WILL SPACE ACTUALLY BE THE FINAL FRONTIER OF HUMANKIND?

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ABSTRACT

Science fiction gave us the idea of space as the final frontier. Strongly supported by the pioneers of spaceflight, this was first questioned in the 1970's. The *Apollo* landings on the Moon did not lead to a permanent human presence on our satellite, the environment of even the most Earth-like planet (Mars) turned out to be more hostile, and the technical difficulties and the cost of spaceflight were worse than expected. So humankind seemed for ever to be bound to its own planet.
These rather pessimistic views are re-examined here, in the light of recent technological advances, scientific discoveries and new perspectives. It is suggested that they result from a lack of vision. Thus the 'final frontier' myth is found still to hold, but with a much more stretched out timetable for future space programmes that was envisaged in the 1960's. The present generation can take its first faltering steps on the path towards a spacefaring civilization, but the outcome will depend on social, political and economic issues rather than technological and scientific ones.

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1. INTRODUCTION: THE MYTHS OF PROGRESS AND SPACEFLIGHT

The very idea that space will be a new frontier for humankind is linked with a dynamic view of human history, to the belief that we are part of a changing world, of a Universe evolving towards a future we do not know but which will be different from the past. Not all societies realized that such variations existed. Most Greek philosophers thought that history would repeat itself endlessly without major changes. Others, like many Indian thinkers, believed that history proceeded in cycles, each similar to the previous one. On the contrary, the Judaeo-Christian view of the world contemplated a more or less linear development of history, from the creation of the world by God to its eventual end.

More recently, the pace of change has accelerated and it has become impossible not to realize that change was at the root of all life and civilization. Enthusiastic views of progress opened up, and the very word *progress* assumed new values and positive meanings. This concept is the basis of European civilization, dating back even before the Renaissance and the birth of modern science. One of the first to forecast changes due to technology was Roger Bacon, in the thirteenth century; he was followed by many philosophers, scientists and engineers, and also by writers and poets.

The word progress was given a wider significance – cultural, moral, social and other progress – accompanying technological progress. By the end of the nineteenth century faith in the continuing progress of humankind permeated the whole of society. It was in this atmosphere that the myth of spaceflight developed and, with the growth in the size of the Universe as new astronomical discoveries were made, the frontier of human ideas, ambitions and hopes became larger and larger.

The pioneers of the nineteenth and early twentieth centuries (Tsiolkovsky and the Russian proponents of cosmism, Goddard and the German pioneers) were adamant that the future of humankind was in space [1, 2], i.e. colonizing celestial bodies, first in our own solar system, and then at interstellar distances. Scientists of all kinds – astronomers, chemists, physicists and sometimes even biologists – were then sure that the conditions existing on the surface of planets (at least Mars and Venus) were Earth-like and could support humans in a shirtsleeve environment (perhaps using a helmet to enrich an oxygen-poor atmosphere). Many, Schiapparelli, Lowell, Arrhenius and Helmholtz among them, were convinced that living beings, not too dissimilar from terrestrial beings, existed on those planets. As late as the 1960’s Carl Sagan was sure that Mars was inhabited by complex lifeforms; he could describe what they should be like based on what was known about the planet. Space was indeed *the final frontier*.

There were some discordant voices, particularly from scientists who were so aware of the unimaginable vastness of the Universe, or even of our solar system, that denied the possibility of us leaving our planet and reaching any cosmic destination. The idea that humans with their technology were becoming almost almighty prevailed.

Then, slowly, the view that progress was just a myth, and a dangerous one at that, grew. The horrors of two World Wars and of tyrannical regimes, which demonstrated that humans with progressive technologies and peculiar cultures could be as barbaric as those who were called contemptuously savages, made many doubt the very idea of progress. Technology, based on science, seemed more involved in bringing death than wellbeing. The very concept of progress was shaken, together with the confidence that humans could take their destiny into their hands and improve their lives. This trend continued during the Cold War, fuelled by the awareness that the actions of humankind could change the world dramatically, could endanger the environment – ecological disasters, nuclear war and the depletion of planetary resources could even destroy the human species.

