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Abstract

The Age of Space Exploration represents an era of discovery and scientific achievement without equal in human history. This paper examines the exciting technical and social consequences of space exploration C past, present and future. Emphasis is placed on the fact that the most significant space exploration missions of the past four decades started in Brevard County, Florida with a successful rocket ride into space from the Cape Canaveral/Kennedy Space Center complex. This paper provides a much needed perspective of how space exploration activities are helping answer some of humankind's most important philosophical questions: Who are we? Where did we come from? Where are we going? Are we alone in this vast Universe? Future missions, such as a human expedition to Mars and an advanced robotic mission to the intriguing Jovian moon, Europa, will help define the cosmic philosophy of an emerging Solar System civilization. As we develop a millennial perspective and continue our search for life elsewhere in the Solar System, we will also learn more about our role and place as intelligent species in a vast and beautiful Universe.

Introduction

On the Gregorian calendar, 01 January 2001 marks the beginning of the Third Millennium. For many, the arrival of 2001 has also stimulated wonderful memories of the epic adventure movie, *2001: A Space Odyssey*. Released in 1968, this science fiction masterpiece was co-written by the space visionary, Sir Arthur C. Clarke, and the late film producer, Stanley Kubrick. With great attention to technical detail, the talented team provided movie audiences with a vivid experience that consciously and subconsciously celebrated space exploration.

Because of its lasting impact, *2001: A Space Odyssey* serves as a convenient launch site when we embark on our present journey to explore the impact of space exploration on human destiny in the Third Millennium. Here are some of the movie's most perceptive technical speculations. Clarke and Kubrick included innovative telecommunications systems, orbiting hotels, commercial space travel to the Moon, a lunar flourishing settlement, the surprise discovery of an alien artifact, and even the downside of creating an super-intelligent machine that can develop a mind of its own. Not bad for 1968!

Sometimes, the apparently "far-out" speculations made by visionaries in producing over-the-horizon technical notes or quality science fiction experience the delightful fate of becoming science fact. Perhaps such out-of-the-box (non-linear) thinking by a bold few is necessary to liberate the bottled-up creative energies of the majority of the population. Outer space is the ultimate physical frontier and its exploration will continue to inspire and stimulate the human mind.

Consider again *2001: A Space Odyssey*. A year after the motion picture's release, two American astronauts, Neil Armstrong and Buzz Aldrin, became the first human beings to walk on the lunar surface. This *real* event occurred on 20 July 1969 and marks the start of our Solar System Civilization. The Apollo lunar expeditions (1968-1972) provide historians with a very definitive milestone by which to divide all human history -- namely, the time before and after we demonstrated the ability to become a multiple-planet species. For our discussions here, it is reasonable to consider the Moon as Earth's nearest "planetary" neighbor, because scientists often treat the Earth-Moon system as a double planet system. Exploration of the Moon (as occurred during the Apollo Project) and the establishment of permanently inhabited lunar bases and settlements (as will occur sometime in the 21st century) bracket the start of a human civilization that extends beyond the boundaries of Earth.

Early in the 20th century, the legendary Russian spaceflight pioneer, Konstantin Eduardovich Tsiolkovsky (1857-1935), boldly predicted just such an interplanetary migration of human beings. Engraved on his tombstone in Kaluga, Russia are the prophetic words: *"Mankind will not remain tied to Earth forever."* To commemorate the centennial of Tsiolkovsky's birth, the former Soviet Union launched Sputnik 1, the world's first artificial Earth-orbiting satellite (4 October 1957). This technical achievement is generally celebrated as the birth of the Space Age.

Following the Sputnik techno-shock, Cold War competition between the United States and the former Soviet Union resulted in a fierce "Space Race" in which highly visible civilian space exploration achievements became directly linked on the world stage with superpower prestige. Ultimately, and perhaps by political accident, this competitive environment helped inaugurate the central space exploration event that identifies the beginning of our Solar System Civilization. This central event, of course, was President Kennedy's visionary response to the early Soviet space technology challenge. Kennedy's lunar landing mandate demanded "the impossible" and resulted in a series of successful Apollo missions that dramatically transformed a century of science fiction into science fact. During the 1960s, we went from a closed world (single planet) civilization to an open world (multiple-planet) civilization. Like Clarke's fictional black monolith, Apollo astronaut footprints on the Moon now serve as a permanent beacon that challenges future generations to follow and seek their destiny beyond the boundaries of Earth.

