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Isolated refuges for surviving global catastrophes

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ABSTRACT

A variety of global catastrophes threaten the survival of human civilization. For many of these catastrophes, isolated refuges could keep some people alive and enable them to rebuild civilization in the post-catastrophe world. This paper examines the potential importance of refuges and what it would take to make them succeed. The successful refuge will have a variety of qualities, including isolation from catastrophes and self-sufficiency. These qualities can be achieved through a variety of specific design features. We introduce the concept of surface-independence as the gold standard for refuge excellence: refuges isolated from Earth's surface will offer maximum protection against both the catastrophe itself and potentially harmful post-catastrophe populations. However, surface-independence introduces significant design challenges. We present several challenges and evaluate possible solutions. Self-sufficiency in food provision can be greatly enhanced via chemical food synthesis. The rejection of waste heat from subterranean refuges can be enhanced via building piping networks and locating refuges near running groundwater or in ice. The high cost of extraterrestrial refuges can be offset by integrating refuges into space missions with scientific, political, or commercial goals. Overall, refuges show much promise for protecting civilization against global catastrophes and thus warrant serious consideration.

1. Introduction

From the perspective of the long-term success of human civilization, a global catastrophe could be a crucial event. A sufficiently severe catastrophe could cause total human extinction, in which case civilization will have no long-term success. Or, a catastrophe could leave some survivors, but the survivors are unable to maintain or rebuild the sophisticated civilization of the pre-catastrophe population, and again there will be no long-term success, or at least no significant long-term success. The stakes here are very high. Absent such a catastrophe, civilization could continue to flourish on Earth for about one to five billion years and in the rest of the universe for much longer; it also has a variety of technological options for scaling up its sophistication. The enormous potential for human civilization provides strong reason to protect it against global catastrophes.[1]

One proposed response to global catastrophes is for pre-catastrophe populations to build and maintain refuges that enable small populations to survive global catastrophes and rebuild civilization. A small but growing literature develops the

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[1] For further discussion of the importance of protecting against global catastrophes, see e.g. Ng (1991); Leslie (1996); Tonn (2002); Posner (2004); Beckstead (2013); Bostrom (2013).

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refuges proposal. Hanson (2008) proposes the idea and explores how selling refuge access could be used to infer catastrophe probabilities: access prices would increase when people felt catastrophes were more imminent. Abrams et al. (2007) and Shapiro (2009) propose a staffed data backup facility on the moon to keep civilization's population, knowledge, and cultural artifacts intact through catastrophes on Earth. Maher and Baum (2013) suggest refuge-like resource stockpiles to facilitate recovery from global catastrophes. Jebari (2014) developed the idea of refuges as a solution to potential unknown catastrophes. Beckstead (2014, 2015) surveys issues surrounding refuges and prior work on the topic and discusses refuge cost-effectiveness, finding that other interventions are likely more cost-effective for facilitating recovery from global catastrophes. All of these publications develop technical specifics of refuges in varying degrees of detail. This paper contributes to this literature by providing novel discussion of surface-independence for subterranean and extraterrestrial refuges.

Several other lines of work are relevant to this discussion of refuges. Some countries have built civil defense facilities to protect their citizens during war and facilities for leadership to preserve continuity of government (e.g., McCamley, 2007). On a smaller scale, disaster response and recovery are ubiquitous throughout the world. Private citizen survivalists or "preppers" often create their own refuges for surviving a variety of catastrophes. Some religious communities such as the Mormons support this sort of catastrophe preparedness. Finally, work on space travel is also relevant, because spaceships and space stations must achieve a high degree of self-sufficiency at low population numbers.

This paper discusses the potential for pre-catastrophe populations to build and maintain refuges that enable small populations to survive global catastrophes and rebuild civilization. The paper contributes to the refuges literature original detail on practical aspects of refuge design, construction, maintenance, and use. A successful refuge would need to be able to withstand the shocks of the catastrophe, keep alive enough people to maintain a viable human population into future generations, and provide its population with the tools necessary to maintain or rebuild civilization. The successful refuge would also need to be either permanently occupied or sufficiently accessible that occupants can reach it before the effects of the catastrophe prevent them.

If successful refuges can be built, they would give long-term human civilization some hope in the face of many of the worst catastrophe scenarios, including nuclear winter, pandemics, contagious biological weapon use, asteroid impacts, volcano eruptions, and geoengineering failure. Indeed, a core advantage of refuges is that they can help across a wide range of global catastrophes, potentially including catastrophes that have not yet been imagined. A civilization intent on ensuring its long-term survival would be wise to consider building and maintaining refuges.

Ideally, such catastrophes would not occur in the first place, and refuges would be irrelevant. Likewise, building and maintaining refuges does not make it unimportant to try preventing catastrophes. One reason is that the success of the refuge and its survivor population is not guaranteed – refuges can increase the probability of post-catastrophe civilization existing, but they do not make the probability 100%. Another reason is that a catastrophe could diminish civilization's long-term success even if there is a post-catastrophe civilization. Indeed, the survivor population could be small and slow to rebuild. Finally, even if civilization would go on to have the same long-term success, it would still suffer the short-term harms of the catastrophe itself. And so, even with refuges in place, it will remain worthwhile to try preventing catastrophes. For comparison, a good helmet can protect a cyclist from fatal injury, but she should still try to avoid crashing in the first place.

Fig. 1 sketches the potential values of refuges and of avoiding catastrophe in the first place. The figure shows civilization wellbeing as a function of time. Civilization wellbeing could be a function of population, per capita quality of life, and/or other measures. The curves show various possible trajectories for civilization. The baseline trajectory depicts civilization avoiding catastrophe and gradually growing in wellbeing over time. The catastrophe causes an abrupt decline in wellbeing. In the absence of a refuge, extinction occurs. (Note, not all relevant catastrophes would result in extinction absent a refuge.) The refuge keeps a small population alive. Absent recovery, this population continues at roughly the same low level of wellbeing. Finally, the figure shows two recovery scenarios, one with the same long-term success as the baseline case and one with diminished long-term success.

The values of refuges and of avoiding catastrophe can be obtained from integrating the Fig. 1 trajectories over time. The baseline trajectory has the highest value, followed by, in order, recovery with same long-term success, recovery with diminished long-term success, survival without recovery, and extinction. The gray shaded areas show the difference in value between adjacent trajectories. The light gray area shows the value of avoiding catastrophe if the same long-term success would follow. This area is large but finite, whereas the dark gray area extends into the distant future and thus is much larger. The dark gray area shows the additional value lost if civilization ends up with diminished long-term success relative to the baseline trajectory.

A few basic insights follow from Fig. 1. First, even if the same long-term success would occur, there is still a significant value in avoiding catastrophes (the light gray area), though this value is small relative to anything that affects the long-term success of civilization. Second, in the (perhaps likely) event that long-term success would be diminished following catastrophe, there is very large value in avoiding catastrophes (the light and dark gray areas combined). Third, if refuges can avoid extinction, then it is especially important for them to also enable recovery, even with diminished success (the added value being the white area to the right of the dark gray area). These basic insights should inform refuge design. Above all, any refuge that could shift post-catastrophe outcomes away from extinction and towards recovery with greater long-term success would be of very high value to human civilization.