Mistrust in science and technology, together with the scientific illiteracy of a major part of public opinion, gave way to irrationalism, belief in the pseudo-sciences, and a widespread feeling that all sorts of conspiracies rule the world. Books asserting absurd 'truths', like the belief that humans never set foot on the Moon, even became best sellers. Post-modern philosophy piled confusion upon confusion. When used in an arbitrary way some concepts (usually just sentences, because there are few concepts among these verbal displays) from modern science further enlarged the gap between the 'two cultures' [3]. In this atmosphere the idea of a space frontier and of a spacefaring civilization was seen by many as the ultimate manifestation of pride. The human species, after wrecking this planet, would only do the same in a larger context.

Many of those who did not share this anti-technological and anti-scientific attitude started to have doubts about human spaceflight and considered it a myth. After the first astronauts stepped onto the lunar surface, and space probes began exploring the solar system, a less attractive view of the conditions existing on extraterrestrial bodies started to prevail. Manned space exploration appeared to be more difficult, more costly, and more energy-demanding than had been anticipated. The very idea of settling on extraterrestrial bodies seemed almost absurd, or at least not very worthwhile.

Scientists were ready to acknowledge that space was an ideal laboratory for many new experiments, with robotic space probes gaining new astronomical knowledge, but with human exploration being limited to low Earth orbit. Maybe space could be *the final lab*, but few would seriously speak of it being the *final frontier* for humankind.

In the debate between the supporters of human exploration of space and the proponents of robotic space exploration, which has been going on since the 1950s, the latter seemed to have the winning hand. Artificial intelligence and miniaturization were promising new space vehicles, as smart as (or even smarter than) human beings, so small and light as to require launch vehicles much smaller than those required for human exploration. The ultimate concept of *Von Neumann probes* was developed [1]. Human beings seemed to be for ever confined to the surface of their own planet and, if they enjoyed the thrill of exploring new environments, they could send robots there to record them and then recreate them as virtual reality [4]. The new frontier would be reduced to just a theme park!

However, the tide of irrationalism now shows some signs of subsiding, and the awareness that only technological advances can help to solve the world's problems is gaining momentum again. The movement for manned, long term space exploration has recently regained some momentum [5]. Some new countries, which in the past were only marginally interested in human spaceflight, are becoming directly involved.

In the meantime, artificial intelligence is showing its limitations and, in spite of the fact that computers are becoming more powerful and faster every day, they are hardly becoming any smarter. Theoretical doubts on the very basis of the 'strong artificial intelligence hypothesis' are spreading. There need be no more debates on whether humans or robots will explore space. It is important to plan for human and robotic space exploration in which humans and machines cooperate closely.

The aim of this paper is to discuss some issues related to the opportunity of transforming human civilization into a spacefaring civilization, and humankind into a species not only living on several planets, both in the solar system and beyond, but also living directly in space [1].

2. THE COST ISSUE

The high cost of human space exploration is primarily linked to the fact that, to date, everything carried into space must come from the Earth's surface, the bottom of the Earth's gravitational well.

Our present generation is now engaged in a 'bootstrap' effort, with every step on the path to the *final frontier* being linked in order to reduce the effort needed for those following.

But is it true that space is very costly? Compared, for example, with the cost of military activities, space is not expensive at all. The cost of space exploration is not higher than that of other human activities, and in several cases it is lower. The cost of the construction of a new motorway or a railway, for instance, is comparable with, or even more than, that of sending a robotic probe to Mars or to the outer solar system. The sum spent every year by any large corporation in advertising compares with the cost of a sizeable space enterprise. Even the yearly budget of large criminal organizations is higher than that needed yearly to maintain an outpost on the Moon!

The point, then, is not just a matter of money. What is lacking is the willingness to invest in an enterprise making little profit in the short term, yet one with good long term prospects for business. In the long term space exploration, or rather space exploitation, is essential to generate resources for a sustainable development on Earth.

The commercial use of space here shows that funding is not lacking in the sectors where space activities are financially rewarding, as in the telecommunications business. This must not be underestimated since, in recent years, privately funded space activities have attracted more money than that directly spent by space agencies. Another important sector is that of Earth observation and navigation satellites, where the large investments required fit well within the traditional fields of governmental organizations [1] and where many countries, such as China, India or Indonesia, are now very active. Obviously the same holds also for defence.

