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Bo Rim Seo

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FUTURE OF SPACE TRAVEL

SPACE TRAVEL FOR THE MASSES: HISTORY, CURRENT STATUS, PROBLEMS, AND  
FUTURE DIRECTIONS

By

Bo Rim Seo

Submitted in Partial Fulfillment of B.S.

Worcester Polytechnic Institute

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## Abstract

Space travel has had a relatively short history. Despite its recency, the field has seen rapid development over the last several decades. Once the domain of governments, space travel is now also in the private sector. Since the first commercial human space flight took place in 2001, several other wealthy space tourists purchased their rides into space. Currently, more than 625 people have signed up for sub-orbital space flights with Virgin Galactic [1]. However, there still are significant barriers in making space travel a reality for the general public. This paper examines and analyzes these problems and posits the problem of conventional propulsion system as the central issue to target. Building upon these analyses, several alternative propulsion sources are discussed as new solutions. Additionally, presentation was performed in front of general public and surveys were conducted to assess the perceived accessibility of space travel to ordinary people. Results indicated the study participants indeed considered space travel to be a personally feasible aspiration when the problems related to cost, safety, and convenience were resolved.

# **SPACE TRAVEL: HISTORY, CURRENT STATUS, PROBLEMS, AND FUTURE DIRECTIONS**

## **I. Introduction**

The human race has been always an adventurous pioneering species. At high risks, we have gone out to explore unknown hostile places, and climbed over difficult mountains and hurdles while not having a clear idea what we might find[2]. Such risk taking pioneering spirits, though at times costly, ultimately helped us to thrive and progress. Since the 1900s, air and space have been two of our biggest new frontiers. With raw passion, the legendary Wright brothers went through 4 years of mechanical aeronautical experimentations before sustaining their first powered and controlled flights in North Carolina in 1903[3], [4]. After their public demonstration of air flight in 1908 at the French Hunaudieres race course, another 4 years passed before 39 countries came to possess hundreds of airplanes and numerous pilots[2]. Through subsequent efforts at birthing new ideas and testing them, aviation technology was able to come to the point of mass producing the safe, cost-effective airplanes that we fly today[3]. Unlike such incredible history of aviation, the history of space flight has not seen innovation for almost two generations[2]. Only recently has there been another wave of new movement in the progress of space travel, since the space aeronautics industry got passed on from the hands of the government to the hands of the private sector. The privatization and commercialization of space travel has been a boon for the industry indeed, with exciting developments in new concepts and possibilities[2], [5]. However, many hurdles still stand in the way of making space travel a reality for the everyman.

Before expounding on the recent waves of innovation in space travel, it is important to acknowledge the lack of progress that had lasted for almost two generations. In fact, it is more accurate to state that we had regressed during those years[2]. For example, in 1998, the U.S. Air Force retreated to jets that were developed in 1956, forgoing the more impressive airplanes like the supersonic *Lockheed SR-71* that was designed in 1959, only 12 years after the first operational jet. The Concorde jet had doubled the speed of commercial airplanes, but since its retirement, the new airliners being currently manufactured are again the same speed as the DC8 planes in 1958. Likewise in space travel, the 1964 *Grumman Apollo Lunar Module* was a superb craft designed to fly only in space, which could land on and take off from the moon without requiring much maintenance[6]. However, this was abandoned in 1972. The number of manned space flights has also decreased. During the first year of human space flight with Gagarin's lead, there were 5 flights in total. In 2003, in the year that all of the crew members sent from the U.S. were killed, there were 3 flights; in 2004, there were only two Russian flights[2], [7]. Also, 40 years after our first moon landing, no plans exist to return to the moon until 2020, until we build the capability to have sustained human presence on the moon[8]. Since the retirement of the Apollo and Saturn V programs, NASA's rockets and space shuttles simply are not capable of going beyond low-Earth orbit to reach the moon, especially with the amount of payload required for such prolonged expedition and semi-permanent settlement[8], [9].

Although NASA is currently developing new taller and larger rockets *Ares I* and *Ares V* to return to the moon and even surpass it[9] – perhaps to Mars – the goals for building cheaper, safer, stronger, faster rockets would require unprecedented amounts of creative innovation and investment. However, the fiscal challenges that face NASA have not been a trivial matter. In fact, this has been pointed out as one of the main reasons for the lack of progress in the last few

decades in space travel. (Another reason stems from the lack of compelling public motivation, unlike the national security concern that fueled support for the Cold War era's space race with the Soviets.)[8] Currently, NASA's cost for the construction of the *Orion* and *Ares I* alone is \$35 billion, not counting other countless innovations that could and should take place in rocket science. Fortunately, recent privatization of the space industry has been, so far, a great antidote to the fiscal problem[2], [10] . Just as getting a 20 million from several billionaire space tourism customers sustained the starving Russian space program, the commercial space flight industry is predicted to add riches to the resource-poor space flight industry. Already more than 1.7 billion investments have occurred in private space flight industry by companies like Google, and that is only half of what is being committed and planned for the next few years. Soon, the investments are predicted to flow in at five times more than what NASA will be doing for human space flight by 2020[2], [10], [11].

The private space flight industry is definitely increasing in volume with a lot of players rising to benefit from the profitable market for public sub-orbital flights. To name a few, these players are Burt Rutan (Scaled Composites), Paul Allen, Elon Musk (SpaceX), Sir Richard Branson (Virgin Galactic), Jeff Bezos (Blue Origin), the Ansari family (Ansari X Prize), and Bob Bigelow (Bigelow Aerospace) , and David Thompson (Orbital Sciences)[12]–[14]. Like the space race for prestige that took place between countries in the Cold War era, now these private companies are engaging in “the capitalist's space race” to claim the honor of first reaching technological breakthroughs, as well as reaching the moon and beyond[15]. Great innovations have already taken place to address the problems of safety, cost, and convenience that had limited space flight, through the development of more fuel-efficient and reusable rockets, better propulsion mechanisms, including solar sails. This paper will discuss in detail these advances as



well as more promising hypothetical alternatives in the later sections. It also aims to target the problem of public buy-in by adding an intervention research component: educational seminar was administered to a group of diverse adults to increase their levels of awareness and sense of relevance in regards to space travel. All in all, with safer and cheaper options becoming available to offer even elliptical orbit trips around the moon like *Apollo 8*, it is believed that about 100,000 people will fly by 2020[2]. Not only that, more excitements are now on the horizon, such as settlement on the moon, colonization of Mars, and intergalactic travel[2], [11].

## II. Background

### A. History of Space Travel

#### 1. History of Rocketry

The outer space has been an object of fancy, inspiration, and study from ancient times. Looking into the magnificent sky and its stars, people have wondered what lies beyond them and whether they could reach the other side. With the development of the telescope in 1609 by Galileo Galilei, people were able to see the universe in more detail and to find out the principles of the cosmos. People discovered that the Earth was not the center of the universe, and that there were other planets orbiting around the sun with their own moons orbiting around them[16]. The Earth's moon is the closest celestial object to us, and it no longer appeared to be so out of reach in comparison to the vast universe[7]. In 1903 the Wright Brothers succeeded in flying their aircraft and fueled the human zeal for air travel more: if powerful machinery could take us up into high skies, couldn't there be machinery developed to take us up even to the moon? The Chinese fireworks, which used gun powder to create explosive propulsion, became the inspiration for the modern rockets. In same century, first rockets – or “rocce” in Old Italian for a long, thin tube – appeared in Europe as crude weapons for war. Though still limited in size, performance, and safety, propulsion charges from black powder (finely ground charcoal), potassium nitrate, and sulfur provided enough power to demonstrate the promising future of rockets. Military rockets eventually increased in size and performance with continual refinement of the technology. Contributing to rocket development as serious science was Sir Isaac Newton's formulation of the laws of gravity and motion. These laws, clearly described in Newton's *Philosophiae Naturalis Principia Mathematica*, are still used today to explain in detail how rockets and propulsion work[17]

Near the beginning of the 20<sup>th</sup> century, the crude gunpowder rockets lost their significance as weapons and modern rocket science began. There are three men who are called “Fathers of Modern Rocketry.” Among them, the first person who researched rockets for the purpose of space travel was a former school teacher from Russia, named Konstantin Tsiolkovsky. He discovered the concept of exhaust velocity, which means that the greater the explosion of the fuel, the greater the thrust velocity. Tsiolkovsky wrote many articles about the principles and theoretical aspects of spaceflight. His work greatly influenced space and rocket research in USSR and Europe[16], [17]. In the United States, Robert Goddard found through his experiments that rockets could fly in a vacuum. Not only do they fly well in a vacuum, Goddard discovered that the rockets fly at even faster speeds in vacuum than in air, because vacuum does not have air resistance to reduce the rocket’s thrust. Goddard also became the first person to develop liquid-fuel for rockets, which were evidently more efficient than solid fuel despite some of its disadvantages (e.g. harder to handle, must be kept in separate tanks, and in very low temperatures of -300°F)[16], [17]. Goddard launched his first rocket in Auburn, Massachusetts in 1926 and continued to build engines and more complex rockets into his later life in New Mexico. Lastly, Hermann Oberth studied the requirements for interplanetary travel. He also was instrumental in promoting rocket science through his paper called, “By Rocket into Planetary Space,” which referenced Goddard’s work to present space travel as more of real science than just science fiction. It is said that by reading Oberth’s paper Tsiolkovsky became incited to publish his own work and new theories[16], [17].

## **2. *History of Human Space Travel***

Thanks to the pioneering work of the abovementioned Fathers of Modern Rocketry, the science of space travel has long reached a level where trained astronauts could travel into space.

After the Soviet Union launched the first artificial satellite *Sputnik* into orbit in October 1957, *Sputnik 2* soon followed a month later, this time carrying the first animal into space. Though the first dog Laika only survived for 4 hours in space due to malfunctioning environmental control system, 13 other dogs and animals were successfully sent and safely returned to Earth before the first human flight[17], [18]. With the Soviet successes in space, the United States joined in competition and started the oft-called space race between the two countries. President Eisenhower instituted the National Aeronautics and Space Administration (NASA) in 1958 to engage more fully in the goal to send human beings into space. Besides this main goal, NASA sent probes to explore the earth's space environment: the moon and other planets, as well as the sun and stars[16]. In the same year, Project Mercury was created with the sole purpose of sending Americans into the outer space, on orbital flights. Starting from the year 1961, the Project trained and sent 7 young pilots who became the nation's first astronauts. Although the Project had hoped that one of these 7 would become the first man in space, in April 1961, Yuri Gagarin of Soviet Union claimed the honor – just a few weeks before the U.S.'s Alan Shepard went into space in May 1961[19].

Yuri Gagarin thus became the first human to be in sub-orbital space, flying in the spacecraft *Vostok*. Despite the concerns over the negative health effects of weightlessness, Gagarin returned unharmed and functioned normally. Valentina Tereshkova soon became the first woman to be in space for 3 days on *Vostok 6* in 1963. These successes of *Vostok* missions were followed by improvements to the spacecraft that would enable even travel around the moon[18]. This new generation of spaceships was called *Voskhod*, and it became the first multi-person spacecraft, carrying 3 cosmonauts crammed into the cabin designed for one. On *Voskhod 2*, Alexei Leonov then became the first man to make a spacewalk that lasted for about 12 minutes

in 1965. However, the *Voskhod* missions were discontinued when the Soviet Union decided to focus its energies on the moon race with the United States[19].

The competition between Soviet Union and United States on striving to reach the moon first was a fierce one. Former President John F. Kennedy even presented this issue in a “Special Message to the Congress on Urgent National Needs,” urging the Congress to quickly create a space program rivaling the Soviets[20]. Thus, in 1961, in the midst of the Cold War, the U.S. created the Apollo program with the aim to reach the moon by the end of the decade. After several successful orbiting around the moon, United States finally had Neil Armstrong land on the surface of the moon through *Apollo 11* in 1969. This feat was accomplished by building and launching two separate space crafts, Apollo and Saturn V, in order to cover the long distance to the moon. *Saturn V*, one of the largest rockets ever flown successfully, took *Apollo* half way to the moon then launched it into the lunar trajectory. The 6 teams of astronauts sent through the Apollo program landed successfully on the moon and collected data on observations and experiments, and brought samples of the lunar dust and rocks[19].

The next challenge for the aeronautical community was forging an international collaboration, leaving behind the era of international competition between the U.S. and the Soviet Union. In 1975, they had *Apollo-Soyuz Test Project* as the first international space mission. Soyuz spacecraft launched from the center in Central Asia, and Apollo from the Kennedy Space Center in Florida. The two crew teams met in orbit and visited each other’s space crafts[21]. This paved the way for the future ventures, including the sending of U.S. space missions to the Russian Mir space station. European nations also joined in this international trend by creating a European Space Agency (ESA) in the same year of 1975. These 15 nations were: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway,

Portugal, Spain, Sweden, Switzerland, and the United Kingdom. The ESA participated in many solar system missions, with a large budget reaching 3.1 billion U.S. dollars in 2003[21]. The active international space collaboration is well exemplified in the establishment of the International Space Station, which now orbits the Earth as the largest artificial object in space as well as the habitat of longest human presence in space (13 years). ISS was created as a merger of three space station projects in 1993, with components for *Russian Mir-2*, *American Freedom*, *European Columbus* space station programs. In this microgravity and space research environment, astronauts and cosmonauts from 15 different nations have visited and conducted various experiments. Finally, in 2003 China became the third nation to launch a human into space, aboard the *Shenzhou 5*. China had been involved in space travel projects discretely since 1940s; in 1992 China made its own space program with the help from Russian experts. China's own space station, *Tiangong*, was finally launched into space in 2011[22].

