Chapter 2
The Dream of Flight and the Vision of Tomorrow

Sometimes, flying feels too godlike to be attained by man. Sometimes, the world from above seems too beautiful, too wonderful, too distant for human eyes to see…

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2.1 Introduction

We consider the possibility that our species may develop into a spacefaring civilization. This represents a future where we rise to the challenges that the universe presents us while enjoying the rewards of discovery and new sources of energy production. In this possible future access to space is not limited to a few but enabled for many, beginning an era of interplanetary and eventually interstellar migration of our species into the cosmos. Our species would be free from the confines of a single planetary body and instead have the opportunities of countless worlds and resources. It is the observations of nature, the flight of the birds, and beyond to the depths of space that drove us towards this vision. Plato said it was astronomy that compelled the soul to look upwards and lead us from this world to another.

2.2 Becoming a Spacefaring Civilization

Let us begin by asking the question of what is a spacefaring civilization? Here is one possible answer: a spacefaring civilization is one with many orbiting space stations, active colonies on all local moons and nearby planetary bodies as well as remote outposts in the outer parts of the Solar System with a Solar System wide trade economy. To date the state of human civilization cannot be described by this

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simple definition. However, our science-based technological society is heading towards this state and there is reason to be optimistic about the future.

In the 1960s the Russian scientist Nikolai Kardashev considered the possibility of advanced civilizations existing in the universe [1]. This seemed a credible idea, considering that there were many stars much older than our own star, the Sun. Kardashev came up with a description for galactic civilizations based around energy consumption. He defined three possible types. A Type 1 civilization is one that has achieved control over its planet's entire resources. A Type 2 civilization is one that has achieved control over the resources of its whole Solar System, including the Sun. A Type 3 civilization is one that has achieved control over its entire galaxy, including the core. Clearly, passing into the twenty-first century humankind has not even achieved a Type 1 status by these definitions. But to take an optimistic perspective, it should also be clear that we are on the brink of moving towards Type 1 if we embrace our destiny (it is believed that we are currently at a level of 0.7), build on the achievements of the Apollo missions and pioneer the outer boundaries of space as the final frontier. It is quite possible that the current period in our history is a very critical one in which we either succeed in winning the Solar System and continue our expansion into the cosmos, or we fail to reach our full potential and the possible collapse of our current civilization is forced upon us.

If this assessment is true then the cold facts of reality should force us to embrace the greater challenges ahead, and in the words of the former U.S. President John F. Kennedy: "We choose… to do these things not because they are easy, but because they are hard."

For this is the challenge of our times; the route we take into the future will determine the ultimate fate of our species. Traveling into interstellar space may be the best way we can ensure our future survival, dispersing the species over a wide area, maximizing the resources available to us and progress our scientific knowledge. This is a highly productive way for our species to direct its energies. And if life from this world is indeed unique, as some may claim – the only instance of intelligence in this vast universe – than ever the more important that we spread that life outwards to ensure the survival and growth of that intelligence.

The first artificial satellite reached Earth orbit in October 1957 and was called Sputnik 1. This achievement from the former Soviet Union had such dramatic consequences on the world that it started what history now records as 'the space race.' For a while, the Soviets dominated the early achievements in space exploration with the first mammal in space, Laika the dog, in November 1957, the first man, Yuri Gagarin, in April 1961, the first woman, Valentina Tereshkova, in June 1963 and then the first space walk by Alexey Leonov in March 1965. These were tremendous accomplishments that would have been welcomed by the world warmly if it weren't for the suspicious motivations behind them. America eventually caught up, and the first American in space was Alan Sheppard in May 1961 followed by Virgil Grissom in July of the same year, and then that historic first orbit by John Glenn in February 1962. Events were moving at a fast pace, and in June 1983 Sally Ride became the first American woman in space.

After the initial Soviet achievements, the huge industry of America woke up and inspired by President Kennedy's vision on May 25, 1961, aimed for more ambitious missions than floating around in Earth orbit:

> I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important in the long-range exploration of space; and none will be so difficult or expensive to accomplish.

The decision of the American political leaders to attempt the seemingly impossible and place a man on the Moon before the end of the decade was a courageous one. This was an open challenge to the Soviets to 'race' in the biggest peacetime competition in human history. Nine years later, in July 1969, the first man, Neil Armstrong, set foot on the lunar surface. A Soviet lander was en route to the lunar surface at the same time as Apollo 11, hoping to be the first to return a soil sample back to Earth, thereby claiming some form of technological and cultural victory over the United States. Although this caused some anxiety for the mission it ultimately had no real effect on the outcome, as Luna 15 crashed and Apollo 11 made a successful landing. America had won and was to be considered the more technologically advanced and thereby ideologically superior nation from a public relations perspective.

