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Human expunction

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Abstract: Thomas Nagel in 'The Absurd' (Nagel 1971) mentions the future expunction of the human species as a 'metaphor' for our ability to see our lives from the outside, which he claims is one source of our sense of life's absurdity. I argue that the future expunction (not to be confused with extinction) of everything human – indeed of everything biological in a terran sense – is not a mere metaphor but a physical certainty under the laws of nature. The causal processes by which human expunction will take place are presented in some empirical detail, so that philosophers cannot dismiss it as merely speculative. I also argue that appeals to anthropic principles or to forms of mystical cosmology are of no plausible avail in the face of human expunction under the laws of physics.

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> *Things perish into those things out of which they have their being, according to what must needs be; for they make amends to one another for their offense, according to the ordinance of time.* —Anaximander, Sixth Century B.C.E.

Introduction

Forty years ago the philosopher Thomas Nagel wrote an article about the 'the absurd' in which he dispatched a seemingly sophomoric argument, once somewhat popular among the Bohemian crowd, for the alleged unimportance of human life and striving (Nagel 1971). The argument starts by throwing out as a premise something almost any reflective person has at some time pondered, even if only in passing.

Nothing I do now will matter one tiny bit in, say, a million years.

Nagel pointed out the logically symmetrical implication that immediately follows from this premise.

If the above statement is true, then by the same token, nothing that will be the case in a million years matters now. In particular, it does not matter now that in a million years nothing we do now will matter. (Nagel 1971, p. 716)

This conclusion eventually reveals an even more interesting 'recursive' aspect to the concept of mattering. Nagel begins the closing sentence of his paper with this clever clause.

> If *sub specie aeternitatis* there is no reason to believe that anything matters, then that doesn't matter either … (Nagel 1971 p. 727).

All that is left, he then says, is returning one's perspective back into an ordinary life and consciousness, but now with a post-absurd 'irony' present (as opposed to a Camus-style existential defiance, which Nagel sees as too 'romantic and slightly self-pitying.' (Nagel 1971 p. 726))

The Future News is Very Bad

In the course of his argument Nagel mentions in passing that 'all of mankind will eventually vanish without a trace' (Nagel 1971 p. 725). Yet this is immediately declared to be only a *metaphor* (his word) for our cognitive ability to step back and see our lives as if from a cosmically high hill – from what he later came to call 'nowhere.' I suppose that we ought to expect that a smart humanist would see the future expunction of 'all of mankind' as a metaphor. Yet it is no mere metaphor – for anything, let alone a sense of the absurdity of human life. It is as physically real and necessary as the law of gravity, the periodic chart of the elements and second law of thermodynamics. The Earth itself as a planetary biosphere is doomed. It will happen as surely as apples fall from the tree to the ground and not the other way round. I doubt if this coming fate of the biosphere is really as irrelevant to the present as Nagel's argument soothingly implies. It is false that something causally connected to the Earth we know will always be here, and I suspect that Nagel's argument is based on an unspoken presumption that the Earth is permanent, permanent in the sense that something causally connected to it (and thereby to us) will always be here. The argument relies in part for its power on a failure to appreciate fully what it means for

(1) the biosphere, and all things human, to suffer total *expunction* under the laws of biology, geology and physics, and for
(2) every last cubic centimetre of the Earth to be burnt into ionized nuclei.

How can this be so? Let us take a ride into the future to see for ourselves how the sad demise of the Earth will take place – over and over, as we shall see, in a kind of merciless overkill – or at least how it will do so according to the best science we now possess.

The Sun is now about 30% brighter than it was four billion years ago. Indeed, under the laws of physics solar luminosity will continue to climb slowly with time. About 500–700 million years from now the solar luminosity will have become so much higher that a very much warmer Earth will occur.

Silicate rocks – which are now a massive carbon sink and therefore a major source of carbon dioxide (CO_2), the 'food' of all plants – will in the future time of that much warmer

Earth begin to weather and wear away at a much faster rate than they do now – for a hotter Earth is a windier and rainier Earth. In fact, the rate of weathering will be so great that the Earth will be unable to replace the lost silicate rocks via volcanism and tectonic plate spreading. Plants will begin to struggle to get enough CO_2 as the latter's main geologic sink is slowly destroyed.

Below about 150 parts per million (ppm) CO_2 mean global concentration all dicot plants (e.g., hardwood trees, conifers, fir trees, flowering plants, etc.) will die off – with only the grasses able to survive the lower mean global CO_2 concentration. When the CO_2 mean global concentration falls below about 10 ppm CO_2 then even all the monocots (e.g. grasses) will die off. The best current estimate of when this will happen is about 800 million years from now. With no plants left on the landforms of the Earth all photosynthesis – which is the main source of breathable oxygen for land animals – will cease everywhere on land. The plankton in the oceans, the very base of the oceanic food chain, rely for essential nutrients on the rotting vegetation that is normally washed into the seas by river runoff; in particular, the plankton need the phosphates and nitrates provided by rotting land plants. Hence, once all plants have died off, the plankton will begin to die off with disastrous ripple effects up the marine food chain, invertebrates, crustaceans, fish, mammals and so on.

As the global plant die off picks up speed, the mean global concentration of oxygen will drop precipitously, both on land and in the oceans. With no plant roots to hold topsoil together the land itself will begin to weather at a faster rate, washing away the last soil nutrients into the dying oceans. When the mean global temperature inches above 40°C (104°F), all multicellular animal forms on land will start to die off, beginning at the equator and moving towards both poles. Current estimates predict that within a 'few million years' of the last plants dying off, the last multicellular land animals will die away.

Let us then try to get a picture of the Earth's landforms at about 900 million years out from now: barren rocks, ever-moving sand dunes and withering high winds under a blistering Sun in a permanently hazy sky (it will look like the worst smog ever seen, an *opaque* sky). Land animal life has a maximum *sustained* temperature limit of about 45°C (113°F). Once the mean global land temperature reaches that value only single-celled microscopic life will be left on the land.