However, the history of space travel was not without tragedy. There were several accidents that cost lives and caused a lot of media coverage and international upheaval. In 1967, for example, Vladimir Komarov of Soviet Union died in a crash of *Soyuz 1* due to a series of technical issues, including parachute failure after re-entry into the Earth's atmosphere. As Komarov's death was the first to occur during space flight, the tragic incident spurred the development of improvements in spaceship design[23]. In the United States, the *Challenger* space shuttle exploded in 1986 after 73 seconds into its flight, killing 7 crew members. In reaction to this tragedy, the U.S. space program was grounded for 32 months, as the public and program questioned and weighed the safety of space flight[2], [23], [24]. After the Challenger accident, further launches were prohibited for any vehicle loaded with commercial payload. As commercial launches were prohibited for the U.S. government space program, this instigated the

development of private sector space exploration companies. As of 2013, the last recorded space casualty occurred in 2003 with the space shuttle *Columbia*, which disintegrated with its 7 crew members while re-entering the Earth after a 2-week mission, due to structural failures after encountering problems in its thermal protection system[23].

In total, 18 out of the 430 humans who flew in space have died, 14 on two shuttle missions and four on two Soyuz flights. This is equivalent to the fatality rate of 4.19 percent, though the rate is somewhat inflated by counting those who have flown on multiple flights. Compared to other adventures, this rate is similar to the one for climbing Mt. Everest. However, Rich Hauck, a former astronaut and CEO of AXA Space, a leading space insurance company, believes the risk of death needs to be decreased before public space travel becomes widely accepted. In order for the public feel safe enough to travel to space, the fatality rate should be reduced to less than 1 percent, Hauck said. As a reference, that is about the same percent risk that the typical American encounters during one's lifetime, dying in an ordinary traffic accident[24].

### **3. *History of Space Shuttles***

NASA has been planning to build a reusable spaceship beginning in the 1960s. In 1972, the Congress gave NASA the permission to start the shuttle program.[25] Due to budget constraints, however, NASA cut the development costs through combining the use of reusable and throw-away elements in the shuttle design[25]. Big wing span as big as a mid-sized passenger airplane, and capacity for up to 8 astronauts. It had several main areas, namely the crew cabin, cargo bay, and liquid fuel for rocket engines that enable the launch and maneuver of the shuttle in space, as well as its return to Earth. Among its protection system, the most important is the thermal protection system to protect the shuttle from intensive heat during the re-entering of the Earth's atmosphere. These orbiter shuttles are designed to land on the runway

of the Kennedy Space Center, gliding in its final moments as an unpowered glider. They made five of these shuttles: *Columbia*, *Challenger*, *Discovery*, *Endeavour*, and *Atlantis*[26].

From its first flight in 1981, space shuttles have flown many different missions. For example, the space shuttle *Columbia* flew 28 missions, before disintegrating during its re-entry after its last mission[26]. The shuttles' missions included deploying satellites, capturing them in orbit for repair, and returning them to earth; leading many scientific experiments, such as the study of how weightlessness affects living organisms; and becoming observational sites for studying the heavenly bodies of the universe. Perhaps the most crucial mission of the U.S. space shuttle was the launching of the famous Hubble Telescope by *Discovery* in 1990. The shuttles even flew secret missions for the Departments of Defense, and played crucial roles in constructing the ISS[26]. Despite its versatility and reusability, the space shuttle program has largely failed in reducing the costs of human space flight. Because of its complexity, the shuttle required lots of maintenance between each mission; and after its risk was underscored after two shuttles crashed and killed all of its crew members, the shuttle program was stopped in 2011[26].

## **B. Current Status of Space Travel**

### **1. Space tourism**

Today, new kinds of space travel are emerging. The year 2001 marked the beginning of space tourism, as a wealthy California businessman, Dennis Tito, became the first paying passenger for space flight[27]. He paid \$20 million to be launched by *Soyuz TM-32* via arrangements made between an American company called Space Adventures and a Russian company MirCorp, which oversaw the Mir space station. The ticket sale was to fund the maintenance of the Mir space station; however, a premature deorbit decision diverted Tito's



destination to the ISS. For 8 days, Tito enjoyed a unique vacation in orbit and spent seven days on board the ISS[27], [28]. Initially, there were many controversies in NASA in regards to the possible delays that such tourism would cause for the scheduled work. However, the concerns proved to be unfounded as no delays were experienced[28]. Many other laypersons followed Tito's footsteps: Mark Shuttleworth, a South African technology entrepreneur in 2002; Gregory Olsen, an American entrepreneur-engineer-scientist in 2005; Anousheh Ansari, an Iranian American businesswoman in 2006; and several other wealthy persons[27]. Given the orbital nature of these flights, most of these commercial space travelers needed to go through arduous training for their missions, alongside professional astronauts. However, several private companies are developing suborbital space vehicles to commercialize space travel, which would take passengers to an altitude of 100 km (62 miles)[27]. In the coming years, it is expected that such suborbital space tourism will become more affordable, safer, and easier for a wider range of customers [28].

In 2004, a concrete step towards realizing suborbital space tourism was achieved. During the \$10 million Ansari X Prize challenge, private companies competed with each other to launch a reusable manned spacecraft twice within two weeks[27]. On October 4, 2004, Virgin Galactic and Burt Rutan of Scaled Composites won the X Prize with their successful *SpaceShipOne* and opened the new era of commercial manned spaceflight. In the same year, U.S. Commercial Space Launch Amendments Act (CSLAA) was instituted to have Federal Aviation Administration (FAA) regulate the safety of commercial human spaceflight in the U.S. Under this Act, every commercial space launch, landing, and operation will be attended and evaluated by FAA representatives; all spaceflight participants will also be guided through an informed

consent process, in writing, about the risks of launch and reentry, including the safety record of the launch vehicle[27].

Although these safety regulations are still in their early stages of development and implementation, Sir Richard Branson's Virgin Galactic has already sold more than 625 seats at \$200,000 per ticket for its 2.5-hour suborbital space tourism flights on *SpaceShipTwo*[1], [29], [30]. *SpaceShipTwo* was officially disclosed to the public in December, 2009 in California and is tentatively scheduled start its operations in 2014[30]. The official date for the inaugural launch has been never been set, but the tentative start date has been delayed since 2007 due to Virgin Galactic's rigorous safety testing. With a new former Air Force pilot joined, spaceport opened, commercial space system license applied for, and powered test flight successfully performed in 2013, however, Virgin Galactic is confident that their customers' trust them to launch when it is truly safe to do so[1], [29]. When that time comes, *SpaceShipTwo* will be carried to launch altitude (15.25 km) by a jet-powered mothership, the Scaled Composites' *White Knight Two*, before turning up its rocket engines to fly up to 110 km in the upper atmosphere. The passengers will feel about 5 minutes of weightlessness as they get amazing views of the planet Earth. The spacecraft will stabilize itself for reentry through "feathering" the wings, then glide back to Earth for a conventional runway landing[27], [30].

Currently, Virgin Galactic remains as the only private space tourism company that successfully air-launched its *SpaceShipTwo* vehicle[12]. However, Virgin Galactic is definitely not alone in its venture into space tourism, as it is being seen as lucrative industry for the upcoming many decades[2], [12], [13]. For example, SpaceDev/Sierra Nevada Corporation has its reusable space plane *Dream Chaser* under development, which would take up to 4 passengers on suborbital flights[12]. Astrium, a subsidiary of European Aeronautic Defense and Space

Company, announced its space tourism project in 2007 and started to develop its rocket plane *Mach 3* in 2008. Mach 3's \$250,000 price tag will include spaceflight participant training, luxury resort accommodation, as well as a round-trip to the spaceport. The California-based XCOR Aerospace also revealed its smaller suborbital spacecraft *Lynx* in 2008, designed to carry a pilot and a single passenger at a time. Its \$95,000 ticket includes pre-flight training sessions, and is scheduled to start providing flights by 2014. The price is significantly lower than the competitors, in order to make commercial spaceflight more accessible to the public. XCOR already has over 175 reservations[27], [31]. Among these suborbital space tourism companies, Texas-based company Blue Origin's *New Shepard* spacecraft is also distinct from its peers, due to its vertical take-off and landing design. Supported by a \$22 million grant from NASA, *New Shepard* boasts its innovative biconic shape that "provides greater cross-range and interior volume than traditional capsules without the weight penalty of winged spacecraft (p. 1)"[32] In addition, the spacecraft features a "pusher escape system" that allows the crew to escape in an emergency situation during any phase of ascent into suborbital flight. Rob Meyerson, president and program manager of Blue Origin, stated that "providing crew escape without the need to jettison the unused escape system gets us closer to our goal of safe and affordable human spaceflight (p.1)"[33]

These developments in commercial suborbital spacecrafts are the fruit of human creativity and passion that persisted in the face of formidable technical challenges and financial constraints. Although still limited to suborbital flights within the confines of the Earth's gravity, it is predicted that the growth of this industry sector will not only profit companies, but also provide the impetus for further progress in human space flight beyond the moon, Mars, and the Milky Way galaxy.

## 2. Private companies

One of the significant changes in the U.S. that gave way to the flurry of development in commercial human space travel is the privatization of NASA's Space Shuttle Program (SSP)[34]. This change in NASA is a significant departure from its management by opening up the space shuttle operations to private industries [33]. However, what characterizes this merger is not a simple handover of government functions to private companies. NASA has taken careful measures to provide the companies with necessary skills and experience to ensure a successful, strong partnership. Likewise, NASA has examined its own organizational integrity, so that it would not continue to rely primarily on outside contracts for important skill and experience-based functions due to a huge loss of their own workforce.

In privatizing the SSP, implementing strong check and balance processes has been paramount. Without such stringent control processes among the numerous new players in the SSP, process drift or creep can easily affect the quality of hardware; organizational factors such as personnel change or turnover can result in critical loss of skills transferred for continual progress of the program[34]. As an illustration, the NASA SSP civil service workforce was reduced by half since 1993, causing the NASA skill base to diminish. As mentioned previously, NASA has therefore put in measures to prevent detrimental losses of skills and talent in its workforce. Secondly, NASA has given the private companies and astronauts a level of ownership for safety and mission decisions, to increase the strength of the check and balance system; in other words, the healthy tension between NASA and private companies and individuals will elicit more challenges to the "assumptions of test results, procedures, processes, problem disposition recommendations, and planned work (p.1)" [34].

## C. Problems, Limitations, and Possible Solutions

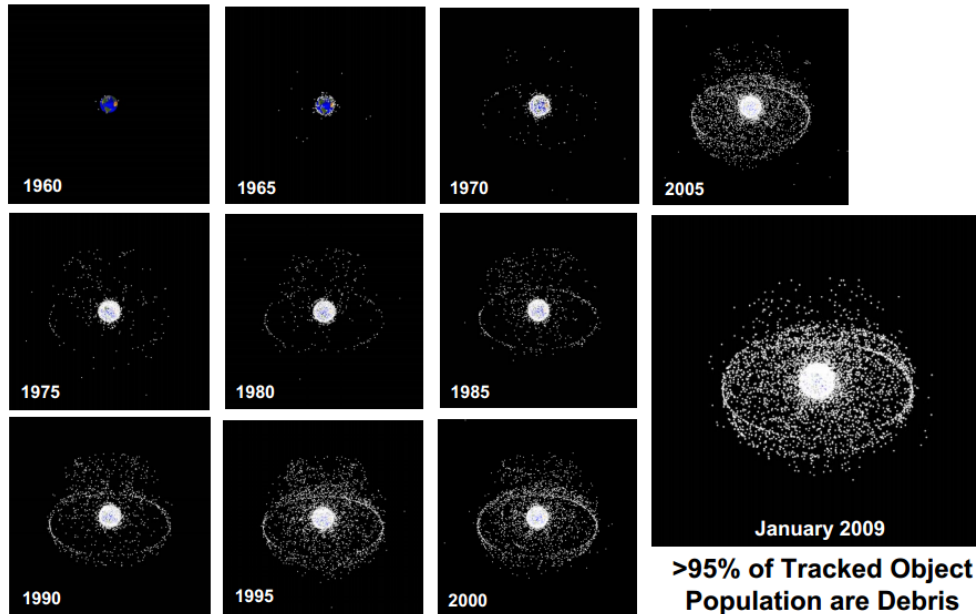
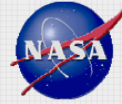
### 1. Safety and Convenience

#### a) Space Junk

One of the major safety concerns for space travel, perhaps surprisingly, has to do with the space debris that we have created since the 1960s[35]. Nicholas Johnson, chief scientist at NASA's Orbital Debris Program Office, stated that orbiting space debris have increased linearly since 1960s (see *Figure 1*), even with the technological advances that decreased the amount of debris left in each space flight[36]. Currently, it is estimated that there are approximately 30,000 items of junk bigger than 10cm in diameter orbiting around the Earth, at speeds higher than 465m/sec [37]. Because of such high traveling speeds of space debris, even pieces smaller than 10cm can penetrate and damage most spacecraft or space suit. In fact, NASA has calculated that a 10cm-long piece of space debris can cause as much damage as 25 sticks of dynamite[38].

This cadre of space junk includes whole satellites, rocket bodies, and fragments from explosions in fuel tanks and batteries, as well as from the colossal impacts between objects[36]. For example, a Chinese missile test on a satellite caused a significant increase in the amount of space debris, as the missile collided with two orbiting satellites. Experts noted that this incident alone had increased the risk for the 2009 shuttle mission to the Hubble Space Telescope by 8 percent[36]; it is also known that NASA needs to replace several windows on their satellites every year due to collisions with space debris [39][38]. To be more exact, during NASA's 54 shuttle missions, space debris and meteoroids struck the windows 1,634 times, and necessitated 92 window replacements; the radiator was hit 317 times, creating holes in the radiator's external body 53 times[36].

