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Department of Social Science and Policy Studies

THE FUTURE OF UNMANNED SPACE: A SPECULATIVE ANALYSIS OF THE COMMERCIAL MARKET

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Abstract:

This report is one of many which deal with the unmanned space race. It is a prediction of who will have the greatest competitive advantage in the commercial market over the next 25 years, based on historical analogy. Background information on Russia, China, Japan, the United States and the European Space Agency, including the launch vehicles and launch services each provides, is covered. The new prospect of space platforms is also investigated.

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Introduction

Literature Review

In March and April of 2004, a project was undertaken to predict the future of a moon race between the U.S. and China. A suggested follow-up to that project was to look into the social and political implications of the group's prediction for the rest of the planet. We liked that idea to some extent, but we wanted to take our project to a different level. The previous project was based on a manned exploration. It gave us a lot of insight into the political and cultural dynamics of the United States, Russia and China. However, the report only presented half of each country's side of the story. This is due to an American bias towards manned space missions. The focus of our project is going to be the technological analysis of unmanned exploration.

From the moon race group's conclusions, it seems like the United States is hell-bent on getting humans into space. When one thinks of the United States, typically he imagines the U.S. as technological leader of the world. However, different circumstances can undermine a nation's power pretty quickly.

The group that did the moon race project last spring obviously focused on agencies that were heavily interested in getting to the moon. Their report drew conclusions that were relevant to the manned space market. NASA's goal in a possible moon race is to build step stones to the stars. In NASA, having the whole human population on Earth is like putting all of your eggs in one basket. NASA doesn't feel the human race should take that risk, given the many risks facing life on Earth, and the next basket it wants to fill would most likely be Mars. (Berirmen 2004)

The area of unmanned space utilization is much more dynamic. In this regime, many more agencies are involved in space development. NASA emphasizes manned space and has bet its future on the continuation of the International Space Station. The agency is against the idea of a space platform because it has so much of an investment sunk into the International Space Station. A space *platform* is similar to a space *station*, but it has no pressurized cabins in which astronauts can live. It is a docking bay and service station for commercial satellites. The platform, which is basically still on the drawing board, is to be serviced by man. If platforms are the wave of the future, we have to reorder the relative starting points of these various agencies, and the United States is not at the top of the food chain anymore.

There were good things about the previous report, but there were also parts of it that we disagree with it. On the positive side, they are correct about the United States being the leader in current technology in the manned field. (Berirmen 2004) Going by this, it is safe to say that they can capture a piece of the unmanned market in dealing with space platforms. However, there is certainly more working against the United States than for it, notably the shear bulk of their launchers. The previous report's conclusions were mostly based on China and the United States and the manned race to the moon. As we will see, these nations--along with the Russians and the Europeans--are going to be facing off in another type of space race, which we will examine in this study.

Though extensive, the moon race group's report did not cover much our unmanned flight topic. Many of the developments mentioned in the manned space report had aspects of unmanned technology leading up to them, which is why we must consider that project. These aspects will be useful to us as we do background research and will help us asses the capabilities of each agency we look at. Aside from the United States, Russia, and China, we will also be looking at the European Space Agency (ESA) and the Japanese Space agency (formerly NASDA).

In the section on background information of the United States, the previous report mentioned a great deal about manned missions, such as the Apollo missions and Challenger. (Berirmen 2004) However, there is another side to NASA that was not explored in the report. Our group is going to look into unmanned missions undertaken by NASA as well as possible private sector agencies along with others that we discover while conducting research will be crucial in assessing the unmanned situation in the United States and complete our prediction.

Similarly, the section about background information of Russia was mostly about the manned missions. The previous report went into detail about the development of the Soviet (now Russian) space program. (Berirmen 2004) It focused greatly on how the Russians got into the moon race under the leadership of their chief engineer Korolev, only to lose the race and instead focus their resources on developing space station technology. (Berirmen 2004) It covers the stages of the Russian space station program all the way up to MIR.

(Berirmen 2004) One thing that was mentioned, but not heavily covered, was the use of unmanned technology to develop, test and build some of these space stations. (Berirmen 2004) The unmanned aspect of Russian technology is where we plan on focusing our report.

As we look at China, we will take an approach similar to that of the group before us only again, focusing on the unmanned technology. One piece of information that will be helpful to us is that much of the Chinese technology stems from information shared by the Russians.

Project Description

We are going to make a prediction of how these major players are going to evolve over the next 25-30 years in a likely unmanned commercial space race. Namely, we are looking into who will have the greatest advantage within that timeframe. Our approach to this problem will be to make predictions on the likely outcome of the race by looking at what is happening now and compare it to what happened in the past. We will take into account the relative rates of technological development and use that to determine who will make the greatest advancements in their unmanned program.

