

# **International Cooperation in Space**

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## **Abstract**

The project goal was to estimate the changes for cooperative international development of the moon. The cooperation or competition issue hinged on whether the moon was “valuable” or not. The valuable scenario depended on whether Helium-3 deposits on the Moon were needed on Earth to fuel fusion reactors. After studying the mindsets of each Space Agency and Corporation interested in the Moon, we investigated the tourism and Helium-3 Scenario. We found that He-3 will not be a feasible power source within our lifetime; cooperation will exist only at low levels due to a lack of common interest.

## **Introduction**

Human expansion into space is a tremendous undertaking that only a select few nations have had the capability of undergoing alone. As technology improves, missions become larger and more difficult, making international cooperation a near necessity. However, because of the cutting edge technology and the potential military applications of that technology cooperation has not been as prevalent as one would expect given the costs involved. Even in cases where international cooperation has been embraced there have been mixed results, causing countries to be even more cautious about taking on partners.

The purpose of this project is to investigate what will drive organizations to cooperate in the future. After a great deal of discussion we have narrowed our research to include only those aspects of space expansion that will lead to a return to the Moon, and the first expeditions to Mars that will follow soon after that. The Moon is our closest celestial body and we feel that it is the most likely stage for future cooperation or competition in space. The ultimate goal of this project is to be able to present probable scenarios for returning to the moon and to predict what the nature of international relations will be like.

In order to accomplish this goal we will first investigate the nature of the world powers in space exploration. Findings from our preliminary research showed that the organizations most likely to be involved are NASA, ESA, JAXA, the CNSA, RKN, and Virgin Galactic. In order to understand each of these groups we will research their plans for the future, their history of cooperation, and their level of technical expertise.

To present possible scenarios we must also investigate what possible reasons exist for returning to the moon. Without a strong driving force it is unlikely that any organization will be willing or able to produce the necessary funds or efforts to achieve anything in space especially on their own. Cooperation on the Moon is more likely if it is not considered valuable or strategic. The South Pole Stations on Earth are examples of peaceful cooperation by nations interested in reaching scientific, rather than commercial, objectives together. The primary motivations we believe are most likely to lead to a resurgence in interest in the moon are space tourism, training to go to Mars, mining the moon for minerals, harvesting Helium-3 as a next generation fuel source, or for predominantly scientific purposes.

After gathering information on the organizations and on the potential missions we will determine under which circumstances the organizations are most likely to compete or cooperate.

## **Organization Profiles**

In the growing space industry there are a number of major players, each with their own plans and distinct “personalities,” sometimes called an organizational “mindset.” An organization’s past history and political ties can be just as influential as their technological expertise on forming plans for the future. In this section of our report we investigate the major national space organizations: the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), the Japanese Aerospace Exploration Agency (JAXA), the Chinese National Space Administration (CNSA), the Russian space agency Roskosmos (RKN), and we will also introduce the private US organization Virgin Galactic. Each section will cover the organization’s mindsets, history of international cooperation, technological capabilities, needs for resources, and their contractors. By analyzing these aspects of each organization we will gain insight into each country’s need, willingness, and ability to cooperate internationally.

### ***National Aeronautics and Space Administration***

#### **Organizational Mindset**

In 2004 and 2005, two major events took place shaping the future attitudes and goals at the National Aeronautics and Space Administration. President Bush announced the Vision for Space Exploration and Michael Griffin was named the new NASA chief administrator. The Vision is a 14-year plan for the development of NASA, and Mr. Griffin was brought in to make it happen.

In 2005 Congress approved Michael Griffin as NASA’s eleventh administrator. Mr. Griffin has an intimate knowledge of NASA, as he was once the chief engineer and administrator of space exploration, and has been involved in the process of redesigning the ISS. After nine months Mr. Griffin had an interview with the Orlando Sentinel, during which he made numerous telling remarks.

In a speech resembling John F Kennedy’s moon speech, President Bush outlined NASA’s direction over the next sixteen years. The first step of the plan is to complete the International Space Station (ISS) by 2010, and upon completion the space shuttle fleet

will be retired. To replace the shuttle fleet and continue the US presence in space, the second step will be to develop the Crew Exploration Vehicle (CEV) by 2008 with the first manned missions before 2014. The third part of the plan includes returning to the moon by 2020 with a long-term presence. Romantic speeches make for good television, but the relative importance of the plan is more realistically represented by its level of funding.<sup>1</sup>

NASA gets its funding from the US Congress, requiring an annual budgetary bill to be approved and passed. This allows for massive amounts of politics to come into play when funding NASA's projects. After announcing the Vision for Space Exploration, President Bush's budgetary aids encouraged him to veto any bill not including the funding for his plan.<sup>2</sup> One of the last proposed budgets fell one billion dollars short of NASA's requests. Not only was there pressure from the President, two congressmen played a major role in securing the remaining funding. Senator Bill Nelson was a NASA shuttle pilot; due to his past, he lobbied the senate to fully fund NASA's budget request. Tom DeLay lobbied for the bill in the House because it represented thousands of jobs for members of his constituency. With funding so dependent on the political whims of so many, NASA becomes a hostage to the people allocating the money for their budgets.<sup>3</sup>

United States Air Force Space Command was created in the early 1980's to ensure America's continued dominance in space with a focus on national security. The Air Force launched a review into the biases in NASA's contracting decision making process following the termination of the \$1.2 billion X-33 program. Although there have been no announcements, Space Command may revive the project to develop their own reusable manned spacecraft.<sup>4</sup> Being a part of the US military, Space Command has access to a large budget and the "other" space agency is interested in the strictest of confidentiality surrounding their work. The full Air Force budget in 2001 was \$560 Billion, about 35 times that of NASA's 2004 budget.<sup>5</sup> Space Command can eclipse NASA's capabilities the moment an interest is shown and often has previous strong relationships with the same contractors NASA uses, and a shared pool of expertise.

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<sup>1</sup> NASA.gov, Exploring the Solar System

<sup>2</sup> Kelly

<sup>3</sup> IBID

<sup>4</sup> David

<sup>5</sup> Department of the Air Force Budget Summary

The Congressional Budget Office analyzed the Vision for Space Exploration and projected NASA's budget over the course of the entire project. The report outlined how NASA would be able to pay for the proposed goals. The plan cuts funding for the shuttle by 2012 and cuts funding for the ISS in 2017. Congress will be expecting these programs to end as planned, and have the ability to cut their budgets appropriately.<sup>6</sup> The space community was concerned The Vision for Space Exploration would take money away from other NASA projects. Michael Griffin tried to lay this concern to rest by saying "I'll do everything I can to make sure that our major themes don't cannibalize each other."<sup>7</sup> Many of NASA's other projects did take budget cuts after the shuttle fleet needed emergency repairs following the Columbia disaster.<sup>8</sup>

NASA's current plans include a long-term presence on the moon. The plans do not include international cooperation outside of the completion of the ISS and reaching the proposed moon base is not easier from the ISS than from Earth. The timeframe is extended, only committing to the first moon mission to be before 2020; given proper motivation and funding, the timeframe can be truncated. Mr. Griffin defended the timeframe and implied that it could be shortened if necessary, saying "People keep asking me 'Why are you taking until 2018 or whatever it takes us to get back to the moon when we did it in eight years the first time?' The reason is that we're not being given the kind of money necessary to do that in eight years."<sup>9</sup> With the plan in place and the ability to accelerate production in the case of urgent motivation, it is unlikely NASA would need to look outwards for international partners to complete a long-term moon base.

## **Skills**

NASA has been developing their expertise since being established in 1958. The administration's main focus has been on manned missions in space, and developing a supporting expertise and knowledge base. NASA has already completed many missions that will be relevant in building a moon base. NASA can boast being the only country to have successfully landed a man on the moon. The Apollo missions resulted in NASA's

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<sup>6</sup> A Budgetary Analysis of NASA's New Vision for Space Exploration

<sup>7</sup> Cabbage

<sup>8</sup> Overbye

<sup>9</sup> Cabbage

massive amounts of manned space experience. NASA has accomplished manned mission launches, missions through earth orbits, missions to moon orbit, and then the lunar landing itself. This experience will allow NASA to focus on sustainability; staying on the moon permanently with food, water and oxygen supplies sufficient to the purpose and gathered locally when possible, since the goal is prepare for a two to three year Mars mission.

NASA was a part of the first joint space mission with Russia in 1975; the Apollo-Soyuz Test Project (ASTP) was mainly a political accomplishment and had little scientific meaning, but proved countries could work together in space despite rival ideologies and technologies not designed to be compatible. This paved the way for other joint manned missions on MIR and the International Space Station.

Running a space station taught NASA important lessons about the long-term effects of space. NASA's first experience was Skylab; the learning process continued through cooperation with Russia on MIR and currently includes the International Space Station (ISS). The ISS is giving NASA experience in areas that past stations avoided. In particular the ISS required NASA to assemble a relatively large structure in orbit. While all the countries involved are learning from ISS, NASA has supplied the shuttle as the main construction tool. The shuttle explored the problems with reusable spacecraft and supported a fairly extensive science of microgravity effects on materials, plants, animals and pharmaceuticals.

## **Needs**

Being a global leader in space technologies, NASA's needs are centered on funding. NASA has the capability to lift things into low earth orbit, but may need foreign technologies developed amidst commercial competition to lower the cost per pound. NASA had to look to ESA, ISAS, and now JAXA to build the four-satellite array for the International Solar-Terrestrial Physics (ISTP) Science Initiative. NASA had originally proposed to complete the OPEN (Origins of Plasma in the Earth's Neighborhood) project alone, but the US Congress only approved funding for half of the four-satellite mission. NASA broadened the program to include a satellite each from ESA and JAXA to achieve the OPEN mission's scientific goals and more, ending up a better, though more expensive,



mission. NASA and its contractors had the scientific expertise to complete the project, but due to the program's low priority NASA was forced to turn to the international community to find the funding and ended up contracting the most interesting satellite design missions to its partners.<sup>10</sup>

NASA also needs to be allowed to work, putting technical criteria first. Meddling from outside political and economic forces have caused some of NASA's biggest problems. After landing on the moon, NASA's next goals were unclear, as it was not given the money to build a Moon Base or go to Mars. Congress had lost interest in the moon and budget cuts forced NASA to abandon Apollo missions 18, 19 and 20 if it was to execute its fallback plan of building a Shuttle to allow it to later build a space station, and set up a supply line for a Moon base. Scientists were focused on space stations to get experience with the space environment and its impact on the human body, and a Saturn V rocket was used to launch the Skylab space station. The budget began to tighten as development on the space shuttle began; Apollo 18 had been planned to become Skylab 5, boosting the station into a better orbit and keeping it in space until the shuttle could utilize it. International politics interfered and Apollo 18 became a photo opportunity in the Apollo-Soyuz Test Project (ASTP). The main goal of the mission was to perform a fairly trivial docking of an Apollo and Soyuz spacecraft. Most of the 44 hours the crafts spent docked were used to exchange goodwill and not science. Had the resources been used on Skylab 5 and not ASTP, NASA would have had its own space station at the beginning of the shuttle program.<sup>11</sup>

The shuttle program itself was hijacked by the Air Force, causing the shuttle to be over engineered. Michael Yarymovych, an Air Force deputy assistant secretary went to a meeting at the home of NASA's Office of Manned Space Flight head George Mueller. Yarymovych recalls this meeting,

*NASA needed Air Force support, both for payloads and in Congress. I told Mueller we'd support the Shuttle, but only if he gave us the big payload bay and the crossrange capability, so we could return to Vandenberg after a single orbit. Mueller knew that would mean changing Max Faget's [A NASA*

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<sup>10</sup> Sigwarth

<sup>11</sup> Wade

Engineer who helped design the space shuttle.] *beloved straight-wing design into a delta wing, but he had no choice. He agreed.*<sup>12</sup>

Strong-arming NASA caused the design of the shuttle to be greatly changed and contributed to the high lift costs of the shuttle. The high costs encouraged the Air Force to use other means to get their payloads into orbit; cutting NASA's income and putting a larger burden on the NASA budget. Had the Air Force not interfered, the Space Shuttle would have been more efficient and more cost effective, possibly attracting other clients, and allowing the shuttle program to consume less of NASA's budget.

During the Space Race, NASA showed the world what it was capable of. With the proper funding and the freedom to let science direct the technology, NASA was able to flourish. Funding shortages do lead NASA to seek cooperation, but fundamental institutional changes are needed to protect NASA's budget from Congressional meddling. This internal problem does not exist in Europe since ex-space scientists run ESA and military involvement is forbidden. Countries are forced to pay into the 15% of the budget devoted for pure science, but further involvement is voluntary. Spin-off companies also run the commercial aspects of space successfully.

### **Contractors**

When NASA was created, the organization had the ability and the funding to complete most technical work in house. If anything was outsourced to an aerospace company, NASA scientists would disassemble the device and rebuild it themselves to ensure it met the organization's safety standards. NASA has since moved into a period where they allow their contractors to harbor all the expertise. Currently, NASA feels contractors should handle the mundane aspects of space travel and NASA should be focused on breaking new ground. This would leave the operation of the completed space station and fleet maintenance up to contractors.<sup>13</sup> NASA also feels contractors should be held accountable for their failures. NASA, no longer holding the expertise to check for lapses and oversights themselves, has recently docked the company running the

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<sup>12</sup> Heppenheimer, Ch.5 A New Shuttle Configuration

<sup>13</sup> Laurent

maintenance and operation of the shuttle fleet 45.2 million dollars for the Columbia disaster.

A company spokesperson commented, “While not directly at fault for the accident, we're part of the team.”<sup>14</sup> The operational experience being lost at NASA leaves the organization hostage to its contractors. The contractors who can achieve a monopoly in their area do not have to focus on lowering costs, but rather on driving up the price of space exploration as a whole.

NASA’s top contractors have heavily vested interest in U.S. Government contracts. Of the 11 billion dollars spend on contractors in 2003, the top ten contractors took in 8.4 billion. These ten contractors represented two American universities and eight companies whose main business is defense contracts.<sup>15</sup> These contractors are not interested in rocking the boat; if they upset NASA they lose multi-million dollar contracts, if they upset Congress they stand to lose enough contracts to bankrupt their company. Launching ventures into uncertain industries or industries yet to be created, does not have a high enough return on investment for these companies to risk their lucrative defense contracts. Depending on how strongly Congress backs NASA, NASA can wield enormous power over the contractors but the contractors have the expertise now, not NASA, so it can not complete a project in-house if the price seems excessive.

## ***European Space Agency***

### **Organizational Mindset**

The European Space Agency’s (ESA) ambitions for the future can be broken down into three categories: maintaining its scientific and research projects, follow through with plans for astronomy-space missions, and very ambitious plans for a manned mission to Mars which include a manned moon mission by 2024.<sup>16</sup> ESA’s mindset in the past has led to a strong emphasis on unmanned technology which has led to strong commercial gains from launch vehicles such as the Ariane 4 and 5. ESA also has a strong interest in scientific research projects such as the recently launched Venus Express, Mars Express, and the upcoming Planck and Herschell probes. In these ventures ESA

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<sup>14</sup> Watson

<sup>15</sup> Top 25 NASA Contractors

<sup>16</sup> Aurora European Space Exploration Executive Summary, ESA 2001

has worked closely with NASA, and will continue to work with a number of international partners under the Aurora Programme with its first two subprograms ExoMars and the Mars Sample Return Mission.

