately, there is a region of low radiation in equatorial low Earth orbit (ELEO). Computational studies suggest that settlements in a 500 km altitude ELEO orbit require little or no radiation shielding, reducing system mass by at least a factor of 20. A 4 rpm cylindrical settlement in ELEO might have a mass of only 8.5 ktons [4]. Thus, the first settlements can be small and close to Earth, both of which make construction much easier than for the multi-million ton systems at lunar distances proposed in the 1970s – if such small settlements are viable places to live.

We are taking two approaches to getting at least some feeling for the minimum viable settlement size, measured in both population and 1g living area. The first is analogous situations, which might include small islands, small residential colleges, cruise ships, and Israeli kibbutz. The second is an Internet survey. We have focused on 4 rpm settlements because anything smaller than 112 m diameter seems unreasonable and the curvature of the hull is already very pronounced at that size. Using reasonable assumptions, this corresponds to a population of about 500 [5] for a cylinder if the length is chosen to avoid rotational instability [6].

Artist concept of a interior scene of a 4 rpm cylindrical settlement. Graphics by Bryan Versteeg

Of the analogous situations examined, the Israeli kibbutz is the most similar. The population of most early kibbutz was a few hundred or less and the settlers were moving into a very hostile environment due to both environmental and social factors. In the case of space settlements, the environment is even more hostile but there is no pre-existing population to antagonize. Most of the kibbutzim were highly motivated by the Zionist ideal. Similarly, early space settlers are likely to be very strong space enthusiasts. As the kibbutz movement was highly

What is the Minimum Size of an Early Space Settlement? (cont.)

successful for many decades, and continues today, we can have hope that quite small population space settlements may be socially viable.

Our second approach involves an Internet survey on the desirability of living in a small space settlement. We have collected over 900 responses and will publish the details when we have more than 1,000. If you want to take the survey, point your browser at https://sjsu.qualtrics.com/jfe/form/SV_cIodLeiNTfaVN5P

Currently, a total of 95% of the respondents consider themselves to be space enthusiasts, so there should be no pretense that this is a random sample of the population. We use 30% agreement as a threshold since early settlements need only attract a small fraction of Earth's seven billion plus people. Using those criteria, respondents say they

- Are willing to live in orbit for the rest of their life
- Are willing to devote 75% of their wealth and future income
- Would accept a population of as little as 500
- Would accept a settlement the size of a large cruise ship, which corresponds, roughly, to a 100 m diameter / 50 m length cylinder.

This study is hardly definitive. However, it does provide some hope that the earliest space settlements can, from a livability perspective, be quite small and thus relatively easy to build.

Clearly, this is an area that requires a great deal more research.

Notes

1. Johnson, Richard, and Charles Holbrow. Space Settlements: A Design Study. NASA, 1975. http://space.alglobus.net/75SummerStudy/Design.html.

2. O'Neill, Gerard K. Space Resources and Space Settlements - NASA SP-428. NASA, 1977. http://space.alglobus.net/spaceres/index.html.

3. Globus, Al, and Theodore Hall. "Space Settlement Population Rotation Tolerance," July 2015. http://space.alglobus.net/papers/RotationPaper.pdf.

4. Globus, Al, Covey, Stephen and Faber, Daniel, "Space Settlement: an Easier Way," by November 2015. http://space.alglobus.net/papers/Easy.pdf

5. Globus, Al, Covey, Stephen and Faber, Daniel, "Space Settlement: an Easier Way," by November 2015. http://space.alglobus.net/papers/Easy.pdf

6. Globus, Al, Nitin Arora, Ankur Bajoria, and Joe Strout. "The Kalpana One Orbital Space Settlement Revised," April 2007.

Competing Future Visions for the Human Expansion into Space as Regularized by Space Law

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Astonishing headlines have appeared in recent months concerning space law and the ownership of extraterrestrial resources. "Companies can now officially own resources they mine from Asteroids," from *Popular Science* [1] is typical. "New law establishes ownership rights for space minerals," appearing in *Space Daily* [2], is another. The USA, these headlines suggest, has enacted legislation guaranteeing property rights to entrepreneurs, enabling them to stake a claim on the Moon, on asteroids, or even Mars, and then work that claim to ensure huge profits. These new laws, the articles imply, are set to usher in a golden era of asteroid and lunar prospecting and mining.

The precise legislation referred to is the 2015 *U.S. Commercial Space Launch Competitiveness Act* ("the SPACE Act") which, as its name suggests, seeks to promote commercial space development. Its last chapter is entitled "Space Resource Commercial Exploration and Utilization" and these are the provisions that have generated such interest. The most relevant part states: "[A] United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained" [3].