During the Project Apollo missions to the Moon twelve American astronauts walked on the lunar surface over six landing missions, the last of which was in December 1972. Around 380 kg of Moon rocks were returned back to Earth. If we had gradually built up a lunar colony over the last four decades, today there would be a permanently manned arctic-like station with spacecraft cycling back and forth between Earth and lunar orbit. Sadly, that was not how history turned out, and we are still waiting for this dream to be fulfilled. Since then, mainly due to a lack of political will, we have withdrawn from the Moon and concentrated on less ambitious missions, low Earth orbit (LEO) operations. This is not to say that the achievements in space over the last few decades have not been stupendous. The establishment of the International Space Station and over 100 launches of the space shuttle have been inspiring and kept the dream of spaceflight alive for many millions of people. But let us be frank in our evaluation – Earth orbit is just that, it is not outer space, with its very thin atmosphere and microgravity environment.

Astronauts are tremendously capable people who have demonstrated 'the right stuff' and earned their place to fly into space. There are many millions of people on this planet who are sufficiently fit to travel in a spacecraft. They do it every day in an airliner over the oceans of the world but at much lower altitudes. OK, so they have gravity to contend with and perhaps would struggle in zero gravity. But is that even true? Wouldn't it be easier to operate in a near-zero gravity environment, provided you allow for corrections in physical movement? The majority of Earth's population is physically capable of undergoing short space missions. So why choose only a select few? The main reason is because currently access to space is expensive, so if you are going to send up an expensive satellite mission you want to guarantee near 100% success, which means only selecting the most suitably qualified individuals.

Consider the opportunities if access to space wasn't expensive – this would change everything. Indeed, today there is an international effort, largely privately financed, to open up space to the world. This is now being called the commercial space market, and tourism is the main reason people want to go into space – for potential leisure activities. Although it is true that leisure in space is a driving factor, it should not be the dominant one. Instead, it should be driven by exploration and business incentives, and this is where the rest of the Solar System comes into its true value for our species. The return to Earth of rare minerals or gases presents a clear business motivation for opening up space to all of industry, and this motivation should be the driving force for future space exploration, opening up new avenues of knowledge along the way and pioneering the boundaries of technological innovation.

2.3 The Promise of the Future

When people are asked for their views on space travel, there are generally two viewpoints that emerge. The first are those people that see the 'heavenly bodies' (the planets and Moons) as almost mystical and take the view that humanity should not spoil them or alter them for self gain in any way. This may be motivated by spiritual reasons or a genuine acknowledgement that we haven't looked after our own planet that well, which sets a precedent for how we will behave on other worlds. The second viewpoint states that humanity should move out into space, exploiting the material resources along the way, purely for self gain and probably profit. But surely there is a third way, somewhere in between these two viewpoints, which states that indeed we should move out into space and exploit the material resources as needed to sustain our expansion and continued survival, but we should do so in a responsible manner. In particular, if we find life on other worlds, we should do our best to preserve it and minimize our potential contamination.

If we think about how humanity will behave when we first move out into space, we are led to inquire which of these three viewpoints are we likely to take in our journey? To address this, let us first examine our behavior on our own home world – Earth.

Our need for energy has resulted in a depletion of many natural resources. This includes the continuous destruction of the rainforests, the poisoning of the world's lakes and oceans, and the extensive burning of fossil fuels. So we must turn to alternative resources. For several decades now nuclear fission reactors have provided a great deal of power for cities. However, fission reactors produce contaminant waste that is difficult to destroy. This is because the radioactive decay time (to a stable non-radioactive state) of the substances being used is of order 100,000 years. One solution to this would be to send all of the radioactive waste into the Sun. However, first we must get that waste into Earth orbit, and the reliability of rocket launches is currently not adequate to take such a risk. The explosion of a rocket during launch containing radioactive waste will spread dangerous particles for many hundreds of kilometers around the globe.

Until we have developed efficient sources of energy we are not ready for the rest of the universe, and more importantly it is not ready for us. This is not such a concern for the time being, because currently, we do not possess the technology to fully exploit the natural resources of the Solar System anyway. However, this situation is changing rapidly, and the technology is being developed with some priority. This is for several reasons. Firstly, there is the belief that global climate change is related to manmade activities of energy generation. Second is the depletion of our natural energy resources. As a consequence of this rapidly moving technological situation, humanity's destiny is either going to go one of two ways. We will either destroy ourselves as our energy reserves dwindle with an increasing population competing for precious resources, or we will be successful, tame our behavior, and move on to other pastures – outer space. Others have argued that all civilized communities must achieve control over their population growth if they are to survive the catastrophe of population explosion and its associated problems of overcrowding and shortage of resources [2]. Whether the universe is ready for us or not, we are likely to be going there soon, and we must prepare ourselves for the exciting journey that awaits future generations. In the words of the Russian physics teacher Konstantin Tsiolkovsky, "Earth is the cradle of mankind, but we cannot live in the cradle forever."

