

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

## ANTIMATTER FUEL

Manoj Lakhan

Assistant Professor, Dept. of Physics, M.L.V. Govt. College, Bhilwara, Rajasthan, India

**ABSTRACT:** The human's quest to explore the universe results in more innovation and newer technologies to our world. In the urge to go even further through space, it has become necessary to develop new and better propulsion systems. Research shows that antimatter energy is more efficient than any other energy. A spaceship that uses antimatter will need smaller volumes of fuel compared to the typical fuel used nowadays. However, the following research concludes that using antimatter as fuel for rockets is still science fiction and is not yet feasible.

Isolated and stored antimatter could be used as a fuel for interplanetary or interstellar travel as part of an antimatter-catalyzed nuclear pulse propulsion or another antimatter rocket. Since the energy density of antimatter is higher than that of conventional fuels, an antimatter-fueled spacecraft would have a higher thrust-to-weight ratio than a conventional spacecraft.

If matter-antimatter collisions resulted only in photon emission, the entire rest mass of the particles would be converted to kinetic energy. The energy per unit mass ( $9 \times 10^{16}$  J/kg) is about 10 orders of magnitude greater than chemical energies,[84] and about 3 orders of magnitude greater than the nuclear potential energy that can be liberated, today, using nuclear fission (about 200 MeV per fission reaction or  $8 \times 10^{13}$  J/kg), and about 2 orders of magnitude greater than the best possible results expected from fusion (about  $6.3 \times 10^{14}$  J/kg for the proton-proton chain). The reaction of 1 kg of antimatter with 1 kg of matter would produce  $1.8 \times 10^{17}$  J (180 petajoules) of energy (by the mass-energy equivalence formula,  $E=mc^2$ ), or the rough equivalent of 43 megatons of TNT – slightly less than the yield of the 27,000 kg Tsar Bomba, the largest thermonuclear weapon ever detonated.

Not all of that energy can be utilized by any realistic propulsion technology because of the nature of the annihilation products. While electron-positron reactions result in gamma ray photons, these are difficult to direct and use for thrust. In reactions between protons and antiprotons, their energy is converted largely into relativistic neutral and charged pions. The neutral pions decay almost immediately (with a lifetime of 85 attoseconds) into high-energy photons, but the charged pions decay more slowly (with a lifetime of 26 nanoseconds) and can be deflected magnetically to produce thrust.

Charged pions ultimately decay into a combination of neutrinos (carrying about 22% of the energy of the charged pions) and unstable charged muons (carrying about 78% of the charged pion energy), with the muons then decaying into a combination of electrons, positrons and neutrinos (cf. muon decay; the neutrinos from this decay carry about 2/3 of the energy of the muons, meaning that from the original charged pions, the total fraction of their energy converted to neutrinos by one route or another would be about  $0.22 + (2/3) \cdot 0.78 = 0.74$ ).

An antimatter rocket is a proposed class of rockets that use antimatter as their power source. There are several designs that attempt to accomplish this goal. The advantage to this class of rocket is that a large fraction of the rest mass of a matter/antimatter mixture may be converted to energy, allowing antimatter rockets to have a far higher energy density and specific impulse than any other proposed class of rocket. Antimatter rockets can be divided into three types of application: those that directly use the products of antimatter annihilation for propulsion, those that heat a working fluid or an intermediate material which is then used for propulsion, and those that heat a working fluid or an intermediate material to generate electricity for some form of electric spacecraft propulsion system. The propulsion concepts that employ these mechanisms generally fall into four categories: solid core, gaseous core, plasma core, and beamed core configurations. The alternatives to direct antimatter annihilation propulsion offer the possibility of feasible vehicles

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

with, in some cases, vastly smaller amounts of antimatter but require a lot more matter propellant. Then there are hybrid solutions using antimatter to catalyze fission/fusion reactions for propulsion.

