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Existential Risks in the Solar System

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There are strong reasons to believe that the long-time survival of life on the Earth is under threat. Human activity is one example, that we are able to control, at least in principle. We might irreversibly pollute, or even blow the planet apart, with thermonuclear devices. Massive epidemics of plague-like diseases might become uncontrollable calamities. Asteroid impact is a risk that could devastate the Earth, although we can hope to take preventive measures by detecting and monitoring orbits of potential killer asteroids at large enough distances.

In the longer term, the sun will evolve into a red giant star and swell out to a hundred times the orbit of the earth. This will occur in about 4 billion years. The earth will burn to a crisp, after losing its atmosphere and its oceans. By then, humanity, or whatever remains, should have found safer havens than the inner solar system.

Existential risk may be defined to be where an outcome would either annihilate Earth-originating intelligent life or permanently and drastically curtail its potential, according to Oxford philosopher N. Bostrom. Here are some examples of existential risk.

- Asteroid impact
- Nuclear holocaust
- Nanotechnology misuse: nanobots and grey goo
- Artificial intelligence badly programmed
- Genetic engineering run amok
- We are living in a computer simulation that is shut down

Events unforeseen should be added to this list, of course. In this lecture, I will consider these various possibilities, as well as the prospects for humanity over the much longer term

Asteroid Impact

The dinosaurs most likely became extinct following a major asteroid impact some 60 million years ago. The risk of this reoccurring tomorrow is about the same as for a traveller dying in a commercial plane crash. The meteorite crater was an impact 50000 years ago of a 50 m size nickel-iron meteorite. Some 66 million years ago there was a much more massive impact that created the 300 km wide Chicxulub crater off the Yucatan coast, due to an asteroid 10-15 km across. It likely led to global climate disruption, by generate dense atmospheric layers of incandescent dust, ash, soot and other compounds, that likely led to mass extinctions of many species.

There were similarly massive impacts long ago. The Vredefort dome in South Africa was made from an impact 2 billion years ago. The early earth suffered many meteor impacts. We infer this from studying the Moon, where the traces of earlier impacts have survived. The lesson from the Moon is that there is a record of impacts over almost its entire lifetime, because surface erosion has been ineffective at deleting traces of craters. We learn that there was a greatly enhanced rate of impacts over the first billion years of lunar history. Sooner or later, we'll have a truly major impact again on the Earth. It is somewhat of a random chance in a cosmic lottery. As Stephen Hawking warned in 2016, *Although the chance of a disaster to Planet Earth in a given year may be quite low, it adds up over time, and becomes a near certainty in the next thousand or 10,000 years.*

Global Warming

The most alarming aspect of global warming will be the rise of the ocean level. At most 10 percent of the world's population will be affected in the most vulnerable countries. But is this is enough to cause massive global upheaval? If one includes the risks of social unrest and mass immigration,

A large part of global warming is attributed to pollution by aerosols and carbon dioxide, which act like a greenhouse that covers the atmosphere. Factors in the resulting rise of the sea level include the melting of the glaciers and accompanying thermal expansion of the ice. Modelling of the ocean rise involves an understanding of many uncertain the next factors that enter into our understanding of the earth's atmosphere. The predicted rise can be up to 10 meters within two hundred years although the uncertainties are large. Many people would be displaced in such a scenario, perhaps hundreds of millions. Associated with global warming, the incidence of other natural catastrophes may be enhanced, including seismic and volcanic activity.

Thermonuclear holocaust

From the earliest studies of nuclear bombs, scientists worried about the possible of triggering a global nuclear catastrophe. These considerations were manifest from the 1940s onwards, when the concept of a nuclear chain reaction was first realized.

Nuclear scientists were seriously concerned whether detonating the first atom bomb could trigger a chain reaction. Reassured by their calculations, they went on to test atomic bombs. Current stockpiles of hydrogen bombs suffice to cause destruction of all the world's population centers, although humanity would survive a nuclear catastrophe. Shortly after the end of World War II, the scientists who developed the atomic bombs dropped on Japan tried to envision the kind of nuclear event that could lead to the destruction of not just cities, but the entire world. The verdict that scientists at the Los Alamos laboratory and test site reached in 1945… found that "it would require only in the neighborhood of 10 to 100 Supers" to put the human race in peril.