To deal with our future energy needs the physics community has been working since the 1950s on the design of a civilian nuclear fusion reactor. Fusion energy is what powers the Sun, and it has the advantage of being a clean source of energy. However, although significant progress has been made in the development of a fusion reactor, we are not there yet. So if we were to move out into space now, we will be reliant upon twentieth century technology and associated industrial processes, which damage any natural environment as well as waste energy. But the development of fusion energy technology is moving ahead rapidly. It is just a matter of time before we have working nuclear fusion reactors powering the majority of the world's electrical supplies. Once these reactors have been built and become operational, the next generation of reactors will be even more efficient and smaller. A consequence of this is that alternative applications of fusion energy will be considered. A whole new field of science will be born based upon the application of fusion energy and household devices not yet conceived by the human mind will become common. This progress will inevitably have applications to both robotic and human spaceflight, and the development of a space propulsion drive based upon the principle of fusion reactions will become possible. Until that time, we must be content with the progress made by our ambassadors among the stars – robotic probes.

As of the year 2011 we are busy receiving data from robotic probes on many different trajectories throughout the Solar System. Our civilization is still in the information-gathering phase. The question is – when we have got the information we want, will we have the courage to explore the outer Solar System and beyond to finally embrace our destiny to become a space faring civilization in the near future? Humanity is at the brink of an incredible age. In fact, it would not be an overstatement to say that we are on the brink of an evolution in humanity's great journey. It is difficult to predict when we will become a space faring civilization, but the taming of fusion energy on Earth (should we be successful) and for use in space travel must suggest that we are near that point – perhaps only a few decades to a century away.

The closely interconnected world that we live in, as observed from the nightly news on our television screens, is enabled by the communication age. What has driven us to these technological accomplishments? What makes us want to go further, faster and better than before? Is it simply the need for self-entertainment or is it something more profound? We always want to know what is over that next horizon. So we walk long distances, we ride horses, we build cars, and eventually we build machines that fly. What all these modes of transport have in common is they all rely upon some system of propulsion to provide the forward momentum. For the human, it is simply the muscles in his legs and the forward movement of his arms and pelvis. The use of the horse is an example of a paradigm shift in thinking; let the energy be expended by some other means rather than due to the muscles of the person, an improvement in efficiency. But then we realize that horses, too, have a physical limit. They also must stop for rest and food. So we build a mechanical horse, which doesn't need rest – the bicycle, motorcycle and motorcar – except when wear and tear of the components require they all be replaced. But these machines also need fuel, and how much we can give it depends upon how much fuel it can carry and the rate at which it is used. It is a self-limiting technology. So we look skywards, and see the birds that effortlessly glide above our heads surveying the ground to horizons we cannot see. Humans mimic nature, master the principles of flight and fly like the birds – perfection is achieved. We have been able to do this because we have something that the rest of the animal kingdom lacks – a highly developed brain. This allows us to seek novel solutions, which ultimately have the purpose of prolonging life or continuing the survival of the species.

Humankind has evolved over many millions of years to a species that can now boast to have traveled on all of the continents, all of the oceans, walked on the Moon and even sent robotic ambassadors to enter the atmosphere of Venus, Mars, Saturn, Titan, several asteroids and a comet. Our robotic probes have also entered the orbits of many worlds, including Mercury, Uranus, Neptune and several other moons such as Gannymede, Europa, Io and Callisto. But all these accomplishments still do not add up to a spacefaring civilization. We are still children playing with toys at the dawn of our destiny. We are yet to send a probe to our most distant world, Pluto, which resides at 40 astronomical units away (1 AU is the distance from Earth to the Sun), although when this book was written a spacecraft mission called New Horizons was en route. We also are yet to send probes to the outer Kuiper Belt and Oort Cloud, which reside at 40 to 500 AU and 2,000 to 50,000 AU, respectively. The most distance spacecraft we have sent includes Voyagers 1 and 2 along with the Pioneers 10 and 11 spacecraft. The furthest any of these have traveled to date is around 100 AU.

If we have only traveled this far away from Earth, how much further do we need to go to the nearest star? Alpha Centauri is 4.3 light years away. That is, it takes light (the fastest thing in the universe) over 4 years to travel the distance of 40,000 billion km, or 272,000 AU. Our home galaxy, the Milky Way, contains several hundred billion stars spread over 100,000 light years. We have a long way to go before we can truly be considered a spacefaring civilization. We have merely dipped our toes into the vast ocean of space, been frightened by the temperature and not had the courage to dive in far enough. This is the 'failure of nerve' that Arthur C. Clarke frequently discussed in his writing. This lack of confidence in our species to go further despite the risks is like a ball and chain around our species, constantly tethering our species to a single star and its neighboring worlds. We must find the courage to shake off the chains of our home world and seek new resources elsewhere. This is the only way to ensure the permanent survival of our species.