Far-travelling exploring machines also contributed to the First Golden Age of Space Exploration. In a magnificent initial wave of scientific exploration, spanning the 1960s, 1970s, and 1980s, NASA used the Cape to sent an armada of innovative robot spacecraft to the Moon, around the Sun, and to all the planets in our Solar System (save for tiny Pluto). One particular epic journey, that of the Voyager 2 spacecraft, clearly defines this rich period of discovery C a scientifically electrifying period within which we learned more about the Solar System than in all previous human history.

The legendary journey of the Voyager 2 spacecraft, started from Complex 41, when a mighty Titan/Centaur vehicle ascended flawlessly into the heavens on 20 August 1977. This hardy robot exploring machine successfully performed its famous "Grand Tour" mission by sweeping past all of the gaseous giant outer planets (Jupiter was encountered on 9 July 1979, Saturn on 25 August 1981, Uranus on 24 January 1986, and Neptune on 25 August 1989). After its encounter with the Neptunian system, Voyager 2 departed on an interstellar trajectory, escaping the Sun's gravitational embrace at a speed of about 3.1 astronomical units per year.

As we examine the significance of space exploration on human culture and philosophy, we should recall that four human-made objects (NASA's Pioneer 10 and 11 spacecraft and the Voyager 1 and 2 spacecraft) have already departed from Earth on deep space trajectories sufficient to hurl them into the interstellar void. Each of these American spacecraft carries a message from Earth. Pioneer 10 and 11 bear a specially-designed plaque that features the stylized image of a man and woman, while Voyager 1 and 2 carry a digitally-recorded message that includes a variety of sounds and images from Earth. Our first interstellar emissaries departed on their pathways to the stars from Cape Canaveral. Perhaps a thousand millennia from now (star date: 1,002,001, if you prefer), an advanced alien civilization will discover one of these space exploration artifacts, decode its message, and learn about our "ancient" 20th century civilization and its first attempts to come of age in the Galaxy.

<u>Our Space Odyssey Continues</u>

In 2001, humankind's space odyssey continues to provide the inspiration and expansion of mental boundaries that often accompany the discovery of new worlds. For example, the Mars Global Surveyor (MGS) spacecraft is providing a marvelous stream of high resolution images of the Red Planet that hint of an ancient time when water flowed freely on its surface and life may have emerged and flourished. Similarly, NASA's hardy Galileo spacecraft has endured the harsh radiation environment of the Jovian system and keeps transmitting new images and data. The Jovian moon, Europa, with a suspected liquid water ocean beneath its smooth, frozen surface, is an especially tantalizing world both for planetary scientists and exobiologists. A bit further out, the Cassini spacecraft glides through interplanetary space and prepares for its June 2004 rendezvous with the Saturnian system. Scientists on earth eagerly await their first close-up view of another "new world," the mysterious, atmosphere-enshrouded Saturnian moon, Titan.

Somewhat closer to home, continuous streams of quality data from sophisticated Earth-orbiting, robot observatories, like the refurbished Hubble Space Telescope (HST) and the Chandra X-Ray Observatory (CRO), amaze astronomers and cosmologists with an ever-improving view of the magnificent, but violent, Universe across space and time. Quite literally, each day represents a new opportunity for discovery, excitement, and surprise. Through space exploration, we are discovering that the Universe is not just a beautiful, violent, and strange place, but a place that is more beautiful, more powerful, and definitely stranger than the human mind could ever imagine.