### **International Cooperation**

The very existence of ESA is based on international cooperation. In the early 60's, European scientists knew that in order to compete with the American and Soviet superpowers they would have to work together. In 1964 the two predecessors to ESA were formed: the European Space Research Organization (ESRO), and the European Launch Development Organization (ELDO)<sup>17</sup>. In 1974 these two organizations were merged to form ESA<sup>18</sup>. ESA originally had 11 member countries: the original 9 members of the European Community (EC) (Belgium, France, Germany, Italy, Luxembourg, The Netherlands, Denmark, Ireland, and the United Kingdom)<sup>19</sup> as well as Switzerland and Norway. The EC, which would later become the European Union (EU), set the groundwork for international cooperation in Europe. The structure of ESA is similar to that of the EU in that it has a central headquarters, a number of member states (now 17), and joint international meetings. ESA differs from other space organizations in that it has had less dramatic political events (ie: the space race for America and the Soviets) so it functions more like a privately owned business than a political entity.

ESA is the best example of a complex cooperative union between nations in the field of space technology. Aside from its internal cooperation, ESA also works with other countries commercially. In 1978 ESA and the United States launched the International Ultraviolet Explorer (IUE), the world's first high-orbit telescope. ESA is now the number one commercial launcher of satellites world-wide, and is open to working with any space faring nation.

ESA's participation in the International Space Station (ISS) is only partial. Full participation was not mandatory, and five countries have withdrawn from participation because of either financial concerns or due to a lack of interest. ESA's largest

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<sup>17</sup> A History of the European Space Agency 1958-1987 Volume I, J. Krige and A. Russo 2000

<sup>18</sup> European Space Agency, <http://www.fas.org/spp/guide/europe/agency/>, Federation of American Scientists 2006

<sup>19</sup> European Union, <http://www.itcilo.it/english/actrav/telearn/global/ilo/blokiteu.htm>, International Labour Office 1999

contribution to the ISS is the Columbus Laboratory scheduled to be launched in 2007. This addition will greatly enhance the station's experimental capabilities.<sup>20</sup>

The Mars Express was headed by ESA working closely with the Italian Space Agency and NASA. The Mars Express is a scientific orbiting vessel launched on June 2, 2003. As of December 2005 it had been in orbit for a full Mars year (687 earth days), and the decision has now been made to leave it in orbit for another Mars year. This vessel had a landing vehicle, the Beagle 2, which did not land successfully and was lost.<sup>21</sup>

The Aurora Programme is a long term international plan aimed at landing a man on Mars by 2033. The program was started in 2001 by ESA as an optional plan, which means even if a country is a member of ESA it does not have to participate in the program. On December 5 and 6 2005, 14 of the 17 joined the program as well as Canada. From the very early stages of the program interest has been shown in international cooperation within and outside of the ESA member countries. The original program summary stated,

*With Aurora, Europe has a unique window of opportunity to take a key role in that endeavor (manned mission to Mars), cooperating with the US, Russia, Japan and China, as well as with all other space-faring nations that might be interested in joining, initiating very early in the process the international framework that will eventually make it possible.*<sup>22</sup>

The ExoMars program is the flagship program and has already been approved with a target launch date in 2011. The Mars Sample Return mission is the second major launch on the timeline and will cooperate closely with NASA. Much of the technology for this mission is still to be developed and tested by the Arrow missions, but if all goes well the series of vehicles required for such a mission could be ready by 2011.

ESA has also been working with the CNSA on a number of projects that make up the Double Star Program (DSP) and Galileo Projects. The CNSA and ESA have cooperated to make the TC-1, TC-2, Comet I, and Comet II

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<sup>20</sup> European Columbus Laboratory for ISS ready for delivery, [http://www.esa.int/esaCP/SEML8AOFGLE\\_Life\\_0.html](http://www.esa.int/esaCP/SEML8AOFGLE_Life_0.html), ESA 2006

<sup>21</sup> Mars Express set off on 2 June 2003, [http://www.esa.int/SPECIALS/Mars\\_Express/SEMNS75V9ED\\_0.html](http://www.esa.int/SPECIALS/Mars_Express/SEMNS75V9ED_0.html), ESA 2005

<sup>22</sup> Aurora European Space Exploration Executive Summary, ESA 2001

telecommunications and scientific observation vehicles that make up the DSP program.<sup>23</sup> The Galileo program is Europe's navigational system similar to and compatible with (by agreement with the US in June, 2004)<sup>24</sup> the US's GPS system. The first of its crafts, the Giove, was launched in December of 2005.

On cooperation in general, ESA Director General Jacques-Jean Dordain said, *ESA is the U.S.'s main partner in space today and, while we have achieved a great deal on our own, what most people don't realize is that almost every task now being undertaken in space, whether by us, by the Russians or by the Americans, is the result of co-operation.*<sup>25</sup>

ESA is NASA's primary partner, but if there is one obstacle to their continued cooperation it would be the US's desire for technological dominance, emphasis on manned technology and their insistence on staying one generation ahead of everybody else.

## **Skills**

ESA has established itself as one of the leaders in space technology and experience. While their skills span a wide area of space technology, their primary strength is still in unmanned launch and space vehicles. ESA's primary launch vehicle has been the Ariane 5 since it replaced the Ariane 4 in 1997. Plans for a small payload launch vehicle called the Vega are in production and will be ready for use by 2007. On January 19, 2005 ESA signed a €340 million contract with Russia to have them produce parts for Soyuz rockets for ESA's use.<sup>26</sup> The use of these launchers ensures ESA's long-term access to unmanned space.

ESA also has experience with the US style shuttles and are involved in the International Space Station. Their manned space flight division is relatively young with the establishment of the ESA Astronaut Corps in 1982, developed 20 years after the USA and Russian equivalents. ESA has experience with human space travel, but really does not have a manned launch vehicle of its own yet. The Hermes manned launch vehicle

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<sup>23</sup> [http://www.cnsa.gov.cn/english/news\\_release/show.asp](http://www.cnsa.gov.cn/english/news_release/show.asp)

<sup>24</sup> The First Galileo Satellites – Giove Brochure, ESA, November 2005

<sup>25</sup> Europe's Great Space Race, by Daryl Lindsey, published by Deutsche Welle, June 25, 2004

<sup>26</sup> Launchers, [http://www.esa.int/SPECIALS/Launchers\\_Home/SEMCDI1PGOD\\_0.html](http://www.esa.int/SPECIALS/Launchers_Home/SEMCDI1PGOD_0.html), ESA 2006

design program was ESA's first attempt at a manned vehicle, but was cancelled in 1995. Plans developed with Russia for the Hopper and Klipper launch vehicles are being developed, and a prototype by EADS called the Phoenix has been tested. The Phoenix/Hopper series is an unmanned series, but is a part of the long-term plan for a manned mission to Mars. These vehicles will not be ready for use until at least 2011.<sup>27</sup>

There are a number of technological breakthroughs that must be achieved if ESA is to achieve their goal of a manned space flight by 2033. Such breakthroughs are needed to develop "the landing system on Mars, the Mars ascent vehicle, the rendezvous system in Mars orbit and the Earth re-entry vehicle or capsule. In principle, all of these can be tested in a near-Earth environment except for the final qualification of the rendezvous and docking system."<sup>28</sup> ESA's history of cooperation with NASA may become a valuable asset in their manned space endeavors as long as US shared technology restrictions do not inhibit such cooperation.

## Needs

One of ESA's greatest needs is for a more defined role with regards to the EU. ESA has a lot of freedom, and can operate nearly independently of what is going on in the European community with the constraint of how such matters affect the contributions of its member nations. But because member nations may or may not be associated with the EU, the individual nations may have ties and obligations to the EU that may interfere with what they are willing to do with ESA. The EU has its own space policy, so in spite of some agreements between the two organizations, the possibility for a conflict is present. This should be a rather short term issue as the EU and ESA are in the process of fixing these internal inconsistencies.

ESA has the second largest space budget in the world behind NASA. However, their budget of €2.977 billion (\$3.598 billion using a conversion of €1 = \$1.2086)<sup>29</sup> in 2005 does not fully represent the agency's activities. Because several of the individual countries that are members of ESA also have their own national space agencies, the total European budget is more than twice ESA's own budget. Certain European projects may

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<sup>27</sup> EADS Phoenix, [http://en.wikipedia.org/wiki/EADS\\_Phoenix](http://en.wikipedia.org/wiki/EADS_Phoenix), Wikipedia 2006

<sup>28</sup> Mars Sample Return, [http://www.esa.int/SPECIALS/Aurora/SEM1PM808BE\\_0.html](http://www.esa.int/SPECIALS/Aurora/SEM1PM808BE_0.html), ESA 2005

<sup>29</sup> European Space Agency, [http://en.wikipedia.org/wiki/European\\_Space\\_Agency](http://en.wikipedia.org/wiki/European_Space_Agency), Wikipedia 2006

also have a special budget that is not a part of ESA's but rather taken from the contributions of individual members of the EU. ESA's budget has also risen 10% since 2004, and is projected to stay at approximately the same level after accounting for inflation for the next five years.

In 2003 when the Agenda 2007 was produced by the ESA Director General, there was a fair amount of turmoil due to restructuring in the EU as well as in the space industry. It was predicted that

*Despite some revival of fortunes expected in the next few years, there is no prospect of the commercial market getting back by 2007 to the levels of activity of the late 1990s. It is estimated that the level of activity generated by the commercial market in European industry will correspond to a workload below 50% of the capabilities of industrial production currently available in Europe.*<sup>30</sup>

ESA's present commercial and financial situations have improved since the time of the report, but are still well below their maximum capacities.

## **Contractors**

ESA itself has no formal in house production, and therefore must contract all of its project work. As stated in the ESA Convention the number of work contracts delegated to each participating country will be proportional to their financial contribution to the specific project.<sup>31</sup> There are two types of contract companies, the Small and Medium Enterprises (SME), and the larger space industry companies, most of whom are members of Eurospace. The European Space Industry Directory (ESID) is a searchable database containing resources for all of ESA's contractors.<sup>32</sup> There are well over 400 companies in the database, but there is no complete list of companies, so you would have to know what product, country, or company you are interested in to use the search.

The SME Initiative is aimed at making it easier for small and medium sized enterprises to be involved with ESA and the space industry. The initiative states that ESA will provide technical support, tailor the rules of co-financing to the size of the

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<sup>30</sup> Agenda 2007 – A Document by the ESA Director General, ESA Strategy Department, Paris

<sup>31</sup> Convention for the Establishment of a European Space Agency; ESA 1975

<sup>32</sup> European Space Industry Directory, <http://www.esidirectory.org/>; ESA 2006



enterprise, and will make provisions to include SMEs in the ESA technology work plan. In order to qualify as an SME the company must have fewer than 250 employees, annual turnover not exceeding 40 million euros or an annual balance sheet total not exceeding 27 million euros, and less than 25% of capital or voting rights held by enterprises not themselves defined as SMEs. The SME program reserves technology and development projects and delegates them to particular SMEs.<sup>33</sup>

Eurospace is a not for profit organization founded in 1961 to organize consultation and dialogue within the industry. It also has its own policies and is independent of ESA though it works very closely with ESA, the EU, and the individual member countries' national space organizations. Activities are carried out within workgroups and panels, each with a specific purpose or area of interest. Eurospace presently has 49 member companies and accounts for over 90% of all European space industry activity.<sup>34</sup>

One extremely large company under Eurospace is Arianespace. Arianespace is in charge of the production of the Ariane series launch vehicles, as well as the marketing and launching of the Vega and soon the Soyuz launch vehicles. Arianespace's primary function is to provide launch services, and they do have a technical staff for that purpose. Arianespace is owned by 23 shareholders representing 10 different countries. Shareholders include several branches of EADS as well as CNES.

The European Aerospace Defense and Space Company (EADS) is an absolutely tremendous company that has a number of divisions including Airbus, Eurocopter, Defense and Security Systems Division, and Space. The space branch has 11,053 employees in 4 different countries, and has 3 primary subsidiaries, EADS Space Transportation, EADS Astrium, and EADS Space Services which are also members of Eurospace. EADS Space also works with external companies such as Arianespace, Starsem, and Eurocket for production as well as launch services. EADS Space Transportation is Europe's primary contractor for civil and military space transportation, while EADS Astrium is the world leader in satellite production.<sup>35</sup>

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<sup>33</sup> Small and Medium Sized Entrepreneurs, <http://smeprojects.esa.int/>; ESA 2006

<sup>34</sup> Eurospace, <http://www.eurospace.org/>; Eurospace 2006

<sup>35</sup> EADS Space, <http://www.space.eads.net/>, EADS 2006

EADS Space had € 2.6 Billion in revenue in 2004, which according to EADS total revenue charts was a much slower year than 2005.<sup>36</sup> EADS is an international publicly traded company on 3 different stock markets. Contractual partnerships with SEPI, Daimler Chrysler, and Sogead hold 65.25% of the company, while the remaining 34.74% is held by the public. EADS does business with nearly every technologically advanced country in the world, and is not run by any particular government.

The real body of scientific knowledge lies in a massive network of individual contract companies scattered throughout Europe. These companies are not government run, though the contracts being delegated to them primarily come from ESA or their respective national agencies. These companies do take on contracts outside of ESA and do work amongst themselves with a great degree of freedom. Because very few of these companies are either military or defense related there are few conflicts of interest in working for countries outside of ESA.

## ***Japanese Aerospace Exploration Agency***

### **Organizational Mindset**

Japan's national aerospace agency is the Japan Aerospace exploration Agency, or JAXA. This agency was formed on October 1, 2003 through the merger of three previously independent organizations, the Institute of Space and Aeronautical Science(ISAS), the National Aerospace Laboratory(NAL) and the National Space Development Agency(NASDA).<sup>37</sup>

JAXA's organization seems to be primarily focused on unmanned missions, with the exception of the International Space Station. The rest of their current projects involve satellites and optical communications, as well as supersonic aircraft development.<sup>38</sup> In the next few years, Japan has many missions planned. They are completing infrared missions, solar sail testing, satellite launches, mobile phone communication testing,

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<sup>36</sup> EADS, Investor Relations, Chart  
Generator <http://www.eads.net/web/lang/en/1024/content/OF0000000400004/6/03/31000036.html>,  
3/31/06

<sup>37</sup> Wikipedia 1

<sup>38</sup> Wikipedia 5

global precipitation measurements, x-ray missions, moon missions, and a solar sail mission to Jupiter. Their primary focus seems to be on observation and unmanned missions.<sup>39</sup>

The three largest companies in Japan's independent aerospace industry right now are Mitsubishi Heavy Industries, Kawasaki Heavy Industries and Ishikawajima-Harima Heavy Industries. Right now, the three companies are working in conjunction with the Japanese government to create a new supersonic commercial plane to be the next Concorde. They are trying to find ways to reduce engine noise and develop light composite materials capable of resisting extreme pressures.<sup>40</sup> They are currently working on a Mach 2.4 300 passenger jet, capable of traveling from Tokyo to New York in half the time it now takes.<sup>41</sup> They plan on using this to show that "Japan can take a leading role."<sup>42</sup> Until now, Japan has been a secondary player in this field to Boeing and Airbus.