It is important to keep in mind that the ultimate instigating cause of all this destruction is astrophysical: the Sun's slow but relentless upward creep in luminosity. This is not something that *we* can do anything about. Figure 1 below indicates that the solar luminosity will continue to increase at a rate of approximately 11.86 watts m^{-2} per 100 million years.

After mean global temperatures become too high to sustain land animal life, then the Earth will begin to lose all its ocean water. About one billion years from now the mean global temperature will be about 70°C (160°F) and the Sun will be 10% brighter than it is now. Under those conditions the seas will begin to evaporate away into outer space, eventually leaving vast salt plains and puddles of toxic brine (the latter will be toxic due to nitric acid in the rain) where the mighty oceans of the current Earth once sloshed. Continued weathering of landforms will wear down the now mighty mountain chains of the Earth into smooth and barren hills (the Himalayas and the Rockies, all gone, no snow caps, just modest treeless and grassless hills made of sterile and bare rock). Oh, and the whole planet will stink – really badly – for there will be no structured biosphere to absorb and recycle all the hydrogen sulphide ('rotten eggs' smell) released by volcanoes and other forms of tectonic plate venting (not that any sentient beings will be there to abhor the stink, of course – and it is perhaps worth noting that hydrogen sulphide is quite toxic to humans).

It gets worse. The weather will become rather apocalyptically violent. The current troposphere, where our weather takes place, is on average about 60 000 ft tall from the ground up to where it transitions into the stratosphere. But on the broiling Earth of a billion years from now the troposphere will expand upwards from the ground to about 320 000 ft altitude. That will produce storms more violent than any ever seen in human history, many of which will dissipate high up before reaching ground level. All ocean water on the Earth might be lost to outer space in as little as 100 million years.

At this point an uncertainty enters our story: scientists dispute how quickly the oceans will evaporate, and the rate at which they are lost to space affects the subsequent outcome. *If the oceans go quickly* – in that 100 million year span – then current theory suggests that the future Earth may be able to avoid a 'runaway greenhouse effect' like the one that gave Venus its current surface temperature of 450°C (842°F), and its current atmospheric pressure 93 times that of the Earth's (Earth: about 14.7 pounds per square inch, Venus: about 1371 pounds per square inch, or over two-thirds of a ton per square inch (!)). *If the oceans evaporate at a sufficiently slow rate*, then a runaway greenhouse effect would likely occur on the Earth, and any organisms – micro or not – that were somehow still left holding on would find it physically impossible to function and reproduce at temperatures over 800°F and pressures over two-thirds of a tonne per square inch.

The loss of the oceans will be – excuse the expression – the watershed event in the destruction of the Earth as a habitable planet. For one thing, it eliminates the extreme strategy of trying to adapt to a broiling planet by living in the ocean. More critically, the loss of the oceans will kill the machinery of plate tectonics – the crustal plates of the Earth will stop moving on top of the Earth's hot mantle. The reason is that ocean water is what 'softens up' the oceanic plates' bottom surfaces so that they can slide underneath the harder (because drier) continental plates with which the former plates collide. The end of plate tectonics means the end of the carbon recycling and replenishment system that now operates on the Earth to keep life going. Thus the last possible mechanism that could have perhaps restarted a process leading back to life will be irremediably broken in that distant time.

In figure 2 below we see a graph presenting the famous climate model published in 1992 by Ken Caldeira and James Kasting in which they predicted the mean global temperature and the CO_2 concentration out to 1.6 billion years in the future.

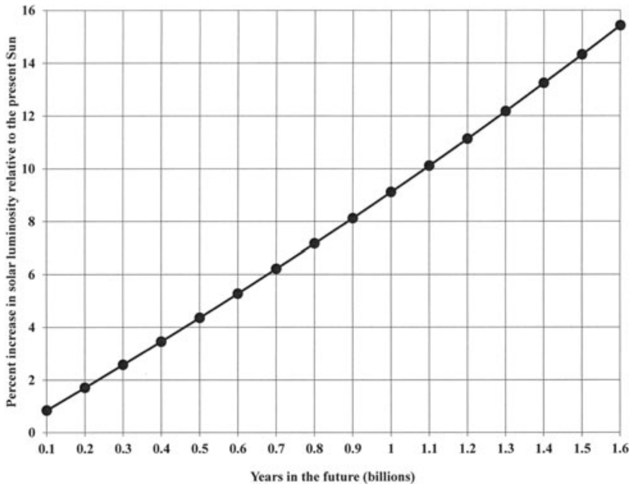

Fig. 1. Increase of solar luminosity over time.

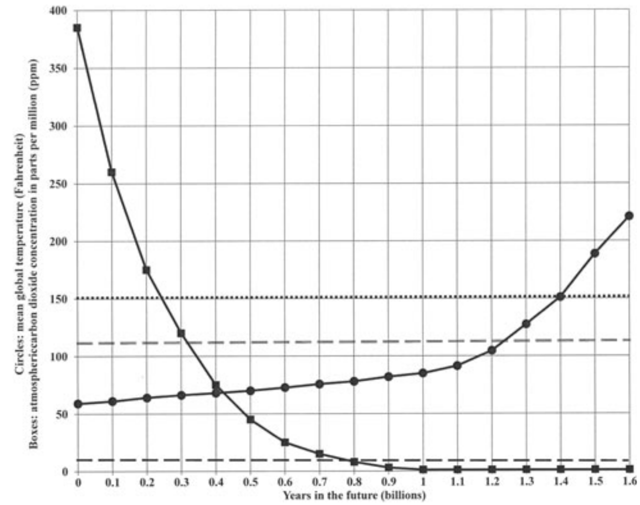

Fig. 2. Caldeira & Kasting's 1992 Model of the 'Carbon Catastrophe' to come in the terran biosphere.

In figure 2 the dotted line at 150 ppm represents the minimum CO_2 concentration below which dicot plants and trees cannot survive. The dashed line at 10 ppm represents the minimum CO_2 concentration below which monocot plants (e.g., grasses) cannot survive. The dash-dot line at 113°F represents the sustained temperature limit above which animal life on land cannot survive.