When we examine Low Earth Orbit (LEO) space operations or robotic missions to the planets today, we also notice a large degree of international cooperation. Is this a model for how the first missions to the stars will one day be achieved? Sending spacecraft to other worlds is likely to be expensive, with high risk, so minimizing these factors necessitates international cooperation. This endeavor also has the potential to unite humanity behind a single vision despite its diverse religions, cultures, and laws. In order to make more progress in exploring outer space, we will need a rocket engine – a very powerful one – which is part of the focus of this book. The first steps towards this vision of becoming a spacefaring civilization are the complete robotic exploration of the Solar System and nearby space. This has already started and with sustained effort should continue further within the current century. We can imagine the sight, a large space vehicle being constructed in Earth orbit over a period of years and eventually a crew of a dozen or more astronauts blasting off towards the first stars on a rocket ship powered by some exotic engine, perhaps already invented. Many today believe that interstellar travel is impossible, but it will be shown throughout the chapters of this book that in fact it is perfectly possible and engineering designs already exists for achieving this goal (Fig. 2.1).

2.4 Why We Shouldn't Go Out into Space

Why would anyone want to go into space, let alone to another planetary system? Over a period of billions of years, humans have evolved on this planet to the complex life forms that we are. We have a wonderful biosphere that has been perfected by nature for us as well as the rest of the animal kingdom on Earth. We have a planetary environment rich in plant life, plentiful in oceans of liquid water and overall a moderate climate, all enabled by our gravitational center – the Sun. Any move to another solar system will involve significant hazards, and even when we get there it is highly unlikely that the biosphere of another world will be ideal for us. Firstly, the surface pressure is likely to be either too high or too low, which

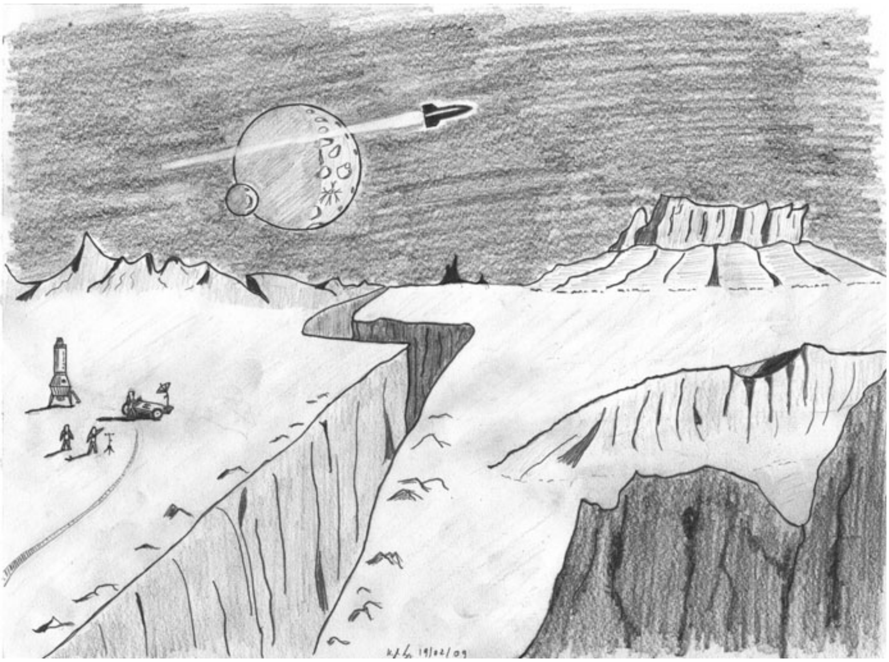

Fig. 2.1 Illustration of a planetary rocket scene, the vision of dreams for centuries

means we cannot breathe the air freely but will require some form of respiratory apparatus. Secondly, the surface temperature will be either too cold or too hot. If too hot any equipment may malfunction. If too low, then we may simply freeze to death. Then there are the charged particles that enter the atmosphere from the local solar wind. On Earth, we are protected by a magnetic field. On another planet, it may be insufficiently strong or non-existent, should a liquid iron core not be present. We would require substantial protection from any cosmic radiation.

The atmosphere of another planet may not be compatible with our basic survival requirements of oxygen, carbon dioxide and nitrogen. In all likelihood, any astronauts stepping foot onto this new world will need some form of space suit to enable them to function. Many of these risks can be mitigated by understanding in advance the many worlds and moons of our own Solar System. Then there is the journey itself to get to this new world. This will involve traveling across vast distances of space, not depending on any rescue parties and avoiding asteroids or dust particles as they approach with large kinetic energies. Even a single particle can present a significant collision risk if the vehicle is traveling at high speed. This is due to the fact that kinetic energy is proportional to the velocity squared, so the faster the ship or particle is going, the higher the collision energy involved. There is also the risk from bombardment of cosmic rays en route, which may cause cancer. If an artificial gravity field is not created then astronauts should expect significant calcium loss and bone decay. So given that there are these significant risks, why go? To undertake such a high-risk enterprise and place humans in harm's way, the potential rewards would have to be very high indeed.