### **International Cooperation**

JAXA seems willing to cooperate on the international level. Their current place in the coalition building the International Space Station helps to support this position. The international space station involves a fair number of the other agencies, so Japan's openness to cooperation seems clear.<sup>43</sup> Additionally, Japan is currently working with ESA on the development of a number of space missions, such as the communication between OICETS and ARTEMIS.<sup>44</sup> In their mission statement they speak of how they intend to work with ESA and NASA on future lunar and Mars missions.<sup>45</sup>

Scientific progress in space is another factor pushing Japan to cooperate. Japan needs NASA's help in the near term future to get parts of the Japanese Experiment Module to the International Space Station because it does not have its own shuttle fleet.<sup>46</sup>

For historical reasons there is little chance of cooperation between Japan and China except in the form of trade. They have been warring for an incredibly long time,

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<sup>39</sup> Wikipedia 4-5

<sup>40</sup> Fackler 2

<sup>41</sup> Fackler 1

<sup>42</sup> IBID

<sup>43</sup> Moring B, 24

<sup>44</sup> Wikipedia.org 4-5

<sup>45</sup> JAXA 34

<sup>46</sup> Moring A, 64

as shown in the pacific wars in the early 20<sup>th</sup> century.<sup>47</sup> However, Japan has been cooperating with the United States and Europe, as shown in trade and scientific development.

### **Skills**

Japan uses the H-IIA rocket to launch satellites, and is developing the first rocket world wide to use liquefied natural gas as propellant. Most of Japan's success has come in the field of X-ray astronomy, such as the ASTRO-E II and use of infrared, as shown in the ASTRO-F. The old ISAS did world class space science; the old NASDA was not quite as respectable but, Japan has been working on satellite communications, in the project names OICETS, showing commercial space coming into its own. Additionally they have been working on climate observation in the MTSAT-2 program.<sup>48</sup>

### **Needs**

Like many other space agencies, one of JAXA's major needs is funding. After a slow but steady expansion for about 20 years it started to lose priority about ten years ago, and the HOPE shuttle is still not operational. Due to "uncertainties of domestic politics and international space-exploration planning,"<sup>49</sup> the agency's vision of the future is clouded. Its budget continues to decline, even though Japan is hopeful to take part in the development of a full-time lunar base by 2025. Japan is the second largest economy in the world. Despite having four recessions since 1991, it is once again recovering at a moderate pace. As of June 2005, the unemployment rate had fallen to 4.2%.<sup>50</sup> The overall state of the economy is improving. According to Greimel, "The Bank of Japan upgraded its outlook of the economy, saying exports and wages were picking up."<sup>51</sup> Japan is plagued with heavy bureaucratic problems, and despite enjoying a fruitful economy, its space agency has an ever shrinking budget.

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<sup>47</sup> Lopez 144-160

<sup>48</sup> Wikipedia 3-4

<sup>49</sup> Moring A, 64

<sup>50</sup> Greimel 2

<sup>51</sup> Greimel 1

## **Chinese National Space Administration**

### **Organizational Mindset**

The published goals of the Chinese National Space Administration (CNSA) as of December 15, 2003 are outlined in *China's Space Activities (White Pages)*:

The Chinese government attaches great importance to the significant role of space activities in implementing the strategy of revitalizing the country with science and education and that of sustainable development, as well as in economic construction, national security, science and technology development and social progress.<sup>52</sup>

With Project 921 approved in September 1992 China began its manned space flight program. Today China has had two manned space missions, the Shenzhou V and VI. This is a determined step toward China's long term goals. China's programs are aimed at a manned moon base. China's long term goals are:<sup>53</sup>

- In 2006, launch an unmanned two-ton satellite called Chang'e to orbit the Moon for at least a year and record 3D images of the lunar surface.
- In 2007, have a man perform a spacewalk during the Shenzhou 7 flight.
- In 2009, unmanned Shenzhou 8 and 9 rendezvous, building a space station in orbit. Also have Shenzhou 10 ferry people to the space station.
- By 2010, land an unmanned probe on the Moon.
- By 2013, launch a rocket with a maximum payload of 27 tons, three times today's largest at nine tons.
- By 2015, land a robot probe on the moon to bring home soil samples
- By 2017, send men to the moon

These plans are heavily focused on the end goal of a manned mission to the moon. This goal is only the beginning for their ultimate goal of setting up a permanent base on the moon. Many possible purposes such as scientific research, mining Helium-3, space tourism, and colonization have been expressed as reasons to build the base. The only

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<sup>52</sup> *China's Space Activities (White Pages)* published by the China National Space Administration CNSA.

<sup>53</sup> China's Astronauts, <http://www.spacetoday.org/China/ChinaTaikonauts.html> edited by space analyst Anthony R. Curtis, Ph.D.

undeniable reason for a moon base is for national pride. Lunar exploration would allow China to “struggle for a more important place in the world space science field and raise our deep space exploration technology to a higher standard,” according to the Chinese news agency, Xinhua News Agency.<sup>54</sup>

### **International Cooperation**

For the most part, the Chinese space program prides itself on maintaining an extremely independent program. Some of what goes on happens in secrecy and is not announced until it has already been accomplished. However, this does not mean that China had or has any intentions to seclude themselves in the area of space exploration and technology. As an aspiring leader in space technology, China has stepped forward to be a leader in many aspects of the industry.

On November 30, 1980 China became a member of the UN Committee on the Peaceful Uses of Outer Space. Though brief and a bit vague, some guiding principles for international space cooperation were set forth and approved at the 51st general assembly of the United Nations in 1996.<sup>55</sup>

China has also shown interest in helping developing nations in their efforts to start space programs. In 1995 a contract on the development and manufacture of Sinosat-1 was signed with DASA and Aerospacia. Sinosat-1 was successfully launched in 1998, and was the first cooperative project on satellite development between the Chinese and European aerospace industries.<sup>56</sup>

China is also working with Brazil in the areas of satellite technology, satellite application, and satellite components. Their first jointly produced and designed satellite was launched in October, 1999. Commercially China had used the “Long March” rockets to launch 27 foreign-made satellites by the year 2003.<sup>57</sup>

China has a very strong interest in working with nearby countries and the Asian Pacific Space Multilateral Cooperation (APSC). In 1992, China, Thailand, Pakistan and

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<sup>54</sup> China’s Moon Flight, <http://www.spacetoday.org/China/ChinaMoonflight.html>, Space Today 2006

<sup>55</sup> United Nations Committee on the Peaceful Uses of Outer Space, <http://www.unoosa.org/oosa/COPUOS/copuos.html>, UNOOSA 2006

<sup>56</sup> China’s Space Activities (White Paper), CNSA 2003

<sup>57</sup> International Cooperation – Delegation of Brazilian Space Agency Visited China, [http://www.cnsa.gov.cn/english/international\\_co/show.asp?id=18](http://www.cnsa.gov.cn/english/international_co/show.asp?id=18), CNSA 2006

a few other countries sponsored the Asian-Pacific Multilateral Space Technology Cooperation Symposium. In 1998, the governments of China, Iran, the Republic of Korea, Mongolia, Pakistan and Thailand have signed the Memorandum of Understanding on Cooperation in Small Multi-Mission Satellite and Related Activities.<sup>58</sup>

## **Skills**

China's space program started "on the basis of weak infrastructure industries and a relatively backward scientific and technological level." (China's Astronauts) It is now one of the world leaders in space technology research and development, and has accomplished much with their focused efforts on specific space endeavors. The Chinese space program focuses primarily on satellites, launching vehicles, launch sites, and now manned space missions.

By October 2000 China had launched 47 satellites with a 90% success rate. The China Aerospace Science and Technology Corporation (CASC) is state-owned and builds China's five primary types of satellites as well as a few others: Dongfanghong communications satellites, Fengyun weather satellites, Shijian science exploration satellites, Ziyuan remote sensing Earth resource satellites, and the Beidou navigation satellites. China's "Long March" launching vehicles have been open to the commercial launching market since 1985. These have a maximum load capacity of 9200kg for near-earth orbit, and 5100kg for geo-stationary transfer. China presently has three launch sites in Jiuquan, Xichang and Taiyuan. The manned space program has evolved from its beginning in 1992 to have the unmanned Shenzhou I launched in November 20, 1999. On October 15, 2003 Yang Liwei became China's first man in space on board the Shenzhou V. On October 12, 2005 China launched its second manned space craft the Shenzhou VI.<sup>59</sup>

## **Needs**

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<sup>58</sup> International Cooperation – APSC Preparatory Work Has Achieved Substantial Progress, [http://www.cnsa.gov.cn/english/international\\_co/show.asp?id=16](http://www.cnsa.gov.cn/english/international_co/show.asp?id=16), CNSA 2006

<sup>59</sup> China's Space Rockets, <http://www.spacetoday.org/China/ChinaRockets.html>, Space Today 2006

In 2003 when the “White Pages” were published, Brian Harvey said, "They have a limited budget and have to manage funds very carefully."<sup>60</sup> Since then China has budgeted and focused their program very well. On top of that the Chinese economy is very much on the rise. In 2005 the economy increased by 9.9%, so with China’s advanced technology, strong interest, and reasonable funding, their need for cooperation is becoming more of a desire than a need. Right now China is very strong in the area of unmanned satellites, and is improving in the area of manned space missions. Where they really want to go is in the direction of space stations and permanent moon bases. Supporters of their space program have stayed in power, so China’s program is expected to make steady progress.

### **Contractors**

China’s primary body for contract investment was the China Aerospace Science and Technology Corporation (CASC). China’s space program started out as the No. 5 Research Academy for the Ministry of Defense, so the program has been very closely tied with the Chinese military and the central government. CASC specializes in developing launch vehicles, spacecrafts, manned spaceships, various types of strategic and tactical missiles, dealing with imports & exports of space-related products, and international cooperation. CASC has over 130 subordinate companies and has approximately 110,000 employees with a large in house technical body of knowledge. It has 41,000 people in its technical staff, and another 1,300 people assigned as researchers.<sup>61</sup> CASC produces Dongfanghong communications satellites, Fengyun weather satellites, Shijian science exploration satellites, Ziyuan remote sensing Earth resource satellites, Beidou navigation satellites retrievable satellites, and other types of satellites.<sup>62</sup> Official information on CASC is a little hard to find as their webpage is only in Chinese.

CASC acts as a shareholder for The China Great Wall Industry Corporation (CGWIC), which is the international branch of CASC. They are the only corporation that

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<sup>60</sup> China's Space Program: From Conception to Manned Spaceflight, By Brian Harvey

<sup>61</sup> The Overview of China Aerospace Science & Technology Corporation, <http://www.cgwic.com.cn/about/holders1.htm>, CGWIC 3/29/06

<sup>62</sup> China’s Satellites, <http://www.spacetoday.org/China/ChinaSatellites.html>, Space Today 3/30/06



has been authorized to provide international commercial launch services, satellites, and international space cooperation technology. CGWIC is in charge of the Long March launch vehicle which has been providing international commercial launch services since 1985.<sup>63</sup>

The CGWIC does not actually have any in house technical staff. Rather, the company manages the business end of three subordinate companies, the China Academy of Launch Vehicle Technology (CALT), Shanghai Academy of Spaceflight Technology (SAST) and China Satellite Launch, Tracking and Control General (CLTC). CALT is almost exclusively in charge of the creation, operation, and maintenance of China's launch facilities. SAST and CLTC deal with developing, producing, and testing the launch vehicles.

The Chinese Academy of Space Technology (CAST) is CNSA's primary body of in house technical knowledge. CAST is responsible for the Long March series of launch vehicles. They also work with CASC to produce satellites and their launch facilities. CAST is sort of a parallel company to CASC and will work with them and under the CGWIC.<sup>64</sup>

Overall the entire body of China's technical knowledge resides in the organizations CASC, CAST, SAST, CALT, and the CLTC, all of which are government owned and regulated. There is no chance of these companies breaking away from the government without a rebellion on the order of what happened in Russia taking place.

## ***Roskosmos – Russian Federal Space Agency***

### **Organizational Mindset**

The Russian's have been involved in space longer than anyone else. Their program is not as large as it was during the Cold War era due to budget constraints, but they are still major players. As a result of their lack of funding and of the ending of the Cold War they have cooperated significantly with the US and other space agencies on projects such as the International Space Station. Their aeronautics companies have been

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<sup>63</sup>CGWIC Overview, <http://www.cgwic.com.cn/about/overview.htm>, CGWIC 3/30/06

<sup>64</sup> CAST Online, <http://www.cast.ac.cn/en/index.asp>, CAST 3/30/06

around for a long time, and their experience and skill at building rockets and engines is part of what drives others to cooperate with them.

Russia no longer feels the need to go into space for the sake of going into space, as they have now been there and back many times. They want landing on the moon to be more than, as Alexei Krasnov, director of manned space flight for Roskosmos says, "just to have your foot on the surface, to plant the flag there again."<sup>65</sup> "They are interested in commercial endeavors such as satellite launches and space tourism to supplement their budget and provide a good image to the public. They are more interested in manned flight than unmanned, as shown by their interest in developing the Kliper, which is supposed to hold up to 6 people at a time. The military launches its own satellites. Cost considerations have lead them to do unmanned missions, such as their answer to the Apollo program in which they got lunar samples without a manned landing, and focused their manned program on space stations.