## Growth of the Satellite Population



*Figure 1. Growing populace of space debris (NASA, 2009)*

With the accuracy of a four-day forecast, NASA does track with radar pieces of debris and meteoroids larger than 10cm to identify impending collision danger, and then makes an evasive maneuver to move space vehicles out of harm's way[36]. NASA estimates that it has had to conduct around one collision avoidance maneuver per year for its shuttles and ISS. However, some difficulty exists in that the ISS generally needs 30 hours of advance notice to be maneuvered, and that several tens of thousands of smaller pieces move undetected and cause harm [36]. With this growing problem of space debris, a larger systemic effort was begun in 1995 by NASA, which issued the first comprehensive set of guidelines for orbital debris mitigation in the world. This became the basis for the U.S. government's issuance of its Orbital Debris Mitigation Standard Practices 2 years later[40]. Other countries and organizations soon followed with their own guidelines; the efforts culminated in the establishment of the Inter-

Agency Space Debris Coordination Committee (IADC) in 2002, with space agencies from more than 10 countries as members. Since February, 2007 the United Nations has also joined the effort through the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS).

Together, these member countries and guidelines are now working to prevent the creation of new debris, to design satellites to withstand small debris collision, and to implement operational procedures, such as inspecting a spacecraft before re-entry to increase the chance of safety in case of collision (e.g. rescue of crew by another spacecraft)[36], [40]. More recently proposed solutions to the space debris issue include developing specialized bulldozer-like spacecrafts that could catch and forcibly deorbit the pieces of debris[37].

#### *b) Sustaining Life during Space Exploration*

Meeting basic human needs, such as food, water, air and adequate shelter, is a challenge in space. First, space travelers must transport their own nourishment and materials with them, as there are no other known environments in outer space that can sustain human life[41], [42]. In terms of food, a typical astronaut on the ISS uses a food ration of about 0.83 kg per meal each day, with 0.12 kg of the weight being packaging material. For a 3-year round trip to Mars, thousands of kilograms of food would then be needed: a crew of four will need to carry 10,886 kg of food with them to space[42]. In the early years, even the food that astronauts could carry were unappetizing and hard to eat, as largely same methods of food preparation and preservation were still used as the early sailing explorers. To be able to store food onboard space shuttles and ISS, astronauts were provided with freeze-dried powders, bite-size cubes, and semi-liquids in tubes[42]. These problems have been addressed by increasing the knowledge of the space environment and developing better ways to prepare and package foods. Today, the types of available foods have become more varied through using techniques such as dehydration,

temperature-stabilization, or irradiation, and can be made ready to eat by just adding water or heat [42].

Second, the amount of water that can be transported into space is limited due to its weight[43]. Therefore, space shuttles are usually designed to produce their own water through using fuel cells that combine hydrogen and oxygen atoms. When these atoms are combined, they produce electricity as well as water; the water produced by this process is then recycled and used by the crew[44]. Onboard crafts that produce electricity from solar panels (e.g. ISS), small amounts of water are recycled from cabin air. Hence, while an average American uses about 132 liters of water per day, the astronauts onboard the ISS must limit their water use to about 11 liters per day[43]. The problem of air, however, is not resolved by the presence of oxygen for the fuel cell, as the human body is tuned to the Earth's atmosphere, with its particular composition of different gases[41]. Among the 14.7 psi of atmospheric pressure, 21 percent or 3psi of it is oxygen – more than that would be toxic to the body. Nitrogen needs to make up about 78 percent or 11.5psi of air in order to dilute the oxygen content, and carbon dioxide must be continually removed from the body to prevent asphyxiation. The correct composition of such breathable air must be artificially maintained for all crafts, suits, and habitats in space to sustain human life[45].

Thirdly, the problem of shelter can be a major hazard for space travel. Proper shelter is crucial in many aspects, including air pressure, temperature, and protection from collision. Even a tiny hole or crack can cause air pressure to decrease sharply, while leaking the mixture of air that is critical to survival[41]. On the return of Soyuz 11 in 1971, three cosmonauts died from asphyxiation due to a small hole in the spacecraft's air valve that was only 1/16 in diameter. When the drop in air pressure does not go to a lethally low level, the dysbarism occurs as the nitrogen in the blood bubbles throughout the circulatory system. Pain, fainting, difficulty



breathing would result, and eventually lead one to death[41]. Temperature control is also critical, as overheating would cause heat-related illnesses and death (e.g. heat stroke) and lack of heat would cause hypothermia and death, if no interventions are made[41].

One of the great ways to be protected from these extreme space conditions is to use well-designed space suits. The space suit provides breathable air, suitable temperature, moisture, pressure, odor and waste gas removal, as well as shelter from radiation and debris[41]. However, the conventional soft space suits have had their limitations. Because having the normal atmospheric pressure (i.e. 14.7 psi) inside the space suit caused it to balloon out and disable the individual from executing flexible movements, the astronauts needed to go through an adjustment process for several hours to become acclimated to just 3psi of oxygen in the space suit. This was accomplished by having the individual breathe pure oxygen and have the nitrogen leave their blood through their lungs. While this process has been effective, its time requirement posed a major limitation in case of emergencies. The new space suits in development improves on these limitations by providing the regular atmospheric air pressure in rigid exoskeletons with flexible joints[41].

### *c) Exoskeletons*

With the recently developed assistive machines and robots, human beings can be less prone to weakness in extreme environments and conditions, such as the space environment and age-related conditions. In the early years of space travel, passengers needed to go through harsh and rigorous training alongside professional astronauts, in order to get acclimated to the extreme environmental changes in space. However, by combining human strength with that of robots, greater strength, speed, endurance, and adaptation can be achieved. In other words, exoskeletons will allow for human intelligence and creativity to stay in command, making use of their copious

past experiences for dealing with various complex situations and emergencies[46]. At the same time, the constant micro environment provided by the exoskeleton can protect human capacities from extreme pressures, temperatures, radiation, or collision in space. This means that lay people would be able to travel into space without as much training by simply wearing the exoskeleton. It will also enable space travel for those who are in less than optimal health conditions, for example due to their age. Indeed, the strength and speed offered by robotic exoskeletons will enable space travelers to avoid asteroids, space debris, and other obstacles easily, thereby ameliorating some of the anxieties about accidents that could happen in space. With the growing market for space tourism, custom designed and versatile exoskeletons will be able to effectively meet the customer's taste, health conditions, and preferences, the suit should also be and customizable.

## 2. Cost

### a) *Cost of Conventional Rockets*

Space travel has been generally perceived to be an expensive venture, and it has been certainly true. The cost of building and launching a rocket through a space program remains exorbitantly high, sometimes costing space program \$2.1 billion[47], in this case for NASA'S *Ares I* program. With such a high cost to developing and constructing a spacecraft, the costs inevitably trickle down to the price of a tourism passenger ticket. As mentioned briefly in previous sections, the first space tourist passenger Tito paid \$20 million to get onboard the *Soyuz* rocket (see Section B1). In the current state of technology, every launch of a space shuttle costs between \$500 and \$700 million; the cost of launching a pound of mass into a low-earth orbit is about \$10,000[48]. The space station costs more than \$100 billion [48], which may increase as agencies attempt to make more habitable space stations for a larger commercial audience. The chart below describes the costs involved in different types of space and near-space flights.

Higher orbital flights evidently require much longer periods of training and are about 250-500 times more costly than suborbital flights.

*Table 1. Space-related tourism experiences (Lubin, 2012)*

Space experience options	Parabolic flight	High altitude balloon flight (Proposed)	High altitude jet flight	Suborbital flight (Proposed)	Orbital flight
<b>Brief description</b>	Flying on a passenger jet in a series of parabolic arcs to create brief periods of weightlessness	A balloon ride in a commercially built "gondola" to the upper reaches of the atmosphere	Flying with a pilot on a fighter jet to twice the altitude of a commercial airline flight	Flying on a commercially built suborbital spacecraft past the threshold of space	Launching into orbit for a multi-day stay aboard the International Space Station
<b>Total flight duration</b>	90 minutes	3 to 4 hours	45 minutes	2 hours	1 to 2 weeks
<b>Weightlessness</b>	30-second bursts for a total of 10 minutes	Brief periods of reduced gravity may be possible during descent	None	1 to 5 minutes	1 to 2 weeks
<b>Required Training</b>	1 hour briefing	1 hour briefing	Same-day training and medical checks	2 to 3 days of training and medical checks	3 to 6 months of training and medical checks
<b>Passenger Capacity (per flight)</b>	Up to 30 people	Up to 4 people	1 person	Up to 6 people	1 person
<b>Price per person (not including transportation to launch site)</b>	\$5,200	\$155,000	\$25,000	\$95,000 to \$200,000	\$50 million
<b>Maximum altitude</b>	34,000 feet (~6 miles)	118,000 feet (~22 miles)	70,000 feet (~13 miles)	327,000 feet (~62 miles)	1 million feet (~200 miles)
<b>View</b>	Similar to the view from a commercial airliner	Curvature of the Earth, blackness of space, and thin blue layer of the atmosphere	Curvature of the Earth, blackness of space	Curvature of the Earth, blackness of space, and thin blue layer of the atmosphere	Orbit the entire Earth every 90 minutes

*b) Cost-reducing Reusable Chemical Rockets*

Fortunately, there are many surprising ways to cut down the cost of building a rocket while still remaining in the conventional realm, meaning that conventional liquid and solid fuels are used for thrust. In fact, progress made by the private space companies has been able to cut down the cost by 75 percent, although the exact percentage depends on how it is calculated[11]. These advances in the technology have been made for virtually every component of the rocket, including the airframe, engines, electronics, and launch operation. These innovations, most of them not patented, ultimately all advance the concept making rockets reusable[7]. Although the space shuttles had been created as an attempt at this, their main tanks still had to be thrown away at each flight, and the reusable parts required 9 months for a team of 10,000 people to refurbish them – totaling to a cost of billion dollars per flight[11]. Therefore, Elon Musk and his company of Space X have been devising ways to have the rocket stages return intact to the launch site and be ready for another launch within a few hours. In their Grasshopper Test Project, engineers at Space X have been testing vertical landing for the terminal portion of the flight, by enabling the rocket to adjust its angle, the pitch and yaw of the main engine, and to maintain roll with coal gas thrusters. Recently, they were able to have a rocket that was the size of a 12-story building to hover at about 40 meters, and return to its landing position[11]. This relatively simple concept of making the rocket itself more reusable can improve the cost of spaceflight roughly 100-fold, as the cost of the fuel only makes up about .3 percent of the total cost of the rocket. Moreover, advances in building rockets with significantly lighter, but stronger material would further decrease the costs for spaceflight, as it would make its energy use as efficient as possible[11].

### III. Problems with Conventional Propulsions and Alternative Solutions

#### A. Conventional Chemical Rockets

There are currently three different types of rockets that use solid, liquid, or hybrid fuels [49]. The commonality among the three types is that they all use a propellant to thrust the rocket forward. Propellants are chemical mixtures of a type of fuel and oxygen, which burn upon contact.

##### a) *Solid propellant*

Solid propellant rockets are the most primitive form of rockets. Solid rockets were invented much before liquid propellant rockets, and this includes the ancient firework rockets that were used in wars long ago. Departing from the use of gunpowder in ancient times, modern solid fueled rockets use more powerful fuels[49].

Solid propellant motors have simple designs and are easy to handle. They are usually consisting of solid compounds which are mad of fuel and oxidizer and contained in a steel casing. They burn at a very fast speed, from the center towards the outer sides of the casing and expel hot gases to produce thrust. The shape of the center channel determines how fast the fuel burns and its patterns, which is a good way to control thrust[50].



Solid Propellant Rocket -  
Taurus  
NASA

The factors used in determining the rocket's performance that is related to the center channel are its surface area and specific impulse. The amount of propellant exposed to interior combustion flames outlines the surface area, giving a direct relationship with thrust. An increase in surface area will increase thrust, but reduces in burning time of fuel because the propellant is being used at a faster rate[50]. On the other hand, if surface area of the channel is decreased, burning time will be increased, thus decreasing the thrust. The most ideal thrust is represented by a constant rate of thrust. This can be achieved by sustaining same surface area throughout the burn. For examples, there are end burning, internal-core burning, outer-core burning, and internal star core burning used as designs of constant surface area. Various shapes are used to optimize the thrust[50].

As previously mentioned, specific impulse also determines rocket performance by controlling internal thrust production through pressure and heat. Specific impulse is defined by the thrust per unit propellant burned in each second. During the ignition of an explosive fuel hot and expanding gasses are created to produce thrust. How large of the fuel's explosive power is and how fast combustion takes place regulate the specific impulse. Specific impulse must be considered carefully to successfully optimize producing thrust[50].

There are two different types of solid propellants, namely homogeneous and composite[51]. Both are dense, and can be easily stored and operated stably at ordinary temperatures. Homogeneous propellants can consist of either simple base or double base. For a simple base propellant, a single compound is used. Nitrocellulose is frequently used, since it has both an oxidation and reduction capacity. Double base propellants have two compounds (usually nitrocellulose and nitroglycerine) and a plasticizer is added to increase the plasticity or fluidity of a material. Homogeneous propellants are relatively weak. Normally, their specific impulses are

less than about 210 seconds, but they have an advantage of not producing traceable smoke. Thus, homogenous propellants are often used as strategic weapons[50]. They are also used as secondary functions of rocket launches in tasks, like discarding spent parts or separating one stage from another[50].

Composite propellants consist of heterogeneous powders or mixtures. Fuel is generally made of aluminum and for oxidizers, crystallized or finely ground mineral salt is used. More specifically, ammonium perchlorate is commonly used as an oxidizer and usually occupies between 60% and 90% of the mass of the propellant. The propellant is held together by a polymeric binder (usually polyurethane or polybutadienes), which is also consumed as fuel. Sometimes catalyst is included to help speeding up the burning rate. Other agents can be also included to make the mixtures easier to fabricate[51]. In terms of their classification, composite propellants are classified or defined by the type of polymeric binder used. The two most common binders are polybutadiene acrylic acid acrylonitrile (PBAN) and hydroxy-terminator polybutadiene (HTPB). PBAN gives slightly higher specific impulse, density, and burning rate than equivalent amount of HTPB. On the other hand, PBAN propellant is a lot more difficult to handle since it is harder to mix and process, also requiring an elevated curing temperature. On the other hand, HTPB propellant is stronger in stronger and more flexible to use than PBAN. Both PBAN and HTPB propellants deliver excellent performance with good mechanical properties, and gives long time of burning[51].