If we look at just these terms, it is clear that the legislation does grant those carrying out mining on the Moon or on asteroids all the property rights one would need to turn such an operation into an ongoing commercial enterprise. Organizations such as Planetary Resources and Deep Space Industries are keen to encourage this type of space resource prospecting and exploitation in the belief that it will lead to large scale human expansion into space, all paid for by the enormous riches to be found there. This legislation is a significant step in creating a much needed framework for this to happen.

The vision of future human expansion into space found here can be characterized as following an aggressively libertarian agenda. The resources to be found on the Moon or in asteroids are there to be utilized to the full, in the hope of making substantial profits, albeit in the long term, given the huge undertakings required. The enormous capital outlay needed to implement these deep space operations can be justified, it is believed, by the dazzling returns space mining might yield. In this vision, society is to be viewed in economic terms and legislation shapes and manages this economic activity. Indeed it goes even further; the law's role is to encourage and liberate economic activity. For example, other sections of this

chapter state that the president is to "discourage government barriers to the development in the United States of economically viable, safe, and stable industries for commercial exploration for and commercial recovery of space resources" [4]. Another states that the president, through the federal agencies of government, is to "promote the right of United States citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference" [5]. It is not clear what is meant by "harmful interference" in this provision, although it is tempting to conclude the reference is to anything that might hold back the commercial exploitation of space resources.

Yet with a broader view of space law, the purity of this vision of an exploitative, commercial future for space development becomes less clear. The provisions in the SPACE Act promoting commercial development conclude with a restriction that any such activity or permission has to be "in accordance with applicable law, including the international obligations of the United States" [6]. The most important international obligations are those set out by the Outer Space Treaty [7] from 1967, of which the United States is a signatory. Clearly the SPACE Act requires that any of the activities it encourages are to be bound by the terms of this treaty. The Outer Space Treaty, often considered as the Magna Carta of space law, is the most important source of norms concerning human activity in space. Its terms are highly significant in influencing any future human activity in space.

The Outer Space Treaty promotes a rather different view of the human expansion into space than just the commercially exploitative. The recitals to the Treaty make this clear by stating that, "the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development." The first paragraph of Article I of the Treaty states: "[T]he exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind" [8]. If taken seriously, such provisions rather militate against a solely libertarian agenda for space development.

The relevant terms of the SPACE Act under discussion here are not generally taken to entitle a space development company to own an area of territory on the Moon or an asteroid. The Outer Space Treaty makes it clear that such a claim to ownership of territory cannot be valid. Article II of the Treaty states, "Outer space, including the [M]oon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" [9]. Nation states cannot claim sovereignty over the territory of celestial bodies and accordingly they are not in a position to grant or permit individuals, companies, or other legal entities such rights of ownership. Nothing in the SPACE Act can alter this position.

The position concerning the direct ownership and utilization of space resources (in this

context, the minerals found on the Moon or on asteroids) is rather more ambiguous. There are certainly no provisions in the Outer Space Treaty that prevent it. Yet a full reading of the treaty makes it clear that space operations of this sort have to achieve the broader aims of being for the benefit of all peoples. It would be difficult to convincingly argue that a purely commercial space operation, focused on returning a profit for shareholders, would clearly fulfil this criteria.

In exploring the ownership and utilization of space resources further, we note that Article I of the Treaty states that the exploration and use of outer space (which includes the Moon and celestial bodies such as the asteroids) is to be the province of all mankind. This concept of the "province of mankind" is expanded upon in more detail in the Moon Agreement from 1979. Article 11 of the Moon Agreement states that, "[T]he moon and its natural resources are the common heritage of mankind" [10]. Here the reference to the Moon is defined as meaning all celestial, natural bodies beyond Earth, including asteroids. The common heritage of mankind is a very profound and important philosophical concept. Drawing upon principles enacted for the protection of Antarctica, this makes it clear that all of space, beyond Earth, is to be regarded as incapable of being owned by any particular individual and is instead the common entitlement of all humanity as a whole. It is in part an attempt at avoiding what are now viewed as misguided episodes from history, in which people acted solely for their own advantage, and yet ultimately society as a whole suffered. Economic theory generalizes these situations as being the "Tragedy of the Commons."

It is also more than that. The common heritage principle suggests a future in which human civilization is rather different from today, in acting together for the common good of all. In this vision of the future human expansion into space, operations such as asteroid mining have to be managed or regulated so that the resources obtained from them are shared equitably so that even countries unable to venture into space can benefit. Taken at its fullest, it is ultimately directly opposed to the strictly individualistic, libertarian vision described with reference to the SPACE Act.

Such a vision entails international relationships that are rather more progressive than at present, with countries fully and openly cooperating in the expansion of human civilization into space. While this may seem idealistic, the heartening history of international cooperation in space exploration (especially the International Space Station) leads to the conclusion that this may not be as entirely impossible as first thought. It is potentially an inspiring vision of human, global civilization at its best.

