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# Space ectogenesis: securing survival of humans and Earth life with minimal risks – reply to Szocik

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**Abstract**

Assuming that securing the long-term survival of humans and Earth life is a valid goal, we briefly compare the strategies of building standard space colonies, such as on Mars, and embryo space colonization (ESC). In ESC embryos of humans and other Earth species would be sent to exoplanets and raised there via ectogenesis and android assistants. We find that the potential for securing long-term survival is far greater for ESC than for standard colonies, while the bioethical and other risks are far fewer.

## Introduction

In commenting on my recent paper in *International Journal of Astrobiology* (Edwards, 2021a), Konrad Szocik (Szocik, 2021a) raises concerns about the effectiveness of embryo space colonization (ESC) in securing long-term human survival and also its bioethics. In ESC, cryopreserved plant seeds and embryos of humans and animal species would be sent to exoplanets, where they would be raised robotically to build up societies and ecosystems (Crowl *et al.*, 2012; Hein and Baxter, 2019). Part of its rationale is that it would allow humans and Earth life to escape Earth and thereby avoid mass extinction events in the near or far future (Ward, 2007; Klee, 2017). An analogous strategy, which I termed embryo Earth recolonization (EER), would enable humans and Earth life to similarly recolonize devastated future Earths after major extinction events. The core of both strategies is complete ectogenesis – the development of an early-stage embryo to a neonate entirely outside the natural womb. While bioethical concerns have slowed research and development of complete ectogenesis (Eichinger and Eichinger, 2020; Baron, 2021), it could nevertheless be available in the near future to assist parents in having children (Bulletti and Simon, 2019; Räsänen and Smajdor, 2020; Kimberly *et al.*, 2020).

In his arguments, Szocik does not focus on ectogenesis itself, but rather on its effectiveness in securing human survival and on certain bioethical risks pertaining to the embryo colonists. His preference is to use standard space colonies, such as on Mars or the Moon, to achieve this survival goal. In replying to Szocik's criticisms, a recent article by Kovic (2021) on the risks of space colonization provides a useful framework to compare the two approaches. These risks include what Kovic terms *prioritization risks*, *aberration risks* and *conflict risks*. As we will show, ESC has a better chance of securing long-term human survival than conventional space colonies, while at the same time taking fewer risks in each of these categories.

## Only embryo missions could secure human survival

To begin with, Szocik argues that human colonization of space to ensure our survival could be a worthwhile goal, but that it should not be accomplished using 'extraordinary' means in regard to the rights of the embryo colonists themselves. In Szocik's view, space colonization should arise more naturally and ethically within the standard context of space exploration and commerce, which might eventually lead to colonies on the Moon or Mars. For many reasons, including low availability of $CO_2$ on Mars and an unexpectedly intense radiation environment on the Moon (Zhang *et al.*, 2020), space colonies of these types are unrealistic vehicles to ensure even short-term human survival (Klee, 2017; Edwards, 2021b). Szocik's position is somewhat unusual in this regard, as he himself has extensively detailed the extremely harsh conditions that such colonies would face, particularly in regard to space radiation (Szocik, 2020, 2021b; Szocik and Braddock, 2019). By virtue of their small size, however, embryos could potentially be much better shielded from radiation than astronauts in their space journeys.

Szocik further argues that ESC might only be permissible to ensure human survival as a last resort if conventional survival strategies such as subterranean/aquatic refuges or orbiting space colonies were to fail. While such measures could indeed be useful for short-duration extinction

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events typically of anthropogenic origin (Jebari, 2015; Baum *et al*., 2015), they would be inadequate for natural extinction events having durations of thousands or millions of years and for all far-future events. To rely solely on Szocik's short-term missions would thus ultimately take us down the path to extinction and so would not achieve the main goal of securing the long-term survival of humans and Earth life.

Szocik then suggests that ESC missions might in any case be pointless, since better technologies might come along that could allow us either to send living crews to exoplanets or to protect Earth from existential threats. Due to technical reasons, however, there is a near-zero probability of manned spaceships ever reaching nearby stars (Klee, 2017; Edwards, 2021b). Concerning near-future extinction events of anthropogenic origin, ESC and EER missions do carry a prioritization risk, of the kind described by Kovic (2021), as they could draw resources away from extinction mitigation efforts. Compared to the prioritization risks in ordinary space colonization, however, we see that it is orders of magnitude smaller. This is because the total time and costs of ESC and EER missions would be negligible relative to colonies of the Martian or O'Neill type. Moreover, there are no convincing plans for defending Earth from long-duration or far-future extinction events of natural origin other than potentially with EER and ESC. For those events, a prioritization risk actually exists in *delaying* these missions. A civilization might decline in its technological capabilities to the point where it can no longer plan for major extinction events with EER and ESC missions, nor might a future civilization ever rise above that point again. In that case, all of Earth's life will ultimately be doomed. To guard against this an advanced civilization must do all it can to launch these survival missions while it still has the power to do so. Other prioritization arguments that have been advanced for delaying space colonization (e.g. Billings, 2019; Schwartz, 2019), while perhaps valid for space colonies in the Solar System, are similarly risky in the long-term context. We simply may not have that much time to launch these missions.