We will analyze technical reports and investigate the five space agencies we have chosen to study. The depth of our analysis will be dependent on our limited time to conduct research. We will use books, periodicals, technical reports, multimedia and online sources, such as the Center for Defense Information online. From these documents we should be able to judge the technological status of each agency today and how it came to be that way due to past events.

Methodology

Our method for making a prediction of what will occur over the next three decades in unmanned spaceflight will be to compare what has taken place in the past and make a best-case scenario for each agency, considering things that have changed over the last 30 years. We will need to look at individual factors that had the greatest impact on the development of each agency's unmanned program, such as the its cultural, political, public and economic motivations, to assess the relative capabilities of each. Our team will do this for both the past and present, and determine any differences that would affect the development of an unmanned program. After this step, we will be able to make our prediction. We are going to assume that no major technological breakthroughs will take place.

Our methodology is similar to that used by the IQP report by Berirmen, Ziolek, Cakkol and Elko, but not exactly the same. Historical analogy will again be the basis of our conclusions, but we have to consider both manned and unmanend capabilities. While the space platform is primarily an unmanned operation, the fact that it is man-tended is necessary to consider. Agencies that are primarily responsible for manned space, like the United States, will be able to claim their share of the commercial market with, say, a 2-man shuttle that will be able to service the platform. Since ESA scrapped Hermes, their link to the world of manned spacecraft, this gives other agencies room to develop their manned technology and capture a piece of the emerging satellite market.

Once we have all of our information gathered from 25 years ago up until now, we will formulate our best-case scenarios to speculate what each agency is capable of in the next 25 years. We will then compare these scenarios and find out whether those who are on top right now are likely to stay on top. We will also need to look at the relative rates at which the countries' space agencies have acquired resources and develop. With these pieces of information, we will be able to make our prediction about how the market shares will be distributed over the next 25 years.

To define "unmanned space," we are going to research the launch vehicles and launch services that each country provides. After some research, we have determined several factors that will help us make our prediction. These important things to consider will be the cost to build, the number of launch sites, the success rates of the launchers (the track record of the launches), and the growth industry of each agency. Upon determining the status of these factors for all of the agencies, from 25 years ago up until now, we will be in position to make the prediction.

Historical Analogy

The driving force behind our prediction is the use of historical analogy. This methodology is similar to what the moon race group used to make their science-fiction style prediction. The following information comes from the Internet site, *Language and Diplomacy*. Historical analogy is a technique used to help people develop understanding in unknown situations based on what has already happened. The past is the source of information, while predicting the future is the point of the analogy. Analogies of this nature are used in many fields to support analyses, and we will use one to predict the future of unmanned space.

According to Drazen Pehar, a researcher on diplomacy and language, there are many reasons to use historical analogies to shape public opinion. “Historical analogizing is an essential part of national narrative and national identity. Nations tend to group around their most central and deeply rooted memories. Over time many of those memories acquire the status of lasting symbols that nations use to describe their contemporary concerns or fears as well. Analogies help people symbolically transcend the limitations of time and space. …the need for spiritual transcendence is one of the main sources of motivation for the use of historical analogies in dealing with international affairs."

Another reason to use historical analogy, which is the reason we are pursuing, is to provide people with a sense of cognitive orientation in global affairs. Sometimes global affairs are so complicated and depend on so many variables that it is just too difficult to make a decision about anything with mathematical certainty. Most focused with difficulty would be a prediction of the future. “Historical analogies ‘indicate a direction for actions in this world, which would otherwise remain too complex to allow for an intellectual grasp. Historical analogy simply projects an image of past developments into the future and thus makes the future cognitively manageable.’”

Some of our research is going to deal with space platforms. After some initial research, it appears that Russia has already developed a prototype platform and launched it back in 1999. ESA originally came up with the idea with the two-man shuttle Hermes and the man-tended space platform, but they put the idea on the shelf. With 70 percent of the commercial market, ESA has a lot at stake if they don't respond to the Russian efforts. China has also jumped onto this bandwagon with plans to build a large capacity public platform for communications technology. ESA must develop a manned capability to perform maintenance on a potential space platform or else they are going to lose a great deal, if not all, of their 70 percent of the commercial market.

Brooks Farnham is going to research the rise of this new Russian space platform. He will also research the Chinese efforts on their communications platform. Peter Brayshaw will be researching the possibilities of Japanese and American platforms. He will pay particular attention to Japan's HOPE--the two-man shuttle that can be attached to the H-2 rocket--and the possible coalition between the two nations. Jon Leslie is going to look into how ESA will react to the new threat.

A study on the actual launch vehicles used by each agency will be important in assessing the capabilities that they have right now. Furthermore, looking into the history of each agency's unmanned activities will help us judge the capabilities they may have the potential to develop.