Alex Wellerstein 2014

These warnings did not deter the detonations of more and more powerful atomic and hydrogen bombs. But these only added to the known effects of burning coal over many decades, basically from acid rain. This is something that has affected many areas of the world where coal is utilized as a fuel.

In the Adirondack Mountains of New York the acid rain includes a mixture of sulfuric and nitric acids from the sulfur dioxide and nitrogen oxides pouring from the smokestacks of power plants, smelters, factories, and vehicle exhausts. Over 200 lakes are dead; their aquatic life gone or dwindling. And in Scandinavia acid rain has destroyed 15,000 lakes in recent years. Inevitably, the death of a lake affects other wildlife as well; fish-eating ducks, loons, otter, mink, and even birds begin to leave, because their food and shelter have been destroyed. On the ground, acid rain leaches essential nutrients from the soil--calcium, magnesium, potassium, and sodium. It prevents some seeds from germinating; it scars leaves.

D. Soran, D. Stillman 1982

Atmospheric testing of nuclear weapons proceeded throughout the 1950s. These culminated in the Czar H bomb, a 50 Megaton monster exploded in the atmosphere in 1961. This was more than a thousand times more powerful than the atomic bomb used at Hiroshima. The devastation from nuclear accidents and health risks from atmospheric testing all played key roles in negotiating the nuclear test ban treaty in 1963. Here is one eye witness account of the aftermaths of nuclear testing in Russia:

About 100 kilometres from Sverdlovsk, a highway sign warned drivers not to stop for the next 20 or 30 kilometres and to drive through at maximum speed. On both sides of the read, as far as one could see, the land was dead: no villages, no towns, only the chimneys of destroyed houses, no cultivated fields or pastures, no herds, no people...nothing. I saw personally… a large area in the vicinity of Sverdlovsk (no less than 100 to 150 sq. km and probably much *more), in which any normal human activity was forbidden, people were evacuated and villages razed, evidently to prevent inhabitants from returning, there was no agriculture or live-stock raising, fishing and hunting were forbidden.*

L. Tumerman 1972

Genetic Engineering and Biohazards

Mass diseases and plagues historically have presented a natural risk for humanity. The bubonic plagues and even flu epidemics are examples in Europe. Others include the impact of major population shifts and life styles, which had devastating effects via transferring diseases on indigenous life in the Americas. Another is fed by biotechnology. The rapid advances in designer gene technology have raised concerns that a terrorist plot or even a mischievous adolescent could design molecules with fatal consequences for humanity. An industrial accident could equally lead to inadvertent spread of fatal viruses.

Physics Hazards

Particle colliders could create tiny black holes. Theories of quantum gravity predict this, albeit at energies higher than any terrestrial particle collider could achieve.

Perhaps these could create a disastrous implosion. Scientists carefully studied this possibility during the construction of the Large Hadron Collider at CERN. Theorists had speculated that higher dimensions are present on scales smaller than, equivalent to energy scales higher than, those accessible by current particle colliders. Unlocking higher dimensions permits formation of tiny black holes. They concluded that no such events have occurred at the far higher energies when cosmic rays bombard the earth's atmosphere. Construction design for the LHC succeeded in passing this environmental risk assessment in a Hawaiian court of law.

Nanotechnology

Warnings have been voiced about the misuse of technology in creating nanobots that could wreak havoc with the environment. Such systems could self-replicate, and accidental or even deliberately engineered mutations might be destructive and for example potentially massacre the biosphere. This has been characterised as the dominance of "grey goo". This is not a reason to halt research on nanotechnology, which provides enormous societal and commercial benefits, but rather calls for development of an active shield approach towards a nanotechnology immune system.

Artificial Intelligence

Computers of unprecedented power could render humanity irrelevant. The rise of the machines has been touted as a possible future, given the enormous advantages, both physically but especially intellectually, that robots would acquire over anything feasible for humanity. One concern is that artificial intelligence could potentially be malevolent towards life, regarding it as a mere irritant, a source of primitive interference.

We are on the verge of developing quantum computers. These tap virtual numbers. As a consequence their power is potentially infinite. Non-biological brains have no limits. Whether with sufficient computing power, they can develop self-awareness and something akin to consciousness is debatable. Given how far in complexity an artificial brain could evolve relative to the neuron-firing limitations of a human brain, it is difficult to see any limits. The issue then arises as to whether such inevitable progress in artificial intelligence would have beneficial consequences for humanity.