Exploration has only occasionally been felt to be an important goal for governments. Even then it is only when other motivations are added to the expansion of scientific knowledge or to the discovery of new 'territories'. National security considerations or a perception of national superiority have always been one of the strongest of such drivers [1]. That was the case for the most active phase of space exploration which culminated in the *Apollo* missions.

Many examples in history come to mind. While Columbus' voyages to America were funded by the Spanish government (in the context of wider political priorities), other expeditions of the same period were funded in other ways. Magellan's expedition around the world proved to be a very good business. In spite of the fact that just one ship out of the three which set sail from Spain came home, the selling of the spices brought back more than made up for the expenses which the organizers had to withstand.

An important issue which suggests that space exploration should rely more on private than on public funding is the low reliability of continuation of the latter. This is the more so in modern times when political priorities can be changed by the result of a single election, or even by the interpretation of public opinion polls. Ben Finney gives an example of a well planned exploration campaign abruptly interrupted for political reasons in his *The Prince and the Eunuch* [6]. Whilst it is true that the return on investments for space exploration, in terms of patents, know how, image, etc., is large, the 'return time' is generally too long for private investors. Even public investors very often lack the required long-term commitment.

While waiting for a reduction of the costs of space activity or for the start of space exploitation to stimulate private investors in space, there are two potential drivers: advertisement and 'edutainment' (mainly tourism, initially virtual and then involving actual travelling into space). Some space agencies have already started using funds from sponsors for some missions, but it is questionable whether they can be aggressive enough in the market. The very fact that there are a few customers ready to pay huge sums for a week in orbit shows that the potential for space tourism could be large. However, little is yet being done for virtual tourism, particularly on the Moon and (even though its distance makes it much more difficult) on Mars. There is no doubt that both advertising and edutainment are very competitive markets, which are greatly influenced by fashion and personal choice, but a strong commitment to promote the public's interest in space is lacking. A few space agencies are making strong efforts in this direction (NASA and CNES for instance), but in several other countries very little is being done. Such efforts are worthwhile not only from a funding viewpoint: everywhere the lack of interest of the younger generation in scientific and technological studies is a problem, and space can do much here. Awakening an interest in space exploration can be a strong incentive in promoting science and motivating the young.

To conclude, it must be noted that technological advances can result in cost reductions which can attract investments in space activities by increasing the returns and reducing the times for return on investments.

3. THE ENERGY ISSUE

Long range space exploration is undoubtedly energy intensive, but only interstellar exploration is prohibitively so when compared with our current energy resources. Space travel does not require large amounts of energy, since, unlike land or air transportation, there are no unavoidable energy losses, except when a planetary atmosphere is crossed at high speed. The point is that, however space travel is implemented, burning a fuel (or even accelerating a jet using nuclear reactions or electric and magnetic fields) is a very inefficient method of propulsion.

Some ways of propelling space vehicles [1] which allow the potential and kinetic energy of inbound vehicles to be recovered and transferred to outbound vehicles have been devised theoretically. NASA has recently worked on skyhooks (spacelifts) [7, 8] and also on rotating tethers, but these are still futuristic technologies. They could become economically attractive in a scenario of greatly increased traffic between the Earth and an extraterrestrial destination (the Moon, one of the planets, or space itself). However, it is questionable whether they could be actually implemented in the foreseeable future.

Even without these devices, travelling to solar system destinations in reasonable times does not involve the expenditure of huge amounts of energy. The point is that what is energy expensive can only be defined relative to the state of the available technology. Even for interstellar travel (at a reasonable speed below the speed of light), it is not how much energy is needed but how much technology has to be advanced [1]. Since technological advances in the energy field are also essential to sustain the development of humankind here on planet Earth, much research work will have to be performed in this field, independently of the needs for space research. Owing to the peculiarities of energy generation in space, both for propulsion and for other uses, specific research is needed.