**KEYWORDS:** human, antimatter, fuel, rockets, spaceship, feasible, research, science, technology

## I. INTRODUCTION

The idea of using antimatter to power an electric space drive has also been proposed. These proposed designs are typically similar to those suggested for nuclear electric rockets. Antimatter annihilations are used to directly or indirectly heat a working fluid, as in a nuclear thermal rocket, but the fluid is used to generate electricity, which is then used to power some form of electric space propulsion system. The resulting system shares many of the characteristics of other charged particle/electric propulsion proposals (typically high specific impulse and low thrust)(here where you can read up more on antimatter power gen

The chief practical difficulties with antimatter rockets are the problems of creating antimatter and storing it. Creating antimatter requires input of vast amounts of energy, at least equivalent to the rest energy of the created particle/antiparticle pairs, and typically (for antiproton production) tens of thousands to millions of times more.[17][18] Most storage schemes proposed for interstellar craft require the production of frozen pellets of antihydrogen. This requires cooling of antiprotons, binding to positrons, and capture of the resulting antihydrogen atoms - tasks which have, as of 2010, been performed only for small numbers of individual atoms. Storage of antimatter is typically done by trapping electrically charged frozen antihydrogen pellets in Penning or Paul traps. There is no theoretical barrier to these tasks being performed on the scale required to fuel an antimatter rocket. However, they are expected to be extremely (and perhaps prohibitively) expensive due to current production abilities being only able to produce small numbers of atoms, a scale approximately 10<sup>23</sup> times smaller than needed for a 10-gram trip to Mars.

Generally, the energy from antiproton annihilation is deposited over such a large region that it cannot efficiently drive nuclear capsules. Antiproton-induced fission and self-generated magnetic fields may greatly enhance energy localization and efficient use of annihilation energy

The gravitational interaction of antimatter with matter or antimatter has not been conclusively observed by physicists. While the consensus among physicists is that gravity will attract both matter and antimatter at the same rate that matter attracts matter, there is a strong desire to confirm this experimentally—although simple algebra shows that the presence of two photons with positive energies following electron/positron annihilations observed frequently in nature is extremely strong evidence that antimatter has positive mass and thus would act like regular matter under gravity.

Antimatter's rarity and tendency to annihilate when brought into contact with matter makes its study a technically demanding task. Furthermore, gravity is much weaker than the other fundamental forces, for reasons still of interest to physicists, complicating efforts to study gravity in systems small enough to be feasibly created in lab, including antimatter systems.

When antimatter was first discovered in 1932, physicists wondered about how it would react to gravity. Initial analysis focused on whether antimatter should react the same as matter or react oppositely. Several theoretical arguments arose which convinced physicists that antimatter would react exactly the same as normal matter. They inferred that a gravitational repulsion between matter and antimatter was implausible as it would violate CPT invariance, conservation of energy, result in vacuum instability, and result in CP violation. It was also theorized that it would be inconsistent with the results of the Eötvös test of the weak equivalence principle. Many of these early theoretical objections were later overturned

The equivalence principle predicts that the gravitational acceleration of antimatter is the same as that of ordinary matter. A matter-antimatter gravitational repulsion is thus excluded from this point of view. Furthermore, photons,

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

which are their own antiparticles in the framework of the Standard Model, have in a large number of astronomical tests (gravitational redshift and gravitational lensing, for example) been observed to interact with the gravitational field of ordinary matter exactly as predicted by the general theory of relativity. This is a feature that has to be explained by any theory predicting that matter and antimatter repel. This is also the prediction Jean-Pierre Petit made in an article published in 2018: "In addition, the Janus model predicts that the antimatter that will be created in the laboratory in the Gbar experiment will behave like ordinary matter in the Earth's gravitational field." The antigravitation described in the Janus model is produced by antimatter of 'negative' masses (the antimatter produced in laboratories or by cosmic rays has only positive masses), and is fully compliant with general relativity and Newtonian approximations.