I stress again that the model shown in figure 2 has nothing to do with humanly produced CO_2 emissions. It represents the fate of the biosphere due to natural causes: astronomical, geological and meteorological. The Earth, according to the model, will exceed the upper sustained temperature limit ($\sim$113°F) for land animal life sometime about 1.25 billion years from now – and this is so even if all fossil fuel burning were somehow to cease tomorrow morning (Caldeira & Kasting 1992 p. 723).

A slightly more recent 1999 climate model by Siegfried Franck, Konrad Kossacki and Christine Bounama generally agrees with the Caldeira and Kasting model. Slight differences do occur in mean global temperature prior to 1.1 billion years out, but thereafter the two models coincide almost exactly (Franck *et al.*, 1999 p. 314).

Next comes the solar 'swallowing' of the Earth. The Sun itself will provide the ultimate overkill. When the future Earth, 1.1 billion years from now, becomes a searingly hellish slab of barren rock, sand storms, opaque ochre skies and an atmospheric pressure so high that it would implode a human body, the Sun will continue to get slowly brighter, probably for another five billion years at a minimum. Eventually however, like all finite systems, the Sun will begin to run out of the hydrogen fuel in its core, fuel that it fuses into helium.

About six billion years from now, after having brightened 2.5 times in luminosity from the luminosity it had when the Earth was first formed, the Sun will begin to undergo very complicated internal structural changes. Once the hydrogen fuel in the core drops below a critical value, the laws of physics will force the Sun to increase its central temperature. The increased core temperature will cause the outer gas layers of the Sun to expand enormously. This will simultaneously make the Sun's diameter swell and its surface cool to a lower temperature. It will appear to a sufficiently far-off observer to have increased a few thousand times in luminosity but to have changed its surface colour to a cooler red. The massively increased luminosity will cook the surface of the waterless Earth to about 2000°C (3632°F), hot enough to melt stone and rock, which will 'smooth' the Earth's surface into a very low relief topography. The pulverizing lethality of the subsequent solar radiation – highly penetrating gamma rays, in particular – will be totalizing. Nothing, absolutely nothing biological in the sense now familiar to us, could survive these conditions (Kaler 1993).

In figure 3 below we see the future stages of the Sun's evolution plotted in terms of solar radius and solar surface temperature, with both axes plotted in log-10. The current distance from the Earth to the Sun is indicated by the dashed line at 214.9 solar radii near the top of the graph. The current Sun is the unfilled circular data point at 1 on the vertical axis of the graph. Future stages of the Sun are indicated by the circular data points other than at 1 on the ordinate. Arrow-headed lines indicate the time order of future solar evolution. Ultimately the Sun will contract to very small but very hot 'dwarf' stages. After that the remnant of the solar core will slowly cool down into a rather dim brown dwarf star (not shown on the graph). As one can see, and as will be explained further below, in the red giant stage (the highest circular data point on the graph) the Earth will be inside of and underneath the approximately 4000 K solar surface. Note that the solar radius and temperature do not change over time in a single direction. Radius and temperature each increase, then decrease, then increase again. The lines of the Sun's evolutionary track are of course more rounded than the straight lines I have used in figure 3 to plot the relevant data points.

I have not provided a time axis, but the Sun will not reach the second data point from its current position in figure 3 until another 5.5–6 billion years have passed. Stages later than the second data point from the present Sun tend to last for progressively shorter time intervals until one reaches the last data point at the bottom of figure 3. There is no supernova event in the Sun's future because its mass is too small – only stars with *core* masses greater than 1.4 solar masses can end up producing a supernova explosion. Our Sun, because of its relatively low mass, will never get hot enough to fuse the carbon or oxygen produced by helium burning in the solar core, although trace amounts of neon and magnesium may accumulate during solar helium burning because of sequential capturing of alpha particles.

Worse is still yet to come. As the Sun nearly exhausts the hydrogen in its core, the helium in the core becomes preternaturally dense. It will become so dense that the helium nuclei form one of the truly exotic states of matter: *degenerate matter*. This is a term from quantum physics and has no moral meaning, of course. Degenerate matter does not behave like 'regular' everyday matter; for example, degenerate matter can absorb more pressure without thereby getting hotter. Put another way, pressure and heat become 'disconnected' from each other in such a way that the Sun cannot obtain pressure relief and a temperature drop by expanding (as it could if its core was composed of regular matter). Instead the Sun will explode quite suddenly in what astrophysicists dub a 'helium flash.' During its helium flash the solar core will burn a significant fraction of its helium into carbon *in a span of minutes*. This will release so much energy that it rivals the energy released in a supernova, with one big exception: the energy produced in a solar helium flash cannot get out of the solar core because of the latter's insanely high density. Instead, all that energy will produce quantum effects that will render the core matter non-degenerate again (I have just oversimplified a knot of arduously complicated solar quantum physics). The result is that the Sun will drop in brightness by an order of magnitude and become smaller by the same amount. It will then burn helium 'quietly' but for only 200 million years (compare: it burned hydrogen quietly for 10 billion years), for the higher the core temperature, the faster the core fuel is consumed.

Shortly thereafter our nearest star will enter an evolutionary stage that is called the asymptotic giant stage. Then, preparatory to getting hot enough to burn its remaining helium in a thick shell surrounding its core, the Sun balloons outward in size again and increases its luminosity over 5000 times – it becomes a *red giant* star. Its radius swells and swells until the Sun begins to 'eat' the inner planets one-by-one. First Mercury is swallowed and vaporized, then Venus. The best theoretical estimates we can now make indicate that the Earth will also be swallowed and eventually vaporized at solar interior temperatures near 100 000° (Rybicki & Denis 2001). Even Mars – that intriguing planet of wistful human longing and obsession – will end up slightly closer to the Sun than Mercury, the closest planet to the Sun, now is; and therefore Mars will become suitably 'fried' in the manner long suffered by Mercury, whose current solar-side equatorial temperature is ~825°K (~1025°F), although because Mercury lacks enough of an atmosphere to transfer heat its polar regions probably average about 167°K (−160°F). At a minimum, Mars' new status as the closest planet to the red giant Sun will result in the volatilizing and blasting into outer space of every water molecule now trapped within its rocks, polar caps and permafrost layers, should there be any of the latter.