4. THE VELOCITY ISSUE

Distances in space are many orders of magnitude larger than those we are accustomed to on our planet. Within the solar system, the need is to develop a suitable technology to achieve acceptable travel times [1]. The first extraterrestrial destination for crewed voyages, the Moon, is so close that present technology is perfectly adequate, as the *Apollo* programme demonstrated thirty five years ago. Advances allowing us to reach the destination in a shorter time would be useful, but this is not a high priority.

The same can be said for other potential destinations, like the Lagrange points in the Earth-Moon system or in the Earth-Sun system where future space stations could be located. Also near-Earth asteroids are close enough to be within the possibilities of present technology. The travel time to the most worthy destination within the solar system, planet Mars, is not very much longer that the duration of the voyages of discovery of the past.

Other destinations within the solar system may be the main belt asteroids, the satellites of the giant planets and, perhaps, the inner or remote outer planets. Here the difficulties are increasing, due more to the hazardous radiation environment than to travel time considerations. To summarize, there is no doubt that, with the help of moderate technological advances, the entire solar system is within the reach of humankind.

On the contrary, the small value of the ratio of a rocket's velocity to the speed of light is a real limiting factor for interstellar exploration [1, 9, 10]. As far as we can say, in the light of present day science, even the most advanced technology will not allow us to realize those options – like two way journeys, commerce or even communications and political relationships at interstellar distances – which science fiction has so many times described.

For humankind to travel to interstellar distances [1, 11], very large space ships (worldships) travelling for tens or hundreds of years have been suggested. Or fast interstellar travel could exploit relativistic effects to shorten the travel time for those on board the space ship. Another possibility is to reduce the rate at which human life passes with some sort of biostasis or hibernation. The study of hibernating animals may, in the future, show us how to induce the same condition in human beings, a feature potentially useful not only for interstellar travel, but also to make it easier to reach destinations within the solar system [12, 13, 14]. All problems linked with human spaceflight beyond the Moon would be simpler if a reliable means of hibernation were to be developed. Hibernating astronauts would require a simpler life support system; problems linked with radiation shielding and psychological problems would become easier to solve. Whilst the problems related to one-way colonization journeys are technological problems (admittedly very severe ones), they are not insurmountable.

When the time comes to tackle the technological problems related to energy and speed, science will have progressed beyond our present understanding. Although it is unlikely that our present basic scientific theories will prove to be incorrect, it is likely that they will have been replaced by more general theories, just as in the twentieth century relativity replaced Newtonian physics, including it as a particular case [15]. There are already some hints that the limitations imposed by the large yet finite, speed of light might not be so severe that they could not be circumvented in some way.

Superluminal travel (in the sense that the travel time between two points could be shorter than the time taken by light to cover the same distance) may, in due course, be achieved.

Even if superluminal travel for ever remains a dream, this will not prevent humankind from settling on other planetary systems, provided that suitable extrasolar planets exist at a reasonable distance from the Sun [1]. The change brought about by the discovery of a method for superluminal travel will be more in the type of society which will result, a society in which relationships of all types (commercial, political, cultural, etc.) between distant occupied planetary systems will be possible instead of a society made up of inhabited 'islands' scattered at large distances, where the only practical contacts could be radio messages which could take years or centuries to reach their destination. The effect of superluminal travel could, in the future, be something like that of modern navigation technology on the societies which settled the islands of the Pacific Ocean [16, 17].

5. TECHNOLOGICAL ISSUES

With present technology we can reach the Moon and travel to Mars [1, 18, 19]. Space exploration, and even colonization, is more a matter of commitment – or the lack of that – than of technology. However, our know-how is barely sufficient to make space travel routine. In this light, research must be more focused on cost reduction than on performance increase, and more on those fields allowing a return on investment than on those linked with science alone. Technology can reduce the cost of space travel to the point where private investors can enter the business of deep space exploration, and exploitation, and not only deal with operations in low Earth orbit.

One field with the potential to change technology deeply and to produce those advances which will enable humankind to become an actual spacefaring species is materials science. All the main revolutions in technology were accompanied by the use of new materials, to the extent that we specify the periods of human development by the type of material which was predominant or which was then first used (stone age, bronze age, iron age). In spite of the fact that the iron age started in the West a few millennia ago, iron was very costly and used only for selected applications. Wood remained the basic material for the construction of machines until well into the industrial revolution. Aviation advances in the twentieth century would not have been possible without aluminium alloys and titanium steel for turbine blades.