The common heritage principle, as set out in the Moon Agreement, also entails that the utilization of space resources must consider future generations and the space environment

itself. Article 11 also requires that the exploitation of space resources is to be governed by an international regime. The international regime will apply the "rational management" of space resources and this will include an "equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon, shall be given special consideration" [11].

It has to be remembered that the Moon Agreement was never ratified effectively, unlike the Outer Space Treaty, and so it cannot be relied upon to regulate activities in space. Nevertheless, it is an important indication of how the "common province of all mankind" under the Treaty is to be interpreted and also suggests the issues that might be raised by members of the international community if large scale exploitation of space resources was to commence.

In conclusion, the legal right to freely utilize space resources by an individual, company or even a nation state is far from clear. While the legal regime does not appear to prevent it, any such utilization has to be in accordance with the approach of the Outer Space Treaty, and this may be rather different than an entrepreneur's strictly commercial aspirations. Those adopting a libertarian perspective may be tempted to advocate that given the presumed nature of asteroid mining, for example, it must be the case that if they have the means to obtain these resources, they must therefore have the right to fully exploit them as they wish. Yet such operations will still be highly connected to Earth, its nation states, and their regulatory systems governing companies, shareholders, and good title to products. Outer space cannot be, by its nature, a free-for-all anarchy.

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It seems an international regime of the type indicated by the Moon Agreement is needed and it is fascinating to consider how it might work. A first point, it is reasonable to conclude, would be to involve the United Nations at its heart. This might include the United Nations granting leases to nation states or companies to carry out mining activities on the Moon or on particular asteroids, with a premium and ongoing rent being paid for such a lease. A variation would be for the United Nations to grant permission for such activity on the basis that a share of any income from mining would be paid to the United Nations. In both examples, the payment can be seen as the mechanism for quantifying the "benefit" to be shared in accordance with the common heritage principle. The United Nations could then distribute or use this money in a way that achieved the common heritage principle of equity.

While attractive due to their simplicity, these ideas fail to appreciate the complexity of the common heritage principle. Can it really be quantified into money in such a direct manner? The common heritage principle is a more subtle concept than a system of payments could achieve. Also, these suggestions would in practice make the United Nations extremely powerful in the

context of a human civilization expanding into space. While the United Nations must be the right institution to be the focus of such a regime, would the nation states accept it having so much power to control their activities? This regime would give the United Nations the highest authority to manage all human activity beyond Earth. It is not clear that world leaders would be keen to accept this.

It is important to remember that as American legislation, the SPACE Act can only deal with American space activity. It can be seen as a way for the American government to encourage space development as much as it can while still recognizing the superior obligations set down by the Outer Space Treaty.

The SPACE Act is an encouraging development for those that are longing for greater human expansion into space, yet we must recognize that these rights are set within the wider context of space law and the provisions of the Outer Space Treaty in particular. This legislative division encapsulates the difference between these two contrasting visions for space development. The way forward for human development in space will be influenced to a large extent by how we think of human society and what we aspire to be.

Notes

1.http://www.popsci.com/companies-can-now-officially-own-resources-they-mine-from-asteroids

2.http://www.spacedaily.com/reports/New_law_establishes_ownership_rights_for_space_minerals_999.html

3. *U.S. Commercial Space Launch Competitiveness Act.* (2015). Also known as *Spurring Private Aerospace Competitiveness and Entrepreneurship Act* (SPACE Act). https://www.congress.gov/bill/114th-congress/house-bill/2262/text

4. SPACE Act, 2015.

5. SPACE Act, 2015.

6. SPACE Act, 2015.

7. More fully the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.* (1967). Also known as the Outer Space Treaty. http://www.state.gov/t/isn/5181.htm

8. Outer Space Treaty, 1967.

9. Outer Space Treaty, 1967.

10. More fully, the *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.* (1979). Also known as the Moon Agreement.
http://disarmament.un.org/treaties/t/moon/text

11. Moon Agreement, 1979.

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Drop an email to ktoerpe@astrosociology.org and we will add you to our contact list.

A Case for Designated Arts Spaces in Space Exploration Habitats

Adrienne Provenzano

Professional Musician and Educator

On April 8, 2016, a SpaceX Falcon 9 rocket lifted off into space, carrying 7000 pounds of science and research investigations to the International Space Station (ISS). Included was the Bigelow Expandable Activity Module (BEAM), which was successfully attached to the ISS on April 16, 2016. In May 2016, the module will be expanded and, over the next two years, tested for human habitability and other performance factors.

