EXPONENTIAL EXPANSION: GALACTIC DESTINY OR TECHNOLOGICAL HUBRIS?

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ABSTRACT. Is it our destiny to expand exponentially to populate the galaxy, or is such a vision but an extreme example of technological hubris? The overall record of human evolution and dispersion over the Earth can be cited to support the view that we are a uniquely expansionary and technological animal bound for the stars, yet an examination of the fate of individual migrations and exploratory initiatives raises doubts. Although it may be in keeping with our hubristic nature to predict ultimate galactic expansion, there is no way to specify how far expansionary urges may drive our spacefaring descendants.

1. INTRODUCTION

The debate over the existence of extraterrestrial intelligence suffers in that we know of only one planet on which life has evolved, and---as witness the species name we have chosen---count ourselves as the only form of intelligent life on that planet, or at least the most intelligent form. It is difficult to argue convincingly from a single case, especially when protagonists feel free to select radically different representations of that case. But that is what has been happening. Opposing models of humanity are used to plot the human future and to guess about the existence and probable behavior of extraterrestrials.

While advocates of the prevalence of extraterrestrials take care not to claim that Earth's biology will be duplicated elsewhere, they do posit that the evolution of life on Earth leading to the appearance of an intelligent creature with the wit to invent radio technology is a natural progression that provides a rough model for what may have occurred in other times and places in the galaxy (Morrison et al, 1977). The correlary assumption is that we, and by extension extraterrestrials, would much prefer to make radio contact across interstellar space than to attempt to colonize or visit other star systems.

Those who proclaim that we are alone in the galaxy argue from the premise that we are being inexhorably driven to colonize space. Emphasizing our restlessness and inventiveness, they prophecy that our descendants will exponentially expand throughout the entire galaxy---a region they see as empty of intelligent life for they argue that had any extraterrestrials arisen before us they would have shared our

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expansionary drive and hence would have already occupied the galaxy (Hart and Zuckerman, 1982).

Lest I be accused of ignoring the "hard realities" of the technical heart of this issue for "soft" notions about the nature of human nature, let me observe that many protagonists exercise a wide latitude in choosing just what are those "hard realities," and that their choices would seem to depend upon whether they adhere to an expansionary, colonizing vision for humanity's future, or a more intellectual one spent communicating with and learning from the Galactic Club of extraterrestrials.

Take, for example, the way protagonists treat the energy costs of interstellar colonization. Expansionists propose that generations of voyagers can and will exile themselves to living and dying in cramped starships in order to deliver a final generation to a new star system. This allows them to forecast slow (0.1c or less), one-way voyages, thereby bringing energy costs down to a level they believe will be one day feasible in a much expanded solar system economy. In contrast, advocates of interstellar radio communication propose that colonists will want to get to their destination within their lifetimes, and arrive there with sufficient fuel for a return trip to the homeland. This adds up to massive starships travelling at some major portion of the speed of light, and consuming fuel at a rate which---when expressed as some impossibly high multiple of current terrestrial energy production---shows how unfeasible the whole idea is.

To start from opposing conceptions of human nature, and then argue accordingly is common, if at times regrettable. Just recall the heated debates over whether we are basically an aggressive or cooperative species, or whether sex roles are biologically or culturally determined. However, whereas the latter issues have generated considerable research leading to new insights, the question of whether or not we are by nature expansionary, or basically a more intellectual, communicative creature, has so far not stimulated a similar level of inquiry or understanding. Assertion and assumption (often implicit) seem to be the norm.

As a first step toward examining the human basis of this question, here I wish to consider critically the proposition that we are by nature an expansionary, innovative animal destined to spread exponentially among the stars by examining relevant phases in human evolution and dispersion over the Earth.

2. THE HUMAN RECORD

First, let me briefly outline the case for the proposition. We are unique among Earth's animals in our ability to adapt culturally to a wide range of environments. This knack for inventing and employing technology to exploit new situations began to come to fore some 5 million years ago when some adventurous apes left the shelter of the tropical forest to seek a living on the savannas of East Africa. There they began to walk upright, and to use their newly-freed hands to manipulate rudimentary tools in order to survive, and eventually flourish,

in the grasslands and scattered woods of their new habitat. The fragmentary fossil remains of the various species of the genus Australopithecus, found from South Africa to Ethiopia and dating back some 4 to 2 million years ago bear witness to this early stage of hominid evolution (Finney and Jones, 1983).