Materials with ratios of strength/mass and stiffness/mass higher than those of present day materials will allow us to build launch vehicles far more compact than those in use today. An example is the

Single-Stage To Orbit (SSTO) vehicle, thought to be impossible in the 1960's. New materials could make them the cheap and readily available access to space in the third millennium. The same is true for skyhooks (space elevators) [7, 8]. When they were proposed, those who analysed their feasibility stated that they were just dreams: not only their stressing exceeded that of the strongest materials, but also the maximum theoretical strength of an ideal material. Today the performance of carbon nanotubes is such that skyhooks seem to be feasible, at least from the technological viewpoint.

Advances in the field of materials are necessarily slow. Apart from the difficulties and the large investments involved, experience in the use of new materials has to be accumulated gradually. Before innovative materials can be applied in critical elements, designers must gain confidence in their use, manufacturers must develop reliable technologies, and many diverse problems must be overcome. Finally, accelerated ageing tests on new materials are only partially reliable, so nobody can actually know how a recently developed material will behave under all conditions for a few years, or even decades, after its invention.

A quick visit to the Moon or Mars is feasible using current materials – most parts of space vehicles are made of the light alloys used for WW2 aircraft. But large space dwellings, like those described by O' Neill [20], or interplanetary reusable spaceships to ferry people and materials to Mars, and beyond, need radically new materials.

Another need is for new propulsion technologies. The limitations of chemical propulsion are well known. Propulsion devices in which the source of energy is separated from the propellant are needed. This was realized in the 1960's when several programmes to construct nuclear rockets were started. The reason that they were discontinued has more to do with politics and ideology than with technology, and more to do with perception than with reality. A nuclear-powered spacecraft could travel safely to Mars with humans aboard.

In retrospect, we can note that the failure to proceed with nuclear propulsion is one of the main reasons for our failure to meet the expectations of the early space age. Nuclear propulsion, either in the form of nuclear thermal or of nuclear electric rockets, is the 'main road' to space. All can agree that, if humankind wants to become a spacefaring species, it must pursue nuclear propulsion [1, 21]. The alternatives (solar thermal, solar electric, or even solar sails) often suggested more for political than for technological reasons, are without doubt very useful technologies which should be pursued [1]. But they fall short of accomplishing what nuclear propulsion can achieve. Nuclear thermal propulsion is the only concept which can simultaneously provide a fairly high specific impulse (even if not as high as that obtainable using electric propulsion) and a high thrust, without the need for a very long period of development. It could propel the large spacecraft needed for carrying humans as far as Mars, and beyond, and within reasonable travel times.

While there is no logical drawback to using nuclear propulsion in Earth orbit and beyond, the issue of whether it is safe to do so for lift-off from the Earth's surface is debatable. There is no problem in using a nuclear thermal rocket (NTR) on the surface of the Moon, or of any celestial body without an atmosphere. For the Earth and planets with an atmosphere the first stage should be a chemical rocket, and NTRs should be used only as upper stages, beyond the planet's atmosphere [1]. Only nuclear technology can solve the problems associated with the low power available, e.g., from solar panels, which has limited most space operations in the past. When exploration of the outer solar system becomes routine, and the colonization of Mars begins, nuclear power will be available. Perhaps only a society which uses nuclear power on a large scale can become a spacefaring society.

Nuclear fission is a proven and fairly well known technology, although its application to propulsion still needs much research. For future propulsion, and energy generation, it is insufficient. Research in the field of nuclear fusion is of primary importance for space exploration and exploitation. Even more advanced technologies, like antimatter propulsion, will be needed in due course, but they may play a role in the near future only in the unlikely (though very welcome) event of some unexpected breakthrough.