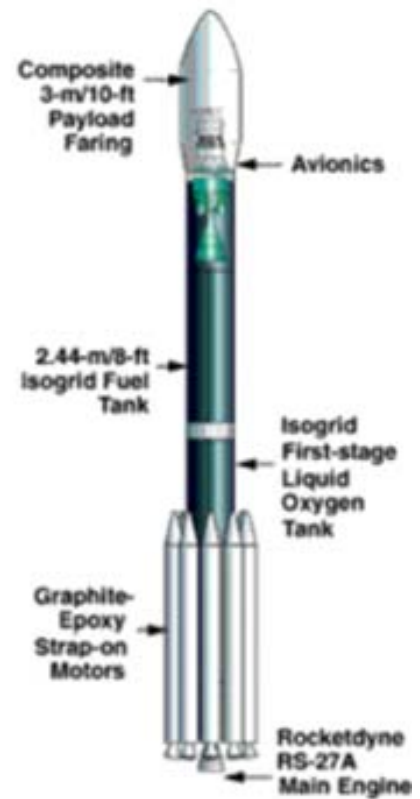
Solid propellant motors can be used in many ways. Small solid propellant motors are usually used to power the final stage of a launch rocket, or attached to cargos to be lifted to higher orbits. Medium solid propellant motors such as the Payload Assist Module (PAM) and the Inertial Upper Stage (IUS) are used as boosters needed to place satellites into geosynchronous

orbit or on planetary trajectories. The Titan, Delta, and Space Shuttle launch vehicles used solid propellant rockets to provide additional thrust during the lift-off. The Space Shuttle uses the largest solid rocket motors ever built and flown. Each booster contains 500,000 kg of propellant and can produce up to 14,680,000 Newtons of thrust force[51].

### b) *Liquid propellant*

Liquid propellant rockets are a lot more powerful than solid propellant rockets. With high thrust capacities, it enabled first human flights into space. Although liquid fueled rockets burn fuel and oxidizer like conventional solid fuels rockets, both fuel and oxidizer are in liquid states[52]. The oxidizer and fuel are mixed and ignited inside the combustion chamber, creating thrust. In liquid propellant rockets, the fuel and oxidizer must be stored separately in two separate tanks made of metal since many liquid fuels catch fire and burn upon contact[52]. Though liquid propellants are more challenging to store in this way than solid fuels, they offer distinct advantages, such as high speed exhaust gas ejection and ability to throttle including stop-and-restart capability and emergency shutdown. Due to these features, liquid propellant systems are used in many upper-stage applications where high escape velocity and high propellant mass fraction are important[52].

Liquid propellants are one of the most variable types of rockets. With a large collection of valves, regulators and controllers, they can adjust, control and enhance rocket performance. During launch sequence two valves open and allow the liquid to flow down the pipe-work. In



Delta II with liquid-propellant engines  
NASA



order to prevent a weak and unstable thrust rate, either a pressurized gas feed (supply) or a turbo pump feed (supply) is used[52]. The pressurized gas feed is simpler than the other. It adds a tank of high pressure gas such as helium that is unreactive, inert, and light to the propulsion system. The gas is held and regulated under a very high pressure by a valve or regulator. Turbo pump, although more complex, is often preferred and used more often than the pressurized gas. It provides solution to the fuel transfer problem. A turbo pump is the same as regular pump in function and avoids a gas-pressurized system by sucking out the propellants and accelerating them into the combustion chamber[51].

For oxidizer of liquid motors, liquid oxygen is used the most. Other oxidizers, such as hydrogen peroxide (containing 95% of  $H_2O_2$ ), nitric acid ( $HNO_3$ ), and liquid fluorine are also used. Among these oxidizers, liquid fluorine produces the highest specific impulse. However, it requires high temperatures to burn, and it is very difficult to handle this corrosive element that might destroy and damage other substances upon contact, liquid fluorine is rarely used. Liquid propellants are classified as petroleum, cryogenic, hypergolic. Petroleum fuels are developed from crude oil and are a mixture of complex hydrocarbon. The petroleum is a type of highly refined kerosene, which delivers a specific impulse which is significantly less than cryogenic fuels, but larger than hypergolic fuels[51].

Cryogenic propellants use liquid hydrogen as the fuel and liquid oxygen as the oxidizer. They are liquefied gases, as hydrogen remains liquid at temperature of -253 degrees Celsius and oxygen remains liquid at -183 degrees Celsius. Cryogenic propellants are difficult to store for long periods of time since they need to be stored at very low temperatures. Thus, they cannot be used in military rockets since they must be kept for months to be ready for launch at any time. Also, liquid hydrogen has a very low density of 0.071 g/ml, which requires a large storage

volume in turn. Nevertheless, liquid oxygen and liquid hydrogen are used as the propellant in the main engines of the Space Shuttle due to their high efficiency. They also powered the upper stages of the *Saturn V* and *Saturn IB* rockets, and the *Centaur* which is the first liquid oxygen and liquid hydrogen rocket in the United States[51]. Other examples of cryogenic fuel are liquid methane (liquid at -162 degrees Celsius) and liquid fluorine (liquid at -188 degrees Celsius).

Hypergolic propellants ignite spontaneously upon contact with each other and require no ignition source as they work as both fuels and oxidizers. They can start and restart very easily, which is deal for systems of spacecraft maneuvering. They remain liquid at normal temperatures, so they can be storage for a longer period time. However, hypergols are highly toxic and must be handled exceptionally carefully. Hypergolic fuels include hydrazine, monomethyl hydrazine, and unsymmetrical dimethyl hydrazine. A mixture of 50% hydrazine and 50% unsymmetrical dimethyl hydrazine fuels is also used and called Aerozine 50. It is as stable as unsymmetrical dimethyl hydrazine and gives better performance. Aerozine 50 was used as a propellant with nitric acid oxidizer for the Titan and the second stage of the Delta II rocket used propellant. Monomethyl hydrazine with nitric acid oxidizer was used in the Space Shuttle orbiter as the orbital maneuvering system and reaction control system[51].

Other propellants were also used as liquid fuels. Alcohols were used during the early years of rocketry. Ethyl alcohol (ethanol) was used as a fuel source for the German V-2 missile and the USA Redstone, but became obsolete after more efficient fuels were developed. Hydrogen peroxide was commonly used as a monopropellant and was once used as an oxidizer in Britain's Black Arrow rocket. Although its performance and density is high, similar to that of nitric acid, and it is far less toxic and corrosive but it is unstable with a poor freezing point. With catalyst, high-test peroxide (high concentrations of hydrogen peroxide) decomposes into oxygen

and superheated steam, producing a specific impulse of about 150 s. Nitrous oxide has been used as both an oxidizer and as a monopropellant. It is used for many hybrid rocket designs and in high-powered rocketry. With a catalyst, nitrous oxide decomposes exothermically into nitrogen and oxygen, producing a specific impulse of about 170 s[51].

To summarize, liquid propellant rockets are currently the most powerful in propulsion systems available in terms of gross thrust. However, its high complexity (a real modern liquid engine has thousands of piping connections and carries various cooling, fueling, or lubricating fluids) and other drawbacks made them quite impractical. Because of so many parts they contain, there is a large chance that one integral function might fail. Also, the most commonly used oxidizer, liquid oxygen, requires a temperature of -183 degrees Celsius to maintain the liquid state. Otherwise, it evaporates and loses a large quantity of oxidizer on the process of loading. Another oxidizer, nitric acid, contains 76% of oxygen and is in the liquid state under the standard temperature and pressure, but it is hazardous in handling (producing a strong acid while mixing with water) and produces harmful by-products in combustion with a fuel. Thus, its use is limited[51].

### *c) Hybrid rockets*

Hybrid propellants use both solid and liquid propellants as fuels to combine the advantages each propellant. They represent an intermediate group between solid and liquid propellant. Usually, the liquid is used as the oxidizer, while the solid is used as fuel. The main advantage of is that they have high performance and can be moderated, stopped, or even restarted. However, given the difficulty and complexity in building hybrid propellant engines, they are rarely built. An exceptional hybrid engine was used, however, for the vehicle

SpaceShipOne, burning nitrous oxide as the liquid oxidizer and HTPB rubber as the solid fuel powered. This engine won the Ansari X-Prize[51].

## **B. Hypothetical**

### **1. Ion Propulsion for Deep Space**

Despite the decades of history now in launching spacecrafts into space, modern spacecrafts still are restricted by the problem of fuel. The conventional ways of propulsion are very inefficient in that the spacecrafts needs to carry the same weight of thrust materials as its own weight. Because fuel ends up being the heaviest single component, the amount of fuel that can be carried by rockets is limited. Therefore, spacecrafts are not able to run long enough to land and explore its destinations[7], [45]. One of the best ways to solve this problem is to find a propulsion system that is efficient and lightweight. In 1998, a spacecraft called *Deep Space 1* was sent with ion-thrusters, where ionized xenon gas was used as propellant. This demonstrated that gas is easier to manage than solid fuel, as xenon's noble gas properties made it very stable, unreactive, and efficient [45]. Moreover, it was able to generate 10 times the power of the conventional rocket engines. In addition to the ionized gas system, *Deep Space 1* contained solar panel wings that could be used to provide electric power required to manage the systems of propulsion. Its solar panels had a combination of 3600 solar cells and more than 700 cylindrical lenses to focus sunlight; when fully charged, its output was more than 2000W. Although this amount is equivalent to the energy needed to operate two hair dryers, it is sufficient for powering the spacecraft's ion-thrusters[45].

## 2. *Field propulsion systems*

Field propulsion system, as its name suggests, is a propelling system with fields with the use of any fuel[53]. It can overcome the speed of the conventional space propulsion systems that are very limited and requires lots of fuels and cost. The principle behind the field propulsion is to assume that space as a vacuum contains a substantial physical structure which can be interacted and used as propulsive thrust force. The invention of this new propulsion method will enable interplanetary travel as well as interstellar travel[53].

Field propulsion theory is based on Einstein's General Relativity Theory in terms of its microscopic structure; it also has basis in Quantum Field Theory in a microscopic structure[53]. Several kinds of field propulsion can be suggested by using different physical concepts. In General Relativity, the gravitational field is explained through curved space and the curvature of space is important. Curvature is related to expansion, contraction, elongation, torsion, and bending of an elastic body. Space-time as a vacuum can be viewed as a transparent, empty continuum that is universal and infinitive, where all these events take place[53]. In Quantum Field Theory, space-time is viewed as possessing zero-point fluctuations (vacuum perturbations) which is the temporary change in the amount of energy with temporal appearance of energetic particles out of empty space. The Uncertainty Principle states that a particle pair can suddenly emerge from the vacuum for a very short period of time. Vacuum perturbations can be controlled by squeezed light technology which generates states of squeezed vacuum and can control energy density through the coordination geometry. Finally, superstring theory suggests string as the fundamental element of the space-time continuum, which is presented as the threads of fabric. Thus, entropy of space-time can be defined as an ensemble of strings, similar to polymer chains in an elastic body[53].

It may seem that field propulsion theory violates the conservation law of momentum since, the system does not expel any momentum. However, essentially, space is not a state of complete void or nothingness, but is a physical reality as a continuum which can be reacted against under a certain condition[53].

### 3. Superconductors and Quantum

#### Locking

One of the exciting developments that open new possibilities for space travel is the discovery of quantum levitation and quantum locking[54]. Using a superconductor, one can demonstrate at

critical temperatures and magnetic fields can lock the object in space, in mid-air, giving the appearance of levitation. This discovery/technology capitalizes on the distinctive characteristics/properties of superconductors. Superconductors are materials that have virtually zero electrical resistance, unlike other conductors in which electrons collide with atoms while flowing through the material[54]. Thus, whereas there is energy loss when using other conductors (usually in the form of heat), superconductors allow electricity to flow freely without

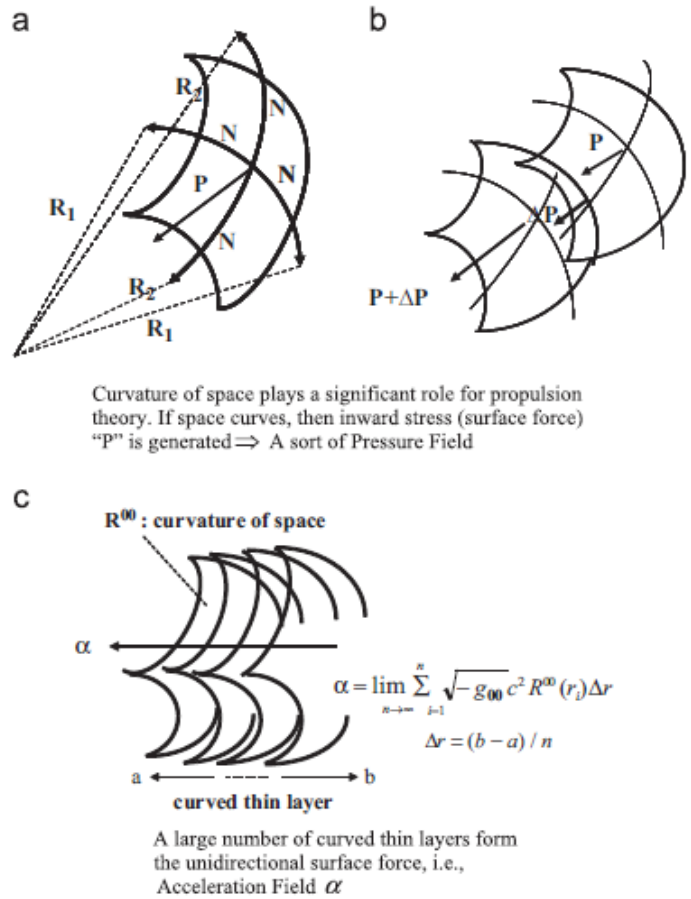


Fig. 3. Curvature of space.