As a professional musician and educator, I see the BEAM, or something similar, as having great potential as an arts designated work and play facility as part of a space habitation. The arts are already an integral part of space exploration, and the BEAM provides one more possibility for expanding (pun intended!) this vital aspect of living and working in space.

Here are seven reasons why it would be good to consider arts-focused spaces as part of space habitations. There are more, of course, and hopefully, this article will spark interesting conversations.

Reason #1: Training and Preparation

One possible function of an arts designated space could be as a rehearsal space for spacewalks and other tasks. On Earth, NASA's Neutral Buoyancy Lab (NBL) in Houston, Texas is where astronauts prepare and practice for spacewalks at an underwater mock-up of the ISS. Soon, a mock-up of the Orion capsule will be added to the NBL's facility. Although perhaps not thought of as a theater or dance studio, the work done at the NBL is similar to the rehearsals done to prepare to present a play or to learn and develop choreography. The unique underwater ballet, of sorts, done at the NBL might be able to be practiced in a micro gravity habitation space, without artistic intentions. Such purposeful artistic creation could also become part of such training and preparation as well, as there seems to be both an art and science to spacewalking.

Reason #2: Collaboration

One great value of the arts is the opportunity for collaboration. Whether a case of musicians performing a Mozart string quartet or Mexican folkloric dancers sharing their heritage, creating, rehearsing, and performing a work of art in a group involves shared experiences. Problem solving is an integral part of the arts as well. As teamwork is a vital aspect of successful space exploration, and participating in the arts together can help bolster that set of skills, spending time in artistic endeavors together in the arts habitation module could boost the effectiveness of non-arts activities.

Reason #3: Connection to Earth

Whether in low Earth orbit (LEO) like the ISS, or further away orbiting the Moon or living on Mars, the arts can provide a way to maintain a connection with Earth. Such a link may be a necessary and significant aspect of the explorers' mental health. Regular communication with "home" is an essential aspect of the ISS operations and there are a variety of ways in which communication is maintained and facilitated. The arts can provide a way to maintain connections with Earth-based traditions, in a similar way in which a person who identifies with a particular nationality or ethnic or other group can reinforce that identity by attending a festival or other event celebrating that group. Earth Day celebrated in a space habitation can take on a very different meaning than Earth Day experienced on our planet, and the arts can be an integral part of such an event. For example, a habitation space as part of an

orbiting complex could serve as a temporary gallery to display Earth images or Earth-inspired art on or around Earth Day. On Mars or another planet, a Museum of Earth might be a part of the design of the habitation site and include virtual and tangible artifacts from Earth for inhabitants to reflect on and thus consider their part in the story of human exploration. Like the National Air and Space Museum in Washington, D.C., and the Cosmonautics Memorial Museum in Moscow, a Museum of Earth can also show the continuum of exploration history, which these spacefarers are continuing.

Reason #4: Building a Community

Over a period of time, participating in shared arts experiences, whether as creators, viewers, listeners, performers, or all of the above, can help to build a community. On the ISS, shared meals, movie nights, and celebrations of holidays are part of this relationship building process. On longer missions, or in permanent colonies – whether orbiting or on the surface of a planet – the arts can become another part of this process. Weekly choir rehearsals, exhibit openings, movie festivals of works created by the inhabitants . . . these are just a few activities that might build community identity while also providing opportunities for individual expression.

Reason #5 Creative Expression and Creating Meaning

We humans seem hard wired to express ourselves creatively – whether through song, story, cave paintings, costume, or any of the other myriad ways arts and cultures and civilizations develop and intertwine. To encourage and celebrate such expression through designated studio, performance, and even classroom space, will validate this important aspect of humanity. Such works can inspire further exploration, as Andy Weir's book *The Martian* is inspiring current and future generations. As brought to the screen through the vision of Ridley Scott, the film version of *The Martian* presents a very classic story of human resilience and human relationships. Women and men strive together to explore; they face and overcome obstacles, and (spoiler alert) triumph! Such a story hearkens back to the ballads and legends of ancient civilizations and new stories will be created through the arts, and humanities, as well.

Reason #6 Connecting with the Habitation Environment

Artists are often inspired by their environments, sometimes utilizing the materials in that environment in their works. Depending on the location of the habitation, it may be possible to use natural materials from the location in art works, much as the astronaut Alan Bean has

used Moon dust from his spacesuit in his paintings or as astronaut Karen Nyberg used found textiles on the ISS to create a fabric toy for her son.