With further development, both biological and cultural, came the appearance some 2 million years ago of Homo habilis, arguably the first species of our genus and, as the name indicates, supposedly a more accomplished tool maker. But it was the next species, Homo erectus, that was to be the first hominid to spread (in any numbers at least) outside of the African homeland. Supposedly using more sophisticated hunting technology, bands of Homo erectus followed game across the grasslands of southern Europe and Asia. With the newly discovered ability to control fire, and probably also to use animal skins and rudimentary structures for shelter, they were able to push far to the north into cold lands for which these relatively hairless, basically tropical bipeds were hardly biologically adapted.

The details and chronology of the evolution and spread of the next hominid species, Homo sapiens, is far from clear as is, for example, the role of Neanderthal Man (Homo neanderthalensis or Homo sapiens neanderthalensis?) in that process. However, what is important for our purposes is that this brainier and more technologically sophisticated hominid was able to take advantage of lowered sea levels during the last glaciation to trek across the Bering Straits land bridge to colonize the Americas, and to raft across the glacially-narrowed channels between a greater Indonesia then joined to the Asian mainland, and an enlarged Australia then linked with New Guinea. These Pleistocene migrations completed the settlement of all the continents, save ice-bound Antarctica.

But the disparate branches of mankind remained largely separated by the oceans until later developments in marine technology allowed people to sail across the sea and, just a few centuries back, to establish regular lines of communication and trade, thereby inaugurating the world economic system and setting the stage for the current age.

Now that the Earth is becoming crowded, and space technology is developing apace, the empty planets, moons and asteroids of near space beckon. Homo sapiens, that highly expansionary animal with the knack for developing technology to adapt to new environments, now stands on the threshold of space.

This argument, as stated so far, seems fairly reasonable and defensible. Cosmonauts and astronauts are now frequently in low Earth orbit, plans are being developed for more sophisticated space stations, and proposals for planting bases on the Moon or Mars are being pushed more and more. Barring worldwide disaster, it seems likely that we will soon try to colonize other places in the solar system. But that is a modest prediction which leaves open the real question. Can we really extrapolate from our record as an expansionary, technological species to predict that our descendants are destined to continue this expansion until they have settled the entire galaxy?

Actually, there are numerous episodes in the history of human

migration which can be cited to cast doubt on the inevitability of exponential galactic colonization. No specific migration has ever gone unchecked. Ecological barriers, the slowing or cessation of innovation, flagging motivation, or the opposition of those in the way of expansion have singly, or in combination, stopped every migration or colonization movement so far. Let me outline a few examples taken from the annals of maritime exploration and colonization---the phase of global expansion most often recalled by space colonization advocates to preview what may happen in space.

Take the case of the Polynesian discovery and settlement of the Pacific islands (Finney, In Press, b; Jennings 1977). Despite the stone age setting, this migration would seem to have the basic elements of a tale of colonization applicable to space as well as the sea: a small number of adventurous people develop a new technology to explore unknown regions and settle worlds never before touched by man. Yet, those intrigued with the parallel between settling distant islands and colonizing far star systems should read on past the story of how the Polynesians sailed their canoes into the Pacific and founded colonies on the unoccupied islands they discovered. They should inquire what happened after the islands were settled and ask why the Polynesians never apparently made it all the way across the Pacific to colonize the Americas.

Not all the Polynesian colonies prospered. Archaeologists have found remains of long extinct settlements on rocky islets hundreds of miles north of the Hawaiian Islands, on lonely atolls straddling the Equator and on rugged Pitcairn Island of Mutiny on the Bounty fame. These small, isolated and ecologically marginal islands were hardly ideal for settlement---as those who attempted to live there must have discovered, for they either died out or fled in their canoes.

Even on sizeable and fertile islands the descendants of the colonists had eventually to reckon with limited resources. When a canoe landed on an uninhabited island the first order of business was building an economic base for survival. However fertile a newly found island might have been, this was not easy, for until the taro, bananas and other food plants brought in the colonizing canoe matured, the colonists had to subsist on fish, birds and their eggs, and what edible roots and berries they might find on these biotically-impoverished volcanic outcroppings. However, once they had made it through this critical initial period, the whole island with its valleys, lagoons and mountain slopes, was open to them. Polynesian settlers responded to this opportunity just as would any other species colonizing an empty island, or more accurately an empty niche in an island ecosystem. They multiplied rapidly, quickly filling the new land. However, once the island became crowded and pressure upon resources became evident, the settlers were forced to change their strategy, both in terms of production and reproduction. They had to intensify their agricultural practices while at the same time attempting to limit population growth by various means of birth control and by infanticide.

In some cases a rough balance appears to have been achieved, but not without costs. For example, the 35,000 or so inhabitants of Tahiti were divided between high status persons will full access to food and

other resources, and the low born with limited access. The right to reproduce was restricted. And there is some evidence that female infanticide was so widespread that a marked skewing of the sex ratio had resulted.