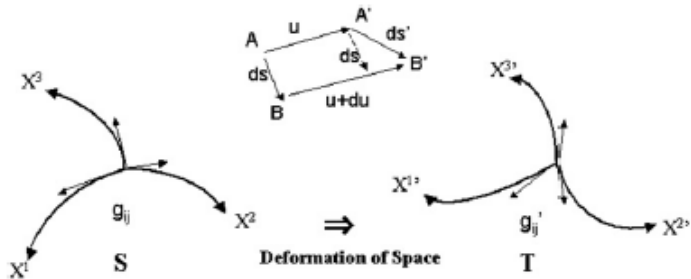


Fig. 4. Fundamental structure of space.

any barriers at the quantum level. In addition to zero electrical resistance, superconductors are known to have magnetic resistance, where they attempt to expel any magnetic strands that tries to enter their interior. When placed inside a magnetic field, the superconductor locks any interiorly trapped magnetic strands in place, as their movements would dissipate energy and breaks the state of superconductivity. By doing so, the superconductor in fact locks itself in place, because any movement of the superconductor will again change the configuration. This phenomenon has been named quantum locking, as it is fundamentally a quantum phenomenon that the fluxons (i.e. strands of magnetic field inside the superconductor) come in discrete quantities and behave like quantum particles[54].

Quantum locking can have a multitude of practical applications that would revolutionize how energy is managed in the world. In a single three-inch disk, approximately a hundred billion strands of magnetic field are inside. With such enormous amounts of currents that can be transferred inside superconductors, it would be possible to produce strong magnetic fields for MRI machines, particle accelerators, etc; they can also be produced as power cables that transfer large amount of electrical current between power stations. Moreover, large amounts of energy can be stored with superconductors, because no energy would be dissipated. What is more, the force of the levitation achieved by a disk that is only half a micron thick is 70,000 times its own weight. This remarkably strong force can be used for many applications. For example, a two-millimeter-thin superconducting layer could hold a small car of 1,000 kilograms[54].

Quantum locking opens new possibilities for space travel as well. As long as the superconductor is kept below its critical cold temperature through insulation and other modes of temperature control, it will stay locked in mid-air on top of a regular magnet. On top of a circular magnet where the magnetic field is equal all around, the superconductor is able to freely rotate

around the axis of the magnet without friction. Even when the magnet is turned upside down, the superconductor will remain locked in the same position in regard to the magnet. The direction of this frictionless travel can be controlled by simply adjusting the magnetic field, in the form of magnets/magnetic field of different shapes. For example, Almog demonstrated that on top of a large circular magnetic rail, the superconducting disk moves freely along the rail as a monorail train would, but without the friction. The position and configuration of the traveling superconducting disk can easily be changed by rotation, and it will continue to move freely in its new position[54].

#### *4. Using Earth's Magnetism as Energy Resource*

Throughout history no one has used the Earth's magnetism as the source for propulsion. Although the Earth's magnetism is quite weak, it is what keeps us from being harmed by cosmic rays, solar winds, causing auroras from cosmic collisions. And what if the Earth's magnetic field could be augmented? Like the sun, magnetism from the Earth's and other planets' magnetic fields are forces that are ever present throughout the universe; however, they have been entirely uninvestigated. If technology can be developed to take advantage of this energy, it will mean that no energy will need to be spent on mining, collecting, and refining this energy to a usable form. It also will save us from the trouble when we happen to run out of fuel during intergalactic/space travel. Imagine having to refuel on liquid hydrogen or whatever fuel out on Mars, and how costly that would be. As the goal of space travel is to be self-sustaining, and travel farther and farther, it would be wise to build a sophisticated spaceship that can utilize multiple energy sources. Like a hybrid car, it would be able to switch between them under appropriate conditions. Though the Earth magnetism may be too weak to provide thrust for escape velocity, perhaps new discoveries on superconductors [54] can magnify the given magnetism and levitate spacecrafts into space.

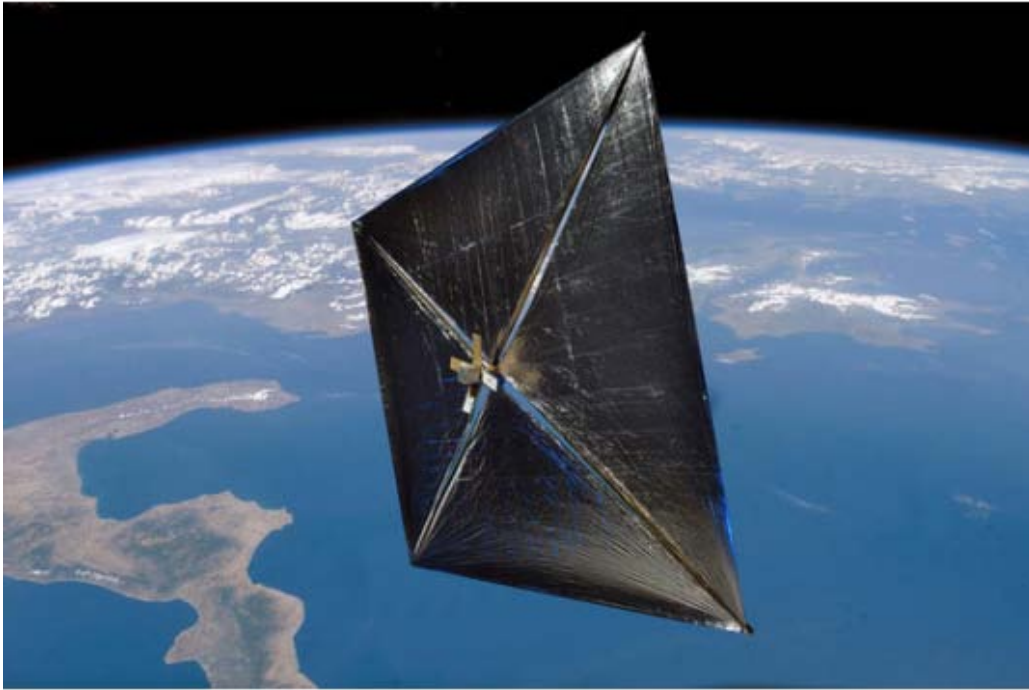


Once in space, not a lot of energy will be needed to keep going; the small amounts of magnetism should be sufficient to keep going.

## 5. *Plasma*

Another new technology that has reached the test stage of development is the magneto-plasma propulsion, named VASIMR (Variable Specific Impulse Magneto Plasma Rocket). In VASIMAR, natural gas is converted into plasma, or very hot partially ionized gas, by high power radio-waves within a chamber[17]. These fast moving plasma particles are guided by strong magnetic fields from the engine's magnet to have them shoot out and create thrust. The magnetic fields will also keep other rocket materials from melting in extreme heat. The hotter the plasma gets, the faster will the gas particles move and provide that much more thrust for the VASIMR to travel, reaching speeds that are a hundred times more than chemical rockets. This is the model that is being developed by the Ad Astra Rocket Company, and it is thought that this technology could take astronauts to Mars in approximately 39 days. The first launch is being planned to take place at ISS, after VASMIR is taken into orbit by a traditional chemical rocket. Then, aboard at the ISS, VASMIR will be switched into plasma drive, just as a car would go into third and fourth gear after the first two[17].

## 6. *Solar sail*



For interplanetary travel that requires even farther distances, the solar sail has been proposed as a promising technology to achieve it. Solar sail stands as one of the most realistic options for interplanetary and even intergalactic travel, as it eliminates both rocket fuel and rocket engines that have been limiting space travel until now[55]. In the solar sail-powered spacecraft, both the rocket fuel and engine are replaced with sails that are powered by the sun's constant pressure of photons. The sails are made of reflective material that has the sunlight's photons bounce off of it; as these light particles bounce off the mirror-like sail, they transfer their momentum to the sail to nudge it along[56]. As for the force of this nudge, it is true that the force on a solar-sail spacecraft is far less than a conventional chemical rocket like the space shuttle. In the distance that the Earth has from the sun (150 million km, or 1 AU), NASA researchers found that sunlight can produce about 1.4 kw of power[56], [57]. Dividing that number by the speed of light, 300 million m/sec, we find that force exerted by the sun is about  $4.67 \times [10]^{(-6)}$  N.

Although this small amount of force does not initially appear like much, especially in relation to the force produced by the space shuttle's engine (1.67 million N during liftoff, 2.1 million N in vacuum), it is important to remember that many photons are being constantly emitted from the sun[55]. Therefore, this continuous force from sunlight will give constant acceleration to the space craft. In the space's almost completely frictionless vacuum, such gentle constant acceleration can eventually thrust a spacecraft to velocities that are 5 to 10 times faster (~90 km/sec) than traditional rockets (8km/sec)[58]. With this eventual top speed, the solar sail vehicle would be able to reach Los Angeles from New York in less than a minute. In another illustration, it would only take only eight years for a presently launched solar sail vehicle to catch up with the most distant Voyager 1 spacecraft that has been traveling for more than 20 years[57], [58]. In addition, the solar sail spacecraft will most likely have laser or magnetic beam propulsion mechanism also onboard, for when it travels even more distant from sunlight. By adding such a transmitter, NASA believes that the speed could go up to 30,000 km/sec, one-tenth the speed of light[56].

On Dec. 6, 2010, NASA finally ejected its NanoSail-D nanosatellite into low earth orbit for it to demonstrate the solar sail system[55]. The successful deployment has been long time in coming since Kepler's original inception of the idea. NASA had designed and operated a solar sail program in the 1970s, but the technology to produce the ultrathin, heat-resistant, highly reflective material was not yet complete[55], [58]. With sails that were too heavy, the design and launch of a solar sailing vehicle was impractical. However, the sails available today are almost 100 times thinner than an average sheet of paper, and NASA's version of the giant sails are called CP-1. Planetary Society, a private, non-profit group in Pasadena, CA, uses the aluminum-reinforced stretched polyester film Mylar (also known as BoPET or biaxially-oriented

polyethylene terephthalate) for its spacecraft Cosmos 1[59]. These sails are about one-fourth the thickness of a plastic trash bag. Alternatively, the Marshall Space Flight Center supports a rigid, lightweight carbon fiber material that is 200 times thicker than today's standard solar sail, but weighs about the same as the thinnest materials being tested due to its thousands of tiny holes[17], [56].

Another challenge for the earlier success of the solar sail spacecraft has been its inability to be launched directly from the ground. Although NASA'S Jet Propulsion Laboratory (JPL) did demonstrate in an experiment that that the solar sails could be powered to liftoff using microwave and laser beams, a second spacecraft is still needed for the launch of the solar sail[58]. Once launched, the sails are ejected from the carrier spacecraft using an inflatable boom system, triggered by a built-in deployment mechanism. This launch mechanism has experienced several failures, however. In 2005, the 100 kg-Cosmos 1 was launched from the Volna rocket from a Russian submarine in the Barents Sea. Rather than its planned orbit at the height of 885km above Earth, the rocket only reached 72.4km into space before falling back into the ocean and never being found again[17]. In 2008, NanoSail-D was launched on Space X's third attempt for Falcon 1. However, this launch also ended in failure after two minutes of take-off, with the solar sail lost in the ocean. First success was seen in June, 2010, when Japan's Ikaros probe ejected its solar sail spacecraft to sail through space propelled only by sunlight. In 2011, NASA's another attempt at launching the NanoSail-D succeeded, but not without some drama[55]. Three days after its ejection from satellite mothership FASTSAT, NanoSail-D satellite was supposed to deploy and start unfolding its 100-square-foot sail with four booms; however, no evidence could identify it in low-Earth orbit. After more than a month later, NanoSail-D popped free on its own and started flying free above Earth. Currently NanoSail-D, which is about the size of a loaf of

bread, is being tracked by amateur radio operators called “hams” by listening for the little satellite's signal at 437.270 MHz. It is expected that NanoSail-D will stay in low-Earth orbit for 70 - 120 days, depending on atmospheric conditions[55].

## 7. *Space Elevator*



*Figure 2. Simulated prototype of space elevator (from Dvorsky, 2013)*

The space elevator is an alternative way to reach space that has been proposed by a handful of futurists, imaging a mechanism that could make a scenario like Jack and the Beanstalk possible[7], [17]. Proponents of this proposal hold that the space elevator would be an inexpensive and reliable method of accessing space as the permanent installment of the elevator could pay itself off. These proponents have suggested that the elevator could lower the cost of space travel from \$20,000/kg (cost of using conventional rocket propulsion to thrust a satellite into space) to as low as \$200/kg[7].

Although at first glance, the image of a long cable ascending from Earth into space seems like something that would appear in a science fiction story or fairytale, the principles behind the idea are real and feasible. The system will begin at an anchor station, where a strong ribbon of carbon nanotube cables will be held from a mobile platform in the equatorial Pacific. (Such location for the anchor station will be crucial in avoiding disturbances by extreme climate conditions, as well as keeping clear of air traffic.) The cable will extend well above the Earth's geostationary orbit – 100,000km from the Earth, according to one design – ending at a platform counterweight. A lifter, most likely powered by electrical motors (receiving electricity from photovoltaic cells, galvanized by free-electron lasers), will ascend and descend along the cable, carrying different payloads as well as humans[7], [17].

The most important forces in play here are the Earth's gravity and the counterweight platform's centrifugal that would be acting in opposite directions. This concept is well-illustrated by imagining a person rotating, in order to swing around a long piece of string with a weight attached at the end of it. This rotating motion of the weight will cause the centrifugal force to be directed radially outward from the center, which will keep the string taut. Along this taut string, an ant could climb steadily to eventually reach the weight attached at the end. Although this analogy falters here because the person, unlike the Earth (the rotating center), does not have innate gravity that would pull the ant back toward himself, this picture is useful in understanding how the centrifugal force works. In the same way, the centrifugal force on the space elevator's counterweight platform will keep the elevator system upright and intact. The mass of the platform will also ensure that the center of mass of the system stays sufficiently above the earth[7], [60].