### **International Cooperation**

After the Challenger tragedy, American companies stopped sending satellites up via the shuttle. American companies looked to corporations to launch their satellites instead, both American and foreign. At first the Russians were not able to launch American satellites because of export restrictions (advanced technology not allowed to cross the Soviet Union's border) but after the fall of the soviet union these restrictions were eased. When Boris Yeltsin met with George Bush in 1992 they agreed to cooperate in space and made it possible for American astronauts to fly on board Russian spacecraft and for Russian astronauts to fly on board American spacecraft. In 1992 Lockheed set up a joint venture with Khrunichev, maker of the Proton, and marketed the Proton for commercial launches internationally.<sup>66</sup>

Severe budget problems existed in Russia during construction of the space station Mir 2. Americans were having budget problems as well and so they agreed on a joint effort. United States agreed to "rescue the Russian manned space program by paying

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<sup>65</sup> Boyle 2

<sup>66</sup> Heppenheimer 341

\$400 million in four annual installments”. They also made extensive use of the Soyuz rockets while the space shuttle was grounded, which saved the space station.<sup>67</sup>

Roskosmos has greatly contributed to the International Space Station, a project which has involved them with four other space agencies (NASA, ESA, JAXA, Canadian Space Agency (CSA or ASC)). They built the core and three of the initial modules, and undertook many of the yearly flights to the station. They are planning to build three additional modules which should be ready by 2011. They see the station as a place to launch spacecraft from: "In the future, it will be not only international territory, but an international spaceport," Sevastianov said. "Your president says that the moon will be the platform for flights to Mars. It's my opinion that the space station is the platform for the next step toward the moon." NASA has a different view of the station, as NASA Administrator Mike Griffin says, for them it will “not be a real steppingstone for exploration.” Krasnov finds this attitude “troublesome for the whole idea of international cooperation in space,...there won't be any guarantees for anybody who might consider joining the United States in the new space exploration vision — that this vision would not be changed again someday.” As far as exploration of the Moon and Mars: "At some point we could combine the two exploration programs," Yuri Karash, a space policy consultant, said. "This would be the most effective division of labor between the countries."<sup>68</sup>

They are also trying to get ESA interested in the “Kliper,” however not all the member states of the EU are in favor of this project. They are trying to get Japan interested in this project as well. The Kliper would hold up to 6 people and it’s flexibility would allow it to be used for different types of missions.<sup>69</sup>

## **Skills**

The Russians have a long history of building engines and rockets. Their experience in launching is unequalled. (They lacked reliable electronics and so had maintained a launch rate of around a hundred per year since the 1960s) Their workhorse rockets are long-proven, including the powerful Proton. The RD-170 has 1.63 million

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<sup>67</sup> Heppenheimer 351

<sup>68</sup> Boyle 3

<sup>69</sup> Boyle 1

pounds of thrust, more than any other rocket engine currently in use, since the Saturn 5 is no longer in production.<sup>70</sup> The Soyuz has a great safety record and has been used for many of the trips to the ISS. Russia has excellent rockets and engines that can be built and launched at low cost. For example launching the Soyuz costs \$60 million, compared to \$550 million for the space shuttle.

## **Needs**

Since its founding after the fall of the Soviet Union, Roskosmos has been troubled by lack of funding from the Russian government. In the 90's this forced them to become involved in the commercial satellite and space tourism businesses. Between 1999 and 2005 the Russian economy has been growing steadily as a result of high oil prices, it is currently at 9<sup>th</sup> in the world as an oil producer and is expected to reach 6<sup>th</sup> if the current trends continue. It is ranked 51<sup>st</sup> in the world in terms of availability of capital, next to Tunisia, Colombia, and Peru.<sup>71</sup> In 2001 their budget was \$200 million a year, but with the higher oil revenues they now have a 10 year budget of \$10 billion, still a very small sum compared to NASA's budget. Their slack resources consist mainly of knowledge, technology, and personnel.

## ***Virgin Galactic***

Virgin Galactic is a multimillion-dollar cooperation founded by billionaire Sir Richard Branson. He began development of the company in the early 1990's when there was no technology to fulfill the company's needs. This changed when Burt Rutan's Scaled Composites developed a craft to win the Ansari X Prize, completing two manned missions into space in a limited time reusing the same craft. Days before the first of the two missions, Virgin Galactic licensed the technology from Scaled Composites to begin commercial travel into space. Richard Branson has made his vision clear; he intends to make Virgin Galactic the Model-T of space travel.<sup>72</sup>

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<sup>70</sup> Heppenheimer 342

<sup>71</sup> Milkin

<sup>72</sup> Virgin Galactic website

Scaled Composites completed Tier One, or their entry into the X Prize, on a budget of twenty to thirty million dollars. The actual budget is estimated, but this estimate shows the scale of work that can be done with this range of budget. Virgin Galactic is designed to make money, already making twenty thousand dollar reservations for two hundred thousand dollar flights starting in 2008.<sup>73</sup> Scaled Composites is mainly funded by Paul Allen, who is worth over twenty billion dollars. He has the option of investing as much money as needed to ensure the company's success.<sup>74</sup> Virgin Galactic has its own billionaire as well, Sir Richard Branson, owner of the Virgin Group. The Virgin Group is a comprised of over 25 companies including Virgin Atlantic, a passenger airline, catering to economy and luxury customers, worth over 2 billion dollars. Both of these sources can be used if the company goes over their current budget and profits from the twenty thousand dollar reservations. The company has also attracted state funding, receiving \$200 million for a spaceport in New Mexico.<sup>75</sup>

The company's motives are noble, but their limited size will severely limit the scale of the projects they can achieve. The company's current trips to the near edge of space will have to be wildly successful to grow the company to a size capable of venturing further into space. Making travel to space more common will help lower overall costs and foster related technologies, helping achieve the longer-term goal of low earth orbit. While this private sector may appear to be booming, they have a lot of cash flow problems and much technology to develop. On the other hand they are focused and have an incentive to reduce the cost of access to space. Another option would be to license certain technologies from organizations with experience looking for funding, namely the US and Russia. Scaled Composites was founded to revolutionize the space industry. Virgin Galactic will have investors to answer to and pay back.

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<sup>73</sup> Virgin Galactic Website

<sup>74</sup> Forbes.com

<sup>75</sup> Virgin Galactic Website

## **Motivations to go to the Moon**

Without some driving force, the growth into space will be slow if not completely stagnant. Luckily there is no shortage of reasons to go into space. Even though the exploration of space is a massive undertaking, there are a number of factors acting to counter the cause for working together rather than competing. This section of our report focuses on the motivational factors that will lead to a return to the moon.

The motivational factors we will be focusing on are the rise of space tourism, the desire to be the first to go to Mars and the related value of training on the Moon for Mars, the prospect of mining Helium-3 from the lunar surface, the possibility of mining the moon for other minerals, and other possible scientific reasons for building a moon base. Each section will outline what the motivation is, what technology is required to make the motivation applicable, which countries will be interested, and how economically feasible is the mission. These sections will also address how these motivations may lead to international cooperation or competition.

### ***Space Tourism***

Space tourism is one of the possible factors that will affect international cooperation in space. Space travel is a costly venture, and space tourism would be an excellent way to generate revenue. Since space tourism is in the early stages of technical maturity, it will follow other similar industries in the early stages. The National Space Society accurately put it when they said, "...money from these early adventurers will in turn fund new technologies and vehicles to meet the needs of a growing industry. As the space tourism industry grows, travel will become better, more efficient, and more affordable to more customers."<sup>76</sup> The potential space tourism market is huge, and when an industry like this explodes, the profits generated always have a large impact on economies, which could make many countries interested in space tourism. Right now it seems that the focus would be on suborbital trips, but eventually, plans for an orbital or geostationary outer space hotel could be possible. A geostationary "hotel" could also be

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<sup>76</sup> NSS 1

located such that it could operate as a spacecraft or transit point for transferring large numbers of people as a “cruise” ship that never landed on the Earth or the Moon.

This motivation for tourism infrastructure is simply an economic venture. The CNSA is really the only government space agency that has expressed any interest in it. It really will not have many implications for China other than a less preferred way to recover its investment in a Moon base undertaken for political and military defense reasons. Much like Apollo, it would be a demonstration of technological prowess in areas related to military capability. Its operational military, political, and scientific implications are quite limited as tourism only demonstrates an ability to move and sustain operations, troops or businesses. At this point, it will require many technological advances, just to sustain life for extended periods of time on space stations and in a Moon base cheaply. It will also require a cheap way of transporting people into space, and this problem is really the only factor that might attract the assistance of any of the existing space agencies. With many privatized companies working to make space tourism possible, the aerospace industry could see technological advances that space agencies can use, but at this point, the future of space tourism is still too uncertain to be a motivational factor refocusing the agencies, on leading them to cooperate.

China has a strong interest in setting up a space base habitat on the moon, and a large part of that will be paid for by the space tourism industry looking for someplace new and exciting to go. It is believed that by permitting space tourists to be passengers on their various missions, they will promote more missions and turn their space program into a self supporting commercial industry. The chief commander of the CNSA, Yuan Jiajun says China will “Establish a sound mechanism to commercialize its space technology.” Dean Cheng, a China space specialist with the CNA Corp. acknowledges the fact that “The Chinese space program is not only government run, it is partly military run, so you’re first problem is a fundamental cultural clash [of commercial openness] with the military.” He does go on to say that if these barriers are overcome there is absolutely a demand for such services from the CNSA.<sup>77</sup> China is not the only agency that is definitely interested in heading to space with an emphasis on manned technology.

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<sup>77</sup> [http://www.space.com/missionlaunches/china\\_shenzhou6\\_041108.html](http://www.space.com/missionlaunches/china_shenzhou6_041108.html)

Tourism has a strong attraction for the Russians, but they find the initial investment daunting. They have sent 3 tourists into space for a fee of \$20 million each and are planning on sending tourists around the moon for \$100 million each.<sup>78</sup> They have come to realize the potential for return on investment by sending opulent spenders into space. Considering that their average worker earns a salary of 1,200 dollars a year, one person being sent into space can pay for approximately 15,000 of their line workers; an engineer earns about 15,000 dollars a year, or 1200 technical staff workers. If the trips around the moon become a reality, the RKA will have found a way to recover the \$11 billion they plan on spending between 2006 and 2015.

Virgin Galactic solely exists for space tourism. Sir Richard Branson and Burt Rutan have been clear on their company's capabilities and currently are setting a goal within their reach. All of their projects are centered around sending paying customers into space; their future plans include an orbiting space hotel, building on the tourism goal. Their plan is to fly a total of about 500 passengers a year at about \$200,000 to an altitude of over 100 km for a total weightless time of 7 minutes. Currently, they have a list of over 7,000 people interested in taking flight, and have plans to create a spaceport. However, since this is a private venture, they really have no affiliation with any of the major space agencies. There are no announced plans for any form of cooperation between them and any existing aerospace agency, so it can be assumed they will compete until a mutually beneficial goal arises. For obvious reasons, the space agencies are not so enthusiastic about sending civilians into space, being responsible for their safety and unable to perform any useful work to justify the mission. .

Space tourism is not something that JAXA is directly interested in, but they will lend their support to private ventures in the form of technical expertise. As stated in their vision statement, "In the possible efforts to be led by private sectors to commercialize space tourism in the future, JAXA will provide support to and cooperate with the entities in such areas as health care for crew and tourists, crew training and human safety design, etc."<sup>79</sup>

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<sup>78</sup> Stenger

<sup>79</sup> JAXA 46



A fairly old but very comprehensive review of possible scenarios for the European space tourism industry is provided by E Eilingsfeld and S Abitzsch in "Space Tourism for Europe: A Case Study."<sup>80</sup> They state that in order for space tourism to be possible a cost effective transportation system is needed, as well as a spaceport. This however, was simply an educated hypothesis. As of right now ESA has not announced any plans involving space tourism. So far the only European space company I could find that has shown an interest in space tourism is Astrium.<sup>81</sup> However, as is the case with the majority of other agencies, ESA does not have any formal plans for space tourism, and any European ventures would be by privatized companies.

While shown to be financially fruitful, NASA has not allowed any space tourists to ride in unused seats of the space shuttle, despite strong urging from accomplished astronauts such as Buzz Aldrin.<sup>82</sup> With tickets estimated at \$20 million it would be a great way for NASA to make back money, but they are not opting to take it given the political disaster the loss of Krista McAniff on board the Challenger in 1987. The exact reasons remain unclear and unannounced. Although the position may change under the new administrator Michael Griffin, plans have not been made and would not be conducive with his priorities; reaching Mars directly from Earth's surface.

Space tourism is of interest exclusively as an economic motivation. It has very limited immediate military, political, and scientific implications. While the CNSA and RKA are interested, no other politically involved agency has any interest in tourism. The only real motivation for tourism is to generate return on investment, and most countries don't seem interested. When you consider the budget of NASA, about \$20 billion per year, the profit generated from putting people in space is relatively insignificant part of the budget.

Considering what a small impact this will have on Europe, Japan and the US, it appears that tourism will not be a factor that affects cooperation involving these agencies. The major players in it seem to be unaffected in their mindset by their decision to take

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<sup>80</sup> F Eilingsfeld & S Abitzsch, October 1993, "Space Tourism for Europe - A Case Study", [http://www.spacefuture.com/archive/space\\_tourism\\_for\\_europe\\_a\\_case\\_study.shtml](http://www.spacefuture.com/archive/space_tourism_for_europe_a_case_study.shtml)

<sup>81</sup> <http://www.spaceref.com/news/viewpr.html?pid=2695>

<sup>82</sup> Stenger

part in space tourism. They continue to follow their own philosophies on cooperation and competition unchanged.

## **Mars**

Mankind entered space by always taking the next step; first to the sky, then into space, then to the moon, now onto Mars. Many of the scientific advances from the space program come as a surprise, making it difficult to develop expectations. Mars presents many scientific opportunities pertaining to Earth, being the planet most similar in size to Earth and once having had water and an atmosphere.<sup>83</sup> Working off these similarities, scientists can try to predict what caused the destruction of the Martian atmosphere, discover if life existed on a planet other than Earth, and possibly investigate the origins of life on Earth. Mars represents the next step in exploration and expansion, representing a new frontier where no person or nation's exploratory team has stepped foot before. A Mars mission carries similar national prestige as the moon missions did in the 1960's. Following in the spirit of Columbus, Magellan and Lewis and Clark, a trip to Mars could one day bring colonization or untold industries.

While the technological scale of the project may demand international cooperation, national prestige and the desire to maintain technological superiority will be acting to limit and maybe stifle it. The executive director of JAXA, Kiyoshi Higuchi, has publicly said their aerospace industry and space program cannot support many space endeavors and that JAXA is interested in participating in larger projects in conjunction with other countries.<sup>84</sup> Russia has shown some interest in a Mars mission, but currently cannot afford a mission without outside funds. Russia would be a valuable asset because of their extensive experience in space, but collaboration might compromise military secrets, and using foreign technologies might take away from a sense of national pride the project would bring.

NASA and ESA have already completed unmanned missions to Mars, and both plan to have manned missions in the future. ESA has successfully orbited Mars with

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<sup>83</sup> Mars Society

<sup>84</sup> Shibata, 1

plans, though failed to land their rover. NASA has had numerous missions orbiting Mars and has successfully landed rovers on its surface. NASA and ESA have collaborated on past Mars missions, but have no joint manned missions currently planned.<sup>85</sup> Some may argue that the lack of announced plans would imply a new space race.<sup>86</sup> In order for this race to occur, neither ESA's Aurora Programme nor NASA's Vision for Space Exploration can fall behind or lose any of their funding over the next 15 to 25 years.

The technological requirements for a manned mission to Mars are daunting. The science behind getting a craft to Mars, orbiting Mars, and landing on Mars has been tested and developed further in past NASA and ESA missions. Landing accuracy and returning samples are both high priorities of NASA, and much research and development will be put into efforts to improve their capabilities in those areas.<sup>87</sup> The ability to return samples will provide valuable test data for future manned missions requiring crew return vehicles. Keeping the crew alive and physically fit in an extended Martian mission will be a major technological challenge. Radiation from the sun will require a heavily shielded spacecraft. The Russian and American programs on Skylab, Mir, and the International Space Station have extensively studied medium term effects of microgravity on the human body. Muscles atrophy and bone mass is lost, requiring exercise equipment designed to simulate the effects of gravity on the body. Oxygen, water, and food requirements will have to be met in one of a few ways. Unrealistically, all the necessities could be carried from the beginning of the trip, requiring a prohibitively large amount of supplies at the beginning of the trip. A more realistic approach might be a combination of recycling and acquisition along the way. Mars has water and rocket fuel can actually be made out of a chemical reaction involving the Martian atmosphere.<sup>88</sup> Being able to re-supply on Mars will greatly reduce the amount of materials needed to be carried, but demand mission success to have any hope for crew survival.