So, how does exploring space influence human activities ten, fifty, one hundred, and even a thousand years into the future? The words of the American space visionary, Dr. Robert H. Goddard (1882-1945), provide some much needed encouragement, as we attempt the challenging task of predicting the consequences on distant tomorrows of exploring activities performed during a period of rapid change. According to Goddard, *"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."*

It is also helpful to appreciate the delicate art of technical prophecy. One of the most delightful tutorials on the subject is Sir Arthur C. Clarke's: *Profiles Of the Future* (1977). In this book, Clarke introduces his famous three laws of technical prophecy C encouraging guidelines for technical visionaries who attempt to fulfill technical dreams within stuffy bureaucracies that thrive on rigid adherence to vertical (strictly linear) thinking.

Clarke's First Law of Technical Prophecy suggests that when a distinguished but *elderly* (note: according to Clarke anyone over 30 years old) scientist states that something is possible, he (or she) is usually correct. However, when he (or she) states that something is impossible, they are very probably wrong. *Clarke's Second Law of Technical Prophecy* suggests that the only way of discovering the limits of the possible is to venture a little past these limits into the impossible. And finally, the most interesting rule of all. *Clarke's Third Law of Technical Prophecy* suggests that any sufficiently advanced technology is indistinguishable from *magic*.

Without too much difficulty, we can uncover numerous examples of how four decades of space exploration have helped demonstrate the efficacy of Clarke's postulations. For example, in the late 1930s, a distinguished scientist wrote a careful mathematical treatise on why a rocket flight to Mars was "impossible." Similarly, President Kennedy's closest advisors politely cautioned him that he was demanding the "impossible" by ordering the fledgling civilian space agency to put a human being on the Moon in less than a decade. Finally, anyone can now enjoy the very latest, high quality views of the Universe in the comfort of their own homes through the combined "miracles" of the Internet and modern spacecraft technology. From the perspective of a person who still remembers pre-Space Age America and the inspiration that Walt Disney's mid-1950s space exploration television series provided, instant access to on-going space exploration activities might quite justifiably be viewed as nothing short of "magic."

Before immediately dismiss these "rules" as the polite suggestions of a *science fiction* writer, it will help to remember that the communication satellite, upon which so much of the today's global information revolution depends, was predicted by the very same Arthur C. Clarke in October 1945. He accomplished this visionary feat with the publication of the technical paper, "Extra-Terrestrial Relays," in *Wireless World*.

As Clarke suggests in *Profiles of the Future*, one very useful way to practice imagining the future is to look back into the past over some appropriate period (perhaps a generation or two) and then consider how much of today's technology would be regarded as "truly magic" by even the most creative people of that time. As a mental exercise, think back for a moment to when your parents or grandparents were children and then ask yourself: "What were the technical 'marvels and dreams' that dominated their youth?" My grandparents (like most at the end of the 19th century) thought that people could never fly through the air; my parents (like most in the early 20th century) assigned the topic of space travel to Flash Gordon, dime novels, and Saturday movie house serials. Yet within less than a lifetime, our civilization now depends on space systems for numerous defense, scientific, and commercial activities and some of us are even paid to work in space. Tomorrow, our children or grandchildren can walk again on the Moon and build settlements on Mars! Space travel is no longer regarded as "future magic." To understand the full consequences of space exploration, then, it is important to recognize that our use of space beyond 2001 will create many exciting "future magic" circumstances and opportunities.

Futurists and strategic planners often use trend analysis and extrapolation to create plausible projections of technology. This is a logical, evolutionary forecasting approach that comfortably supports organizational planning, involving a time-horizon of five years or less. Unfortunately, meaningful strategic (long-range) planning requires a time-horizon that extends well beyond 5 years -- to perhaps 25 years or more. When commonly, but improperly applied, to long-range thinking, the trend analysis/extrapolation approach becomes hopelessly stretched beyond the "elastic limit" of its practical time-horizon. In addition, because of its inherently conservative nature, this technique cannot anticipate very well those exciting scientific discoveries and technical breakthroughs (i.e., *nonlinearities*) that promote revolutionary change. While such nonlinearities are by their very nature difficult to imagine and plan for, no credible long-range projection is complete without some recognition of their presence. The trick is to keep the organizational vision flexible enough to recognize and seize revolutionary change when it first appears. Unfortunately, because established organizations (like individuals) gravitate toward positions of stability, revolutionary changes (even when properly identified) are normally viewed as threats, rather than as special opportunities. Often, workers within today's space industry - an industry that generally enjoys a socially-recognized futuristic image - find their search for and promotion of "future magic" a most demanding task.