## Why humans must be included

Szocik reasonably argues that if we were really concerned with the survival of life in general it would be easier just to send microbes or tardigrades to exoplanets. There is a precedent for this in *directed panspermia* – the idea that advanced civilizations might choose to deliberately disperse life to other exoplanets (Crick and Orgel, 1973; Mautner, 2009). Margulis and Snoeyenbos-West (1993) later linked this idea to the Gaia hypothesis, likening the colonization of another planet by Earth organisms to planetary procreation. Given this alternative and the bioethical issues in ESC, is the last step of including humans really necessary?

Clearly, if the long-term survival of humans as a species is our top concern, then humans would have to be included in embryo arks. Less obviously, to fully secure the long-term survival of other Earth species *also* requires that humans go along. By including humans, successful colonies would have a chance of undertaking subsequent EER-type missions themselves (to survive extinction events on exoplanets) and of ultimately sending ESC arks to different exoplanets themselves. It cannot be assumed that an intelligent, technological species like us would evolve from a tardigrade or even from a higher organism. Without humans, the various species of Earth life that were successfully planted on exoplanets would all eventually succumb to mass extinctions there. Our huge effort would have amounted to just a brief flickering of life in our little corner of the galaxy. It is only with humans onboard that ESC missions could potentially create a growing galactic chain of living worlds.

## Space ectogenesis is biologically and bioethically sound

In perhaps his strongest objection, Szocik proclaims a basic 'nonsensicality of the concept of self-preservation of the human species with ESC'. He states that the only kind of survival of the human species worth having is one where some fraction of a currently living human population is preserved following a calamity on Earth. Szocik supposes the embryo colonists would not feel any connection, unity or identity with a human species that may have been extinct for a million years. He calls for living human 'witnesses' who 'link the generations and can tell the story', without which the embryo colonists will essentially function 'as a new species'. In this sense, ESC would thus fail in its goal of securing long-term survival of humans.

Underlying these assertions is the idea that humans have always lived in groups – families, tribes, etc. – and thus to break up these groups destroys humanity itself. While accurate on a certain level, in strictly biological terms this is a narrow conceptualization, one which could restrict the survival of humans and Earth life generally. Survival in deep space and deep time could require that humans borrow from the reproductive playbook of an oak tree, a fish or a cicada fly – just for a short time – before 'continuity of generations' can be re-established on the new world. The sacrifices of the first colonists cannot be weighed without consideration of the thriving generations who could come after them.

At the same time, the challenges and risks of raising infants on an exoplanet (or a future Earth) without actual parents might not be as extreme as Szocik posits. It is important to appreciate the full context of the children's development. The embryo missions will have been designed to cover every possible aspect of it and will already have been thoroughly tested on Earth. The infants would essentially be born into a farm-like setting with animals and parent-like androids present. These together with cohorts of 'sibling' colonists would engender a certain degree of emotional security. Speech and emotional recognition with artificial intelligence would by then have enabled android guardians to care for and teach the child colonists. Given such considerations, Szocik's categorical statement that the colonies would feel no link to us is unmeasured. Their grasp of Earth and its history – and their emotional links to us – could indeed be strong.

Szocik also insists that colonists of space environments generally have a right to assurance of a certain quality of life. As noted above, not only would the embryo colonists be born into stable 'living worlds', having food, oxygen, warmth and water, but they would also be part of a growing social unit. Compare their level of security to that of colonists in a lunar or O'Neill-type space colony, who in their hermetically sealed confinements would always have to fret about such basic needs; would likely slowly decline in their behaviour and moral state (Tachibana, 2019; Kovic, 2021); and could end up suffering in isolation, like David Vetter, the famous 'boy in the bubble' (Oman-Reagan, 2019). The aberration risk discussed by Kovic (2021) that millions of people could be condemned to lives of suffering due to genetic illnesses or other causes would be minimized in ESC. Humans would only be raised after many other animal species had first been introduced and found to be free of such illnesses. In the event that some infants nonetheless developed poorly or fell ill

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for unknown reasons, further births could be delayed until the causes were found and rectified.