While leaving the earth's atmosphere seems trivial in today's generation of technology, it will have a major impact on the nature of Mars missions. If getting the Mars craft into earth orbit remains prohibitively expensive, the mission will be more

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<sup>85</sup> [www.esa.int](http://www.esa.int)

<sup>86</sup> [cnn.com](http://cnn.com)

<sup>87</sup> <http://marstech.jpl.nasa.gov/>

<sup>88</sup> Mars Society

likely to resemble NASA's moon missions; few in number and very expensive. Due to the cost, after the first successful mission interest will dwindle, as will the budget, and little science will be completed. This type of mission will be mainly driven by national prestige and possibly a race between space organizations. If there is a cheap way to get supplies into orbit, weight will be less of a problem in the near zero gravity environment. Lower mission cost will allow for a longer Mars program, more scientific research, and possibly colonization. ESA and JAXA both have commercial launch industries working towards technologies to cheaply transport supplies into earth's orbit. This would be the technical hurdle JAXA would be able to overcome NASA because of the compatibilities in their rocket technologies.

NASA and ESA are the only two organizations with announced long term plans to go to Mars. Despite having coinciding goals, the two mission programs are entirely independent of one another. If a new space race develops, NASA has a history of cooperation with both JAXA and Russia, and could call upon a outside resources to help win the race. ESA is equally as likely to join with another organization to beat NASA, and since it is already multinational will not have the national pride issues that may make NASA balk at cooperation.

As a logical step on the path to going to Mars, both countries plan on going to the moon. NASA will return by 2017 and ESA plans on being there by 2024 in spite of having very little manned space experience and no manned space craft of their own. The area of manned space experience is really where ESA will have to reach out for cooperation with either Russia, the US, or even the rapidly advancing China. The return to the moon for the US is the most distant plan on their timeline. Because this is what they are budgeted for, NASA will to return to the moon in a craft that could just as easily go to Mars as soon as they receive approval for that mission.

### ***Helium-3***

As a potential motivation to go to the moon there is no doubt Helium-3 is the most potentially interesting. Helium-3 has been praised as the fusion fuel of the future. It produces no greenhouse gasses, produces no radioactive waste (in the case of the He3-

He3 reaction), and is inherently safer than fission reactions. The reaction itself also gives off protons rather than neutrons which are believed to be able to be coupled directly into electrical energy at an efficiency of about 70%. The research for this technology is presently being investigated and will be discussed in depth in later sections.

Helium-3 is an isotope of Helium, but unlike the commonly used Helium-4 it is not found in abundant quantities on earth. However, solar winds have deposited at least one million tons of Helium-3 on the lunar surface. It is estimated that 40 tons of Helium-3 could produce enough fusion power to power the US for a year. If the technology breakthroughs making Helium-3 a valuable fuel source on earth become a reality, mining on the moon could become a very profitable venture.<sup>89</sup>

This breakthrough would also have vast social implications and political agendas tied into it. The UN is trying to establish the moon as the common property of all nations, so it may be assumed that benefits from mining common property should be distributed evenly for the benefit of all man kind. It also seems appropriate for some benefit to go to those bold enough to put forth the financial capital to fund such a large scale project. This could potentially lead to an international mining colony on Mars, possibly involving cooperation in the private sector by large corporations like Exxon or Boeing.

There may also be other developments that spawn from the need for frequent transportation, such as a new space station or an orbiting trade depot. There would be a demand for rapid advancements in long term moon base technology, possibly manned or unmanned. If the base were to be manned, other breakthroughs and improvements in space habitats would have to be made.

The potential for Helium-3 to become a valuable fuel source leads to very exciting scientific and social possibilities. It might usher in a new era of international cooperation or possibly a grueling battle over property rights. This was one of the primary inspirations for researching the possibilities for international cooperation in space, and was the deciding factor in focusing on the moon. However, the investigation into all those exciting possibilities has been left to another research group.

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<sup>89</sup> Kulcinski, G.L., Using Lunar Helium-3 to Generate Nuclear Power Without the Production of Nuclear Waste, IFT University of Wisconsin, 2001

The investigation into Helium-3 done in this paper was done from a scientific standpoint. The exciting picture painted in this section represents the possibilities *if* Helium-3 becomes a viable fuel source. They do not represent the conclusions of our group. A more in depth look at the science behind fusion technology as it exists today is presented in the *Feasibility of Helium-3* section.

## ***Mining the Moon***

Launch costs for the space shuttle are \$10,000 per kilogram. Lewis estimates that in the future this should be closer to \$1,600 per kilogram. Computer models developed by NASA indicate that with the mining of propellant on the moon the ultimate ratio that can be achieved is 2.4 tons delivered to low earth orbit for every ton launched from earth. Therefore the material being mined on the moon would have to be worth more than \$667 per kilogram to eventually turn a profit, after the \$20 billion dollar initial investment.<sup>90</sup>

In comparison with mining Near Earth Objects the moon has advantages and disadvantages. The moon is only a week away, compared to NEOs which would take a trip of 2-5 years. On the other hand NEOs have much lower gravity, and this makes the return trip from them much easier than from the moon, where there is a comparatively strong gravitational field.<sup>91</sup>

The alternative to mining on the moon is mining near earth objects. There are asteroids which contain significant amounts of platinum and gold. It is estimated that the first trip to and from a NEO would result in a payback ratio of 3:1. With the value of gold and platinum being as high as they are this is enough to make a profit. “It is estimated that after 5 round trips from Highly eccentric Earth orbit... a payback ratio of 100:1 is possible”. This makes the NEO’s a much more attractive option for mining than the moon, though it would take longer to achieve.<sup>92</sup>

Japan is interested in establishing a moon base. The Selenological and Engineering Explorer (SELENE) mission includes a lunar satellite that will gather extensive information about the moon’s surface. They are considering “a future

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<sup>90</sup> Lewis 122

<sup>91</sup> Lewis 123

<sup>92</sup> Lewis 125

‘international human lunar base’ that might be developed as the place where Japan could fully utilize, maintain and further develop its capability for conducting human space activities.” They are primarily interested in developing technology and doing scientific research, such as “examining internal stratification structure, raw materials constituting planets, process of planetary evolution at the initial stage, tectonic histories, such as those evidenced by craters formed after collisions, as well as geological features.” Their mission statement does not mention mining on the moon. JAXA will only develop a lunar base if the government approves it, this decision will be made in 2015.

The SELENE project would “determine the distribution profiles of lunar crust constituents and the crust structure as well as increase understanding of the exposed parts of the materials constituting deep layers of lunar structure, areas of concentration of particular materials, and unique topographic features.” This kind of information would be necessary before mining on the moon could occur.

Japan and China are the countries who have shown an interest in establishing lunar bases. If China is doing it for reasons of national pride it is not very likely that they would cooperate with Japan, they wouldn’t want to share the limelight with anyone. They do have a history of cooperation with Russia however, and Russia would be willing to help with technology in exchange for money. Japan could cooperate with the US if NASA is interested.

The Russians have shown that they are willing to cooperate with everyone. They don’t have nearly the financial resources that they used to, but their technical ability is still first rate. They still want to be involved in the space exploration as much as possible and are likely to cooperate with whoever will offer them money. Not long ago they were cooperating with Chinese on Cosmonaut training, space suits and capsule design. Now they are mainly cooperating with ESA, supplying them with the manned capability ESA never developed after Hercules was cancelled. Now they will have access to the Soyuz and the Russians are looking for European support in building the Kliper.

## ***National Pride***

The issue of national pride has been among the most powerful driving forces in the history of space exploration. In every case where national pride was a country’s

driving force, space technology has improved at a highly accelerated rate. The best example of this was during the space race of the 1960's between Russia and the US. No other period of space exploration can compare to the pace of development maintained during this period. But just as these periods of national pride driven space involvement accelerate the rate of technology development, few developments were real breakthroughs, competition also inherently drive walls between rivals.

National pride most frequently leads to fierce competition between politically opposed nations rather than cooperation. However, in the case of China it is leading to cooperation with other countries trying to develop their space programs. In this section we will investigate the ways in which national pride may lead to competition or cooperation, and how that will affect the growth of the space industry.

The very idea of national pride is closely tied to military power. Establishing a nation's technological advancement has been another method of establishing a nation's military power since the Cold War of the 1960's. The reason space was such a big deal was because it was generally believed that space technology could be used for espionage purposes and to deliver atomic weapons from intercontinental distances. Space activity was to awe, impress and caution rivals about one's technological prowess in strategic technical fields.

National pride was the driving force behind the US's Apollo program as well as Russia's early rocketry and satellite experiments. Since the pressure to compete ended after the Cold War, space activity was cut back. Russia's economy plummeted causing their space budget to be cut drastically. It was not essential to the government, so it turned to commercial contracts to survive. The RKN has become less driven by national pride, and has no real military or political enemies who might be difficult to work with. Because of this they have become one of the world's most valuable and common partners when other nationals are working on space projects, especially manned space endeavors.

The US on the other hand still has the world's largest space budget and takes a great deal of pride in being the world's leader in this field of technology. The US will work with any country under the right conditions, but maintaining military and technological superiority is a priority. There are some political tensions keeping them from working with China, which is not only another very pride filled country but on



displaying its technical prowess, but actually a country the US wants to embargo from technical transfers. In the case of working with ESA on Mars based projects, NASA is currently cooperating with the Mars Explorer program. However, they are not involved in the Aurora Programme in spite of having very similar long term goals. While nothing has been officially written saying that the US does not want to cooperate because of their desire to stay ahead of ESA technologically, it has been argued that this is a substantial part of the reason why two common allies are not working together on such a massive common goal.<sup>93</sup> The other reason is the radically different organizational mindsets of the two space agencies, especially in manned technology.

As ESA becomes “less and less a civilian space agency dedicated to science, technology, and exploration and more and more an institution dedicated to enhancing the power and prestige of the European Union”<sup>94</sup> their relationship with the US is beginning to strain. ESA’s willingness to just follow along on any blatantly US-driven project has severely dropped. ESA is also working with China on the Galileo and Global Monitoring for Environment and Security (GMES) projects. Even though these programs will be compatible with the US’s GPS system<sup>95</sup>, the US may feel threatened by ESA’s cooperation with China on projects with potential military implications.

It should be kept in mind that ESA and NASA have a long history of cooperation, and are presently involved on a number of different projects together. ESA and NASA are partners, but if there were any inhibitor on greater cooperation in the future it would be national pride. Also, due to ESA’s loosening association with NASA it is likely that expanded global cooperation with other space agencies will be ESA’s trend in the next period as it becomes a rival. ESA has already won the commercial space launch contest with NASA and it is much closer to a space program that pays for itself. Now the question about what to do with the so far unprofitable manned space missions.

As China is pushing to establish their space program, what they are really establishing is that they are a global power and are capable of advanced space and

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<sup>93</sup> Stuart Brown, Martian

Missives, [http://www.firstscience.com/SITE/editor/040\\_ramblings\\_23012004.asp](http://www.firstscience.com/SITE/editor/040_ramblings_23012004.asp), 2004

<sup>94</sup> Dinerman, Taylor; NASA and ESA: A Parting of Ways? <http://www.thespacereview.com/article/539/1>

<sup>95</sup> The First Galileo Satellites – Giove Brochure, ESA, November 2005

military technology. This underlying message has not gone unnoticed, and in the past has been a large reason why the US and China have no joint space projects.

China's economy has been enjoying a very rapid rate of growth due to their strong educational system and increasingly technological society with government subsidizing industrial expansion. For them their involvement in space is a way of announcing to the world that they are a technologically advanced modernized society. This attitude has led them to take on a leadership role with a number of developing space programs. China has an interest in working with nearby countries and formed the Asian Pacific Space Multilateral Cooperation (APSC). In 1992, China, Thailand, Pakistan and a few other countries sponsored the "Asian-Pacific Multilateral Space Technology Cooperation Symposium." In 1998, the governments of China, Iran, the Republic of Korea, Mongolia, Pakistan and Thailand have signed the "Memorandum of Understanding on Cooperation in Small Multi-Mission Satellite and Related Activities." China is also working with Brazil in the areas of satellite technology, satellite application, and satellite components. Their first jointly produced and designed satellite was launched in October, 1999.

Even if some of these missions and projects seem symbolic, that is half the point of national pride. China's dominance in Asia, symbolic or otherwise, is their first step to establishing dominance on a global scale. The CNSA's future projects are aimed at this end. They are attempting to land a man on the moon, which only one country has done, and they plan to set up a permanent moon base which no country has ever attempted. There is very little definitive information as to what will actually be done at the moon base. There is speculation that there will be mining for Helium-3, space tourism, a scientific lab, possibly an astronomical observation center, or the base could be a first step toward colonization. It is unlikely that one could to alleviate China's growing population problem, but there is a whole new world to populate. This could be a result of the base being so far in the future, but a project of that scale is usually not planned for and funded without a definite purpose. Project 921 has always been semisecret and the Chinese space program has been called a maze inside a maze.

Lunar exploration would have an “immeasurable usefulness to raising national prestige and inspiring the nationalistic spirit,”<sup>96</sup> said Luan Enjie, vice-minister of the Commission of Science, Technology and Industry for National Defense and director of the CNSA. In a separate interview he said,

Lunar exploration represents a leap in aerospace technology and a new point of scientific and technology innovation, it helps promote implementation of the principle for rejuvenating the country through science and education... At present when the world program of returning to the moon has not yet been in full swing, we must seize the opportunity and start China's lunar exploration project as quickly as possible, to ensure that China has a niche in the international lunar exploration activity.<sup>97</sup>

It is not to say that China will be sight seeing on the moon. Luan sighted a number of other good reasons to go to the moon, but it cannot be denied that national pride is a large part of the reason for the moon base.

According to a CDI (Center for Defense Information) security update, after a visit to a Chinese base for manned space missions, it seems more optimistic that the US and China may be able to work together in space in spite of their national pride issues.<sup>98</sup> However, this is a first gesture of good will in this area and there are no official plans for cooperation between these two countries that can hardly be considered allies.