Included in many science fiction books and movies, antimatter is a topic that can bring doubt, fear, and hope to many people. Antimatter can be described as a mirror appearance of normal matter. This implies that antiparticles are the same in regard to the mass of their underlying regular complements, but its electrical charges are upturned. Moreover, an anti-electron has a positive charge instead of a negative charge, and an antiproton has a negative charge instead of a positive charge. When antimatter collides with matter an explosion occurs, and the two particles are converted to pure energy. Antimatter is considered a perfect fuel since all the prevailing mass taking part in the collision between matter and antimatter is converted into energy. This report's intention is to study the feasibility of using antimatter as fuel for rockets. Using antimatter as fuel for rockets could be extremely beneficial. Antimatter is the most efficient source of energy in the entire universe, when antimatter meets its equivalent matter; they annihilate each other resulting in an explosion that converts all the mass of the particle and its antiparticle into pure energy. However, the technology required, its cost and storage of the technology required. It is not feasible due to the antimatter make it unfeasible to use as fuel for rockets in today's world.

Use of spaceships driven by chemical fuel is a primitive technology that may not be of any help to man when planning to explore outer and remote orbits and planets. For instance, sending a space shuttle into the earth's orbit at a speed of 17,500 MPH requires the rocket to carry chemical fuel equivalent of 15 times its weight; this is a gross inefficiency in space exploration (nda, 2012). The fuel inefficiency greatly limits the effectiveness of chemical based fuels in steering space ships to outer orbits. Moreover, for the spaceship to attain the escape velocity from the earth's gravitational pull towards the solar system, which requires a speed of about 25,000MPH, more fuel is needed for this difficult undertaking (n.d.a, 2011) [1-4].

In other words, as the figure indicates, spaceships propelled with chemical fuels have had major limitations and are the single cause why man has delayed in exploring outer orbits, which requires significant time of travel and much higher speeds. The amount of fuels required to undertake this endeavor is unjustifiable and may, in fact, be impossible to take along the space ship due to weight limitations. For instance, currently, the average cost to put a single spaceship into space is approximately 450 million USD per every mission, a cost that is too high and a great limitation to exploration. The high cost makes chemical fuels inefficient and a limitation in man's exploration strategies. With the dwindling economic fortunes in the country, the high cost could lead to scrapping the shuttle program, unless a cheaper option. Considering the high rate of fuel use by spaceships, it becomes impossible for these vehicles to leave for space with inadequate fuel to maneuver the expected orbits. The heavy weight of the fuel leads to high costs and is also a potential risk in case of an accident near the earth's surface. For instance, any plans to leave the solar system en-route to the nearest star in reasonable time, which may be about 900 years using chemical fuel propelled rockets; the voyage would need about 10137 kilograms of fuel, an amount that by far exceeds the amount of fuel on our planet (nda, 2012). The above limitations of chemical based fuels call for more research towards developing a more robust and efficient fuel to propel spaceships more efficiently and for longer durations if man's dream to leave the solar system in search of remote stars would be a reality.

In order to deal with the above shortcomings, scientists are forthcoming with different possibilities of propulsion methods. These achievable sources of energy would not be so heavy or expensive, nor would they have as much volume as is currently required of the chemical fuel used for space travel. The following figure shows the efficiency of what is next for fuel to replace chemicals

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

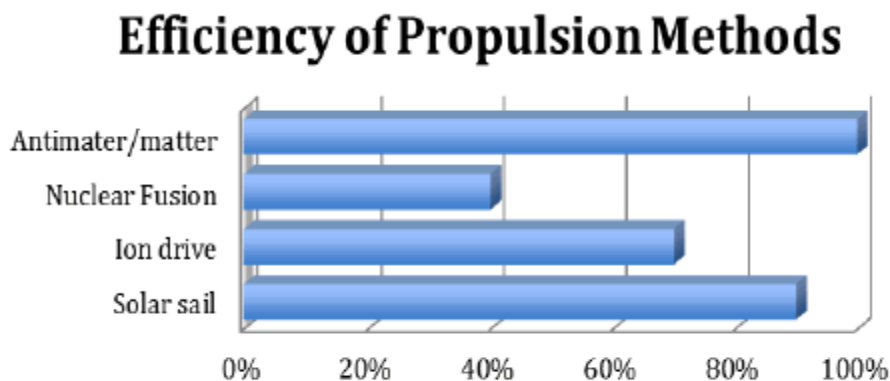
Vol. 7, Issue 4, April 2018

## II. DISCUSSION

Antimatter comets and antimatter meteoroids are hypothetical comets and meteoroids composed solely of antimatter instead of ordinary matter. Although never actually observed, and unlikely to exist anywhere within the Milky Way, they have been hypothesized to exist, and their existence, on the presumption that hypothesis is correct, has been put forward as one possible explanation for various observed natural phenomena over the years.