Reason #7 Recreation and Catharsis

Lest the above reasons seem too lofty, however appropriate for a discussion of the arts in space habitations, the sheer enjoyment and catharsis, which the arts facilitate, can be reason enough to encourage their integration into space exploration with designated spaces. The daily wake-up-call music that was part of the Space Shuttle program provided a way to start the day with a song. More recently, Canadian astronaut Chris Hadfield's music video of the classic David Bowie song, "Space Oddity," created when Hadfield was commander of the ISS in 2013, is another example of the value of the "arts for arts sake." The lyrics include " . . . sitting in a tin can, far above the world . . . " and we see images of Hadfield in the ISS cupola looking out on Earth. This is the arts – the sheer joy of celebrating life and human aspirations and accomplishments. Even David Bowie tweeted his appreciation of this out-of-this-world "cover" version, calling it "possibly the most poignant version of the song ever created" [1]. Likewise, the arts often provide a source of comfort and solace, as with the use of music at the annual astronaut remembrance ceremonies at the Kennedy Space Center and elsewhere, such as the playing of "Taps" when wreaths are laid, or to remember those lost in the Apollo 1 fire and in the *Challenger* and *Columbia* tragedies. Music and other arts and humanities can and will likely play vital roles on such solemn occasions at habitation sites, and during other rites of passage. Whether listening to a musical performance, dancing together at an informal event, engaging in a sing-a-long of favorite songs, watching a movie, or telling a story, the arts provide ways to experience catharsis alone or shared through laughter and tears.

As humans continue to venture forth into space to live and work, we bring our full humanity. The arts are an essential and integral part of what it means to be human. By designating specific arts spaces as part of space habitations, we will further integrate, elevate, and honor that aspect of who we are as we explore and continue to strive to reach those "impossible stars" which, eventually, we will likely find not so impossible to reach after all.

Notes

1. Bowie, David. (2013, May 12). " . . . It's possibly the most poignant version of the song ever created and you may recognise the name of one of those involved in its creation. . . ." [Facebook status update]. Retrieved from https://www.facebook.com/davidbowie/photos/a.424610777664.193516.30899502664/10151372549242665/?type=1&theater

Adrienne Provenzano is a professional musician and educator. A volunteer with NASA's Solar System Ambassador program, she has presented workshops on S.T.E.A.M. (science, technology, engineering, arts, and mathematics) education at the Space Exploration Educators' Conference in Houston, Texas, and has spoken and published on how arts and humanities can engage more women in S.T.E.M. careers. She can be contacted at adrienneprovenzano@yahoo.com.

Matjaz Vidmar

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One Morning in 2065 . . .

This essay by Matjaz Vidmar, entitled "One Morning in 2065 . . . ," has been shortlisted in the "World in 2065" competition (http://www.esrc.ac.uk/about-us/50-years-of-esrc/the-world-in-2065/) run by the UK Economic and Social Research Council (ESRC) and the publishing house SAGE.

The competition is celebrating the 50th anniversaries of both ESRC and SAGE, and is designed to encourage students to reach out to audiences beyond academia, answering the question: "How will your research or discipline change the world by 2065?"

Vidmar, whose research project concerns innovation in the space industry, wrote a science fiction account of a radical social change brought about by the advancement in (space) technologies, including the ability to populate the universe beyond planet Earth.

The essay is reproduced in full below, with kind permission of ESRC. ***[Editor's Note: The essay has been edited to reflect American conventions in punctuation and usage.]***

* * * * *

One Morning in 2065 . . .

"Beep, beep, beep . . . The alarm goes off ringing – my personal assistant, Thor, is scheduled to wake me up as ever for 7:30 am. Would be easy to hit the red button now, kill Thor off, and enjoy some more peaceful slumber next to my wife, but I knew it was not to be."

The red button is not there to avoid getting up in the morning, only to avoid mindfulness and "the Biggy." Thor is a machine, of course, or not even that; it is a technology, which enables total connectivity anywhere and everywhere, and helps me with anything as long as it's about getting information or communicating.

"Beep, beep, beep . . . The red button seems so tempting . . . "

One Morning in 2065 . . . (cont.)

"The Biggy," of course, is the worry that either humans or technology itself could use our personal information inappropriately or against us. Orwell's "Big Brother" from 1984 – that sort of thing. We call it "the Biggy" now, as a joke, as we hope to have found a solution for it. Every single one of our PA devices has the ultimate switch – press the red button and the thing is off, all power cut! If we notice anything odd or prying, we can just stop the thing – and the PAs know this, too.

"Beep, beep. Finally, I hit the blue button – 'message accepted.' Thor predictably voices in his clinical tone: 'Alarm deactivated. Status check-up in 5 minutes.' He will auto-text me in 5 minutes to ask if I am ready for my run. As I run, he will update me on all the news, read my e-mails, send my replies and put music on, as I like it. He will keep track of my run and let me know when I am slipping off my desired tempo."

Still sounds like Big Brother? Well, apart from being able to switch the thing off, we now also have true democracy and complete control over the "big data," so no evil masterminds can take over our lives.