Japan historically has been willing to cooperate with pretty much every space agency other than the CNSA. Their plan to become a leader in aerospace technology does not seem to undermine their willingness to cooperate. As stated in their vision statement, they realize that the scope of the future of aerospace is too broad for them to handle alone, and will look to other nations for help with finance and technical support.<sup>99</sup>

National pride is the primary driving force behind the CNSA and is leading to an increase in international involvement with everyone but the US. Political history more so than national pride is what's keeping Japan from working with China, and other than that

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<sup>96</sup> Oberg, James, China Takes Aim at the Space Station, <http://www.msnbc.msn.com/id/3077826/>, MSNBC 2001

<sup>97</sup> Interview: Why does China start lunar exploration program?, [http://news3.xinhuanet.com/english/2003-03/04/content\\_3601024.htm](http://news3.xinhuanet.com/english/2003-03/04/content_3601024.htm), Xinhua News Agency 2003

<sup>98</sup> CDI Space Security Update #3 Feb 12, 2006

<sup>99</sup> Japan Aerospace Exploration Agency, JAXA Vision – JAXA 2025, March 31, 2005

national pride has no real affect on either Japan or Russia's involvement internationally. National pride certainly has the potential to be the determining factor for competition or cooperation between the US and ESA as they advance toward the moon.

The economic case for cooperation is at odds with the political desire for prestige. It is not yet clear what the potential partners/rivals will do yet. The world has never seen anything quite like this since the European nations of France, Spain, England, Portugal and the Netherlands all went to sea together and competed their way to a global economy while planting colonies around the world in search of empire and glory. Hopefully this new age of discovery will be more peaceful than the last, but again people are thinking in terms of strategic bases from which to expand operations. This is the logic that made Jamestown, Hong Kong, Macao and for made the Caribbean Islands and later the Pacific Islands so valuable.

## Feasibility of Helium-3

The majority of information and research done for Helium-3 is focused on the social implications, and feasibility of mining the material from the lunar surface. Very little research has been done to see how feasible Helium-3 is as a fusion reaction fuel. It is clearly an outstanding fuel source in terms of being a clean burning fuel that produces a tremendous amount of power, but how difficult is it to start the reaction, collect the energy, and to do this for a gain of power? The use of Helium-3 as a fuel depends on the success of Inertial Electrostatic Confinement (IEC), and the relative success and interest in the Deuterium-Tritium reaction. This section will introduce the basic idea of fusion reactions and explain why the He3-He3 reaction is so difficult and to show why He3 is unlikely to be the next fuel source for the Earth's economy.

### ***Fusion Basics***

Current nuclear technology is based on a fission reaction which has proven to be extremely dangerous. It requires radioactive fuel, produces radioactive waste, and the neutrons released \ make other things around it radioactive. A fusion reaction can be done with non-radioactive (or slightly radioactive) fuel and will produce a normal helium atom which is also not radioactive and possibly either a non-radioactive proton or a single free neutron. A fusion reaction is inherently safe, so the only possible danger would come from a breakdown in the energy supplying or capturing processes. There have been great advancements in chamber technology that will reduce the rise of radioactive byproducts and equipment.

There are a number of different possible fuel combinations that will result in a fusion reaction. So far, the only combinations to have been demonstrated in fusion are the Deuterium-Deuterium (D-D) reaction, the Deuterium-Tritium (D-T) reaction, and the Deuterium-Helium-3 (D-He3) reaction. Deuterium and Tritium are isotopes of Hydrogen. Deuterium is very common, can easily be extracted from ocean water and exists in any structure containing hydrogens at an average rate of 0.015%. There is an estimated 5 trillion tons of it on earth. Tritium is a slightly radioactive material and must be artificially produced as there are no reliable natural sources for it. Tritium can be

manufactured by bombarding a lithium atom with a free neutron, which could be provided by the fusion reaction itself.<sup>100</sup> Reaction equations and energies for all possible fusion combinations of Deuterium, Tritium, and Helium-3 are shown below, with fusion reactions that have been demonstrated in bold font.<sup>101</sup>

**1.- D+D=n+<sup>3</sup>He+3269 keV**

**2.- D+D=p+T+4033 keV**

3.- T+p=n+<sup>3</sup>He-764 keV

**4.- D+T=n+<sup>4</sup>He+17589 keV**

5.- T+T=n+n+ <sup>4</sup>He+11332 keV

**6.-<sup>3</sup>He+D=p+<sup>4</sup>He+18353 keV**

7.-<sup>3</sup>He+<sup>3</sup>He=p+p+<sup>4</sup>He+12860 keV

8.- <sup>3</sup>He+T=n+p+<sup>4</sup>He+12096 keV

9.- <sup>3</sup>He+T=D+<sup>4</sup>He+14320 keV

One reaction choice of interest that has not yet been performed is the He3-He3 reaction. This reaction is of great interest as far as radioactivity is concerned because it produces no radioactive waste. This could be said of the D-He3 reaction as well, but because there are more than two atoms in the fuel the D-D reaction will occasionally occur and produce a free neutron. Both the D-He3 and the He3-He3 reactions will result in released free protons. Because this is a charged particle, it can theoretically be coupled directly into electrical energy at an efficiency of about 70%. However, this proton may lose kinetic energy trying to escape the electric or magnetic field the fuel was confined in, and the actual coupling into current is much more difficult than expected.

The likelihood of a reaction occurring at all is related to the Maxwellian velocity-averaged cross section  $\sigma v$ . As seen in figure 1 the reaction that has the highest probability of occurring is the D-T reaction. Other charts include the He3-He3 reaction, but the x-axis was only in terms of IEC parameters. The He3-He3 reaction would start around the  $10^2$  mark on this graph.

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<sup>100</sup> L.A. Booth, D.A. Freiwald, T.G. Frank, F.T. Finch, "Prospects of Generating Power with Laser-Driven Fusion", IEEE 1976

<sup>101</sup> Prospects on the use of Inertial Nuclear Fusion, [http://www.worldenergy.org/wec-geis/publications/default/tech\\_papers/17th\\_congress/4\\_1\\_31.asp](http://www.worldenergy.org/wec-geis/publications/default/tech_papers/17th_congress/4_1_31.asp), 4/10/06

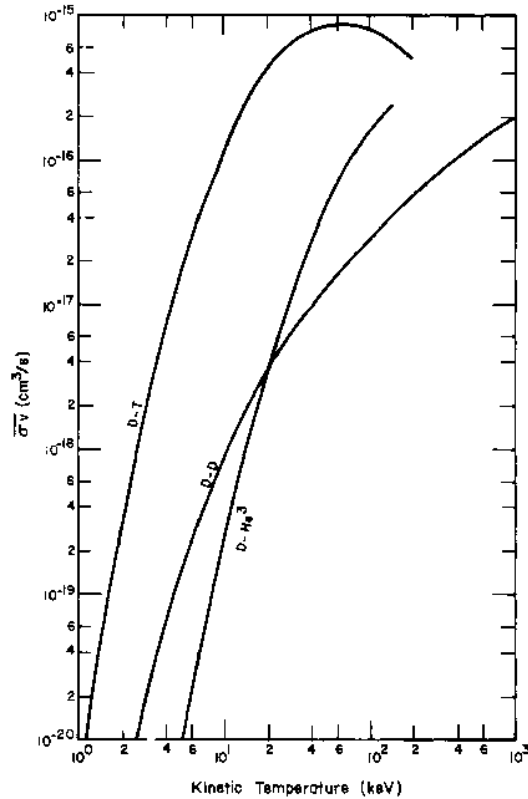


Figure 1: velocity-averaged cross section vs. kinetic energy present

## **Inertial Electrostatic Confinement**

According to Dr. Gerald Kulcinski<sup>102</sup> of the University of Wisconsin, and Dr. Wilson Greatbatch<sup>103</sup> the Helium-3-Helium-3 reaction and Inertial-Electrostatic Confinement Fusion (IEC) are the future of fusion. So far the University of Wisconsin has demonstrated the world's first D-He3 reaction and hopes to have the world's first He3-He3 reaction in the near future. The D-He3 reaction was performed with an efficiency of less than 1%, and energy benefit estimates are just based on energy received, not net energy gain. Some new breakthroughs such as the Pennington and Pennywell IEC chambers have overcome some of the technical challenges involved, but need to be tested and will still be a long way out from the break even point.<sup>104</sup>

<sup>102</sup> University of Wisconsin, Engineering Physics, <http://www.engr.wisc.edu/news/ar/2000/ep.html>, 4/6/06

<sup>103</sup> American Stewardship of the Moon, <http://www.meaus.com/moonproject.htm>, 4/6/06

<sup>104</sup> Santarius J.F., "Brief Overview of Inertial-Electrostatic-Confinement Fusion," 2002

The best and most credible source on why IEC will more than likely not become a reality came in the form of a review of IEC technology present and future in 1995.<sup>105</sup> Some large steps have been made in the design of IEC fusion chambers, but the physics have not and never will change. The design focused on in the paper is the exact electron grid structure that Dr. Kulcinski has been using in his laboratory.

### ***Technical Feasibility***

There are a number of losses involved in the IEC process, some of which are due to the present designs, while others are inherent losses due to the physics of IEC. The general idea of IEC is that a system containing a plasma of the fuel is created so the electrons are stripped from the nuclei. Within this system a highly negative source is created at the center which attract the positively charged protons, while a highly positive source on the outside draws away the electrons. This creates an electrostatic potential well at the center where protons will be attracted at high velocities and (ideally) collide with each other.

The reason this style of fusion is used as opposed to inertial or magnetic confinement is because it is believed that a non-Maxwellian distribution can be maintained by this system. This means the reaction rates would no longer be distributed as shown in the reaction rate figure shown earlier. This would make it easier to perform a He3-He3 reaction at lower temperatures. It is also believed that the energies of the ions can be kept at significantly different energies. That is the system could keep the electrons cooled while super heating the protons. This condition is necessary in order to get the positive ions to travel at a velocity high enough to collide and result in a fusion reaction.

Neither one of these two conditions can be maintained by the present designs. The rate at which the ion distribution falls from the mono-electronic distribution back to the Maxwellian distribution is much greater than the rate of fusion reactions, which means a tremendous temperature would be needed to start the reaction. Also, it can be shown that the ion energies are not significantly different, and that the electron temperature will be within 5% of the nucleus temperature at equilibrium. This means the

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<sup>105</sup> Rider T.H., "A general Critique of Inertial-Electrostatic Confinement Fusion Systems," MIT 1995



electrons would have to be cooled by an external source to maintain their energy separation. If this is not done, the reaction will not be able to take advantage of resonant peaks in the fusion cross section (peaks where reactions are much more likely to occur). This means the overall probability would be taken over several resonant peaks and gaps, lowering the average probability and rate of reactions. These two problems do not make it impossible to create a fusion reaction, it just means a significant amount of energy must be added to make the reaction occur.

Some losses exist that are not engineering obstacles, but rather facts of physics that cannot be changed. Ion upscattering losses are the losses due to ions escaping a useful proximity to the IE well. Bremsstrahlung losses are radiative losses as a result of electron-ion collisions. These collisions result in a cooled electron colliding with a hot ion and reducing the equilibrium temperature. However, this is the primary loss component in all fusion confinement types.

Design losses are due to present IEC designs, and could possibly be overcome if a new design were to be made. Electron grid losses and ion grid losses are the result of electrons or ions colliding with the wire grids. This loss can be several orders of magnitude greater than the fusion power produced. These collisions also cause the grid to heat up which means energy must be used to cool the grid. These losses can be reduced by introducing a magnetic field to the grids, repelling the charged particles. However this fix results in electron cusp losses which are presently the most severe source of loss in the Penning-trap (charged grid) device. Electron cusp losses involve the escaping of electrons through edges in the magnetic field; giving the system a lower input to fuel efficiency and also making it harder to get a high density core. These losses are only present in IEC, and were overwhelmingly high in all fuel choices except for DT, and even in the case of DT the losses were very high.

Other loss mechanisms include electron thermalization, synchrotron radiation, poor core density, deviations from spherical symmetry, anisotropic instabilities, and the technical issues with the energy coupling to extract energy from the system. Even though the emitted product is a charged proton, with the present design it is extremely difficult to position enough reverse charge inductors to capture a reasonable portion of this charge. This means that the ECF technique has tremendous inherent losses, many problems that

require engineering breakthroughs, and even if these losses and problems were to be overcome DT would still be the best fuel choice for its higher reaction rate and higher gain.

Since the time that the article was written, a D-He3 reaction has been successfully performed, but with the devastatingly high loss. Right now the reaction produces 1mW of power for every 1kW it consumes. This means it takes one million times as much energy to start the reaction than it produces.<sup>106</sup> This number falls even below the numbers reported in the MIT article that said IEC was not a viable option.

Even assuming optimal 70% gross efficiency (presently only about a 1% efficiency), the long term projection for the uses of He3 as a power source is only for 50-100MWe power plants, when the US presently uses over 10,000 MWe.<sup>107</sup> And this information is coming from an optimistic source that is focused on “Lunar” Helium-3. As a frame of reference, the Hoover Dam is a 1500MWe facility, a large fission reactor produces about 1300MWe, the ITER MCF project predicts up to 3000MWe, and the HYLIFE II and Z-pinch ICF designs predict about 1000MWe.

## ***Economic Feasibility***

The problem is that Dr. Kulcinski, Dr. Greatbach, and their team of 2 researchers and 2 grad students are the only ones pursuing the He3-He3 reaction. The reality of the situation is that there is no budget for He3-He3 and very little for the D-He3 reaction research. A huge amount of money has gone into magnetic confinement fusion (MCF) research and into inertial confinement fusion (ICF) research. The ITER program is primarily the EU’s international magnetic toroidal core program and is scheduled for completion around 2020.<sup>108</sup> The National Ignition Facility (NIF) is the US’s ICF program and was originally scheduled for completion in 2010, but is now ahead of schedule and predicts a completion date of 2008, and expects to have lasers performing above output specifications. Outside of the US, Japan’s Institute for Laser Engineering

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<sup>106</sup> Hedman, E.R., “A fascinating hour with Gerald Kulcinski,” 2006

<sup>107</sup> Using Lunar He3 to Generate Nuclear Power, [http://fti.neep.wisc.edu/presentations/glk\\_isdc.pdf](http://fti.neep.wisc.edu/presentations/glk_isdc.pdf), 5/28/01

<sup>108</sup> FES flier for MFE [http://www.sc.doe.gov/Sub/Organization/program\\_offices/Fusionflier.pdf](http://www.sc.doe.gov/Sub/Organization/program_offices/Fusionflier.pdf), 12/04

(ILE) is creating the FIREX I and II to have a gain of 10 by 2015, and France is planning on completing their MegaJoule facility with a gain of about 60 by 2012.

Both the ICF and MCF programs are using a D-T (Deuterium - Tritium) reaction. At the moment ICF and MCF are really the only two options as far as the US government Department of Energy is concerned. The University of Wisconsin research team was operating under a \$35,000/year budget now up to just over \$100,000, where as \$13M have just been appropriated for an addition to the OMEGA laser fusion facility in Rochester, \$3 billion have been spent on the NIF project with another \$1 billion projected before its completion<sup>109</sup>, and the US is planning on spending \$1.1 billion on the ITER program which is only 9.1% of the total proposed budget of \$12.1 billion.<sup>110</sup> In fact, if you go to the department of energy webpage, there is absolutely no mention of the D-He3 or He3-He3 reactions.