In revisiting the counterweight, its necessity is indubitable, given that it will work against the Earth's gravitational force to keep the cable taut. The cable would provide the lifter with something to climb along the cable. In the design of the space elevator, this lifter would be the robotic platform with traction-tread rollers that would clamp on to the ribbon and pull the ribbon through. The lifter will be powered by a free-electron laser system located on or near the anchor station. The laser will beam 2.4 megawatts of energy to photovoltaic cells, perhaps made of Gallium Arsenide (GaAs) attached to the lifter, which will then convert that energy to electricity to be used by conventional, niobium-magnet DC electric motors, according to the ISR[7], [17], [60].

However, in order for this to happen, there is a big limiting factor in the cable itself. Although all of the other pieces of the space elevator can be constructed using known technology, including the robotic lifter, anchor station and power-beaming system, the cable needs to be strong enough to withstand the expected forces. It is estimated that the cable will need to have a tensile strength that is above a 100 GPa, and recently carbon nanotubes have been touted as the answer to realizing the space elevator dream, with its theoretically possible strength of 100 GPa[7], [17]. Carbon nanotubes are microscopic structures that have cylindrical walls. They are only 30% denser than water, but 32 times stronger than steel, and have a theoretical breaking length of more than 10,000 km. Some optimistic scientists state that in theory, the tensile strength of a well-produced carbon nanotube could reach up to 300 GPa. However, not everyone is optimistic about its attainability, as the current state of our technology only affords the means to produce carbon nanotubes with the tensile strength of 63 GPa and the length of 1 meter[61].

Nevertheless, when and if the necessary 100 GPa is reached by the advancement of technology, the process of constructing the space elevator has been estimated to take up to 2

years from that time[7]. The process will involve first launching a rocket to geosynchronous orbit at about 35,900km from the Earth's surface. Thus remaining in hovering position, the satellite would then lower a cable back to the Earth, and be fixed to its anchor station. From then on, climbers would be sent up to the satellite to create a stronger ribbon by adding strands of new carbon nanotube cable to the existing one. The satellite would also climb higher at this point, reaching up to 100,000km above the Earth surface, and become the counterweight platform at the end to hold up the system upright. Once operational, the lifters could be climbing the space elevator nearly every day. The lifters will vary in size from 5 to 20 tons. The 20-ton lifter will be able to carry as much as 13 tons of payload and have 900 cubic meters of space. Lifters would carry cargo ranging from satellites to solar-powered panels and eventually humans up the ribbon at a speed of about 118 miles per hour (190 km/hour). For any of such cargo, it is also estimated that if released from the elevator at 100,000km, they could have enough tangential velocity to reach even Saturn, as they will be whirling around the Earth at more than 11km/sec by that point. Thus, the elevator would provide an alternative method of propulsion for space travel[7], [60].

However, many critiques exist for the feasibility of the space elevator, enough to render the idea impractical and dangerous. These critiques have to do with the dangerous vibrations caused by the natural resonant frequency of the cable; the wobble and whipping action caused by gravitational pulls of the sun and the moons well as solar wind; possible impact with asteroids and space junk; possible terrorist attacks and impracticality of constant preventative surveillance system[61]. First, it has been warned that the gravitational pull from the moon and sun, along with pressure from solar wind may shake the cable dangerously. In violent motions, the cable could potentially whip into orbiting satellites and space junk, and become unstable due to its lack of resistance against folding or bending[61]. This possible movement is no light matter. Even the



smallest movement could cause a wobble or a swing in the cable, that the velocity of any spacecraft or object exiting the elevator would be either boosted or reduced. This could put the objects seriously off from the intended course, by as much as ten or more kilometers[61]. Even if thrusters are attached to the cable to counteract any movement, the simple logistics of attaching, maintaining, and refueling them, as well as bypassing them during the elevator climb will pose serious complications. Secondly, the problem of vibrational harmonics caused by the cable's natural resonant frequency, as well as vibrational energy caused by the lifter and climbers may overwhelm the system's tolerance. The addition of a dampening system to the cable, however, poses similar complications as adding thrusters for addressing the issue of violent shaking[61].

Thirdly, it is important to remember that there are other objects in orbit that could collide with the cable. As mentioned in a previous section, among the most problematic objects in orbit are space junk, comprised of pieces such as non-functional space crafts, abandoned launch vehicle stages, mission-related debris, and fragmentation debris[35], [39]. Given the Earth's rotational speed 465.1m/sec, the velocity of the debris in orbit at 2,000km above the Earth can be estimated to be about 609.3m/sec[61]. The damage done by collision with even the smallest debris could be devastating, as it has already destroyed many spacecraft components at even lower orbits[37]–[39]. However, the challenge in finding all of the debris in orbit and cleaning them up remains a formidable one. At the present time, NASA is operating an Orbital Debris Program since 1995, conducting research in modeling, measurements, protection, mitigation, and reentry aspects[40]. However, the best known and practiced method to address the space debris issue still remains debris tracking and avoidance maneuvers[37] – and adding built-in detection and maneuver systems for debris avoidance would be as tricky as it would be for resolving the

issue of movement with thrusters, as mentioned previously. Other concerns raised by critics and scientists are multiple, and they include corrosion and ionization due to radiation[61].

## **IV. Other Considerations**

### **A. Contribution to Society**

The secondary use of space technology in everyday life has enhanced the quality of life for people around the world. It would not be an overstatement to say that the applications of space technology have improved the medical system in the U.S. as well as its economy. In fact, it is estimated that more than 30,000 re-applied technologies from space exploration are now used in homes, schools, offices, markets, outdoors, fields, hospitals, etc [62]. For example, exercise machines in gyms and sports centers were originally designed for the astronauts in space to prevent long-term weakening of their muscles and bones. Ergometers were built for astronauts to measure their muscles work output; they now aid in stimulating the muscles of the paralyzed.[62] In the medical field, artificial pacemakers designed to control the patients' heartbeat from irregularities caused by cardiac conditions are applications of the machinery that controlled the engine pump of a rocket. Many other portable medical devices in ambulances were also originally made to meet the needs of transportability of equipment in space[63]. Moreover, remote monitoring devices for intensive care patients were derived from the telemetry systems that first monitored astronauts and spacecraft. The technologies that led to the computer bar codes in retail stores, quartz timing crystals and household smoke detectors were originally developed for NASA[63].

### **B. Contribution to Science and Technology**

In addition to the benefits that technological innovations in rocket science brought to the world, research done in outer space has also contributed much to society. A big area of research done in space has to do with microgravity. The microgravity environment afforded by satellites,

ISS, and other spacecrafts has enabled lab experiments that could never be done on earth.

Although the state of vacuum has always been thought as a threat from the ancient times, it is no longer a threat, as many innovations have resulted from past and present microgravity research[64]. To name a few, these innovations include “light bulbs, integrated circuits, freeze-dried foods, particle accelerators, electron microscopes, weather forecasting, human flight (p.1)”[64]. These varied innovations were able to come out of microgravity research, because the experiments done in ISS are not limited to rocket science or astrophysics. Rather, they include experiments in “fundamental physics, biology, firefighting, medicine, climate, etc. (p.1)” [64]

In space, even the most familiar things that we take for granted on earth behave differently. For instance, flames on earth have a shape of a teardrop, due to the rising hot air within a gravitational field. In space, flames instead break apart into little balls that move around freely, burning while using almost no fuel. Therefore, research projects such as SOFBALL-2, have attempted to light up some flame balls, measure their properties, and hopefully replicate the fuel saving effect on energy saving cars on earth[64]. In the state of weightlessness, human brains and bodies also behave differently in their efforts to adjust to the foreign environment. It has been found that the brain adapts to weightlessness, and therefore directionlessness, by building a mental model that could guide the body in making sense of the unusual experiences. Soon after such adjustment, sleeping “upside down” becomes normal; studying this process of adaptation is thought to reveal new insights into the capacities of the human brain [64]. Lastly, even the difference in smell of flowers have been noted and applied into an actual fragrance by the Japanese cosmetics company Shiseido, naming this unique floral scent “Zen”[64]. Although it is hard to expect what other aspects of normal life and behavior would be different in space, these fascinating discoveries will challenge many assumptions and boundaries of science.

## Gaining Energy from Outer Space

Although solar power has huge potential to be used for energy source and many scientists have dreamed of collecting the solar energy and use it in everyday life, its limitations has prevented it from being used. While people need electricity whole day around the year, there is no sunlight at nights to collect solar energy and no region close to centers of population has cloud-free 365 days a year. The best locations to gather solar energy are the deserts of Southwest America, far from civilizations. Thus, it is necessary to find some ways to store the energy to use in times and places where no sunlight is provided, yet not one found the way to do this in a large scale. Back in 1960s and 1970s, some innovative thinkers have thought ways to provide solar power from space and sending it back to earth, but this concept seemed impractical and somewhat like a science fiction at that time. However, recently, the idea of providing solar power from a base in space to the earth gained some possibilities and more supports. A group of engineers in 2008 led a successful experiment by using technology that can be deployed in space-based solar power. They succeed in taking energy from solar cells and beaming it to the Big Island of Hawaii, 92 miles from Maui after converting it to microwaves and gained 20 watts worth of electricity[57]. In reality, California's biggest energy utility, Pacific Gas & Electric (PG&E) signed an agreement with a startup company, Solaren Corporation, to purchase 200 megawatts of electricity gathered from the solar power beamed to Earth from outer space, beginning in 2016 for 15 years. Solaren Corporation is planning to produce the power through solar panels in Earth orbit and convert it to radio-frequency transmissions that will be beamed down to a receiving station in Fresno. The energy will then be converted into electricity and stored into a power grind of PG&E[65]. This project is based on communications satellite technology and will become the first real-world application of space solar power if succeeded.

Nevertheless, there are still many obstacles. A series of large satellites are needed to launch into space, as well as robotic technology to assemble the solar arrays and microwave technology to transmit the energy 22,000 miles to earth from space, then finally, converting that energy to electricity on the ground. Due to the advancements in technology, these became feasible nowadays, despite the fact that many have doubted only a decade ago[65].

John Mankins, the manager for advanced concepts for NASA, talked about one of the ideas from NASA about what to do with the space shuttles was to launch space habitats, which is to get as many people to live and work in space. These people in space can work on building satellites that are solar-powered. Mankins' team also assembled to find out in mid 1990s whether advances in technology would make space-based solar power more feasible. And it was so as we can see with our advanced robotic technology, far more efficient solar cells cheaper, more precise digital devices that can beam energy accurately back to earth, more reliable launch technology, and lighter and stronger materials available, it is possible to build a better solar station as well as solar arrays in outer space. One way PG&E is planning to increase efficiency of solar cells is to use parabolic reflectors that will concentrate sunlight onto the cells. However, as Cal Boerman, the director of energy services at Solaren, said, the biggest expense will be the cost of getting into space[57]. This can be solved using the alternative propulsion methods mentioned in previous chapter. Thus, by developing the space program, along with modes of transportation into space, will help gain environmental energy and produce many other possibilities in saving energy[57].

## **V. Experimental Study on Generalizing Space Travel**

### **A. Methods**

In order to increase the perception of feasibility of space travel for the general public, two educational talks were delivered to 2 different groups of audience over the course of two days. These talks comprised of the same content, and included the administration of a pre and post survey. One group of participants was chosen randomly at a Language School, in Brighton, MA. The group was consisted of mostly ESL (English as Second Language) students, several ESL teachers and program coordinator. Their background varied widely as well as their age. The other group was the members of a Christian community in Newton, MA. The participants were of a homogeneous racial group from South Korea, except for four younger participants who were considered Korean-American. Although their ages varied from elementary school children to adults, participants all readily understood the content of the presentation and indicated that they subscribed to the same culture. The two paper-and-pencil surveys were administered on site to the participants, providing both written answers and responses to multiple choice questions. Several comments were also provided to improve the talk for the future reference.

### **B. Measures**

Participants with different backgrounds completed the pre and post surveys to indicate their view on space travel, as well as any changes to their views after listening to the informative talk. During the pre-surveys, participants were asked to rate their interest in space travel for 6 items on a scale of 1 to 5, with 1 being “Not at all, “ and 5 being “Very much.” In addition, 14 true-and-false questions were asked to assess their background knowledge of space travel as well as their attitudes toward it. During the post-survey, participants provided demographic information (i.e. race and nationality, culture, primary language, gender, age, level of education,

field of study or occupation, yearly income, and number of household) as well as the answers to the same 14 true-and-false questions for comparison (see Appendix C and D). On the post-survey, participants also indicated general comments and suggestions for improvement for the speaker. These questions included how much percentage of the talk was comprehensible based on participant's English level, how the talk did help them to consider traveling space, whether the talk increased their excitement, found the space travel as a real possibility in the future, saw the benefits of exploring space to the society. Participants could choose not to answer if they are not sure about the answer, or did not feel comfortable answering them.



## VI. Results and Discussion

*Demographics.* At Language School (LS), 27 participants attended the informative talk. Among those participants, the pre-survey was completed by 25 participants, and post-survey by 22 participants. At Christian Community (CC), 16 attended the talk, but 12 completed both pre and post surveys. Data from the survey showed that the participants were from 5 different racial groups: White/Caucasian (18.9%), Latino/Latina (21.6%), East Asian (48.6%), Southeast Asian (2.7%), and Middle Eastern Asian (8.1%). Their origins were from 14 different nations, including Korea, China, Japan, Thailand, Saudi Arabia, Mexico, Brazil, Ukraine, USA, Tunisia, Colombia, Portugal, Poland, and Croatia. The average age of the participants was 26.9 years old, with a range of 10 to 49. The participants' primary languages were English, Spanish, Portuguese, Polish, Russian, Croatian, Korean, Chinese, Japanese, Arabic, and Thai.