For the Earth and the things upon it, however – obviously our more immediate concern – every chemical bond of every broiling artefact ever left behind by humans will melt into its constituent nuclei, a radical enough transduction of physical structure that any information that might once have been extractable from those artefacts will be expunged from the Universe.

The Starkness of Expunction

To be expunged is far worse than to become extinct. Extinct creatures leave causal traces of their once having existed – at least the leaving of such traces is physically possible in a variety of circumstances. By contrast, to suffer expunction in the sense in which I am using the term is to die off as a species along with all our causal traces, to have all the causal effects of one's species having existed obliterated, to have the very dwelling space in which one's species lived obliterated. The obliteration will be total, not even our electromagnetic wave output, our bandwidth 'trash,' will survive as decipherable information after that much time has passed. It will become, first, undetectable against the natural galactic electromagnetic noise background, then it will finally degrade by scintillation effects and dust disruption into disorganized white noise or pink noise. This is an identity-destroying transformation in which what was once, say, a satellite-based phone call that escaped into space as a traveling wave, withers away into random noise bytes, something utterly devoid of humanity and, more importantly, intentionality.

How can it be irrelevant to us now that there is a date certain by which all marks of human endeavour as we know it will be gone from this place that has always been our home, our place of dwelling? What does it mean for nothing human to be left in the place where humans dwelled? There will be no ruins, no remains, not even the faintest signature of human culture and sentience. What does it mean that the human project of living, barring an absurdly unfeasible colonization of other star systems – they are too far away to get to any of them in one piece, and space travel of the sci-fi movie kind is assuredly physically unfeasible, more on this later – will leave no permanent record that it was ever here? I do not think that we understand the significance of this fate.

It is important to appreciate how calming it is to believe that *something or other* will carry on the mark of the human project of living after we are personally each gone. It is this soothing background belief, one buried so deeply in our everyday expectations that it mostly goes uncommented on, to which the inexorable laws of physics give the lie. Completely insentient and inanimate physical processes will utterly wipe out a richly articulated locus of sentience and 99.99% of that locus's causal marks of having existed at all (the 0.01% are those HBO movie satellite broadcasts hurtling through space where even they will eventually become so much electromagnetic toast, and, of course, the two Pioneer and two Voyager spacecraft

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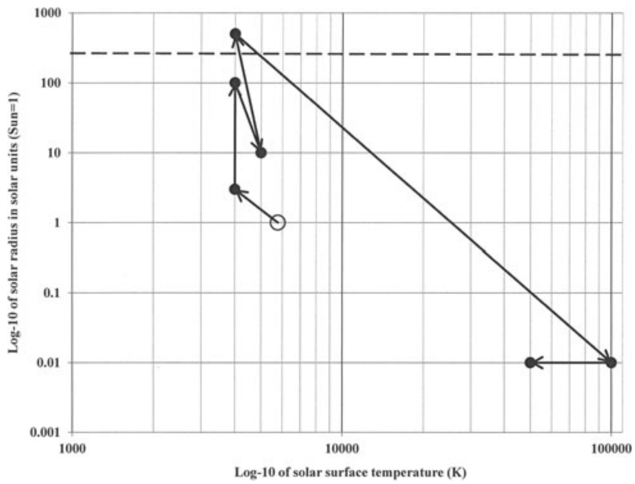

Fig. 3. Future evolution of the solar radius and surface temperature.

launched in the 1970s[1]). What is it like for there to be no something-or-other that comes after us *because* of us? This is difficult for us to grasp in terms of everyday concepts, but perhaps we should nevertheless make some attempt to do so. It will, when the Earth vaporizes, not matter one bit that anyone ever had offspring. There will be a last cohort of kids to which anyone is genetically related. The human line will be extinguished. There will come a time when no living thing in the Universe in any way represents us, not even at 270 million removes or a billion removes. As the saying goes among a clinically definable subset of the chronically depressed, it will be as if you had never existed at all; and this will be true of everyone, including Pelé, Juliette Binoche, Adolf Hitler, Isaac Newton and everyone's mother.

There is No Feasible Escape or Rescue

What about Captain Picard and the crew of the starship *Enterprise*? – surely they can take the humans sweltering under an expanding and approaching Sun off the Earth and transport them to a new planet to colonize, can't they? Well, no. The physics portrayed and presumed in *Star Trek* is like your average Hollywood movie: mostly bullocks and phony as a seven dollar bill. There are three intractable problems with interstellar travel by humans in a spaceship, the reaction-mass problem, the distance problem and the interstellar medium problem.[2]

The reaction-mass problem is entirely of an engineering nature. There is no known technology by which humans could carry enough fuel aboard a reasonably sized spaceship so as to be able to accelerate the ship to significant fractions of light speed at the start of the interstellar voyage, and then decelerate it from significant fractions of light speed at the end of an interstellar voyage. On-board fuel is called 'reaction-mass' by those who ponder this problem, because any form of propulsion requires that the mass bound up in the on-board fuel must undergo some kind of reaction, chemical or nuclear, that releases energy to be turned into propulsive force. Ingenious ways around this problem have been concocted on the drawing board, but they all require the spaceship to have a structure nothing like what we can feasibly build. For example, there is the 'solar sail' spaceship design, in which the propulsion is providing by a huge and extremely thin sail made of foil or some other metal that traps energy from the light photons emitted by the Sun in an outward direction and converts the energy into forward drive power. To achieve even miniscule acceleration would require sails that are tens or hundreds of miles across. No one knows how to attach such a huge sail to the main ship in a stable way, and doing so would appear, if not strictly impossible, indefinitely unfeasible.

Then there is the nuclear-bomb spaceship design. Load the ship up with all the nuclear warheads now on Earth, place an 'inertial plate' of sufficient thickness in the rear of the ship, then detonate the warheads against its external surface to produce a 'putt-putt' acceleration in spurts. The blast and radiation effects of nuclear explosions are somewhat mitigated in interstellar space where there is no atmosphere or strong local gravitational field. How would you test this design? Could we be sure that the inertial plate would not melt, and that not too much radiation would seep inside the living spaces of the ship? About the only good thing with this design is that, as

1 *Pioneer 10* (launched in 1972) and *Pioneer 11*(1973) each carry a gold-anodized aluminium plaque designed by Carl Sagan, Frank Drake and others. The plaques are identical and contain etchings of a nude man and a nude woman (Caucasian and without pubic hair), an illustration of our Solar system with lines indicating that the spacecraft originated from the third planet, the location of the Sun relative to the galactic centre and 14 galactic pulsars, and a drawing illustrating the hyperfine oscillation states of atomic hydrogen.