According to Dr. Kulcinski the reason IEC is not being funded by the DOE is because they don't trust NASA to get the fuel, and he also says NASA isn't getting the fuel because they don't trust the DOE to produce the technology.<sup>111</sup> The fact of the matter is the DOE did research on IEC back in the late 50's and early 60's when all confinement technologies were in their infancy. The conclusion that was reached by researchers at the Los Alamos National Laboratory was as follows, "Although we conclude that it is of doubtful utility as a thermonuclear reactor, it may be possible to produce in this way small regions of thermonuclear plasma for study."<sup>112</sup> More research was done by Dr. Hirsch and Dr. Farnsworth through the late 60's to bring the technology to where it stayed until the mid 90's.<sup>113</sup> The University of Illinois<sup>114</sup> and University of Wisconsin<sup>115</sup> brought interest back into IEC in the mid 90's, but used essentially the same technology. Dr. Kulcinski of the University of Wisconsin is the only one to claim

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<sup>109</sup> Livermore Lab's future tied to risky laser project Fusion attempt fosters doubt in Congress and among scientists, San Francisco Chronicle 11/13/05

<sup>110</sup> ITER, US DOE Office of Science, [http://www.sc.doe.gov/Sub/Newsroom/News\\_Releases/DOE-SC/2006/ITER/ITER%20updated%202002-13-06.pdf](http://www.sc.doe.gov/Sub/Newsroom/News_Releases/DOE-SC/2006/ITER/ITER%20updated%202002-13-06.pdf), 2/06

<sup>111</sup> E.R. Hedman, "A fascinating hour with Gerald Kulcinski," Space Review 2006

<sup>112</sup> Elmore, Tuck, Watson, "On the Inertial-Electrostatic Confinement of Plasma" Los Alamos Scientific Laboratory 1959

<sup>113</sup> Hirsch, R.L., "Inertial-Electrostatic Confinement of Ionized Fusion Gases" Journal of Applied Physics 1967

<sup>114</sup> G.H. Miley, "The Inertial Electrostatic Confinement Approach to Fusion Power," FSL Univ. Illinois 1995

<sup>115</sup> J.F. Santarius, "Brief Overview of Inertial-Electrostatic-Confinement Fusion," Univ. Wisconsin 2002

even modest possibilities for Helium-3 as a fuel for power production on earth. It is safe to say the DOE's decision not to fund IEC is not based on political distrust, but rather on decades of scientific research, and the fact that ICF and MCF are both very promising technologies. An ICF reaction is expected to produce a better than break even reaction by 2008, and MCF reactions should produce gains in the hundreds by 2020.

Helium3 does not only have to overcome technical challenges, but also has to be competitive in a very aggressive industry. Robert Zubrin said "A Kilowatt is a Kilowatt;"<sup>116</sup> referring to nature of the power grid. The consumer does not know exactly which power plant their power is coming from, and the bottom line is the price per kilowatt. There are many ways to fulfill the world's energy needs without leaving the face of the planet and they do not require as high of an initial investment. The advantages of a Helium3 reaction are largely ignored in an industry with a history of tolerance for massive amounts of pollution. For rough cost estimates, Helium3 is often compared to the price of oil; computing the equal amount of energy output and using the price of oil. This ignores the difference between the theoretical efficiency of Helium3 and the actual efficiency. The oil comparison ignores the portability of oil; as petroleum and diesel fuel oil supports our transportation needs, a niche Helium3 will be unable to fill directly, as it is only a source of electricity. The inadequacies of Helium3 will drive its price down, making the return on investment in lunar mining operation worse.

### ***Prospects for Helium-3***

Even though IEC, the D-He3, and the He3-He3 reactions are not technically feasible, that does not mean a lunar Helium-3 mining colony is impossible. Helium-3 might one day be used as a propellant for space crafts.<sup>117</sup> It does have potential medical applications that are very promising. But there are no known areas of application that make Helium-3 a reason to go to the moon, only something interesting to get if you already happen to be there. The US Department of Energy has paced its bet on Lithium

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<sup>116</sup> Zubrin, [Entering Space](#)

<sup>117</sup> Velarde, Guillermo, Martinez-Val, "Prospects on the use of inertial nuclear fusion," [http://www.worldenergy.org/wec-geis/publications/default/tech\\_papers/17th\\_congress/4\\_1\\_31.asp](http://www.worldenergy.org/wec-geis/publications/default/tech_papers/17th_congress/4_1_31.asp) Instituto de Fusion Nuclear, Madrid, Spain 2001

to tritium as far as the Earth economy goes. Helium-3 will however be the local fuel available on the Moon for Lunar operations.

Another interesting aspect is that perception and persuasion may play just as large a role in the decision making process as the science behind IEC. Dr. Kulcinski has recently become an advisor for NASA, and if he could potentially convince NASA and the DOE that Helium-3 is the fuel of the future, then it is not inconceivable that plans for a Helium-3 production plant on the moon could come to be. I have not been able to find any information on China's plans for a Helium-3 reactor, though I did find some for a Chinese ICF DT reactor. According to Luan Enjie, director of the CNSA, one of the many proposed reasons for China's desire for a moon base is to mine the surface for Helium-3. In the US case, the DOE has absolutely no intentions of funding research for Helium-3, so even if NASA did want to develop the technology and go mine the moon, they would not have the US Department of Energy budget and would more than likely not be able to fund it themselves. So, the desire to mine lunar Helium-3 may be more dependent on perception and budget than on the reality of the technology. So far, the only nation interested in a moon base for lunar Helium-3 is China, and they could be thinking in a time frame well beyond the end of oil on Earth. We have a few more centuries before the coal supply is exhausted. The question is whether global warming and other environmental concerns will allow us to use coal that long.

## **Forecast for Cooperation**

In this section we will forecast possible scenarios for space activity and cooperation. We will use the mission goals sections and organization outlines as the basis for our predictions. Some of these scenarios may also be time dependent, so we will also discuss how the timeframe will affect the scenario. This discussion will be presented in order of how likely a boost in space activity would be as a result of the scenario occurring (not necessarily likelihood of becoming a reality).

### ***Helium-3 Becomes the Fuel of the Future***

#### **Scenario 1: Rapid Development of Electrostatic Confinement**

The event most likely to cause a major boost in space activity would be if Helium-3 fusion were to become a reality and generate large investment. Unfortunately, as previously discussed, this also happens to be among the least likely events to take place. Completely ignoring how long the technology has been around, the rate of present research, both effort and funding, being put into the technology, the present state of Helium-3 reactions, and the political barriers between the DOE and NASA, we can say that even in the event of a TECHNO-MIRACLE breakthrough it is an absolute impossibility for Helium-3 to become a viable fuel for at least another fifteen years. That would make the development twice as fast as either inertial confinement or magnetic confinement has been.

Let's assume this miracle does happen, there is a breakthrough in the field, the  $10^6$  order loss is overcome, everything goes well in production, funding, and politics, and Helium-3 becomes the fuel of choice in 2021. Right now China is the only country with established plans to go to the moon with intentions of building a permanent base. Their present plan is to have a man on the moon by 2017 (or 2020 depending on the source). Because there is no history of how long it takes to build a moon base, it is hard to say how quickly the CNSA could get a mining moon colony set up. But based on China's present rate of acceleration through technological advances in space, their history of cooperation in space with Russia, and their increasing space budget, we could make an estimate of five years from touchdown on the moon to the beginning of a mining colony.

This time could be further reduced if the moon base is automatically constructed as suggested by Zubrin. If this were the case, a small mining colony might already be set up by the time China lands on the moon in 2017 and Taikonauts would be there to test and expand it. Under this scenario China would have a tremendous advantage and develop a near monopoly on the Helium-3 industry, as well as control of the south pole's ice water supply, eighty percent of the total water supply on the moon.

However, there are also considerations such as the time between the time of technology breakthrough and the time of technology realization. Even considering the extreme simplicity of the electrostatic confinement setup, it is safe to assume the facility would take at least five years to build before the technology could be confirmed and used. So, let's say the last of a number of essential technological breakthroughs occurs in ten years, and it takes another five years to build the facility, landing at our target miracle year of 2021. With a five year window between breakthrough and usability (2016-2021), this places the breakthrough just before China's expected moon landing.

If NASA does not do anything on the moon between now and then, this would make the United States and China about even in experience with the moon. However, it could be assumed that China would already have some plans for a base at the time of the breakthrough, giving them an advantage. It is possible that NASA could get a new budget approved very quickly under these circumstances and begin plans for their own mining colony and beat China to the moon using spacecraft designed for Mars.

Given NASA's diplomatic history with ESA and Japan it is also likely that NASA would team up with one or both of these organizations as well. It is possible that ESA could team with the CNSA, but we believe that would be too serious of a political statement for ESA to be authorized to make as their ties with the EU are becoming stronger and better defined. Also, Japan has already shown interest in making a moon base for scientific purposes, so they may already have tentative plans comparable to those of the Chinese by the time of the breakthrough. Under this scenario it is likely that the ESA/NASA/JAXA team (ENJ team) would beat the CNSA to the moon, but none of the participants would have the national monopoly China would have had in the first part of this scenario. The CNSA would arrive shortly after the ENJ team and the infrastructure for trade with Earth would begin to be developed.

Even in this extremely short term timeline it is likely that there will not be global cooperation in developing the Moon. We envision cooperation between JAXA and NASA, and friendly relations with ESA, but some internal tension as well and at least some level of competition between the NJ unit and the CNSA. The CNSA dominance model is only possible if the technology breakthrough happens very late in the development of a Moon base, and realization of the breakthrough occurs very shortly after. Also, keep in mind that ICF and MCF fusion technologies will both have become realities by the time of an ECF breakthrough, giving Helium-3 competition in the fusion fuel market. It will be a desirable but not an essential fuel. However, Helium-3 will always have several advantages over DT fuel, and would be more desirable if made possible and D-He3 can be implemented at a comparably low cost. The scale of operations will have to be large enough to make imported fuel from the Moon competitive with fuel found or manufactured on Earth. If it were essentially a free byproduct of some other lunar activity, it may be used, but this is a long shot.

## **Scenario 2: Slower Development of Helium-3**

Electrostatic Confinement technology has been around since the early 60's and has only in the last ten years even begun to be developed. Based on how long it has taken other fusion technologies to develop and get close to breakeven technology, it is much more likely that Helium-3 will not be developed for another thirty or forty years. With this sort of a timeline it is possible that Helium-3 might possibly be used by ICF or MCF. This timeframe is hard to make predictions for because no organization has plans that extend beyond the early 2030's. By then it is likely that ESA and NASA will have either landed on Mars or have come very close to doing so. By then one or both of them will have more than likely trained Astronauts on the moon and will at least be somewhat familiar with moon base technology. Because JAXA has intentions of building a scientific moon base it is also possible that they may work with NASA and maintain and develop whatever setup NASA used for Mars training.

Under this very long timeframe, if the technology for Helium-3 is developed it is likely that China will have a slight advantage because they will probably have the most advanced moon base, that was originally been designed to be the hub of a mining colony.



JAXA and NASA would probably be a close second if JAXA succeeds in getting NASA or the US Energy Industry to help fund their moon base. However, it is also possible that China will have already begun mining Helium-3 with the express purpose of developing fusion technology to incorporate the fuel. One of the factors holding Helium-3 fusion back is the extremely limited source of Helium-3. If China had an ample supply for testing and research it may be possible that the People's Republic of China could develop a Helium-3 reactor faster than any other country. They could then sell the technology and be the only provider of Helium-3 for a few years, possibly a decade. Even if the reactor technology is leaked they will still make profits through the Helium-3 trade, and be able to invest the profits in their space and fusion programs. China will want to use Helium-3 technology on the Moon itself since the energy requirements for a mining colony will be very great, and Helium-3 will be the local energy source.

Assuming Helium-3 fusion can be done for reasonable gain and cost at some time in the later part of the century, this scenario seems likely. China would likely have a brief monopoly on the fuel supply when the technology is developed and could have a brief monopoly on the reactor technology. Because of the previously mentioned time lapse between breakthrough and realization, this monopoly would only occur if the technology was developed and kept in China at least until the time of realization. If it is developed elsewhere or leaked early enough for Japan or NASA to develop mining stations, then there would be no possibility of a monopoly, and then a case could be made for cooperative development of the Moon's resources. The participating nations would then specialize in a trade region and exchange services among themselves. They may divide different Helium-3 rich regions for development and exploration and cooperate on the transportation infrastructure to get the product back to Earth.

This scenario still relies on a scientific breakthrough. In the only scenario that is guaranteed to be possible, given that the other two forms of fusion will become dominant sources of fusion power on Earth first and are not expected to produce an unacceptable amount of waste and damage. Without an early breakthrough Helium-3 would be a non-factor in space productivity. Cooperation is more likely to occur on the Moon if resources are tight and nothing important is considered to be at stake. That is presently the most likely scenario, at least in terms of US efforts toward ECF and Helium-3

reactions. The US will be focus on Mars and trying to hold down costs on its Lunar operations. It will want a partner, public or private, to take over on the Moon. If Helium-3 were valuable it would take on a corporate partner to take over and run operations on the Moon. If there is no financial interest it will be other space agencies, especially those of Japan and Europe and later India and Brazil.

No matter what the timeframe, we believe China will work closely with Russia to develop their manned space program. They will take as much training and knowledge as possible, but will ultimately have more of a contractor relationship than a partnership with Russia. This is because China's primary reason for going to the moon is to establish a reputation for technological capability, and in order to do that they need their moon base to have their name on it, however friendly they may be to subcontracted Russian experts. This mindset is evident in their present operations as they take a great deal of pride in having developed their own space technology, even though they have worked closely with and have learned much from Russia. This kind of international cooperation is almost guaranteed to happen and can co-exist with rivalry between the US and China, or after the US shifts it's focus to Mars, leaving Japan and China to develop the Moon.

## ***Space Tourism***

Space tourism may sound trivial, but its potential financial impact, as well as its potential for private sector involvement make it very interesting. China is going to setup a moon base and a space station, and they will be welcoming space tourists as steps along the way as part of their goal of commercializing their space industry. Russia has already allowed tourists to tag along and has sparked an interest among wealthy adventurers. Sir Richard Branson owns Virgin Galactic and purchased Burt Rutan's Scaled Composites which was the company that designed the Ansari X-Prize winner SpaceshipOne. Branson has substantial funds and could rival the space investment being made by several nations claiming to have space agencies. He fully intends to set up a space tourism industry. He has the visionaries, the technical experts, the personal and public interest, and the money to accomplish this feat. It can therefore almost be considered just a matter of time before they succeed.

It has been shown that there is a demand for space tourism even at a fairly high cost per person. Both Virgin Galactic and the CNSA have gotten a tremendous technological return for their money, which means they can do more for less, and will also experience the greatest gain. The realization of space tourism for China will be along the same path that everyone else has already taken to get to space, but the Virgin Galactic approach will most likely be accompanied by a whole new wave of space vehicle development.

Space tourism will not lead to much cooperation at the national level, but there is much room for growth and cooperation in the private sector which could spill over into some of NASA's contractors' territories. This will also create an environment of competition between China and Virgin Galactic, and if Virgin Galactic needs a temporary destination for tourists, the CNSA may even be willing to accommodate them on the Moon if the price is right.