Technological progress does not proceed at a steady pace; the different disciplines go through phases of rapid advance followed by periods of consolidation. This was the case for aerospace technology in the 1950's and 1960's, followed by the solid-state computer technology which is still going strong. Many predict that it is now time for micro- and nano-technologies to take the lead [22], with methods which we now associate more with biology than mechanics. It may well be true that, while the twentieth century was the century of physics, the twenty-first century will be the century of biology and biotechnology. Construction methods based on the 'bottom-up' approach typical of biology are capable of being the enabling technologies for human expansion in space. New nano-engineered materials, like carbon nanotubes, are very promising, not only for their performance but also for their very complex shapes expected at low cost. As usual, it is impossible to predict future technological advances (true innovation is, by its very nature, unpredictable), but we can foresee that this field has the potential for breakthroughs which will make everything simpler and cheaper.

A final consideration: technology transfer is a powerful means of making progress. Enabling technologies are often not so much the direct consequence of intensive, 'focused' research, but the outcome of a progressive technological environment. While in the 1960's and 1970's many new technologies diffused from the aerospace sector into other fields, a transfer in the opposite direction is now possible. Space technology might receive much from fields in which the large scale of production encourages intensive research, such as the automotive field.

6. HUMAN ISSUES

Since its beginning the human species expanded beyond its immediate natural habitat thanks to its ability to develop suitable technologies. The use of animal skins, and then woven material, to cover a body which is not naturally protected against cold weather and the ability to light fires and to build shelters enabled humankind to colonize practically all the lands of our planet. In particular, after the neolithic revolution, when we learned to grow our own food and to tame animals, our human environment became increasingly 'artificial'. Lifestyles which we now regard as 'natural', like that of European peasants some centuries ago, are almost as artificial as ours. We perceive as being natural what is old technology, i.e. a technology which we are so used to that it appears to us as a part of nature, while we feel as artifical a technology we are not yet used to. As an example, a rose garden or a wheat field is as artificial as a nuclear reactor or a spacecraft. They all exist because of the ingenuity of humans in transforming nature; they are all a product of one form of technology or another.

When the human species starts living on other planets or in space itself, this trend will continue further; no doubt the unusual environments will strain the adaptation capabilities of our descendants. But, within a few generations, the settlers of the Moon will find it as natural to wear a space suit to go outside the pressurized dwellings as Inuits today find it natural to wear their boots and outer garments (pieces of high technology which required centuries of development) to go outside their igloos. Both Moon dwellers and Arctic people could not survive outdoors without their specific technologies.

Moreover, the adaptation will be mutual: planetary environments will be changed by the work of humans [1, 23, 24]. The adverse conditions which humans will encounter in space may then not be the limiting factor preventing the human species from becoming a spacefaring species. Human beings have a large capability to adapt. In the past the living conditions which many people endured were far worse than those which will be encountered by space travellers and settlers.

Psychological problems must be considered, and solved, but they are no more than human beings have faced many times in the past. Besides psychological problems there are other dangers to health, like radiation or microgravity. The dangers to health of a Mars expedition will be no more severe than the risks due to scurvy and other diseases for the sailors of the fifteenth and sixteenth centuries.

The willingness to take risks and the value which we attribute to human life are cultural issues. Today's western (and Japanese) civilizations have a very conservative attitude on these points; if other actors, like China or India, play an increasing role in space exploration – both countries have expressed their interest in building a lunar outpost – their approaches may be different.

Safety, after all, is a problem of technology. A reduction of the travel time to any destination will be beneficial. The capability to carry larger payloads into space may allow gravity to be simulated via rotation of the spacecraft, or provide a better shield against harmful radiation. Whatever our attitude is towards the risks which will be faced by people directly engaged in space exploration and colonization, we should not let those problems be an obstacle which cannot be overcome.

7. THE TIME ISSUE

Those who tried to predict the path of humankind into space were completely wrong, mainly in the timing of these enterprises. The incredibly fast pace of the first steps of humankind beyond the Earth led to overoptimistic expectations and predictions made in in the 1960's. By 2003 we were expected to have permanent Moon bases and already to be well on our way in the colonization of Mars, in the human exploration of some satellites of the giant planets, and in the exploitation of extraterrestrial resources. There is no doubt that this vision was over-optimistic [1] even if the commitment shown in those years earlier did not falter.