The Impact of Two Possible Space Exploration "Discoveries"

With that note of caution, here are two nonlinearities that could dramatically influence the pathway of space exploration and development over the next century. The first is the *confirmation* of large (thousands of tons) water ice deposits in the polar regions of the Moon. The second is the discovery of extraterrestrial life in the Solar System C perhaps only extinct or existent microscopic organisms on Mars or some slithering aquatic critter in the suspected subsurface oceans of Europa. The first discovery represents the "Holy Grail" of an emerging Solar System civilization, while the second discovery fulfills the cherished dreams of many curious people down through the ages who looked up at the night sky and wondered if life existed elsewhere. The second discovery would also trigger a major philosophical reassessment of who we are as a species and what our true role might be in a Universe potentially teaming with life, perhaps species like our own or far more intelligent beings.

In March 1998, a team of NASA scientists announced that data from the *Lunar Prospector* spacecraft indicated the presence of water ice deposits in the perpetually frozen recesses of the Moon's polar regions. If confirmed by future exploration, this discovery will significantly change all strategic planning concerning the permanent human habitation of space. The availability of lunar ice in sufficient quantity (perhaps thousands of tons) greatly simplifies surface base logistics. In situ water resources could accelerate base expansion and even promote the formation of a self-sufficient lunar civilization. Because of its strategic position near Earth and its inherently low gravity level, the Moon could easily become the main space logistics center, supplying all future exploration missions (human and robotic) to Mars and beyond. However, while technically reasonable, the value and impact of this possible discovery on the Moon only makes sense in the context of a strategic plan that embraces a century-long, societal commitment to create a Solar System civilization.

Space visionaries, like Krafft Ehricke, have suggested that the early lunar settlement will successfully demonstrate industrial-scale applications of native Moon materials (now believed to include water ice). The fledging lunar economy will grow as pilot factories start supplying selected raw materials and finished products to customers both on the Moon and in a variety of orbital locations within cislunar space. With a thriving lunar spaceport as part of the permanent Moon settlement, access to all points in cislunar space could actually become easier and less energy-intensive than from the surface of Earth. The lunar spaceport could become the busiest launch complex in the Earth-Moon system. From the surface of the Moon, traditional chemical rocket propulsion techniques might even be supplemented by more exotic launch techniques, including electromagnetic mass drivers, mechanical catapults, and compressed gas systems. These high-impulse launch techniques are especially suitable for shock-resistant, "dumb-mass" payloads that are quite literally thrown into space at very high velocities from the surface of an airless Moon. At the close of the 21st century, it might cost a few dollars per kilogram to provide bulk lunar materials to orbital destinations throughout cislunar space.

With the rise of highly-automated lunar agriculture (performed by robots in special greenhouses), the Moon may also become "extraterrestrial breadbasket" C satisfying the food needs of all human beings living beyond the boundaries of Earth. When the combined population of several large lunar settlements reaches about 500,000 persons, a social and economic "critical mass" occurs that could support technical, social, and economic self-sufficiency from Earth. This moment of self-sufficiency for the lunar civilization also represents a very historic moment in human history. From that moment on, the human race would exist in two distinct and separate "planetary niches" C we would be terran and nonterran (or extraterrestrial). If the lunar inhabitants cherish and maintain the space exploration ethic, it is not too unreasonable to suggest here that their descendants will go on to become first the interplanetary and then the interstellar branch of the human race.

The discovery of extraterrestrial life, extinct or currently existing C no matter how humble in form C will force a major revision of the *anthrophic principle*, that comfortable premise by which human beings have tacitly assumed over the centuries that planet Earth and (by extrapolation) the Universe were created primarily for their benefit and use. The discovery of life beyond Earth will shatter such a chauvinistic (terrestrial) viewpoint and encourage a major reevaluation of key questions, such as: "Who are we as a species?" and "What is our role in the cosmic scheme of things?" Right now the subject of extraterrestrial life resides in the nebulous buffer realm between science fiction and highly speculative science. But, through space exploration, the topic of native Martian life or native Europan life could easily become 21st century *science fact*. At this point, it is not unreasonable to speculate that future science students could investigate the behavior of alien life forms (ALFs) in the oceans of Europa as part of their general science curriculum.