There are many educated people who take the view that traveling to the stars is either impossible, a useless expenditure of our energies or both. In particular, they cite many reasons why interstellar travel should not be attempted. The first objection is an obvious one, the stars are too far away and any travel times will be prohibitively long. They also cite massive fuel requirements. Then there is the risk and difficulties with sustaining any crew in space for long periods, as discussed above. One way to offset the presented objections is to launch a mission with minimum mission duration. This would mitigate the risk to any crew and reduce the probability of dust or other impact hazards as well as radiation exposure. The key driver then for any mission has to be, *minimize travel time*.

Many people also take the viewpoint that sending missions to distant destinations is a waste of our useful resources, both scientific and financial, when we should be concentrating on solving the problems back here on Earth – that is, problems such as poverty, war, unemployment, education, health and of course surviving global climate change. The cost of such a mission is considered to be a major factor.

There are two further objections to interstellar travel, which are more technical. The first relates to the fact that technology is continually improving, and so why launch a mission with an engine, when it could be overtaken by a more advanced engine in a later decade. This is the so-called incessant obsolescence postulate, when no matter when a mission is launched eventually another mission will overtake it with faster engines. This postulate may not hold however in the case of identifying an optimum launch opportunity, where launching a mission several years later with faster engines may not get the second spacecraft there sooner than the first. There is also the question of waiting for the technology to come to fruition. This has been discussed in the literature and the author Andrew Kennedy [3] described the problem in terms of the incentive trap to progress. In such a situation a civilization may delay interstellar exploration in the hope that an improved technology, perhaps based on radically new insights, will be ready later on. Kennedy describes the problem thus:

> It is clear that if the time to wait for the development of faster means of travel is far greater than the length of the journey, then the voyagers should go ahead and make the journey. But if the likely future travel time plus the length of wait is equal or less than the current journey time then they should definitely wait.

However, using the equations associated with growth theory, it was shown that a window of opportunity exists where the negative incentive to progress does turn positive and so a spacecraft can arrive at the destination earlier than a later launch. Leaving before the minimum time allows future growth to overtake the voyagers; leaving after the minimum time will mean the voyagers cannot catch up to those who left at the minimum. Similarly, in the event of a propulsion physics breakthrough that does not rely on the conventional methods of crossing space, this postulate would become irrelevant. This relates to the time dilation effect of

Einstein's special relativity, where any crew that accelerates at high fractions of light speed away from home will become time separated from the loved ones they leave behind. Poul Anderson elegantly explored this in the science fiction novel *Tau Zero*.

2.5 Why We Should Go Out into Space

Now that we have discussed some of the objections to interstellar travel, we shall consider the arguments for it. If a calamitous disaster were to occur tomorrow, such as a sufficiently large asteroid, we would be doomed as a species. We have insufficient protection and nowhere else to go. The situation is so serious that we may not even notice the impending threat until it is too late. There is currently no internationally organized, government-supported program to watch the skies for this threat. In effect, Earth is naked in space and the priority of any technologically developed civilization must be to protect it from the hostile elements of space, if we are to expect Earth to continue to look after us. This is not science fiction: the threat is real and we simply have two choices – defend ourselves or run. However, we cannot run because we are not a spacefaring civilization, although our chances for survival would be increased if we had somewhere to go. Therefore all we can do is to defend ourselves where possible.

For some reason, the existence of this threat is controversial in some quarters and still being actively debated, with many not taking the threat seriously, despite being shown evidence of a recent impact of the comet Shoemaker-Levy 9 in 1994 into the atmosphere of Jupiter at a speed of around 60 km/s. A similar event occurred in 2009. There are also internal risks such as natural catastrophes from earthquakes and tsunamis or even rapid global climate change. Then there is the fact that both our Sun and planet have a finite age of around 5 billion years. If our existence is to be permanent, at some point we must grow up and leave this Solar System, finding alternative homes among the stars. Natural disasters originating on Earth and from space do threaten the stable existence of our cherished human civilization, and such threats should be taken as real and present dangers.