Initially there was a struggle (well documented by my colleagues researching public policy), when corporate firms tried to fight off these ideas about free absolute connectivity being a human right – but ultimately they failed. Indeed, how could these profit-driven companies compete with the new co-operatives, which were based on open innovation and have had pre-funded all their technology products, making them free for all customers?

Since this Space Revolution 35 years ago, free Internet everywhere is no longer a dream and portable devices like Thor are standard issue to all new-borns since 2050. The co-operatives built large constellations of small satellites, enabling anyone to access the web from anywhere. Soon, people started to truly talk to each other, and political and social change was inevitable. We have done away with the nation state and we now have community administration and global governance, as the free absolute connectivity enables citizens' participation in all key decisions.

"The air is cold and as soon as my feet touch the floor, I shiver just a little – but the heat immediately rises from the PWC carpet and I feel like immersing in a warm pool. I just put on the running suit as Thor texts: 'Ready to go?'"

I am particularly proud of the PWC – "Personal Warmth Carpet" – and many other technologies, which I helped develop with my research in innovation systems and knowledge networks. We started small, with the Scottish Space Sector, but soon the understanding we developed led to national and international interventions, supporting the crowd-funded campaigns with access to technical expertise previously locked away in science labs.

Not all of these interventions worked, but by using our Quantified Correlated Impacts Evaluation framework we were able to weed out the struggling projects and invest more in those which returned sustainable new businesses with great potential. As predicted, as soon as new companies supported by the right tools entered the knowledge network, their success was inevitable.

"I reply to Thor: 'Sure.' 'Unlocking the pressure passage,' he responds. I step outside. The sky is pale blue due to the thin, carefully constructed layer of atmosphere, and the warm shimmering white light from the Sun is rising from behind the silvery hills. Who would have thought 50 years ago that being here, living here was possible? But possible it is – as soon as humanity started to leave in peace and harmony, pulling together resources and expertise previously used to fight each other, this became a very small step indeed."

"As small as the one I make through the door of the compound, filling my lungs with clean morning air. I start to run, ready for another day of my future – living on the Moon in 2065."

Matjaz Vidmar is a postgraduate research student in The Institute for the Study of Science, Technology and Innovation; part of Science, Technology and Innovation Studies Subject Group in the School of Social and Political Science at The University of Edinburgh, UK.

His main area of research is acceleration of business incubation and development of Space Sector in the UK, and in Scotland, and he has a specific interest in advancing the field of astrosociology, including being an Assistant Editor of *The Journal of Astrosociology*.

HONEY, I SHRUNK THE SPACE SETTLEMENT! Dunbar's Number & Radical Politics in Space

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When one thinks about human space settlements, one most likely imagines enormous space cities that look like spinning American suburbs complete with clean roads, luscious parks, and baseball diamonds. During the 1970s, NASA Ames Research Center sponsored studies on massive space settlements that could theoretically hold 10,000 to 1,000,000 people [1]. Artists began to illustrate the concepts dreamed up by NASA engineers, which permeated into the social imaginary of space advocates.

While these enormous structures – with names like *Torus Colony* and *Bernal Sphere* – spark the creativity and engage with the dreams of many space advocates and science fiction fans alike, I have asked myself: are these gigantic settlements really the most harmonious way of living in space and other planets?

Bernal Sphere Illustration. Art work by Rick Guidice. Image: NASA Ames Research Center.

In 1992, Robin Dunbar, a British anthropologist and psychologist, theorized a cognitive limit to the number of people with whom humans can have a stable social relationship (i.e. relationships in which an individual knows who each person is and how each person relates to every other person) [2]. Although he never named an exact integer – he suggested it was between 100-230 – the common number that is accepted today is 150. This is now referred to as "Dunbar's number." A recent study analyzing the conversations of Twitter users has shown that users can entertain a maximum of 100-200 stable relationships, seeming to confirm Dunbar's theory [3]. Could this be a contributing factor in why many residents of enormous cities like New York and Los Angeles report loneliness and alienation? Do we want to extend this kind of alienation – and potential conflict – into a resource-deprived and potentially dangerous environment of space?

Instead of always thinking about living in massive Torus Colonies or Bernal Spheres, we should begin to think about the possibility of living in a network of smaller settlements utilizing Dunbar's number. Living within Dunbar's number would combat apathy and strengthen the sense of community because it would maximize the limits of the strong ties of which human beings are capable. Creating smaller communities would also allow for a radically democratic system of (anti-) governance to flourish. Rather than utilizing the increasingly corrupt system of Earthling electoral politics, decentralized space "pods" (for lack of a better name) would be able to utilize an anarchic, consensus-based model of decision making. While it is possible to engage with anarchist models of power in large populations, it is easier and quicker to make group decisions when you are in a space settlement limited to 200 people.