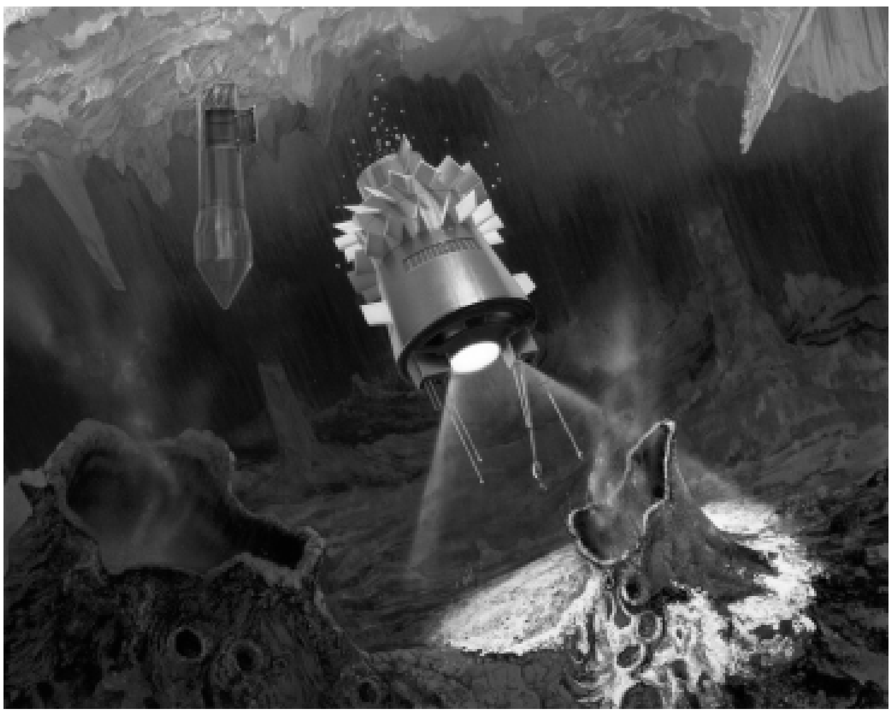

Figure 1. Future underwater robot explorer, called a hydrobot, searches for alien life in the ice covered liquid water oceans of Europa; an ice-penetrating “mother” spacecraft appears in the background. Artist’s rendering courtesy of NASA/JPL/CALTECH.

Conclusions

Absurd? Perhaps. But less than five hundred years ago, a bold Polish church official

(Copernicus) and a fiery Italian scientist (Galileo) helped trigger the first scientific revolution -- an event that completely revised the traditional and long-cherished view about Earth's central role in the physical scheme of things. Likewise in the 21st century, as we poke around interesting locations in our Solar System (especially on Mars and Europa), we must be prepared for the arrival of a similar technical and philosophical revolution. For some, demonstrating that life abounds in the Universe represents a logical and exciting pathway for science and space exploration; for others, such a discovery could create cultural and religious turmoil — as did the Copernican revolution.

Each time a rocket vehicle leaves Cape Canaveral and successfully rises into space on a pillar of fire, we should marvel at the event and recall the prophetic words of the German space visionary, Hermann Oberth. When asked why space exploration was so important, Oberth responded: *"To make available for life every place where life is possible. To make inhabitable all worlds as yet uninhabitable, and all life purposeful."*

At the dawn of a new millennium, space exploration offers us the Universe as both a destination and a destiny. Hopefully, future galactic historians will look back and note how life emerged out of the Earth's ancient seas, paused briefly on the land, and then boldly ventured forth into the Solar System and beyond. The arrival of 2001 heralds a very special moment. For us now it is the Universe or nothing!

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