Martin Beech from the University of Western Ontario (London, Ontario, Canada) referred to the various hypotheses and experimental results that support non-existence of antimatter in the Universe. He argued that any antimatter comets and meteors that exist must be (at least) extrasolar in origin because the nebular hypothesis for the formation of the Solar System precludes their being solar. Any antimatter in a pre-formation nebula or planetary accretion disc has a comparatively short lifetime, astronomically speaking, before annihilation with the terrene matter that it is mixed with. This lifetime is measured in the hundreds of years, and so any solar antimatter present at the time that the system was formed will have long since been annihilated. Any antimatter comets and meteors must therefore come from another solar system. Furthermore, not only must antimatter meteors be extrasolar in origin, they must have been recently (i.e. within the past 104 ~ 105 years) captured by the Solar System. Most meteoroids are broken down to sizes of 10–5 g within that timeframe, because of meteoroid-upon-meteoroid collisions. Thus any antimatter meteor must be either extrasolar in origin itself, or broken off from an antimatter comet that is extrasolar in origin. The former are unlikely to exist from observational evidence. Any extrasolar meteoroid would have a hyperbolic orbit, but less than 1% of the observed meteoroids have such, and the process of perturbation of ordinary (terrene) solar objects, by planetary encounters, into hyperbolic trajectories accounts for all of those. Beech concluded that a continued null result, however, does not constitute a proof ('Absence of evidence is not evidence of absence', M. Rees) and a single positive detection negates the arguments presented

The four propulsion methods are seen in **Figure 1** (antimatter/ matter, nuclear fusion, ion drive, and solar sail) are considered by scientist as the possible answer for a substitute for chemical based rockets. Antimatter/matter is the most energy efficient fuel source. In other words, as indicated above, an enormous amount of chemical fuel is required for a successful mission to space. However, just a handful of milligrams of antimatter is adequate for this same mission.



**Figure 1: Efficiency of Propulsion Methods: Adapted from Zidbits (What is the future of space travel, 2012).**

When antimatter meets its equivalent matter, they annihilate each other. The neutrinos<sup>1</sup> are the only part of this explosion that is carried away. Since neutrinos are considered massless, and energy is equal to the multiplication of mass and the square of the speed of light, they do not influence the energy output ( $E=mc^2$ ). Therefore, an antimatter/matter explosion converts all the mass of the particle and its antiparticle into pure energy. The complete

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

conversion of antimatter to energy is what makes the fuel so powerful and promising in breaking barriers that had been set by chemical fuels. While previous spaceships using antimatter as fuel were designed to use antiprotons, which resulted in high energy gamma rays after annihilation, the newer design uses positrons whose gamma rays have over 400 times less energy than the gamma rays produced using antiprotons (Steigerwald, 2011). This discovery makes use of the new antimatter not only more powerful alternative to chemical fuel, but also more efficient in the reduction of the harmful effects of high energy gamma rays during reactions. Use of positrons in antimatter makes the fuel more environmentally friendly by reducing such high emissions.

“While tons of chemical fuel are needed to propel a human mission to Mars, just tens of milligrams of antimatter will do (a milligram is about one-thousand the weight of a piece of the original M&M candy).” (Steigerwald, 2011)

Based on the scope of efficiency, since antimatter/matter explosion results in a complete conversion of mass into energy, using antimatter as fuel for rockets is, by far, the best alternative to the type of chemical fuel currently used in space trips.