However, this does not mean that these small, anarchist space pods need to roam the cosmos

as isolated communities. Current anthropological research has shown that although humans may be restricted to 100-200 strong ties, they are capable of utilizing thousands of weak ties in order to accomplish tasks [4]. A decentralized network of these pods would be able to interact with each other in order to accomplish larger scale, communal projects as well as respond to emergencies while still maintaining autonomy. This may seem like the realm of science fiction alone, but we can see a version of this system working today in northern Syria by the Kurds. Working from the political theories of Abdullah Öcalan [5], directly recallable delegates are scaled to represent neighborhoods, cities, and regions in order to make consensus-based decisions with tens of thousands of people.

Illustration of a Torus Colony. Image: NASA Ames Research Center.

The dream of living in space consists of more than romantic notions of exploration and a human "need" to wander. The dream of space habitation is about freedom. And not the flag-waving, nationalistic, earthly bastardizations of freedom; I'm talking about true freedom. The ability to live, to sing, to create art, to write, to love, to build wondrous things, to read, and to share the beauty of the cosmos with the people that you care about. It is becoming harder and harder to engage with these vital human needs on Earth today. Do we really want to continue the status quo in the cosmos or can we dream of something better?

Notes

1. Oman-Reagan, Michael. 2015. "Three Visions of Human Space Settlement: 1970s." Space+Anthropology. March 22. https://medium.com/space-anthropology/three-visions-of-human-space-settlement-cfd64a6fe7c6#.xjttoohk2

2. Dunbar, R. I. M. 1992. "Neocortex Size as a Constraint on Group Size in Primates." *Journal of Human Evolution* 22 (6): 469–93. doi:10.1016/0047-2484(92)90081-J.

3. Gonçalves, Bruno, Nicola Perra, and Alessandro Vespignani. 2011. "Modeling Users' Activity on Twitter Networks: Validation of Dunbar's Number." *PlOS ONE* 6 (8): e22656.

4. Shaindlin, Andy. 2016. "Dunbar's Number & the Strength of Weak Ties." Alumni Futures. Accessed April 1. http://www.alumnifutures.com/2007/08/dunbars-number-.html

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Jim Pass, PhD

Chief Executive Officer

Astrosociology Research Institute

Notes from the CEO

2016 is a busy year for ARI. We are working on the second volume of *The Journal of Astrosociology* and starting the editing process of our book, *Launching Astrosociology*. Our other projects and programs are also moving forward. Even now, we have also started discussions for preparations for the tenth anniversary of the establishment of the Astrosociology Research Institute. Look for announcements as that year draws closer.

My attendance at the Contact Conference (www.contact-conference.org) was highly informative and enjoyable. Many of the attendees are well known and celebrities in the space community, yet they are all approachable to everyone in attendance. If you check my Twitter account (@astrosociology) coverage of the Contact Conference between April 1 and April 3, you will find an extremely diverse collection of presenters over those three days. They include social scientists, space scientists of various types including astrobiologists and astronomers, science fiction authors, movie experts, and others. Each of their names, photos, and presentation topics are in the timeline. I certainly encourage everyone to strongly consider attending – and presenting at – the next meeting in 2018. You will not be disappointed! Students, I have no doubt that you will especially learn a lot and enjoy yourselves.

Space Societies (and Smaller Space Settlements)

I would like to take this opportunity to discuss a few issues regarding space societies. It is not too early to take migration into our solar system seriously. The Astrosociology Research Institute is currently seeking social scientists, humanists, and artists interested in pursuing astrosociology to join the growing astrosociology community regarding space settlements and other relevant

subfields (see a listing in our Call for Articles on our *Journal* page at www.astrosociology.org). There are many ways that you can participate. Contact me at jpass-at-astrosociology.org.

It is certainly arguable that some or even most of the first generation of settlers on Mars or elsewhere will become homesick; or worse, suffer from some form of psychological impairment over time. Therefore, it makes sense to provide as many comforts and recognizable elements of home as possible. It is easy to expect that these intrepid settlers will just "tough it out" since they knew what they were getting in for. I have heard people mention that if we must send humans to a moon or other planet we should not waste money and mass for "frills." However, social science research on Earth has shown that favorable social conditions that encourage social interaction have positive psychological consequences. How much money to spend is an important question, but the well-being of the settlers must be considered in concert with expenditures related to the launch, excursion, and landing phases of the journey. Living on another cosmic body is a difficult proposition, so we must take advantage of social scientific findings that are applicable to off-world settlement. This is one vital example.