Then, there were other islands where more Malthusian checks to population growth came into play: famine, war or the forced expulsion of whole segments of the population. Despite their lack of metal tools or higher forms of technology, the Polynesians were fully capable of degrading an island environment. Reef and lagoon life first felt the impact of these hungry, fecund newcomers. Then the land biota suffered as growing numbers of the colonists applied themselves to farming. Clearing with stone adzes and fire created cultivable land, but it eventually led to the development of infertile grasslands and to soil erosion. On some islands this process of environmental degradation had advanced to the point where sharp falls in the human population had resulted. This may have occurred even on a rich and fertile archipelago like Hawaii. By the mid-1600s, after some 12 centuries of exponential population growth that saw a population probably founded by a single canoe load of migrants balloon into a complex society of upwards of 300,000, the islands were crowded and the environment was under heavy pressure. Thereafter, say some archaeologists, the population began to fall, and wars that pitted chiefdom against chiefdom and island against island proliferated. But this does not seem to have led to any movement to flee the islands. By the time Captain Cook arrived in 1778, the Hawaiians had apparently given up long-range voyaging and had no thought of emulating their pioneering ancestors.

Easter Island provides an even more dramatic example of environmental degradation, population collapse and the end of further colonization. This tiny island was settled around 500 A.D. As the population multiplied to perhaps as many as 8-10,000, the Easter Islanders cut back the forest to clear more and more land for farming, and used what good timber was available for building canoes and houses and for moving and erecting their famous stone statues. By the time the first Europeans arrived in the 18th century the island and its people had suffered a catastrophe. The forests were gone, replaced by dry, windswept grasslands. Food had to be grown mostly in sheltered pits or behind stone walls, and timber was virtually non-existent. After a period of bloody inter-tribal warfare and famine, the population had been cut back to a few thousand divided and dispirited survivors. They had stopped making their huge stone statues, and had toppled over those which once stood upon the temples. What is more, they could no longer take to the sea, for their largest vessels were but tiny outrigger canoes made up of small scraps of wood painstakingly sewn together. The survivors had been trapped by a disaster of their own making, unable to regain their former prosperity and numbers, or to recreate their ancestral voyaging canoes so that they might flee their lonely and degraded island.

The moral of this Polynesian tale, as recounted so far, might be that running off to distant new worlds resolves nothing. It only transfers the inevitable population/resources crunch to a new setting--one which may, as in the case of Hawaii or Easter Island, leave the

people without the desire or means to flee farther, or to otherwise work their way out of their predicament. A space migration future might be strewn with many such dead ends.

Ming Dynasty China provides another example of stalled maritime expansion (Needham, 1971; Finney, In Press, a). In the early 15th century China was the leading naval power in the world. This rich and populous nation had long been a center for maritime innovation. The compass, the stern-hung rudder, battened sails for windward sailing, and compartmentalized hull construction are generally credited with being Chinese inventions. These and other features were combined to build the largest ships in the world---huge, multi-masted vessels of up to 500 or so feet long, which sailed together in the greatest fleets yet seen anywhere on the ocean.

Between 1405 and 1435, the Chinese mounted a series of expeditions into the Indian Ocean and began exploring down the east coast of Africa. These well-disciplined undertakings of an enormous feudal-bureacratic state involved scores of ships and tens of thousands of men. Under the command of the famous admiral Zheng He, the voyagers showed the flag around the Indian Ocean and established tributary and trade relations with states and princes from South Asia, the Middle East and Africa. These ventures also had a natural historical component for the Emperor's agents collected gems, minerals, drugs and exotic plants and animals to be brought back to China.

But this initiative never developed further into either a fullscale colonial expansion or a concerted program of scientific exploration. In fact, after the seventh grand expedition returned in 1435, the whole initiative was abandoned. The great junks were broken up or left to rot, and no new ones were built. China abruptly turned inward to the point of forbidding overseas trading ventures and, in 1500, even making it a capital offense to build a sea-going junk of more than two masts.

Scholars still debate over exactly why China abandoned overseas exploration. Was it because the land-oriented Confucian bureaucracy triumphed over the outward-looking Imperial eunuchs? Was it because the completion of the great inland canals brought a general reorientation away from the sea and toward the interior? Or, was it because of the rise of a brand of neo-Confucianism which favored introspection over action? Whatever the reasons, the fact remains that as a nation China lost the motivation to expand overseas. The lesson of this story might therefore be that there is no technological imperative to expand. Mere possession of the technology for expansion is not enough. The motivation to expand must also be there.