*Interest in Space Travel.* On average, participants indicated that they had average or above average interest in outer space/universe, sci-fi movies/fantasies, going adventures, taking risks, trying new things, and leaving familiar places to go out. The means of all these 6 categories were between 3 to 4.

	first question	second question	third question	fourth question	fifth question	sixth question
mean	3.421	3.37	3.632	3.474	3.47	2.87
standard deviation	1.287	1.28	1.261	1.33	1.37	1.26

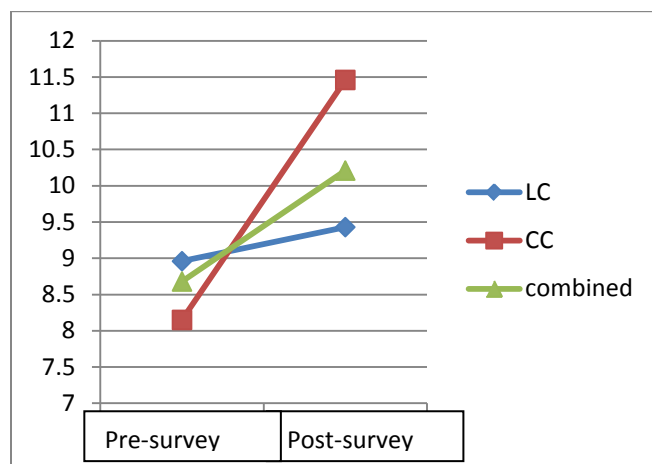
*Background Knowledge of Space Travel.* The number of correct answers that participants provided for the pre-survey questions was on average 8.68 out of 14 questions asked. The number increased to 10.2 questions out of 14 questions asked in the post-survey. Although a statistical test of mean differences could not be performed due to the small population,

descriptive results suggest that the participants' knowledge about space exploration did change in the expected direction through the talk. For each true-and-false knowledge question of the post-survey, more than 50% of the participants gave the right answers; this also was an improvement from the pre-survey, where only 8 questions out of 14 gained correct answers from more than 50% of the group. Also, majority of people (more than 50%) answered positively, indicating that the talk did help them to give consideration about space travel (64.7%), to increase their excitement about space travel (73.5%), to feel space travel as a real possibility for the future (55.9%), and to see the space exploration beneficial for the society (58.8%). Few participants gave negative answers to the abovementioned evaluative questions: 4 out of 34 participants responded "no" for the first 3 questions (11.7%), and 3 out of 34 participants gave a negative response to the last question (8.82%). Some participants chose to answer with "I am not sure," even when given yes or no answer choices; 23.55%, 14.7%, 32.4%, 32.4% of the participants, respectively, answered that they were not sure.

	<b>first question</b>	<b>second question</b>	<b>third question</b>	<b>fourth question</b>
total positive	22	25	19	20
%	64.7058824	73.5294118	55.8823529	58.8235294
total negative	4	4	4	3
%	11.7647059	11.7647059	11.7647059	8.8235294
not sure	8	5	11	11
%	23.5294118	14.7058824	32.3529412	32.3529412

Comparing between the two groups, the first group from LS answered more correct answers ( $m = 8.96$  correct out of 14) than the other group from CC ( $m = 8.15$  out of 14) for the pre-survey questions. However, for the post-survey, CC group showed greater gain scores than the LS group. CC group participants obtained 11.46 correct answers on average out of 14

questions, whereas the LS group obtained 9.43 out of 14, on average. Such differential gain scores may be explained by cultural factors, environmental factors (CC had a better audio/visual system to support the delivery of talk), or the number of participants in each group (n= 26 vs. n=16). It is possible that in the smaller CC group, the interaction between the speaker and audience was more intimate and engaging. Moreover, the Korean culture of learning may have helped the CC group to focus during the presentation and learn more. Indeed, younger children CC participants asked more fundamental questions during the talk, such as how and why; older participants tended to ask more technical questions. The participation of young elementary school children in the second group may have helped the rest of members of the group to hear more fundamental answers from the basic questions asked, which might have affected the result. More detailed results of the survey are shown in Appendix E and F.



<b>number of right answers</b>	<b>LC</b>	<b>CC</b>	<b>combined</b>
pre-survey	8.96 (SD=1.695)	8.15 (SD=2.85)	8.68 (SD=2.16)
post survey	9.43 (SD=2.08)	11.46 (SD=1.76)	10.21 (SD=2.19)

Given the limited, exploratory nature of the study, it was challenging to find any statistically significant correlations between the participant’s background, interests, and knowledge on space travel. In future renditions of the study, it would be more effective to speak louder, as the survey comments suggested. Furthermore, more sophisticated techniques in engaging the adult audience may be helpful. On the whole, however, the results demonstrate

some evidence that an informative presentation on the history, problems, and solutions of space travel helped the public's perceptions to change. Specifically, the talk helped the public to feel that space travel will become more accessible and that they would be willing to travel into space.

## VII. Conclusion

Space travel has had a relatively short history, beginning from the 1960s. Despite its recency, the field has seen rapid development over the last several decades. Once the domain of governments, space travel is now also in the private sector. In 2001, the first commercial human space flight took place: Dennis Tito travelled to the International Space Station in exchange for providing funds to NASA. Since then, several other wealthy businessmen purchased their rides into space. Currently, it is estimated that more than 625 lay people have signed up for sub-orbital space flights with Virgin Galactic, one of 6 privately-owned companies that could launch humans into space[1]. Exciting developments in space tourism does not end there. The destinations in space accessible to the public are also expanding to the moon, Mars, and asteroid belts and moons of Jupiter. However, there still are significant barriers in making space travel a reality for the general public, namely the concerns over cost, safety, and convenience. This paper examined and analyzed these problems in depth and posits the problem of propulsion as the central issue to target. Building upon these analyses, several alternatives were discussed.

Additionally, a brief exploratory intervention study was conducted to investigate whether an informative presentation on the current developments of human space travel would increase the public's perceived accessibility of space travel. Results indicated that when issues of cost, safety, and convenience are targeted and resolved through offering alternative solutions in recent developments, participants indeed considered space travel to be more of a personally feasible aspiration. Through the brief study, it also became evident that the topic of space travel is inherently very interesting to everyone, as all participants indicated at least an average degree of interest in space travel. As the exciting decades of the space race had also demonstrated, the new frontiers of space indeed sparks the human imagination, inspires us, and gives us a larger goal to

aspire to. It is through this aspiration that we came to develop many technological innovations that we now have come to enjoy in everyday life; it is through this aspiration that we will surpass even higher boundaries and become a space-faring civilization. However, in order to make this aspiration into reality, bringing such topics closer to the general public may be an important aspect of the process. Once made aware of the benefits and excitement of space travel, all will see that it is a worth to topic of study, development, and investment for the future of our race.

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## Appendix

### A. Timeline: History of Space Travel

On October 4<sup>th</sup>, 1957, the first artificial satellite Sputnik was launched into orbit by the Soviet Union.

On November 3<sup>rd</sup>, 1957 the Soviet Union launched Sputnik 2, which was carrying a dog called Laika and orbited around the earth for seven days.

On January 31<sup>st</sup>, 1958 US launched the first satellite Explorer 1 which discovered the earth's radiation belt.

On October 1<sup>st</sup>, 1958 the National Aeronautics and Space Administration (NASA) was founded.

On January 2<sup>nd</sup>, 1959 the Soviet Union launched the satellite Luna 1, orbiting the sun for the first time.

On October 4<sup>th</sup>, 1959 Luna 3 photographed about 70% of the far side of the moon.

On April 1<sup>st</sup>, 1960 the US launched the first weather satellite Tiros 1.

On April 12<sup>th</sup>, 1961 the Soviet Union launched Vostok 1 carrying Yuri Gagarin and who became the first man in space.

On May 5<sup>th</sup>, 1961 the US launched Mercury Freedom 7, carrying Alan Shepard who became the first American into a sub-orbital space.

On June 16<sup>th</sup>, 1963 Valentina Tereshkova from the Soviet Union became the first woman in space by orbiting the earth 48 times on Vostok 6.

On March 18<sup>th</sup>, 1965 Soviet astronaut Aleksey Leonov made the first spacewalk which lasted about 12 minutes.

On November 26, 1965 French Army launched their first satellite A-1 which was built by their own and later renamed as Asterix.

On February 3<sup>rd</sup>, 1966 Soviet Union's unmanned Luna 9 landed on the moon for the first time.

On April 23<sup>rd</sup>, 1967 the first space tragedy (in-flight fatality) happened when the Soviet Union's Soyuz 1 encountered technical problems and crashed during its return to the earth, killing cosmonaut Colonel Komarov.

On July 20<sup>th</sup>, 1969 Neil Armstrong became the first human being landed on the moon, using Apollo 11.

On April 24<sup>th</sup>, 1970 China's first space satellite Dongfanghong 1 was launched.

On April 19<sup>th</sup>, 1971 the first space station Salyut 1 was launched by the Soviet Union.

On May 14<sup>th</sup>, 1973 the United States' first space station Skylab was launched and operated by NASA.

On July 20<sup>th</sup>, 1976 the US launched Viking 1, which landed on Mars and performed its mission by returning global images of Mars to the earth.

On April 12<sup>th</sup>, 1981 the first manned US Space Shuttle Columbia was launched.

On January 28<sup>th</sup>, 1986 the US space shuttle Challenger exploded right after lift-off, 7 crew members.

On February 20<sup>th</sup>, 1986 the Soviet Union launched the space station Mir.

On April 24<sup>th</sup>, 1990 the Hubble Space Telescope, one of the largest space telescope built by the US space agency NASA and European Space Agency (ESA) was launched by the Space Shuttle Discovery.

On September 11<sup>th</sup>, 1997 the US spacecraft Surveyor that was launched on November 1996 reached Mars and entered its highly elliptical orbit to closely investigate the surface of Mars.

On January 26<sup>th</sup>, 1998 the International Space Station (ISS) was signed by 16 countries as joint collaboration.

On November 20<sup>th</sup>, 1998 the first module of ISS Zarya, also known as the Functional Cargo Block (FGB) was launched.

On April 28<sup>th</sup>, 2001 Dennis Tito, US engineer and multimillionaire, became the first space tourist by boarding on Soyuz TM-32.

On February 1<sup>st</sup>, 2003 the US Space Shuttle Columbia exploded during re-entry after completing 27 missions, resulting in the deaths of all crew members aboard.

On October 15<sup>th</sup>, 2003 China became the third country in the world to send the manned spacecraft Shenzhou 5.

On March 11<sup>th</sup>, 2008 Japanese Experiment Module called Kibo was launched for the first time in Asia.

On September 29<sup>th</sup>, 2011 China's first space station Tiangong-1 was successfully launched.



On May 22<sup>nd</sup>, 2012 the first unmanned commercially built spacecraft Dragon was developed and launched by Space X, an American private space transportation company.

On April 29<sup>th</sup>, 2012 the Virgin Galactic's SpaceShipTwo, a private spaceship in the US designed to carry space tourists, made its successful first rocket-powered test flight, reaching supersonic speeds.

## B. List of 6 private companies capable of sending human into space

Company	SpaceX	Virgin Galactic	SpaceDev/Sierra Nevada Corp.	Orbital Sciences	Blue Origin	Bigelow Aerospace
Founder	Elon Musk	Richard Branson	Jim Benson	David W. Thompson, Bruce W. Ferguson, Scott L. Webster	Jeff Bezos	Robert Bigelow
Foundation date	2002	2004	1997	1982	2004	1999
Funds	\$100 million personal, \$20 million from outer investors	Personal fortune comes from Virgin group	Sierra Nevada Corp., of Sparks, Nev.	\$1.1 billion in revenue as publicly traded company	Personal fortune come as a founder of Amazon.com	\$180 million personal come as owner of the Budget Suites of America hotel chain.
Location	Hawthorne, CA	Longdon, England and Spaceport, NM	Poway, CA	Dulles, VA	Kent, WA	North Las Vegas, Nevada
Spaceships	Dragon spacecraft, Falcon 9 rocket	SpaceShipTwo	Dream Chaser	Cygnus, Taurus	New Shepard	Sundancer, BA-330
Launch dates	Tested in 2010, operated in 2011	Early 2012	Under development	2011	Mid-2012	Planning for 2015
Number of passengers	Maximum 7, change according to cargo	6 passengers and 2 pilots	4 on suborbital, up to 6 on orbital	Unmanned, but might change Cygnus as a manned-rocket	3 astronauts	Sundancer: 3 crews, BA-330: 6 crews
Interesting fact	The Dragon capsule is a solar-powered spacecraft	Planning suborbital space tourism with \$200,000 per seat				

<http://www.space.com/8541-6-private-companies-launch-humans-space.html>

## C. Pre-Survey before the presentation

### Pre-Survey: FUTURE OF SPACE TRAVEL

**Instructions:** Thank you for participating in this short survey. Your responses on the survey will be completely anonymous and private. You are encouraged to give each question a thoughtful response to guarantee the integrity of our findings.

#### Part A: Interests

---

Please answer the following statements on a scale of **1 (not at all) – 5 (very much)**.

How *interested* are you in **outer space** or **universe** in general?

1      2      3      4      5

How much do you *like* **science fiction** and other **fantasy** books, stories, movies, or games?

1      2      3      4      5

How **adventurous** are you?

1      2      3      4      5

Compared to my peers, I tend to **take more risks** in life.

1      2      3      4      5

Compared to my peers, I like to **try new things** (e.g. I am one of the first ones to go and buy a new gadget like iPhone).

1      2      3      4      5

Compared to my peers, I tend to *like* **staying at home** and be comfortable in **familiar places**.

1      2      3      4      5

#### Part B: Scientific Knowledge or Experience

---

**True or False:** For each of the statements below, mark "T" for True, and "F" for False

\_\_\_ Human space travel is only for trained astronauts and fictional characters in Sci-Fi movies/

\_\_\_ Until now, a passenger ticket into space cost about \$20 million.

\_\_\_ Taking vacations to space will be too costly even in the future.

\_\_\_ Only countries and governmental agencies like NASA, ESA, RKA are allowed to build space crafts and launch them into space.

\_\_\_ Several private companies have successfully built and sent powerful rockets into space.

\_\_\_ There is no difference between orbital and suborbital space flights.

\_\_\_ The first time humans landed on the moon was 40 years ago, and we have not gone back since.

\_\_\_ In previous rockets, 95% of their weight was fuel.