Voyager I (1977) and *Voyager II* (1977) each carry a gold-anodized phonograph record and stylus needle, along with pictorial instructions for how to rotate the record at the proper speed. The record carries greetings in 55 human languages, as well as sound effects of Earthly life (dogs, crickets, wind, rain, etc.), and samples of human music (just a few among them, Chuck Berry singing *Johnny B. Goode*, the First Movement of Bach's *Brandenburg Concerto No. 2* in F, a 'Night Chant' by Navaho Indians, a New Guinea 'Men's House Song,' and *Dark Was the Night*, sung by Blind Willie Johnson). Visual scenes are constructible from the analog data on the record (elephants, the Taj Mahal, Boston, mathematical formulae, a chart of human conception, a house interior with an artist by a fireplace, children touching a globe, etc.). The full lists of greetings, sounds, music, and scenes are each at (VS, 1977a, b, c, d), respectively. All four spacecraft either have escaped or are in the process of escaping the solar system. Although the metal artefacts described are placed aboard the spacecraft to minimize degradation by space dust and debris, Sagan himself admitted, with particular respect to the Voyagers that '*The spacecraft will be encountered and the record played only if there are advanced spacefaring civilizations in interstellar space*.'(VS, 1977e) It is thus absurdly improbable that any of these four spacecraft will land on or hit a planet, let alone a planet with intelligent and technologically advanced life-forms. Both Voyagers are expected to exhaust all on-board power sources no earlier than 2025. The Pioneer spacecraft lost all power capacity no later than 2003.

2 Since I am about to argue that a mutual solution to the three problems is unfeasible for the foreseeable future fairness dictates that the reader be allowed to consult a more upbeat look at these problems. For a breathlessly positive take on the feasibility of interstellar travel see Crawford 1990 and Dyson 1968.

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Carl Sagan once pointed out, it would be the best use of nuclear weapons we'll ever come up with, and not a bad way to get them all off the Earth.

As an example of how desperate theorizing about the reaction-mass problem can get, consider the Bussard ramjet spaceship design. This ship carries very little on-board reaction-mass as fuel because, as it moves, it collects its reaction-mass from the interstellar/interplanetary medium with a 'large scoop' protruding off the front of the ship. All the debris and dust and gas in the interstellar medium thus become the fuel, converted to thrust power in the manner of a ramjet engine. The largeness of the scoop required is, of course, absurd: a minimum radius of 10 000 km (620 miles). Obviously no solid object will do, so the idea arose to make the scoop an electromagnetic one that scoops up debris with magnetic or electric fields. Several technical problems beset this strategy: the electromagnetic fields would deflect away a good portion of the interstellar debris rather than scooping it into the ship; and worse, for even moderate speeds the magnetic fields generated must be millions of teslas in strength, which is a practical engineering impossibility.

The reaction-mass problem is connected with the second problem: the distances between stars make travel between them utterly pointless in terms of the average human lifespan. At 1% light speed, surely close to the upper limit even our descendants with advanced technology will ever feasibly achieve given the reaction-mass problem, it would take 430 years in on-board time to reach just the nearest star system, Alpha Centauri. One per cent light speed is about 6.5 million miles h^{-1}. The fastest humanly piloted vehicles in history to date moved about 22 000 miles per hour, over two orders of magnitude slower than 1%of light speed.

Interstellar distances are preternaturally huge. Proposed solutions to the distance problem include building spaceships to accommodate many generations of human crew members. The crew at the beginning of the voyage would start it knowing that they have no chance of experiencing the voyage's end. Going to Alpha Centauri, which may or may not have any habitable planets orbiting it or its companion stars, would require a ship outfitted to accommodate at least 10 generations, if not 12–15, of human inhabitants. This is very likely not psychologically possible. What are the chances that in 430 years of serial cabin fever the ship's social structure will self-destruct – 99%? No problem, say some theorists – most of the crew members, except for some small contingent to run the ship – will be cryofrozen or placed in some other kind of 'suspended animation,' a technology whose feasibility is highly questionable. If suspended animation turns out to be, as many think it will, not physically feasible (e.g., freezing and unfreezing cause too much microcellular damage, killing or disabling the frozen human), then we have the daunting problems of how to house, feed and keep healthy, 10–15 generations of fully animated human passengers aboard a small rather than a large spaceship (in order to maximize acceleration and shorten the voyage). It is not out of the realm of possibility that such a multigenerational crew would essentially become psychotic under such gruelling and harsh conditions. By comparison, Earthly pioneers had only to endure a few years of travel at the most, and in some cases mere months – and look at the number of those who cracked under that strain.

The interstellar medium problem is next. Interstellar space is not as empty a vacuum as the popular conception makes it out to be. It is a non-homogeneous medium, containing dust, rocks and clouds of hot ionized gas, often of enormous size. The gas that fills the interstellar medium, with an average estimated density of about a million atoms per cubic meter, is often a hot gas of several thousand Kelvin. This is a rarefied gas and of little danger to a moving spacecraft. Interstellar dust grains are spread even more thinly, a billion times more thinly, so they are of no concern to a rapidly moving spacecraft. But no one knows at present whether the interstellar medium contains larger solid debris with macroscopic masses. It may be that it does not contain any such debris. On the other hand, it may be that it does contain some interstellar equivalent of the occasional large rock or small asteroid that is found much more abundantly inside the heliopause of a star system like ours.