One of the first challenges, when considering using antimatter as a source of energy, is its availability. Collisions of high-speed particles called cosmic rays create antimatter in space. There are large amounts of antimatter in space, but there is no technology capable of capturing this antimatter. When considering our planet, antimatter must be created in particle accelerators. The major restrictive factor is production of antimatter in greater volumes. Data released by the European Organization of Nuclear Research (CEARN) shows that a particle accelerator available for antimatter creation as of today would take approximately 100 billion years to produce 1 gram (or  $6.02 \times 10^{23}$  atoms) of antihydrogen.

The main challenge would be coming up with efficient huge particle accelerators More Enough to smash atoms together to result in antimatter. There is a need for more advanced technologies to handle such antimatter than the use of the existing particle accelerators.

## III. RESULTS

The technology to capture antimatter from space does not exist as of today. The solution would be to create the antimatter in a device that uses electromagnetic fields<sup>4</sup> to propel the particles to high speeds until they collide and create antimatter. This device is called a particle accelerator. **Figure 2** is a picture of the CERN Hadron Collider, the first particle accelerator to actually create antimatter.

As seen in **Figure 2**, the Large Hadron Collider (LHC) is a massive internationally funded particle accelerator located in Switzerland.

There are different particle accelerators around the world. The most intense source of antiproton today is the Fermi National Accelerator Laboratory (Fermilab), located in the USA. According to data from the book IT04612E, Fermilab's record production over a month was in June 2007, when it produced  $10^{14}$  antiprotons. If it were possible to produce that same amount for 12 months, Fermilab would be able to produce about  $10^{15}$  atoms, which equates to 1.5 billionths of a gram. If it were possible to annihilate them, the total energy released from it would be about 270 Joules, which is only enough to keep a light bulb turned on for about 5 seconds. Based on the outcomes of this section of the report, the technology to create antimatter does exist. However, even after adding all the production of antimatter created in antiparticle accelerators together, the total world production falls extremely short of the optimistic hopes of using antimatter for space fuel.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

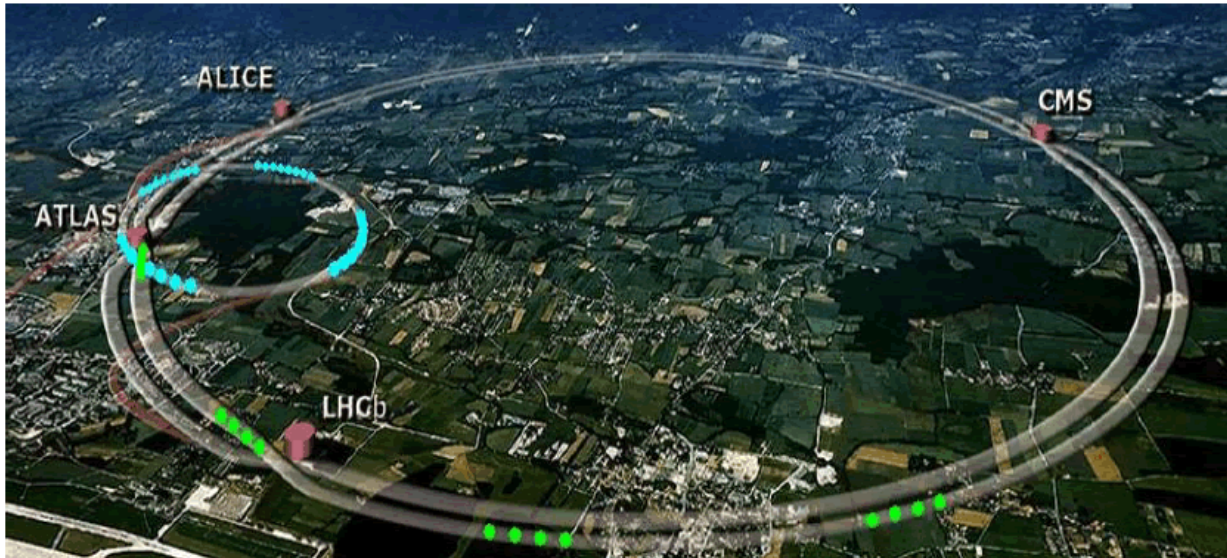


Figure 2: Cern Hadron Collider: From Popsci (Great Dreams, 2010).