Kovic (2021) also noted the significant aberration risk that space colonization could pose in threatening alien life forms, such as microorganisms on Mars. By comparison, embryo missions would be far better able to respect the rights of indigenous species, whether they be evolved forms of Earth species in EER or alien life forms in ESC. The missions could simply delay touchdown on Earth (in EER) or exoplanets (in ESC) until such time as the rights of indigenous species would not be threatened. Space telescopes will likely have advanced so far by launch time that the nearest exoplanets will have been thoroughly mapped and even their atmospheres known. It would thus be known to a high degree which planets are Earth-like and habitable – both for us and for extra-terrestrial forms. Szocik's supposition that embryos might be sent to exoplanets without those planets first being thoroughly scanned is thus invalid.

Lastly, Szocik notes the realistic risk, which he deems potentially unacceptable to future 'moral conservatives', that many cryopreserved embryos in ESC would remain in a perpetually frozen state. Should a morally conservative view indeed prevail near launch time, there is a potential workaround that I mentioned: the embryos could be replaced by egg and sperm cells. In addition, it should be noted that a similar but much larger problem already exists, with many thousands of embryos in *in vitro* fertilization clinics having been abandoned by their would-be parents and stranded in a frozen state (Cattapan and Baylis, 2015; Pflum, 2019). But just as this risk has been accepted on the individual level, so might an advanced civilization be willing to accept it too: in order to keep the human line and Earth life in a perpetually *living* state.

## Conflict risks minimized in ESC

In space colonization, Kovic (2021) listed a number of what he termed conflict risks. Space colonies could attempt to secede from Earth governance, engage in mutual conflict or develop a retrograde 'reactionary' focus, if for example the colonists were of a breakaway religious group. Kovic supposed that these risks could potentially far outweigh any survival benefits from space colonization. While Szocik did not include such considerations, it is evident that they are of very little concern for ESC colonies. Those colonies would be too far from Earth or each other to have much more than radio communication. They could indeed wander far from religious/political norms, as all societies can, but they would at least be initiated culturally with whatever values the android guardians are programmed with.

## Gene editing and mind uploading

Szocik himself proposes some rather extraordinary means to allow for human colonization of the Solar System or potentially exoplanets, notably gene editing and mind uploading. He deems gene editing to be possibly essential and even a 'moral duty' in this regard. Gene editing could indeed be useful on certain exoplanets, allowing humans to survive in conditions of low oxygen or high radiation, for example. On the other hand, gene editing, at least using CRISPR, is thought to have possible dangers associated with it, such as 'off-target edits' or 'runaway' gene editing. The overall risks to the colony could thus outweigh the possible benefits. A safer alternative might be to draw animal and human colonists from low-oxygen, high-radiation environments here on Earth, such as the Andes or the Himalayas.

Szocik suggests that mind uploading – the hypothetical transfer of a human mind onto a digital platform – could be a better alternative to ESC if human survival is what we are really concerned about. It could also be more ethical, in his view, since only these uploads might suffer at exoplanets, not embryos or astronauts. Mind uploads are not a realistic substitute for humans, however. To begin with, it rests on the highly questionable hypothesis that the essence of the human mind *can* be digitally uploaded, for which there is zero evidence thus far. Let us suppose, however, that we *were* able to upload human minds onto androids. On the one hand, such androids would still not have the human capacity to serve as catalysts for life, in the galactic context discussed above. This is because the mind uploads would not be able to survive in their digital formats long enough for them to be able to initiate follow-up EER-type or ESC missions themselves. They would thus be unable to extend the chain of Earth life through the cosmos. On the other hand, they *would* be able to improve the overall performance levels of the android guardians in parental care and colony organization – and even serve wonderfully as Szocik's 'witnesses', linking the embryo colonists to previous generations on Earth. It is only in this context of enhanced guardianship for the embryo and animal colonists that mind uploading could potentially be useful. To use it as a *substitute* for ordinary humans would lead us once more to eventual extinction.

## Conclusions

In summary, embryo colonization of exoplanets is superior to standard space colonization as a way for Earth life to move through the galaxy and survive indefinitely. It also takes fewer bioethical risks, as it respects the species survival rights of humans, Earth life and indigenous forms, while giving the embryo colonists a reasonable chance of having a good life. The loss of some embryos would be regrettable, but this has to be balanced against the survival of the human species – and Earth life generally – that the successful embryos might secure. There will in any case be many years to debate these issues before such time as complete ectogenesis has been clinically demonstrated and many more before it could conceivably be available, first for EER and later for ESC. Let these issues thus be debated fully and openly. To rule these embryo missions out at this stage, as Szocik has done, is highly premature.

## Conflict of interest

None

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