Then there is the *Oort Cloud*, named after the Dutch astronomer Jan Oort. This is a roughly spherical shell of solid debris – comets-to-be, rogue planetoids, rocks, ice, pebbles, dust – that surrounds the immediate outside of the Solar system: it is what a spaceship leaving our Solar system would hit right after passing through the heliopause. The Oort Cloud is left over debris from the initial formation of the Solar system. It is believed to be a significant source of the many comets that dot the Solar system proper – there is some causal interplay between the Oort Cloud and the Solar system proper, at least on occasion. A consensus estimate of the total number of solid objects in the Oort Cloud is 1–10 trillion. Any rapidly moving spacecraft leaving our Solar system would have to plough through the Oort Cloud, a task that the starship *Enterprise* seems to be able to do in the science fiction tales without being damaged, presumably, only because of its enormous pulverizing mass. But any spaceship real humans build will have to economize on total mass in order to maximize on thrusting power. This reveals an intriguing quandary: the larger the rest mass of the ship (to plough through the muck of the Oort Cloud safely) the larger the thrust required to accelerate the ship; the larger the thrust required to accelerate the ship, the larger the reaction-mass fuel load stored on-board; but the larger the fuel load stored on-board, the larger the ship's mass must be. This is a cycle out of which we cannot feasibly break. While safety requires a large ship's mass, speed requires a small ship's mass. To be safe means to travel slowly; but to travel slowly, as we have seen, guarantees psychological/social unfeasibility.

How about a Move to the Suburbs?

Interstellar migration is a nonstarter solution. That still leaves moving to one of the outer planets to escape the swelling Sun – in fact, the swelling Sun should heat up those currently frigid outer members of our planetary system. This may happen, although the distances between the outer planets (Jupiter, Saturn, Uranus, Neptune and Pluto) are disproportionately huge when compared to the distances between the inner planets (Mercury, Venus, Earth and Mars).

The prospects for a local move out to the far suburbs of our Solar system are not auspicious. Jupiter, Saturn, Uranus and Neptune are not planets in the same sense that the inner planets are planets. Those four huge outer planets are what astronomers call 'gas giants.' They do not have rocky solid surfaces. They are not made of soil of any kind. They are enormously complex collections of gas. Pluto we know less about, but current evidence gives it a solid surface of frozen ice and rock – not actually the kind of fertile soil in which we could successfully plant those corn seeds we brought with us on the spaceship – and at 3.6 billion miles from the Sun, it will still be at a frigid 2.4 billion miles from the Sun after the latter swells into a red giant star.

Before we survey the various far-off moons, however, we must first of course deal with that perennial favourite of sci-fi terraforming fantasies, Mars. It may be that more science-fiction novels have been written about human terraforming and habitation of Mars than about any other single sci-fi theme.

To *terraform* is to mess with a planet or Moon in such a way as to permanently alter its atmosphere, surface temperature and pressure, weather and perhaps even its soil (if it has any), so as to render them all more Earthlike, more user-friendly to humans, with the ultimate goal being to pioneer or colonize the said planet or Moon. There exist some technical papers on this theoretically intensive project (see for example, Zubrin & McKay 1996). Table 1 below comparing the present Earth and Mars can show us at a glance the doleful odds we are up against.

One can sense from the disparities in table 1 below what a baleful fantasy terraforming Mars will remain for us. A perusal of the literature – scientific, not science-fiction – shows such gargantuan and ridiculously expensive manoeuvres as: (1) placing several huge 'mirrors' in orbit around mars to reflect sunlight onto its surface. (2) Sending a human spaceflight out to the edge of the Solar system to 'find' an ammonia-rich asteroid (ammonia is an excellent greenhouse gas), and then, by using nuclear bombs (how exactly is never specified in detail), to disrupt the asteroid's orbit and crash it into Mars. (3) Setting up on Mars enough (robotized?) halocarbon (i.e., fluorocarbon) factories so as to release into the Martian atmosphere the equivalent of three times the *total* human production of halocarbons from 1972 to 1992 (when their manufacture was banned or severely restricted) – three times 43 million tons, or about 129 000 000 tons. No one knows for sure if enough Martian ores exist to act as a local raw material supply. Maybe they do; but if they do not, and then how would we transport the enormous tonnage of necessary raw materials to Mars?

Mars has no magnetic field and therefore no magnetosphere to trap or deflect the most lethal and constant wavelengths of the Sun's radiation output. We can forget humans ever being able to zip around on the surface even of a fully terraformed Mars. There really is no fancy technological solution to this problem except (4) to have the transplanted human population live underground in old lava tubes, or, in 'igloos' made of sintered regolith; and all this, mind you, is to buy human life at most another five billion years – for, as mentioned, eventually even Mars will be roasted by the swollen Sun into a broiling mound of melted rock.

Table 1. *Vital biospheric stats of earth compared with Mars*

	Earth	Mars
Surface pressure	1 atm	0.006 atm
Atmospheric oxygen	20.9%	0.13%
Atmospheric CO_2	0.04%	95.3%
Atmospheric nitrogen	78.1%	2.7%
Mean global temperature	59°F	Less than −81°F
Mean surface magnetic field	~30 microteslas	None

The outer planets all have multiple moons (Pluto, which has recently been reclassified as a 'dwarf planet,' has just one Moon that we know of, as icy and uninhabitable as Pluto itself), and many of those moons do have solid surfaces that are to some extent rocky. But nothing breathable has ever wafted across any of these outer planetary moons and none of them have 'soil' in the sense we understand it. Hence, what would we eat if we moved to one of them? Worse, none of these moons, except for one, have any kind of atmosphere. They are airless worlds. So, what would we breathe if we moved to one of them?

Neptune and Uranus, even after the Sun goes giant, would still be too far away, at 2.5 billion miles and 1.5 billion miles, respectively, to benefit from a slightly nearer Sun. Forget them and their moons: too cold, too organic-unfriendly. What about the two closer outer planets, Saturn and Jupiter. Saturn would move from being 880 million miles away from the current Sun to being 680 million miles from the giant Sun. Jupiter would go from being 480 million miles away from the current Sun to being 280 million miles away from the giant Sun. That will make a difference to them, and to their moons, particularly when the Sun moves into the carbon core stage of its life cycle and its surface temperature goes up to about 50 000°K. But the problem should be obvious. By the time those two outer planets and any of their moons, under the influence of a closer and hotter Sun, improbably evolve slowly into habitable environments, we here on Earth will have long ago fizzled into hot gas. We would need those outer moons to turn habitable *before* the Sun becomes a red giant – but they won't.