But, does flagging motivation explain why the Polynesians never apparently colonized the Americas? It is true that by the time of European contact in most Polynesian societies the idea of setting off in a canoe to find a new home seems to have been given up. However, a few societies, notably those in the Marquesas Islands, were still sending out canoes at the beginning of the 19th century, and legends tell of distant voyaging some six centuries earlier by other societies, such as Hawaii, which had become sedentary by the time Captain Cook arrived. Actually, the prime reason usually offered as to why the

Polynesians never apparently colonized the Americas is technological inadequacy: their canoes could not have sailed that far east against the prevailing easterly tradewinds and equatorial currents. However, lately we have come to realize that Polynesian navigators might have used massive wind and current reversals, such as those which occurred during the 1982-83 El Nino event, or high latitude westerlies, to help them to sail far enough east to have reached the American shore.

If, then, neither flagging motivation nor inadequate technology can explain why we have no evidence of Polynesian colonies in California or Peru, perhaps the most cogent reason is simply that their impact would have have been so slight as to be unrecognizable today. As tropically-adapted voyagers used to colonizing virgin oceanic islands, they would have been ill-equipped to cope with continental conditions and especially the inhabitants on whose territory they would have been encroaching. Those who might have reached the coast would probably have been repulsed or killed, or at best absorbed, and thus would have left no more imprint that did their Viking counterparts on America's Atlantic shore. While such a scenario might lessen the appeal of the Polynesian experience for those who see us as alone in the galaxy, it may provide a cautionary tale that deserves consideration.

3. DISCUSSION

So, here we have two sets of data that bear on the problem. The broad sweep of human evolution and history can be cited to support the image of our being a highly expansionary and innovative animal, Yet, episodes of stalled migrations and exploratory initiatives suggest that expansion is not automatic. The former set of data tells me that we are predisposed to colonize space, while the latter makes me wary of any thesis that we---or rather our descendants---will automatically and exponentially fill the galaxy. Therefore, although I am ready to bet that we will try to colonize space, I am not willing to wager how far that expansion will extend, or whether or not we will meet any extraterrestrials out there. Let me explain my caution further.

We are members of a highly technological culture steeped in the idea of progress and nurtured on the recent decades of accelerated growth (Nisbet, 1980). As such, the temptation is to look back and interpret the past in terms of the technological progress of the present, and to forecast a future of more and more of the same. The central premise for such technological optimism is that whatever is not forbidden by natural law will come to pass. Applied to space colonization, that means that the starship drives, life support systems and whatever else will be needed to cross interstellar space and found colonies on or around new worlds, will be invented, subject to the constraints of natural law. Correlary to this belief is a faith that our descendants will keep growing in number and keep trying to expand outwards. Working from this perspective it only takes an extended thought experiment to fill the galaxy.

In this thought experiment not every human space culture, or

later, not every human-descended species dwelling in space, needs to keep expanding for galactic filling to come to pass. Just as long as at least one group keeps establishing colonies, and at least one of those colonies establishes more colonies, and so on, the wave front of expanding intelligent life will keep moving outwards. One can even develop a scenario of natural selection on a galactic scale, whereby it will be those species most adapted to expansion whose descendants would inherit such a "brave new galaxy."

What we have to ask ourselves is whether such a galactic expansion would represent the working of some universal law of the inevitable course of intelligent life, or whether it is not just a figment of the imagination of a technologically presumptuous, but still adolescent species. In other words, has a general principle governing the evolution and expansion of life been discovered, or is this just a reflection of the hubris to which we humans are so given?

The term, hubris (hybris) is of Greek origin, and refers in classical ethical and religious thought to an overweening presumption that oversteps natural limits to man's actions. For example, in The Persians by Aeschylus, the emperor Xerxes arrogantly builds a bridge across the Hellespont, attempting to turn land into sea, an impious act for which he is punished by defeat at the hands of the Greeks (Aeschylus 1970). It may seem natural for some members of a culture which has experienced an unprecedented rise in scientific understanding, and in the application of that understanding to practical problems, to forecast virtually unlimited technological growth. From this perspective the prospect of inevitable exponential galactic expansion may seem self-evident. But, we really have no way of knowing whether such a forecast is a reasonable reading of reality, or so much hubris.

It is often said that the presence or absence of extraterrestrials is a question that can only be answered experimentally---by looking and by listening. Similarly, how far and how wide our descendants will spread cannot now be specified by any logical argument or equation, or settled by debate. It can only be ascertained through observation. That we will attempt to colonize space seems likely---for we are a most hubristic species. But, as to the outcome of our efforts to leave Earth, and perchance to meet extraterrestrials along the way, we must leave that to future natural historians of the galaxy.

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