All human enterprises proceed at a discontinuous pace, with sudden rushes forward followed by periods of consolidation or even regression. From this viewpoint, apart from the disappointment of those of our generation who hoped to see these developments or to take part in them, there would be no problem. After all, if Columbus could not obtain the ships for his journey to America, sooner or later someone else would have set foot on the new continent, perhaps sailing under a Portuguese, Flemish or British flag. The details of history would have been different, but the overall picture more or less the same. A few decades do not matter much in the context of the history of our civilization, which is increasingly a planetary civilization.

On the other hand, it is often said that the opportunities for space exploration and space exploitation must be taken without delay. Our planetary resources are becoming increasingly scarce for a growing population. Without the contribution offered by the ‘space option’ our civilization could well meet a global demise accompanied by an impoverishment which would make it impossible to implement the space option in a significant way later. If this is true, we are facing a sort of last chance, which we must not miss. However, the fears dating back to the 1960’s [1, 25] now seem to have been exaggerated, and the future which we have in front of us is not as catastrophic as was then thought. Even if it is likely that the alternative which humankind will face is between expansion into space or extinction, it is very unlikely that the next few generations will reach that bifurcation point. So we should now proceed without delay with our space exploration and exploitation. It will bring us many benefits, in terms of technology and resources, but also in terms of a new inspiration and new opportunities for fulfillment at both the personal and societal level. It is more an opportunity not to be missed than a last chance to try before it is too late.

8. FINAL REMARKS

Life started on this planet almost 4 billion years ago. Life slowly developed in the seas and, in the meantime, it changed our planet deeply, in a process of mutual adaptation. Then it accelerated its pace of evolution, gave way to beings of increasing complexity, who settled on the dry land and soon colonized the whole planet. Now the human species is on the verge of leaving its home planet to expand into space.

The Italian writer Primo Levi, after seeing the *Apollo 11* landing on the Moon wrote: *Why are we doing this? We do not know, we mention too many reasons… under the intricacies of motivations perhaps there is the obscure obedience to an impulse which originated with life and inherent to it, the same which causes the seeds of poplars to surround themselves with wool to fly far in the wind, and frogs … to migrate obstinately from pond to pond, at the risk of their life…*[26].

Perhaps this is the essence of the myth of the final frontier, the tentatively defined *Conscious Life Expansion Principle*: *An intelligent, self-conscious species evolving on a planet is eventually able to set about space exploration. This enterprise in neither an option nor a casual event in the* *species' history, but represents an essential way to spread high-level life beyond the place where it developed* [1, 9, 10].

9. CONCLUSIONS

Space is likely to become *the final frontier,* but the time required for this to come to pass may be much longer than was predicted a generation ago. Several generations might be needed for just the initial phases. Our generation might again go to the Moon and the next one or two to Mars, to settle there. In the long term, humankind should become a spacefaring civilization [1, 27, 28, 29]. Progress in this direction will depend upon our solving all the pressing social, political and economic problems associated with such an ambitious programme in the context of other Earth-bound problems, rather than solely solving the attendant technological and scientific problems.

In this paper we have briefly explored seven crucial issues

- The cost of space exploration and exploitation is large, but not that large – both private and public sources of funding are required, and some return on investment; the time scale is quite long..
- New ways of converting energy into the kinetic energy of a space vehicle are essential.
- It would be advantageous for the space vehicle to approach (or even to exceed) the speed of light, and for astronauts to be able to hibernate on long journeys.
- New materials, with better strength to mass and stiffness to mass ratios, such as carbon nanotubes, are needed, as are new propulsion technologies, e.g., using nuclear fission or fusion rockets.
- Humans will have to adapt to live and work permanently in different space environments, sometimes in harmful radiation environments.
- Progress should be made in these directions in the current and next centuries, before anthropogenic changes to the Earth environment become catastrophic.
- Humans are 'programmed' to spread intelligent life beyond the planet where it developed.

We must live our time: the future is open in front of us. We need to have a new vision, a new commitment to take the initial steps soon, so that the human species can indeed make a start on its way towards the *final frontier.* We should boldly go forward, to our long term future, a spacefaring civilization.