The direct impact of successful space missions has a positive effect on society that is difficult to calculate and long lasting. We are still reaping the benefits of the Apollo program today. However, one of the issues we currently face is that most of the tremendous achievements in spaceflight were accomplished in the 1960s and 1970s. The people involved in those programs are getting older, and we may find ourselves in a position where no one living has worked on manned lunar projects, for example. If this were to occur, we could have a failure of confidence or even a failure of capability. This is the reason why we must continue to build upon the achievements of the past in the old tradition of an apprentice. If we do not, we face the prospects of returning ourselves to the Dark Ages and taking centuries to catch back up with ourselves. Hence, bringing all this together we are led to our first of seven motivations for space travel which has to be continued survival. The philosopher and writer Olaf Stapledon understood this well:

> Is it credible that our world should have two futures? I have seen them. Two entirely distinct futures lie before mankind, one dark, one bright; one the defeat of all man's hopes, the betrayal of all his ideals, the other their hard-won triumph.

The second motivation for space travel is related to a balance of resources. There is a limited amount of material on the planet and an exponentially increasing population cannot be sustained indefinitely within those limits. It is simply a question of numbers. To sustain the population growth, resources must be found and better distributed, but once depleted the population must be curtailed or move on. Imagine a hypothetical lift with a maximum capacity of 30 people. Let's assume that each person is a clone and to begin with there are 2 people in the lift. Each clone produces 2 more clones so that there is a clear geometrical progression in the total population. By the second generation there are 6 clones in the room. By the third generation there are 14 clones, and by the fourth generation there are 30 clones. The maximum capacity of the lift has been reached. Now let us go back and assume that by the second generation half of the total population leaves the lift and goes into a different lift, so that there are now only 3 clones per lift. Carrying on the same geometrical progression by the third generation there will be 7 clones per lift and by the fourth generation 15 clones per lift – half the total capacity of the original setup.

Now, with planet Earth's human population it's a bit different, because we are talking in very large numbers, of order 6 billion people growing at a population increase of around 2% per year. With the limited resources of the planet this growth is not permanently sustainable. Indeed, when the population does eventually hit the resource limit this could result in a very unstable world as nations compete for what resources remain to sustain their national populations and economic prosperity.

Now let us pretend that we had built a gigantic housing complex on the Moon. It is not simply a question of just shipping that population off on many thousands of rockets to the new homes. A simple calculation shows that this is impractical. If a rocket were to ship off from Earth carrying 100 people every day of the year for 10 years, this would still only be a total population move of 365,000 people. If this were continued for a century, it would still be much less than 1% of the total population, which was continually increasing anyway. So hoping to ship vast quantities of the population off to other worlds is not the solution to population control. Instead, we must seek alternative mechanisms to ensure a continuing and successful civilization. The first is population growth control. This necessitates extreme and draconian measures such as limiting childbirth or even longevity – clearly not desirable options in any culture that values liberty. The second mechanism is expansion of the population outwards off Earth, so that the population can grow on other worlds and out beyond the Solar System not limited to the resources of one planet.

The third motivation for interstellar travel is creating new economic opportunities, although more directly relevant to interplanetary exploration. For a growing and healthy civilization the creation of new business opportunities is vital to the economic growth of a nation and the world, as well as important for the growth of technological innovation. There are several potential business markets associated with space exploration, from space tourism to the mining of rare resources off world. This could be iron ore from an asteroid or helium-3 from the Moon. This will also slowly bring to fruition a Solar System-wide infrastructure that could be vital to the eventual expansion of our species to the outer Solar System and beyond.

The fourth motivation for interstellar travel is the quest for knowledge. This can be knowledge in the scientific sense, such as geological or astronomical. Alternatively, it may be related to understanding our place in the grand scheme of the universe, a kind of spiritual or metaphysical knowledge. How can anyone seeing an image like that of the Sombrero Galaxy shown in Plate 1 not be moved by the immensity of space? This may be a necessary part of any religious faith that needs to continually re-invent itself in order to offer comfort, guidance and relevance to its members.

Arthur C. Clarke said: [4] “Any sufficiently advanced technology is indistinguishable from magic.” Certainly, if humans were to travel back in time and showed Victorian England a laptop computer or a 3D computer game, they would think it was magic. Indeed, it could be argued that this is ultimately the test of any advanced civilization. If a comparison is made of the current technology to a previous era, and there are no products that can be presented as magic, then technological progress is too slow. There is no evidence that we on Earth are reaching that point currently. The last 100 years has seen astonishing advancements in technology, and there are many visionary ideas around today that may become reality tomorrow. However, eventually we may reach a point where the limit of our knowledge dries up, and the only way to replenish it is to go to other places in the universe to learn more about it. Knowledge also brings about other benefits, such as medicines to cure diseases or technologies to ease the burden on our hard existence and increase our overall quality of life. Seeking knowledge about ourselves and our environment is also a fundamental part of our makeup. Speculating further one may go as far as to say that curiosity itself may even be a reflection of a survival instinct.