### ***Moon as a Training Ground for Mars***

Right now ESA is the only organization that has announced a plan and timetable for a manned mission to Mars. Their international Aurora Programme has an expected manned mission landing on Mars in 2033. NASA has not explicitly stated its intentions of going to Mars, and thus has not set a budget or a timeline for a manned mission to Mars, but it is clear that Mars is their goal at present. This gives ESA only a slight head start. However, ESA has a severe disadvantage as the Europeans have very few man hours logged in space, and next to no experience designing an operational manned space craft. NASA has extensive manned space experience, and in the event of competition this may be the deciding factor. ESA is having Russia set up a launch pad for Soyuz at its base in French Guiana, near the equator and manufacture Soyuz parts for them. However that cannot make up for the difference in technological expertise. ESA would have to work closely with Russia and start using their expertise in order to begin to catch up with NASA. Russia has already sold training and equipment to China, exemplifying their willingness to cooperate internationally as a contractor, partner, or both.

The outcome of this scenario will depend on time and money. We believe that NASA has a strong desire to go to Mars as is evident in their rationale for a return to the moon. The only issue is when will they have an official plan and budget for a manned mission to Mars, and how far along will ESA be by the time they get it. If, as time goes on and ESA begins to close the technology gap with NASA it will become more likely that NASA will decide to cooperate with ESA in a joint mission, or turn to Congress and suggest a faster pace is necessary to maintain our nations technological advantage for economic and strategic reasons. As ESA gets closer to their mission goal, their incentive to cooperate with NASA will decrease, especially once they approach technological parity. This leaves a window for cooperation initiated by technological need at 2010 to 2020, unless the US furthers its lead and ESA becomes willing to accept a subordinate role to be involved in a mission that would precede their planned arrival by 5 or more years.

NASA has plans to return to the moon in a craft that is designed for a trip to Mars, and they plan to do this no later than 2017. So, presumably the NASA technology advantage will be increasing but to do this they are going ahead with an old technology and design they call “Apollo on Steroids”, rather than trying to substantially advance the state of the art to a single stage rocket to be refueled in Low Earth Orbit or a nuclear drive. The capsule and launch vehicle will not be as luxurious as the Shuttle or carry as many people. As ESA’s capabilities grow so will NASA’s, so for a while the technology gap will either be staying constant or only growing or shrinking slightly, depending on the relative rates of progress of the respective organizations. After 2017, however, everything is up in the air.

By 2017 the Aurora Programme is scheduled to only have a “Human Mission Technologies Demonstration,” and will not land a man on the moon until 2024. Keep in mind, by this time NASA will presumably have returned to the moon seven years ago, and even China will have been on the moon for five to seven years! Because ESA is going to the moon as a stepping stone to Mars they may not be as far behind as that may make things seem. It places them considerably behind NASA in terms of first arrival, but that does not reflect the level of innovation or the sustainability of their design. ESA's delayed timeline and decision to buy rather than develop manned space technology

adequate for a Moon trip allows them to delay design decisions until 2020 to see what new drives and other capabilities develop in the near future. China has not mentioned any plans to go to Mars, but judging by their reaction to the Moon race and the ISS, they do not like to be left out of major space initiatives. China may decide that the moon was not a large enough accomplishment and may join the race for Mars, especially if allowed to join the ESA effort as an equal. The Xinhua news agency is already raising questions as to what China's role will be in the future of Mars.<sup>118</sup> An ESA, Russia, and China (ERC) collaboration would almost certainly result in NASA and JAXA teaming up to match the resource base of the ERC collaboration.

Keeping things simple and just between NASA and ESA, given the present budget plans NASA would be seven years ahead of ESA which does not present much incentive to take on a partner. However, if like the International Solar Terrestrial Physics (ISTP) program, NASA cannot get full funding to go to Mars in the short run, they may be interested in taking on a partner rather than risk having someone else there first. ESA and NASA's parts and programs will more than likely already be designed to be reasonably compatible, as has been the case with early Mars probes. NASA generally does not like to take a back seat role in major space missions, and if they have as massive an advantage as experience in space suggests that they have, then they would not be taking a second seat, and it would be up to ESA to submit to a less than equal partnership. ESA traditionally does not have issues with being either the leader or the follower, but in the case of the Aurora Programme it is an optional program with a lot of investment from individual countries that may have their own agendas. Changing plans to take a subordinate role may not be acceptable, especially if by getting there later the Europeans can stay longer and do more.

Two scenarios leading to cooperation between NASA and ESA would be NASA not receiving an adequate or timely budget for going to Mars and deciding to take on a partner, or NASA getting tied up in politics and ESA closing the technological gap and offering NASA a role as a partner to save money. However, this second option is much less likely than the US Congress realizing that the US technological advantage in space is

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<sup>118</sup> Expert: China's Mars Probe "years away," [http://news3.xinhuanet.com/english/2003-06/19/content\\_926880.htm](http://news3.xinhuanet.com/english/2003-06/19/content_926880.htm), Xinhua News Agency 2003

eroding and boosting NASA's budget. The situation where NASA would be subordinate to ESA would rely solely on NASA's complete inability to produce, which history has shown to be unlikely, but given post-Apollo performance is not impossible. NASA is not the powerhouse it used to be in the Apollo days; having been humbled by errors in the Hubble, Space Station and Space Shuttle programs. NASA will brute force something together before they outright fail to get to Mars, regardless of whether or not they stay and develop a base. Probably the most ideal scenario would be an equal partner joint operation between the two previously competing space agencies.

Right now what is happening is the two organizations have their own separate operations in the planning stage, but are more than happy to help each other out on a particular information gathering mission, as was seen in the ExoMars program. Keep in mind that this cooperation was done for the sake of working together more and not required by mutual financial need. Cooperation was considered desirable as a matter of principal by influential members of both the NASA and ESA organizations. We believe that due to the number of investors and separate planning teams on the part of ESA, in conjunction with NASA's preference for taking leadership roles, the two organizations are most likely going to proceed exactly as they are now as a statement of independence and claim for equality on the part of ESA. They will have two separate Mars missions, but will more than likely aid each other in minor ways upon request and after arrival. These two programs are also interested in maintaining compatibility between their programs, just in case they can't afford to go it alone in the end, or need mutual assistance.

As far as outside competition from China goes, we would not be surprised to see them enter the "race," again out of national pride but to show less interest in being first than in doing it "right", arriving prepared to stay and making the base self supporting very quickly, certainly within 10 to 20 years. They plan on going to the moon for national pride (among other reasons), they plan on making their own space station after not being invited to join the ISS consortium, among other reasons. Face and respect matter, so we would not be surprised to see them enter the Mars race as a statement of national pride if the opportunity arises. Otherwise, they will proceed with their plan to dominate and develop the Moon. Russia is already (and will continue to) work with ESA

in their manned space program unless they get a better offer from someone else, who has money and wants to ramp up rapidly. If the ESA Russia partnership is enough to keep the Russians occupied over the long run it may deter them from taking a strong role in support of China's possible Mars program using its Moon technology. China may be able to get to Mars without Russia's help because Russia does not have Mars expertise, only manned space expertise, which China has already started to get on its own. However, without some outside help it may be difficult for them to compete on the timeline and scale required. Russia has many unemployed and underutilized Aerospace engineers already trained. China's capacity to grow is already strained by a lack of slack resources. However it has a lot of trained people "in the pipeline" as nearly 45% of college students want to major in science and engineering.

What this means in terms of the moon is that both ESA and NASA will go to the moon, ESA by 2024 and NASA by 2017, and China will be there somewhere between 2017 and 2020. China is the only one of the three with expressed intentions of staying, so because none of these countries have both a timeline and a mission goal that coincides with either of the other two nations, we find that cooperation in using the moon as training for Mars is very unlikely, though cooperation when the Mars missions are actually flown is still quite possible.

### ***Moon Base for Purposes Other than Helium-3***

Because China already plans on building a moon base and plans on making it pay for itself they will most likely rely on space tourism, mineral mining, and possibly space manufacturing, all of which are in demand now without the need for a technological breakthrough. We have already established that they will be working alone or with Russia as a subordinate or contractor on given missions. This relationship will be particularly valuable when building a space station and initial habitats on the Moon will closely resemble space stations.

Neither ESA nor NASA plan on staying and developing a colony on the moon. JAXA would like to go to the moon for scientific purposes for their SELENE program, but do not yet have the funding or government approval to do so. This decision would be

made in 2015. Based on past history in space and on earth, JAXA would have little or nothing to do with the Chinese base other than to coexist and have some mutual aid treaties. Their most likely ally in making a moon base would be NASA. JAXA needs money, and NASA may want somebody to tend to their base and interests on the moon other than China as they reach for Mars. NASA has been known to aid Japan financially and has a post World War Two history of cooperation in the development of nearly all technologies. So, if JAXA is to build a moon base (with its decreasing budget), it would almost certainly be done with the assistance of NASA. ESA also has the money to help JAXA and has similar goals as NASA in terms of the moon. They have also worked with JAXA in the past on satellite projects, so they may be the ones to help get JAXA to the moon, but would have to do it much later as they themselves are not planning on going to the moon until 2024. Russia, having what ESA lacks, is more likely to partner with Europe than Japan.

We have also shown that mining minerals can be done with a much greater return ratio on Near Earth Objects than on the moon, but on a longer time scale. Because the minerals being mined are valuable, but not exactly running out on Earth, there is no rush to setup this trade system. We also believe that if NEOs are to be mined they will be mined either by China or large independent corporations. Commercializing space could become a top priority for NASA or more likely ESA. In the past, ESA has been more focused on keeping cost and yield in balance than NASA. NASA may develop an organization similar to Arianespace to sell developed technologies and services, but is more likely to just let its contractors use the technology developed under government contract to seek profit making opportunities.

### ***Independent Contractors Take Initiative***

The reason we did the research on each country's contractors is because the contractors hold a major portion of the real body of space expertise, especially in the United States. Russia is the only country that operates its main facility almost completely as a contractor at the international level. One possible scenario that was proposed to us



was the possibility that maybe independent contractors could break away and team up with each other on either a national or international scale.

Our research shows that there is no chance that China's contractors will break away as they are extremely closely tied to the government and would not have the interest or ability to break away. The majority of NASA's major contractors are government/defense related, and the others are universities that have many interests that are not commercial. For this reason there will probably be no US contractor revolt as long as defense contracts keep flowing. ESA is the only group that uses contractors that are predominantly not government related. They could do work outside of ESA and may do so due to the fact that their involvement is limited by their countries' contributions to ESA projects. However there are no signs of discontent or any partners for them to team up with other contractors outside of ESA.

Even if there were a great desire by the independent contractors to split off from their national space agencies, there is no funding for such a break away. The only way it would make sense for a contractor to take initiative in space would be to make a huge investment with intentions of getting an even larger return. Otherwise they would need someone to fund their rebel project, possibly a Branson type investor. This relationship is not impossible, but would not be on the scale of a contractor revolt. The American Aerospace companies would have to see the United States turn its back on space and dismantle NASA; giving them no alternative to finding contracts elsewhere.

The fact is there is no incentive for a contractor rebellion, no money to fund a rebellion, and there are few contractors that could survive without government grants and contracts. The reason this option was considered was that if there was suddenly a huge demand for Helium-3 and independent contractors with either ESA or NASA felt that they would lose out if they did not establish a Moon base while the space agency was focused on Mars. Clearly this scenario of Exxon forming an alliance with Boeing to mine the Moon for Helium-3 is not going to happen so long as the value of He3 is subject to question. Even if there are all of the necessary breakthroughs to make Helium-3 reactions a reality, it will still not be able to compete with other sources of energy here on Earth, due to complexity, politics and production and transportation costs.

## **Summary**

To sum up the previous sections in a single run on sentence, Helium-3 will not become urgent enough to provoke competition or demand cooperation, space tourism will lead to private sector competition rather than international cooperation between space agencies, training for Mars will be done mostly by independent space agencies. There is not enough incentive to drive the establishment of a mining colony on the moon unless you were already going to be there anyway. The contractors do not have the money or the incentive to revolt, and bring down the cost of access to space enough to make other Moon resources worth bringing to Earth. The only two countries definitely interested in building moon bases will absolutely not work together, though Japan may be interested in a partnership with the United States simply to keep China from having a monopoly on the Moon. Cooperation on the Moon will probably be at a very modest level between ESA, the CNSA, and NASA, and Russia will work with anyone who will pay them. JAXA is really the only organization that will definitely need to cooperate if they are to go to the Moon in time to be a factor driving the United States.

This is not to say that cooperation in space will not happen, just that the most reasonable scenarios for Moon development do not require it and thus its unlikely. Cooperation on efforts toward Mars are very possible and should be looked into more in depth. Also, cooperation on the construction of space stations may become a factor. ISS in LEO is no longer attractive to NASA and ESA, but it is in a position that makes it accessible to Russia and Japan, whom plan to use it for materials research. CNSA wants to at least lead the construction of their own space station, but will probably welcome Russian help. NASA and ESA will need a departure point for the Moon and Mars, hence a station in GSO would be of some value to them.

## Future Projects

In the conceptualization of this project we began with a much broader look at international cooperation in space, public and private. But after much debate we decided to focus on international cooperation just focusing on the moon. While completing this research we realized that it may have been a good idea to further investigate other space missions as well as the Moon is part of plans and policies involving space stations, Mars, Trade, Energy, etc. We believe that the upcoming missions to Mars will be of great interest. There is much debate as to why exactly NASA and ESA are not presently working side by side when their goals seem nearly the same. There is not major political conflict between the space organizations despite different organizational mindsets, so what possible political factors are playing a role in keeping these two organizations apart? Europe's integration and aspiration to end the post World War Two domination of The West by increasingly conservative American government will be a trend to watch. It is not yet clear whether the historical alliance will hold up for the next ten years.

We also believe as trips to the moon become more frequent there will be growing interest in moon bases. NASA put the ISS in the wrong orbit for it to be a useful stopping point to the moon or other celestial bodies, but the Russians find the orbit convenient, so they are interested in finding a use for it. There are also many questions about the quality of life support on space stations. After the trials and tribulations and cost overruns of the ISS it will be difficult for there to be another international space station. If future space stations are not to be international, will each organization need its own form of stopping point en route to the Moon for training, transfers and refueling. The CNSA already has plans to use the docking Shenzou 8 and 9 as a space station and as a possible response to not being invited to be part of the ISS, what else will follow from the rest of the world?

A third project that we strongly recommended is to further investigate the scientific merits of Helium-3. We feel that the research we began in this paper could easily be continued and debated for the duration of an IQP. An in depth knowledge of fusion physics is required and could be attained over the course of three terms. This is, however reaching a little beyond the traditional notion of what an IQP as a non-technical

Society-Technology issue. Thus could easily be the focus of an MQP but the social implications are large enough to warrant the intense review of the technical issues. Other aspects such as the debate between NASA and the DOE over fusion research should be looked into. As a primary source for nearly all Helium-3 papers, it is very important to investigate just how likely it is that Dr. Kulcinski and his team at the University of Wisconsin will make the breakthroughs needed to make Helium-3 a valuable fuel.

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