Considering that antimatter cannot be brought into any contact with matter, there is no possibility of having it inside a physical container. The answer for antimatter storage comes with a purely magnetic trap in vacuum.

The trap used in some experiments conducted lately is called Penning trap, where charged positrons and antiprotons can be held by electricity, and magnetic forces. The drawback of these traps is that they cannot store many particles since these particles naturally repel one another. (Alpha, n.d.a). Considering that positrons have an electric charge and will tend to naturally repel each other, storing about 0.0001% of the positrons required for a successful voyage to mars would result in enormous and incomprehensible tons of repelling electric force acting on the fuel tank walls (Anderson, 2010). A fuel tank that can withstand such an enormous pressure may not be possible to make with the current level of technology.

The storage of antimatter is costly, and, with current technology, not effective enough to trap large quantities of antimatter, as would be needed for space travel.

In 1971, fragments of antimatter comets or meteoroids were hypothesized, by David E. T. F. Ashby of Culham Laboratory and Colin Whitehead of the U.K. Atomic Energy Research Establishment, as a possible cause for ball lightning (Ashby & Whitehead 1971). They monitored the sky with gamma-ray detection apparatus, and reported unusually high numbers at 511 keV (kilo-electron volts) which is the characteristic gamma ray frequency of a collision between an electron and a positron. There were natural explanations for such readings. In particular positrons can be produced indirectly by the action of a thunderstorm, as it creates the unstable isotopes nitrogen-13 and oxygen-15. However, Ashby and Whitehead noted that there were no thunderstorms present at the times that the gamma-ray readings were observed. They instead presented the hypothesis of antimatter meteors as an interesting one that did explain all of what their observations had recorded, and suggested that it merited further investigation.

## IV. CONCLUSIONS

In order to go further with space travel a, new propulsion system is needed. This report explores the idea of utilizing antimatter as fuel for rockets. It focuses upon efficiency, availability, technology, and storage. Research has hinted at the possibilities of developing a positron, which would steer spaceships to outer orbits in much higher speeds and for extended periods by using just a handful of the fuel. However, developing this fuel on such a large scale is still a

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 4, April 2018

mirage. There are huge challenges in having effective particle accelerators making positrons, storing the particles and even developing a fuel tank that would withstand the huge electric forces generated by these particles. Therefore, though science has made it possible to develop such fuel, the use of antimatter is not feasible currently unless more advanced technologies to solve these currently limitations are put in place.

Using antimatter as fuel for rockets is not feasible. Although a promising technology that may propel man to remote planets with much less energy, the use of antimatter in propelling space ships remains a distant possibility unless more complex technology advancements are made to make the use of antimatter a reality. The following technologies should be explored further, so in the future antimatter propulsion becomes possible:

Particle accelerators capable of producing antimatter on large scale and more efficient storage of antimatter

The cosmic background hard radiation will ionize the rocket's hull over time and poses a health threat. Also, gas plasma interactions may cause space charge. The major interaction of concern is differential charging of various parts of a spacecraft, leading to high electric fields and arcing between spacecraft components. This can be resolved with well placed plasma contactor. However, there is no solution yet for when plasma contactors are turned off to allow maintenance work on the hull. Long term space flight at interstellar velocities causes erosion of the rocket's hull due to collision with particles, gas, dust and micrometeorites. At  $0.2c$  for a 6 light year distance, erosion is estimated to be in the order of about 30 kg/m<sup>2</sup> or about 1 cm of aluminum shielding.

## REFERENCES

1. Mark A (2017) Antimatter-Rocket Plan Fuels Hope for “Star Trek” Tech. National Geographic News.
2. Madsen N (2010) "Cold antihydrogen: a new frontier in fundamental physics". *Philosophical Transactions of the Royal Society A* 368 (1924): 3671–82. Bibcode:2010 RSPTA.368.3671M.
3. Bill S (2011) Beyond earth: Expanding human presence into the solar system. NASA.
4. Zidbits. What is the future of Space Travel (2012) zidbits.