<u>REFERENCES</u>

[1] G. Genta and M. Rycroft, *Space, the Final Frontier?*, Cambridge University Press, Cambridge, 2003.

[2] V. Lytkin, B. Finney, L.Alepko, *Tsiolkovsky, Russian Cosmism and Extraterrestrial Intelligence*, Q.J.R. Astr. Soc., 36 (1995) 369-376.

[3] A. Sokal, J. Bricmont, *Intellectual Impostures, Postmodern Philosophers' abuse of Science*, Profile Books, London, 1998.

[4] B. Parkinson, *Shaping the Flux – the Myth of the Future in Spaceflight*, 48th International Astronautical Congress, Torino, October 1997.

[5] W.T. Huntress Jr., *Science Goals for Human Explorers in Deep Space*, World Space Congress, Houston, 2002.

[6] B. Finney, *The Prince and the Eunuch*, in *Interstellar Migration and the Human Experience*, University of California Press, Berkeley, 1985.

[7] R.L. Forward, *Indistinguishable from Magic*, Baen, Riverdale, 1995.

[8] http://liftoff.msfc.nasa.gov/academy/tether/spacetowers.html

[9] G. Vulpetti, *On the Viability of Interstellar Flight*, 49th International Astronautical Congress, Melbourne, September-October 1998.

[10] G. Vulpetti, *Problems and Perspectives in Interstellar Exploration*, Journal of the British Interplanetary Society, 52 (1999) 307-323.

[11] E. Mallove and G. Matloff, *The Starflight Handbook*, Wiley, New York, 1989.

[12] T. Kondo, *Approaching Artificial Control of Hibernation*, III IAA Symposium on Realistic Near-term Advanced Space Missions, Aosta, July 2000.

[13] D. Singer, *The Human Adult: a Former or a Future Hibernator?*, IV IAA Symposium on Realistic Near-term Advanced Space Missions, Aosta, July 2005.

[14] M. Ayre, *Human Hypometabolism for Long Duration Spaceflight: Possibilities and System-level Consequences*, IV IAA Symposium on Realistic Near-term Advanced Space Missions, Aosta, July 2005.

[15] http://www.grc.nasa.gov/WWW/bpp/

[16] B.R. Finney and E.M. Jones (editors), *Interstellar Migration and the Human Experience*, University of California Press, Berkeley, California, 1985.

[17] B. Finney, *From Sea to Space*, The Macmillan Brown Lectures, Massey University, Hawaii Maritime Centre, 1992.

[18] R.M. Zubrin, D.A. Baker, *Mars Direct*, *A Proposal for the Rapid Exploration and Colonisation of the Red Planet*, in *Islands in the Sky*, Wiley, New York, 1996.

[19] R. Zubrin, R. Wagner, *The Case for Mars,* Touchstone, New York, 1997.

[20] G. K. O'Neill, *The High Frontier: Human Colonies in Space*, Bantam Books, New York, 1977.

[21] Genta G., I*nterstellar Space Exploration: What is Going on?,* III IAA Symposium on Near Term Advanced Space Missions, Aosta, July 2000.

[22] K.E. Drexler, *Engines of Creation*, Anchor Press, New York, 1986.

[23] M.J. Fogg, *Terraforming: Engineering Planetary Environments*, Society of Automotive Engineers, Warrendale, Pennsylvania, 1995.

[24] R.M. Zubrin, C.P. McKay, *Terraforming Mars*, in *Islands in the Sky*, Wiley, New York, 1996.

[25] D.H. Meadows, D.L. Meadows, J. Randers, W.W. Behrens, *Limits to Growth: Report for the Club of Rome's Project on the Predicament of Mankind*, Potomac Associates, New York, 1972.

[26] P. Bianucci, *La Luna*, Giunti, Firenze, 1999.

[27] Robert Zubrin, *Entering Space: Creating a Spacefaring Civilization*, Tarcher/Putnam, New York, 1999.

[28] N. Prantzos, *Our Cosmic Future,* Cambridge University Press, Cambridge, 2000.

[29] F. White, *The Overview Effect: Space Exploration and Human Evolution*, The American Institute of Aeronautics and Astronautics, Reston, Virginia, 1998.

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