Thus, not all types of habitats are best suited for all types of missions. For crews who visit another moon or planet for a limited time, the space habitat can be less elaborate. Yet even for crews who live in habitats such as those shown in Figures 1 and 2, it is inevitable that social, cultural, and psychological problems will occur. It is really a matter of degree. Some elements of home should exist within the habitat. We have seen that astronauts take photos and music with them to the International Space Station (ISS), for example. However, distant isolated existence on Mars will require much more. Taking plants for food will be vital for long-term stays, but greenery for aesthetic purposes is also important. Can we afford to construct a park? If so, residents would certainly benefit, especially compared to a stark interior. A park setting and various forms of entertainment would certainly provide that familiarity to a well-regarded terrestrial location. Will movies and TV shows increase homesickness or provide a needed escape and connection to Earth?

Isolated modules may well be acceptable for "temporary" scientific missions involving highly trained astronauts, but we have witnessed problems in past missions close to Earth. The number of people involved makes a difference. A social space that encourages interaction with others rather than separation from others becomes more mandatory as the population size, excursion length, and/or distance from Earth increases. Early one-way settlement plans must involve habitats that include public spaces in addition to individual quarters, though I am not convinced that humanity is ready for such excursions.

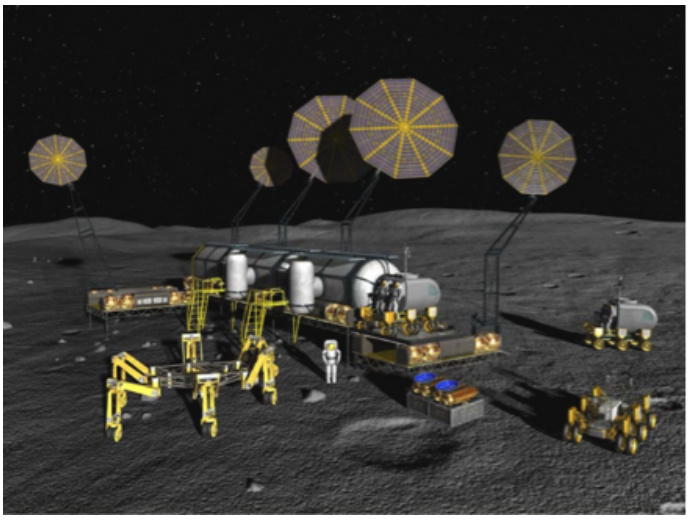

Figure 1: Not Conducive for Long-Term Settlement
Credit: NASA

Figure 2: Not Conducive for Long-Term Settlement
Credit: Mars One

For a permanent settlement, a single common area is desirable rather than multiple nodes; but is it cost effective? It is important to reproduce as many Earth-like conditions as possible; especially for the "first generation" of citizens. It cannot be all work, as with a crew in low Earth orbit, because leisure time is extremely important.

Many other issues are relevant for settlement of the Moon or Mars. Social interaction also becomes much more complex as the population grows in size. What about social institutions? What cultural ideas are to be emphasized? At what point does a crew become a micro-society, a mini-society, a community, or a society? Social structures must adapt to growth, which means that pre-mission planning is essential. Haphazard implementation of cultural ideas and social structures can become confusing and result in social problems.

There is debate about whether to use the Moon as a testbed for human habitation off the Earth or to bypass it for a direct mission or the private settlement of Mars. The gravity field is different and the lunar regolith is more harmful to human health than Martian soil, but the close proximity is helpful for the easier transfer of resources and especially beneficial in case of emergencies. I have argued for a lunar settlement as a stepping stone to Mars [1], but there are many very intelligent people who disagree. In my view, many technologies still require testing. More directly relevant to astrosociology are the social, cultural, and psychological issues that will arise in an isolated habitat regardless of where it is located.

For that reason, we need to recruit more social scientists, humanists, and artists under the astrosociology umbrella to study these issues as part of a single interactive astrosociology community. We need to build a cohesive and comprehensive literature. Moreover, social

scientists need to be present in the habitat to conduct research as the settlement evolves over time, just as they do here on Earth. It will prove beneficial to current residents, but will also become vital for those who live in future settlements due to the ability to learn from past mistakes (as best as is possible).

In closing, be assured that ARI and its supporters will continue to work in this topic as well as other relevant issues involving the human dimension of space exploration and settlement. We hope that you will join us in any way that you can. If you have an idea for a future theme for our newsletter, please let us know!

Best Regards,

Jim

Notes

1. Pass, Jim (2007). "*Moon Bases as Initial "Space Society" Trials: Utilizing Astrosociology to Make Space Settlements Livable.*" *Space Technology and Applications International Forum (STAIF) Conference Proceedings*, Volume 880: 806-813. ARI Library Link: http://www.astrosociology.org/Library/PDF/STAIF2007_Moon%20Base.pdf

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