The fifth motivation for interstellar travel is the spreading of life. Given that there are around 400 billion stars in our galaxy and around 100 billion galaxies observed in the universe, the probability that Earth is the only world with life is very small. Any conservative estimates for parameters such as the lifetime of planets and stars will still lead to a substantial number of possible worlds with life. However, we also have to consider the evidence, and to date with our limited knowledge of space we are not aware of any substantive evidence of life (let alone intelligent life) existing outside of our home planet. If this was the case, then the responsibility of us to spread our life seed to the rest of the universe is very great. Indeed, there can be no nobler cause for the purpose of humanity. Of course, it is most probable that there are many worlds out there with life. Several moons in our own Solar System are good candidates for life of some form and there is evidence that life may once have existed on Mars, as discussed in Chap. 7.

However, intelligent life is another issue altogether and could even be considered a reason to embark on such missions itself – to trade knowledge with another species. If we were to meet such intelligent life then this would have profound implications for humanity and our knowledge of biology and medicine. Meeting intelligent beings from another world will also challenge humanity socially. We have already shown throughout history that we struggle to overcome our racial and cultural tensions, although things are slowly improving. If we as a species react so poorly to someone of a different skin color, how would we react to someone who looked literally alien or even had social values and ethics vastly different from ours? The occasional incident of physical birth defects in a human and how that person is treated by the rest of society also demonstrates that even today we still have deep prejudice and fears that suggest we are not yet ready to meet our interstellar neighbors. We must first become a society where appearance is not a factor for determining social ranking and behaviors.

The sixth motivation for interstellar travel is the freedom factor. The development of human beings to their modern form has been a slow process. Homo sapiens have evolved from hominids (great apes) and in turn from placental mammals over a period of several million years. The oldest discovered human skeleton is around 4 million years old. As humans have developed we have learned to adapt ourselves to the hostile world around us. The application of technology has then enabled us to exploit that world to our advantage. It started with our technological use of stone in the so-called 'Stone Age.' We then progressed into the 'Bronze Age' and eventually into the 'Iron Age.' This technological progression has given us unparalleled power on Earth to control all other life, derived from our intelligence, and helping to place us firmly at the top of the food chain. But as Clarke clearly explains we should not be complacent: [5]

> Most of this planet's life remains to this day trapped in a meaningless cycle of birth and death. Only the creatures who dared to move from the sea to the hostile, alien land were able to develop intelligence. Now that this intelligence is about to face a still greater challenge, it may be that this beautiful Earth of ours is no more than a brief resting place between the sea of salt and the sea of stars. Now we must venture forth.

We are now in a different age, having exploited all metals heavier than iron and those lighter such as aluminum. Do we call this the 'Metal Age'? Or is it the ability of our species to develop a language and record our history by written records that characterize us. This has led to what we may call the 'Information Age,' dominated today by computing technology that is largely based on silicon materials. The development of computers has allowed us to calculate very large sums, with direct application to space travel. However if one reviews the eras of human history, a clear trend emerges: humankind develops technology as a means to dominate the environment to aid in survival. But what happens when we reach the peak of what we can develop within the confines of this planet and its natural resources? This is a difficult question to answer, but one way to avoid this situation is to not reach this point. Hence, in order for us to continue to develop technology we must expand in all degrees of freedom possible. Hence we are led to an interesting question: What is meant by freedom?

We tend to think of freedom as flexibility to move in any particular direction, freedom to go left or right, for example. But there are other types of freedom; such as to go where you want and when you want. This includes a temporal component to freedom. There is also financial freedom to purchase what one requires, political or religious freedom to hold certain views. Speculating, we could postulate that freedom is a manifestation of built-in (evolved) human desires to dominate the environment wherever possible, in order to survive. This partly explains why we explore all environments on our planet, be it sea, air, land or beneath Earth itself. This is a continuing quest, and there is still much to explore, and so what about space? Humankind is fascinated by the endless possibilities of space, the infinity of stars in all directions. We want to go there and our desire to do so may be an expression of our continued freedom.

Today, a select few elite individual governments dominate space travel. All space operations are run from large government organizations, which heavily regulate the activities of private industry. It is not easy today for a private individual to independently raise the capital, build a rocket and launch themselves to the Moon. This will firstly be very difficult to achieve due to the structure of our society. Secondly, some governments may not allow the individuals to fly in the fear that they may perish in the attempt. They may have the intellectual skills to build the rocket, and courage to attempt the journey, but they won't be allowed to fly (incidentally this situation is now being directly challenged by the emergence of the space tourism market). This is a form of constrained freedom. They are prevented from directly expressing their evolutionary desires. These desires are what conquered the American frontier, to explore the boundaries of known reality, to know what is over the other side and exploit the resources for self-benefit and hopefully for the benefit of those around you.