I mentioned that there was one Moon in the outer Solar system that has an atmosphere. This Moon is an object beloved to many astronomers, professional and amateur, for that very reason. I am referring to Titan, the largest moon of Saturn. What a delicious mystery Titan was when I was a child peering into my father's amateur telescope. It is reddish in colour because its atmosphere is a very thick fog of organic hydrocarbons, like ethane and methane, so thick that no Earth-bound optical telescopes can see through it to the surface. Radio telescopes can peer a little deeper into the shrouded moon's atmosphere, but even the details radio waves could elicit from the moon have been scanty. Titan came to have a cult status, and was often the subject of fantastic artists' conceptions of what the surface was like underneath the thick atmosphere. We did know that Titan had a solid surface, the radio data made that clear. But the physical conditions gleaned from the radio and optical spectroscopy were potentially exotic: Titan could have oceans of liquid methane, not water; it could rain gasoline on Titan. And where there are hydrocarbons, there is the hope of more complex organic molecules. But alas, although there is clearly a greenhouse-gas effect taking place in Titan's atmosphere – some cloud layers are rather warm – its average surface temperature is a life-snuffing 94°K (−290°F).

In January of 2005, the European Space Agency successfully landed its Huygens probe on the surface of Titan. The first pictures ever taken of Titan are now available for public viewing on the ESA's website. One mosaic photo is astounding because no solid body in the outer Solar system has a surface that looks so quasi-earthlike. We see structures that resemble river channels and shorelines. Further data analysis seems to suggest, that nothing we see in the mosaic is in liquid form, appearances notwithstanding. The probe landed on a local surface that appears to have the consistency of wet mud, but of course it cannot be real mud in the sense of Earthlike dirt, and it is not wet because of water, which cannot be a liquid under Titanic surface conditions. It may be semisolid methane that the probe landed on – that is how cold it is there. The question the experts want answered now is whether Titan has some kind of internal source of heat or energy, some Titanic equivalent of volcanoes or geysers. As of this writing, there do appear to be 'lakes' of frozen/liquid hydrocarbons on the surface of Titan. It is so cold that the place is remarkably dry; enormous dune-like structures stretching up to 900 miles in length and towering up to 2800 ft in height have been revealed by the orbiting ESA spacecraft. The crests of these dunes line up so perfectly symmetric as to baffle human scientists with regard to how they were formed, especially because the substance they are made of is neither sand nor dirt. Perhaps they are *ice dunes* made of frozen hydrocarbons, not frozen water.

Obviously, not much heat gets to the surface of Titan, and it is too cold for humans feasibly to live there. I know of no crops that grow in solid simple organic substances that are all gases under present-epoch biospheric conditions. No food crop here on Earth has evolved to grow in those gases. Titan, like the other moons of the outer Solar system, will not be compatible with human needs in time for us to move there before the Earth is vaporized. Combined with the unfeasibility of interstellar travel, quite simply, there is no escape.

What about our being saved by intelligent spacefaring aliens? What spacefaring aliens are those, we must ask? Any space aliens have the same three problems with interstellar travel that we do, in particular, the same daunting interstellar distances isolate them as much as they isolate us.[3] There is no escape, and no rescue either.

The Mysticism Option

We now come to the many versions of the *anthropic principle* and the mystical views of physicist Frank Tipler and his 'omega point' theology. The only form of an anthropic principle that survives serious rational scrutiny is a very weak one (WAP) that can do no work for us in the present context. WAP: *what we currently observe the Universe to be like must be compatible with our existence as contingently evolved intelligent observers* [see Carter 1974]. I will note that even if the WAP is true, nothing logically follows from its being true that human minds or human intelligence will become immortal in any way, mystical or non-mystical. That is because the WAP's logical scope is restricted by its own language to the time at which it is asserted, which for us is the present epoch.

Many stronger versions of an anthropic principle have been devised, including Tipler and Barrow's yearningly wistful claim that *the Universe must evolve so that intelligent life like us arises and achieves cognitive immortality* (see Barrow & Tipler 1986). These strong anthropic principles are all either abjectly implausible, utterly question-begging, or false. I appeal on this point to an expert on the topic, Nick Bostrom.

> Many 'anthropic principles' are simply confused. Some, especially those drawing inspiration from Brandon Carter's seminal papers, are sound, but . . .they are too weak to do any real scientific work. (Bostrom 2002 p. 8)

Then there is the case of Frank J. Tipler, once upon a time a perfectly ordinary physicist at Tulane University who become the chief contemporary advocate for the views of the Catholic mystic Teilhard de Chardin. Tipler tries to update and render mathematically respectable de Chardin's 'omega point' theory – in which humans achieve 'cognitive immortality' as an end-state evolutionary necessity – even though Tipler argues that the immortality is of a vicarious kind such as having our brain-contents, our minds, or rather the information contained in those minds, preserved in cyberform.

A *vicarious* trace of us after we have been expunged will not do, however. In this paper I demonstrate the physical doom of the earth and everything that lives upon it. It strikes me as an equivocation fallacy, a change of the subject matter, to argue that nevertheless our 'human intellects,' transduced somehow into bytes of computerized information, will end up being stored in a computer somewhere outside the zone of destruction. For a human mind's informational content to be downloaded into a computer is not the same thing as for the particular human

3 And therein lays the hopelessness of placing our sense of legacy, our solace at having left detectable traces, in the four tiny spacecraft that have left the solar system, or are in the process of leaving it. If Sagan is correct (see footnote 1), then cold comfort it is, indeed, to know that aliens would have to have miraculously solved the three big problems of interstellar travel even to encounter the 'Golden Record' aboard each of the Voyagers. Those four human space vessels themselves, in order to function as human legacies, would require the existence of 'space aliens' whose starships, with woeful improbability, somehow notice or bump into them. Would a Pioneer plaque (PS, 1972–73) that looks like figure 4 really satisfy our hunger for the Human Story to have meant something in the end? That's *it?* (And why is only the male waving hello—or is it goodbye? And if it is the latter, then, well, at least we had a sense of humor, cosmologically speaking.)