\_\_\_ It is possible to use solar energy to fly through space with currently available technology.

\_\_\_ Space exploration has been just a political show for big countries, and has not brought any benefit to society.

\_\_\_ The heart pump that doctors use for heart surgery was originally designed as rocket fuel pump.

\_\_\_ In the future, we will be able to travel to Mars.

\_\_\_ NASA plans to return to the moon by the year 2020 and build a livable colony there.

\_\_\_ In the future, regular people will be able to go into space.

THANK YOU FOR COMING AND ENJOY THE TALK!

## D. Post-Survey after the presentation

### Post-Survey: FUTURE OF SPACE TRAVEL

**Instructions:** Thank you for participating in this short survey. Your responses on the survey will be completely anonymous and private. You may choose not to answer questions that you are not comfortable with. However, you are encouraged to give each question a thoughtful response to guarantee the integrity of our findings.

#### Part A: Demographic Questions

---

What is your **age**? \_\_\_\_\_

What is your **gender**?

- A. Male
- B. Female
- C. Transgender
- D. Other: *(Please describe \_\_\_\_\_)*

How would you describe your **race**?

- A. White/Caucasian
- B. Black/African Descent
- C. Latino/Latina
- D. East Asian
- E. Southeast Asian
- F. Middle eastern Asian
- G. Native American
- H. Bi-racial
- I. Other: *(Please describe \_\_\_\_\_)*

What is your **nationality/country of origin**? *(If two are different, please indicate both)* \_\_\_\_\_

What is your **highest level of education** completed?

- A. Elementary or Middle School
- B. High School or equivalent diploma
- C. Some college (Associates Degree, etc.)
- D. Bachelor's
- E. Master's
- F. Doctoral (Ph.D.) or professional degree (JD, MD, PharmD, PsyD, etc.)
- G. Other: *(Please describe \_\_\_\_\_)*

What is your **occupation**? \_\_\_\_\_

What is your **primary language**? \_\_\_\_\_

How fluent are you in **English**? *(Circle one)*    Beginner                      Intermediate                      Advanced                      Fluent/Native

Was this talk *hard to understand* in English? (Circle one)      Yes      No

IF YES, approximately what percent of the talk did you understand? \_\_\_\_\_%

What is your approximate **yearly income**?

- A. No income
- B. Under \$10,000
- C. \$10,000 - \$19,999
- D. \$20,000 - \$29,999
- E. \$30,000 - \$39,999
- F. \$40,000 - \$49,999
- G. \$50,000 - \$74,999
- H. \$75,000 - \$99,999
- I. \$100,000 - \$150,000
- J. Over \$150,000

What is the number of other people in your **household** (that you support)?

- A. Just myself
- B. 1
- C. 2
- D. 3
- E. 4+

### **Part B: Scientific Knowledge or Experience**

---

**True or False:** For each of the statements below, mark "T" for True, and "F" for False

\_\_\_ Human space travel is only for trained astronauts and fictional characters in Sci-Fi movies/

\_\_\_ Until now, a passenger ticket into space cost about \$20 million.

\_\_\_ Taking vacations to space will be too costly even in the future.

\_\_\_ Only countries and governmental agencies like NASA, ESA, RKA are allowed to build space crafts and launch them into space.

\_\_\_ Several private companies have successfully built and sent powerful rockets into space.

\_\_\_ There is no difference between orbital and suborbital space flights.

\_\_\_ The first time humans landed on the moon was 40 years ago, and we have not gone back since.

\_\_\_ In previous rockets, 95% of their weight was fuel.

\_\_\_ It is possible to use solar energy to fly through space with currently available technology.

\_\_\_ Space exploration has been just a political show for big countries, and has not brought any benefit to society.

\_\_\_ The heart pump that doctors use for heart surgery was originally designed as rocket fuel pump.

\_\_\_ In the future, we will be able to travel to Mars.

\_\_\_ NASA plans to return to the moon by the year 2020 and build a livable colony there.

\_\_\_ In the future, regular people will be able to go into space.

**Part C: Comments on Presentation**

---

*Please circle one:*

Did the talk *help you to consider* space travel?

Yes      No      Not sure

Did the talk *increase your excitement* about space travel?

Yes      No      Not sure

Did the talk make space travel feel like a *real possibility for yourself* in the future?

Yes      No      Not sure

Did the talk help you see the societal benefits of space exploration?

Yes      No      Not sure

Do you have comments for Borim, or suggestions for improving the talk? Please write them below:

THANK YOU FOR COMING AND PARTICIPATING IN THE SURVEY!

## E. Result from the pre-survey (*In Italics*)

### Part A: Interests

---

Please answer the following statements on a scale of 1 (not at all) – 5 (very much).

Q: How interested are you in outer space or universe in general?

A: *The averages scale from the respondents was 3.42, and Standard deviation was 1.29.*

Q: How much do you like science fiction and other fantasy books, stories, movies, or games?

A: *The averages scale from the respondents was 3.38, and Standard deviation was 1.28.*

Q: How adventurous are you?

A: *The averages scale from the respondents was 3.63, and Standard deviation was 1.26.*

Q: Compared to my peers, I tend to **take more risks** in life.

A: *The averages scale from the respondents was 3.47, and Standard deviation was 1.33.*

Q: Compared to my peers, I like to **try new things** (e.g. I am one of the first ones to go and buy a new gadget like iPhone).

A: *The averages scale from the respondents was 3.47, and Standard deviation was 1.37.*

Q: Compared to my peers, I tend to *like staying at home* and be comfortable in **familiar places**.

A: *The averages scale from the respondents was 2.97, and Standard deviation was 1.26.*

### Part B: Scientific Knowledge or Experience

---

\_F\_ Human space travel is only for trained astronauts and fictional characters in Sci-Fi movies. **55.3% of participants got it right.**

\_T\_ Until now, a passenger ticket into space cost about \$20 million. **57.9% of participants got it right.**

\_F\_ Taking vacations to space will be too costly even in the future. **52.6% of participants got it right.**

\_F\_ Only countries and governmental agencies like NASA, ESA, RKA are allowed to build space crafts and launch them into space. **44.7% of participants got it right.**

\_T\_ Several private companies have successfully built and sent powerful rockets into space. **63.2% of participants got it right.**

\_F\_ There is no difference between orbital and suborbital space flights. **84.2% of participants got it right.**

\_T\_ The first time humans landed on the moon was 40 years ago, and we have not gone back since. **44.7% of participants got it right.**

\_T\_ In previous rockets, 95% of their weight was fuel. **73.7% of participants got it right.**

\_T\_ It is possible to use solar energy to fly through space with currently available technology. **52.6% of participants got it right.**

\_F\_ Space exploration has been just a political show for big countries, and has not brought any benefit to society. **71.1% of participants got it right.**

\_T\_ The heart pump that doctors use for heart surgery was originally designed as rocket fuel pump. **57.9% of participants got it right.**



\_T\_ In the future, we will be able to travel to Mars. **78.9% of participants got it right.**

\_T\_ NASA plans to return to the moon by the year 2020 and build a livable colony there. **42.2% of participants got it right.**

\_T\_ In the future, regular people will be able to go into space. **81.6% of participants got it right.**

## **F. Result from the post survey**

Q: What is your **age**?

**A: Average age was 26.9 with range from 10 to 49.**

Q: What is your **gender**?

**A: There were 21 females (58.3%) and 15 males 41.7%).**

Q: How would you describe your **race**?

**A: There were 7 White/Caucasian, 8 Latino/Latina, 18 East Asian, 1 Southeast Asian, and 3 Middle Eastern Asians.**

Q: What is your **nationality/country** of origin?

**A: Participants were from Korea, China, Japan, Thailand, Saudi Arabia, Mexico, Brazil, Ukraine, USA, Tunisia, Colombia, Portugal, Poland, and Croatia.**

Q: What is your **highest level of education** completed?

**A: 3 are still in Elementary School, 5 went to High School, 6 went to Some college (Associates Degree, etc.), 14 have Bachelor's degree, and 7 have Master's degree.**

Q: What is your **occupation**?

**A: Majority of participants (23) were students, 3 were teachers, 1 was a small business owner, 1 worked for Real Estates, and 1 was associated director/teacher.**

Q: What is your **primary language**?

**A: English, Spanish, Portuguese, Polish, Russian, Croatian, Korean, Chinese, Japanese, Arabic, and Thai were used.**

Q: How fluent are you in **English**?

**A: There were 4 beginners, 4 at intermediate level, 18 were at advanced level and 8 were Fluent as Native speakers.**

Q: Was this talk *hard to understand* in English?

**A: 8 participants (22.8%) replied yes, and 77.2% participants replied no. Among those 8 participants who had some hard time in understanding the talk in English, 2 replied they could understand about 50% of the talk, 3 said 70%, 1 said 80%, and 1 said 95%.**

Q: What is your approximate **yearly income**?

A: **Majority (20) had no income since most of the participants were students, 5 said around \$10,000 - \$19,999, 2 said around \$20,000 - \$29,999, 2 said around \$40,000 - \$49,999, and 1 said over \$150,000.**

Q: What is the number of other people in your **household** (that you support)?

A: **16 said they live alone just by himself, 3 said they live with 1 more person, 5 said with 2 more people, 1 said with 3 more people, and 7 said more than 4 people are in household.**

## **Part B: Scientific Knowledge or Experience**

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**\_F\_ Human space travel is only for trained astronauts and fictional characters in Sci-Fi movies. 63.3% of participants got it right.**

**\_T\_ Until now, a passenger ticket into space cost about \$20 million. 47.6% of participants got it right.**

**\_F\_ Taking vacations to space will be too costly even in the future. 40.9% of participants got it right.**

**\_F\_ Only countries and governmental agencies like NASA, ESA, RKA are allowed to build space crafts and launch them into space. 42.9% of participants got it right.**

**\_T\_ Several private companies have successfully built and sent powerful rockets into space. 57.1% of participants got it right.**

**\_F\_ There is no difference between orbital and suborbital space flights. 76.2% of participants got it right.**

**\_T\_ The first time humans landed on the moon was 40 years ago, and we have not gone back since. 61.9% of participants got it right.**

**\_T\_ In previous rockets, 95% of their weight was fuel. 66.7% of participants got it right.**

**\_T\_ It is possible to use solar energy to fly through space with currently available technology. 76.2% of participants got it right.**

**\_F\_ Space exploration has been just a political show for big countries, and has not brought any benefit to society. 81.0% of participants got it right.**

**\_T\_ The heart pump that doctors use for heart surgery was originally designed as rocket fuel pump. 75% of participants got it right.**

**\_T\_ In the future, we will be able to travel to Mars. 76.2% of participants got it right.**

**\_T\_ NASA plans to return to the moon by the year 2020 and build a livable colony there. 66.7% of participants got it right.**

**\_T\_ In the future, regular people will be able to go into space. 85.7% of participants got it right.**

**Part C: Comments on Presentation**

Q: Did the talk *help you to consider* space travel?

A: **22 said yes (64.7%), 4 said no (11.7%), 5 said they were not sure (23.5%).**

Q: Did the talk *increase your excitement* about space travel?

A: **25 said yes (73.5%), 4 said no (11.7%), 5 said they were not sure (14.7%).**

Q: Did the talk make space travel feel like a *real possibility for yourself* in the future?

A: **19 said yes (55.9%), 4 said no (11.7%), 11 said they were not sure (32.4%).**

Q: Did the talk help you see the societal benefits of space exploration?

A: **20 said yes (58.8%), 3 said no (8.8%), 5 said they were not sure (32.4%).**

Do you have comments for Borim, or suggestions for improving the talk? Please write them below:

## G. Flyer for the presentation

### Approach Language School Lunch Seminar

#### Bo Rim Seo "Future of Space Travel"



#### **Abstract:**

The purpose of this presentation is to bring space travel closer to ordinary people as something that is relevant and feasible. The talk will cover brief history of space travel, the reasons for lack of progress in the last few decades, and some recent exciting developments in the field. More specifically, the topics include hazards of space travel, principles of current rockets, privatization of space travel enterprise, and possible alternative sources for rocket propulsion such as using earth's magnetic field, superconductors and quantum locking. This 30 minute presentation will include multimedia and lively discussions. A survey will be administered afterwards.

**Monday, August 27, 2013**

**2:00 pm**

**Light refreshments and snacks will be provided!**

*Bo Rim Seo is a senior at Worcester Polytechnic Institute, majoring in Mechanical Engineering. She has had a passion for space travel, cosmology, and astrophysics since she was a very young girl in Korea. Her favorite space movies include Star Wars. After spending her childhood in South Korea, she came to the United States to pursue her dreams. This Interactive Qualifying Project is a step towards achieving her dream in making space travel a reality for everyone. She plans to pursue graduate school to study Physics in the near future and hopes to become a researcher in Astrophysics.*

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*508-257-1616*

## H. Outline of the presentation

Pre-Survey and refreshments

- I. Overview and Purpose of this presentation
  - a. Personal Introduction
  - b. Bring space travel closer to ordinary people as something that is relevant and feasible.
- II. Basic knowledge
  - a. How do we define space?
  - b. What is the difference between orbital and suborbital space flight?
- III. Why Space Travel?
  - a. New frontiers, new resources, new technology
    - i. A lot technology developed for space travel are what we use today
    - ii. GPS system, Parachute System, Teflon coated stadium, Mechanical arm for surgeries, Remote Robotic surgery, Fabrics, Smart Materials, Heart pump
  - b. It's FUN!
- IV. Brief history of space travel [Timeline]
- V. Hazards of space travel
  - Extreme Environment
  - Space Trash
  - Long-term Health Effect of astronauts
- VI. Where are we now?
  - a. Principles of current rockets
  - b. Problems with conventional rockets
- VII. Recent exciting developments in the field
  - a. Elon Musk and SpaceX
  - b. Possible alternative sources for rocket propulsion
    - i. Space elevator
    - ii. Solar sails
    - iii. magnetic field
    - iv. superconductors and quantum locking

Post-survey and wrap up

The whole event took about an hour and half including surveys .