One of the most bizarre predictions that arises as a consequence of unlimited computer power is that in some remote future, should humanity survive, our descendants will have developed such powerful computer games and simulations that they could reproduce the history of humanity in such detail that it would be indistinguishable from the real thing. There would be parallel histories. We would live in one. The existential risk is that they could pull the plug, and we are extinguished.

The Future of Humanity

We need to plan for the long-term future. This is difficult as most governments have a planning horizon of less than a few years, and are very much dependent on election prospects. We need to develop a longer term perspective. This is especially true in science. Exploration of the Moon, most likely our next significant step in space, demands such a vision. So does building the next generation of particle collider, necessarily at least ten times more powerful than the LHC. And beyond science goals, we need to better assess the risks that lie ahead over the next centuries at the very least.

> "*Space-ship Earth" is hurtling through space. Its passengers are anxious and fractious. Their life-support system is vulnerable to disruption and breakdowns. But there is too little planning, too little horizon-scanning, too little awareness of long-term risks.*
>
> Martin Rees 2015

Space Hazards

Some day we will establish space colonies. Careful planning should enable us to avoid many of the mistakes we have made on planet Earth. The first barrier to surmount will be that of space debris. Low earth orbit is an especially crowded environment. There are many thousands of pieces of rocket launchers and satellites in orbit at speeds of some ten thousand miles per hour. As many as a million fragments of metal or plastic larger than a cm are in perpetual orbit. Impact with a space craft would have potentially dangerous consequences. Fortunately most of this debris is being tracked, but the amount of debris is increasing rapidly.

The Long-Term View

The universe will exhaust its energy supply. Stars do return about a third of the gas they consume, so it will take a while to run down the gas supply. But once new stars can no longer form, it's all downhill. No new stars will form. There will still be planets, surrounding white dwarfs and neutron stars, and even black holes. Life will survive even in such cold environments. However there are prospects for extracting gravitational energy from compact stars. Gamma ray burst are the most luminous phenomena in the universe. Black holes especially are potentially powerful sources of energy. Accretion of gas clouds onto black holes releases energy at 10 percent efficiency, some ten times more efficiently than by fusion of hydrogen in stars, Capturing this energy source is our best bet for immortality, or as close to it as is feasible.

Of course we can't live on a black hole, we need the solid surface of a planet for example. There is an ultimate limitation here in the very distant future. The end approaches when protons will decay. There will no longer be planets, or rocks. This will take about 10^{36} years from now. That leaves us with electrons and with black holes. Even black holes are not forever. While one the mass of a mountain evaporates in ten billion years, those produced by stellar deaths survive a million times longer than protons. That should be the end for intelligent life, which at the very least needs a supply of energy.

If one is prepared to speculate more wildly, quantum theory offers a possible solution. The quantum vacuum generates fluctuations that come and go on a time-scale too small to be measureable. Disembodied brains can appear out of nothing:

> *The most likely fluctuation consistent with everything* you *know is simply your brain (complete with memories..) fluctuating briefly out of chaos and then immediately equilibrating back into chaos again.*
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> A, Albrecht and L. Sorbo (2004)

Perhaps this is too extreme a fate for most followers of this discussion. Here is piece of quantum thinking. There was no Big Bang, at least from infinite density, but there was a Big Bounce. Particles can act like waves and avoid hard collisions. Their trajectories can take them into otherwise inaccessible regions of space because of what can be considered to be a manifestation of quantum uncertainty. A treatment of the expanding universe as a quantum entity has led advocates to argue that the Universe began as a Big Crunch via collapse from some almost infinitely large state. At some maximum density, near the Planck limit, when particles and black holes are indistinguishable, the universe switched from collapse to expansion, whence the origin of the Big Bang.

As a theory, there are many loopholes in, and there is no evidence for, a Big Bounce. But at least philosophically, it answers one fundamental question: where did we come from? It provides us with an infinitely long period of contraction that preceded the expansion phase. And even the future might be affected. If there is indeed a cosmological constant, the universe will accelerate forever. But if the cosmological constant is not truly a constant, but the energy of the vacuum, its physical manifestation, decays, then another fate is possible. The universe could reach a maximum size in a few tens of billions of years, then recollapse to a future Big Crunch. And the series of cycles would continue, to an infinite future from an infinite past.