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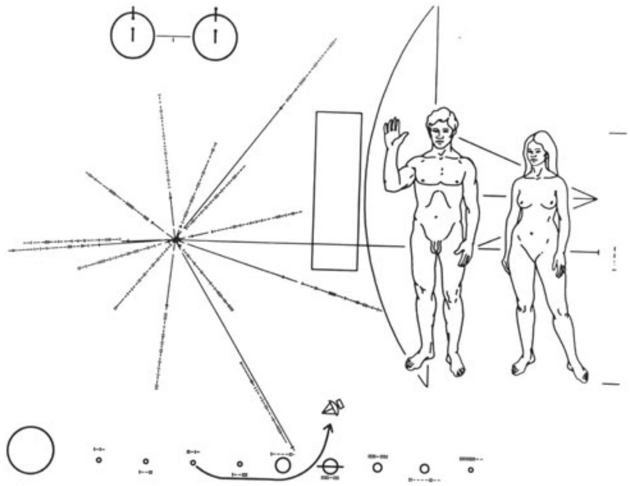

Fig. 4. Pioneer Plaque.

mind whose informational content it is to be downloaded into a computer, and so I hardly find Tipler's omega point to be a source of personal comfort or any kind of species-specific survival.[4]

Perhaps in response the mystical de Chardinites will nevertheless assume that even personal perceptual memories that are represented in the brain can be digitized and stored in full colour and sound, but there is currently no evidence for such a science-fiction fantasy. No one knows how or precisely where the human brain stores event-specific cognitive contents. Even worse, brain-stored *perceptual memories* are qualia-laden and qualia are currently not taken to be information-theoretic phenomena – indeed, it is hard to conceive of them as any kind of physically storable entities.[5]

But things are even worse yet for this particular mystical option. Tipler's omega point theory requires that the *Universe stop expanding*, for otherwise intelligent information-processing (Tipler's term) could not, as Tipler argues, inevitably fill the entire Universe in a spatiotemporal sense. As of this writing, there is no evidence that theoretically guarantees a stop to the expansion of the Universe. On the contrary, the effect of the dark-energy-driven and therefore nonzero cosmological constant appears to argue for a Universe whose expansion increases in the future, perhaps all the way to an eventual 'heat death' of the Universe. The point is arguable (e.g., other evidence suggests that the Universe is nearly flat – neither expanding indefinitely nor recollapsing), and no one knows for sure at the present. Thus if anyone is guilty of being too 'speculative,' it is surely Tipler, not the present author.

Bury My Heart in the Ice Dunes of Titan

There will be those who suspect that my species-apocalyptic pessimism is merely a function of the blindness of finitude, the unavoidable effect of the limited imaginative horizons that a single lifetime confers upon a human being. Just as flying in the sky in a big metal machine was inconceivable, except as hallucinatory fantasy, to our medieval ancestors, so whatever clever solution to the problems of interstellar travel that our descendants will invent is inconceivable to your author in the present. 'It's no big deal,' my critics will say. I am not the first person who ever spoiled a party, and I certainly won't be the last.

The critics miss my point. They are correct that I am not the last such party-pooper; but, mark my words, there will be a *last* such human party-pooper, although by then the label won't be quite as apt as it is now. Technology runs out, just like gasoline and linen supplies. Technology has limits, just like cities and mountain elevations. (An instructive case to ponder is the sad history of frustrating failure in fusion power research.) Even the craftiest engineering technology can sometimes run smack into an unyielding wall of physical laws and fundamental constants that give the lie to the popular television ads that claim 'anything is possible.' I want to suggest that escape from the doomed Earth and resettlement elsewhere will be denied our descendants, as much as it is denied to us now. The laws of physics may be endlessly refined in the coming years, but their basic structure will be the same five billion years from now, just as it was the same five billion years ago. Short of a belief in supernatural miracles – something it would be irrational on which to base present hope – the human story will come to an end in a kind of slow roast from the heavens. After that time, because the human life-world has been expunged, it will not matter that anything once mattered to us. Indeed, it is hard to conceive of what such post-expunction mattering would be like or *to whom* it would matter that things once mattered to us.

Yet it does not seem correct to me that the certainty of a sad end-date to all things human should not matter to us in the present because it will not matter post-expunction. I can give a short empirical proof of this if need be: most readers of this paper up to this point are probably a bit rankled by what I have written. If the inevitability of human expunction did not matter to us now – once we become aware it as more than a mere metaphor – then why would we feel any tension about what I have written here? I believe that one does and should feel such a tension, that one is properly repulsed by the prospect of human expunction, that one understandably frowns and fidgets in one's seat at hearing of this future date

4 Philosophers distinguish between one's mind and one's personal identity. The former may be a key part of the latter but the former is not fully constitutive of the latter. Indeed some philosophers argue that one's physical body is no less a key component of personal identity. Philosophers as diverse as the phenomenologist Merleau-Ponty and the analytic philosopher Wittgenstein have, each in their own idiosyncratic way, argued that the human body is essential to human cognitive experience. In Wittgenstein's words:

> '. . .It amounts to this: that only of a living human being and what resembles (behaves like) it can one say: it has sensations; it sees; is blind; hears; is deaf; is conscious or unconscious' (Wittgenstein, 2009 § 281).

5 *Qualia* (singular: *quale* or *qualium*) is a highly contentious term in the philosophy of mind that allegedly refers to the first-person felt qualities of perceptual experience: for example, the *blueness* of peering into a clear daylight sky, the unique 'coffeeness' taste upon drinking hot fresh coffee, and so on.

certain when the whole *Sturm und Drang* of human striving, when the cosmically local nexus of rich and subtle sentience it has produced, will turn into so much hot gas. Or worse, it will be woefully and forlornly under-represented by four tiny, lost, meandering spacecraft that were made and launched by us during a more expansive era in our past, spacecraft that will never encounter anything in their future travels but interstellar bleakness.

Acknowledgements

I would like to acknowledge as a major influence on this paper my father, Howard H. Klee (1912–1994), the lonesome stargazer, among vast galaxies.

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