The U.S. Declaration of Independence contains the inalienable rights of man, namely life, liberty and the pursuit of happiness. There are many people not just in the United States but also throughout the world who desire space travel but are prevented from doing so, largely due to cost. This is a constraint on their individual freedom, their liberty and their right to pursue self-happiness for the benefit of all humankind. Space travel must be opened up to the world at large and humanity allowed to continue to explore the cosmos. In his autobiography *Disturbing the Universe* physicist Freeman Dyson says: [6]

> Space travel must become cheap before it could have a liberating influence upon human affairs. So long as it costs hundreds of millions of dollars to send three men to the Moon, space travel will be a luxury that only big governments can afford. And high costs make it almost impossible to innovate, to modify the propulsion system, or to adapt it to a variety of purposes.

This is absolutely right, and this must change if we are to become a spacefaring civilization. It is worth adding that the recent X-Prize competition developments and the successful flight of SpaceShipOne illustrate that opportunities for space travel are expanding to the general public.

Other than the rights of individuals to pursue their chosen happiness, the situation could actually be made worse if an oppressive government dominated the world and prevented space travel in its entirety [7]. This could be due to a cultural belief that such exploration is either immoral or not the best choice of funds, which could be directed to less nobler pursuits. Alternatively, such oppression could actually stimulate space exploration as civilized humans attempt to find a safer place to exist. In the circumstances that an oppressive government had reach throughout the entire Solar System, then the only route of escape for the human colony would be towards more distant locations – planets around other stars. Global war could also force people to seek other places to inhabit, not confident that governments have the capability to ensure their continued safety.

Finally, there is a possible seventh reason for interstellar travel that is very profound if true but also highly speculative. It relates to an unconscious reaction to return to the stars. We already know that the atoms that make up our body derive from the fusion cores of stars and indeed this is true of everything around us. All matter on Earth is made up of atoms that were built within the core of a star. It is quite possible that there is a mechanism in our build up that is driving us into space, a 'starstuff driver' – a concept closely related to evolution. This is an idea similar to 'why do birds sing?' and it is plausible that the answer is hidden within our genes. Others have discussed this idea, such as the physicist Greg Matloff, who states: [8]

> In one of his books, the late Carl Sagan states that we are all 'starstuff,' since the atoms that compose us were mostly generated in the explosive demise of a super giant star. To take the poetic analogy further, it is interesting to note that interstellar flight requires us to either behave like a star or fly very close to one. So starstuff can use the stars to visit them.

Many a species of bird will return to its original nesting site from which it was born to begin its own generation, and then they too will feel compelled to do the same. It is a possibility, although highly speculative, that in our quest to understand ourselves better, the intelligence level of humans has led to an unconscious desire to return to the source from which we are fundamentally derived – the stars themselves.

To summarize, we have identified seven key motivations for interstellar space travel: continued survival; balance of resources; economic opportunities; quest for knowledge; spreading of life; freedom factor; and starstuff driver. Many other motivations can be thought of, but ultimately, they can be reduced to a subset of seven reasons. Sending human beings to worlds around other stars is the ultimate expression of a noble civilization that wishes to know more about itself and the apparent reality that it inhabits throughout its physical existence – called by us the universe.

Finally, in this section it is worthwhile quoting Arthur C. Clarke from his book *Profiles of the Future* to show clearly where his opinion was on the so-called impossibility of interstellar travel:

> Many conservative scientists appalled by these cosmic gulfs have denied that they can ever be crossed. . .And again they will be wrong, for they have failed to grasp the lesson of our age – that if something is possible in theory, and no fundamental scientific laws oppose its realization, then sooner or later it will be achieved.

The idea of humankind going to the stars, of being a spacefaring civilization, is what can be termed Clarke's Vision, although many others have shared in the origin of this idea. To this author's mind this vision is an optimistic future, which fully embraces technological progress for the use of a compassionate and forward looking society in search of like-minded races. Those today who pursue that vision with the same passion are in essence children of Clarke, ambassadors of a great dream that humanity's destiny lies not just here on Earth but also on another Earth orbiting another star. To encourage others in successive generations to steer our civilization towards that goal is the greatest legacy Clarke and his literature left behind.

2.6 Practice Exercises

2.1. Make your own list of reasons why space exploration should be continued, listing both the benefits and the costs to society. List the main scientific discoveries that could be made with the sending of only robotic probes throughout our Solar System. Think of the economic, political and cultural implications to our species of a world determined to explore space. What effects would this have on our society?

2.2. Think about the infrastructure requirements for a Solar System-wide economy that includes regular manned space missions out as far as Pluto. Describe this future, the heavy industry background as well as the transport requirements for Earth to orbit and from orbit to the planets. Using your derived model extrapolate from current technology to the future you have envisioned and estimate a time period for when you think the first unmanned and manned interstellar missions would occur.

2.3. Using the future you have described in the last problem think about how we go from our current technological-political world to that future. What key technological, social, political and economic steps are required to make that future happen? Describe your own roadmap.

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