As a first step for our report we will be doing background research on each space agency. The point of this is to learn how each agency got its start and how fast it develops its technology, and gives us insight about the politics involved. Combined with an assessment of the current standing of each agency we will be able to use this information to help predict where each country will be in 25-30 years from now. To help get a jump start on it, we plan on having Brooks start writing right away with what we already know, while Jon and Peter start on research. We will follow this plan for the next three and a half weeks until we have all the research we need. At that point we will all take up writing to bring the report to a finish.

Organizational Mindsets of the Agencies

ESA's mindset is to be the "eyes and ears" of planet Earth. Completely dominated by space scientists, there is no military involvement as it is outlawed by charter. Their main goal is to make scientific advancements, with no emphasis on getting humans to the stars. NASA is just the opposite. Its goal is to get humans into space, while pure space science is of secondary importance to it. Japan's recently joined its two agencies into JAXA, a single organization. JAXA has very little military involvement. The mindset of its space science agency, ISAS, is similar to ESA, while NASDA is less influenced by space scientists and is more like NASA but is far more Earth oriented, and is interested in commercial success. Both Russia and China have significant military involvement, and both have a history of manned achievements. However, Russia and China are both seeking to strengthen their unmanned programs by looking into the space platform as a feasible short term future goal with commercial potential.

Current Situation

As we have mentioned, ESA is currently the leader in commercial unmanned space with 70 percent of the market in their hands. Russia and China are not far behind in capability but far behind in market share, while Japan and the United States are even further behind in both capability and market share. Russia is threatening to take the lead in this market with the idea of a commercial space platform.

The platform, adding to our previous definition, is a framework for the instruments previously flown on satellites. The platform is a holder that the space agency provides to the instrument manufacturer along with a service contract, for a price. In other words, the space platform is like a motherboard for a computer, and the instruments are like the hard drives, CD-ROMs, USB ports, and others. The instruments may require the use of certain interfaces--like IDE rather than USB--but the satellite manufacturer will have to meet certain standards, just like a standard IDE interface is 39 pins. And, of course, different companies will make instruments that use the same interface, just as Western Digital and Maxtor both make hard drives of such a nature.

Russia launched a prototype of this new platform in 1999. The European Space Agency (ESA) had a man-tended platform idea on the drawing board but it never went into production. As the leader in unmanned space technology, ESA has always been reluctant to develop a manned capability. It was not considered cost effective. This was apparent when they threw away Hermes, the two-man shuttle that was going to be used to tend the proposed space platform. Now, their 70 percent of the commercial launch market is threatened by the Russians if the platform idea they pioneered takes hold. Also, the Chinese have announced their plans for a universal space platform, standing on the shoulders of giants in the field whose space technology is their model, the Russians.

Preliminary Research

The following information comes from the Internet site, *Center for Defense Information*, accessed October 11, 2004.

The USA has two major space agencies. The first, NASA, is the more famous of the two. With an operating budget of 19 billion dollars in 2003, NASA is the largest space agency in the world. However NASA is run through a bureaucratic system which severely hampers many projects that NASA attempts. Space Scientists have very little input in NASA and they need to use it sparingly. NASA has a strong focus on manned space exploration. This is currently a problem because the shuttle has been grounded due to the Columbia explosion. NASA has been the main backer of the International Space Station and the shuttle is the main thing used to get equipment to the still incomplete station.

Space Command is the other American space agency. It is run completely by the Air Force so the military has control over everything Space Command does. It had an operating budget of approximately five billion dollars in 2003 and the budget will probably do nothing but go up over the next several years. Space Command is almost the polar opposite of NASA in that while it is a bureaucracy, it is run quite a bit more efficiently and it is also quite secretive about its programs where as NASA is very open. Space Command also has almost a complete focus on unmanned technologies and no involvement with the International Space Station.

JAXA, which is Japan’s space agency, was formed in October of 2003 when NASDA combined with 2 other smaller agencies. It has an operational budget of 300 million dollars. JAXA has a much larger focus on unmanned technology then NASA and actually developed designs using old American technology for their expendable A1 booster. JAXA is involved in the International Space Station and has made public statements about a desire to go to the moon within the next decade.

Currently the big focus for ESA is the Aurora program. Aurora is “the European Program for the Exploration of the Solar System.” As it stands the main focus of Aurora seems to be Mars via unmanned robot missions. ESA is planning a rover mission for 2009 that will collect samples from the Martian surface and return to earth. ESA is also assessing the possibility of a manned mission to mars.

Currently there are a few tensions between the UK and the rest of the EU/ESA. In 2003, the Beagle 2 probe went missing after being launched from the Mars Express (part of Aurora). The last contact ESA has of Beagle 2 was it descending towards Mars after being launched off of the Mars Express. A large portion of the funding for Beagle 2 came from the UK. Now the UK is debating whether or not they want put more money into the program. Without adequate funding the UK would not be able to take advantage of all that was learned from the Beagle program, or the findings from future Mars landings. UK supporters of

ESA/Aurora feel that the money already spent would be wasted if the UK drops its support of the program and therefore should continue to give funding. The European Nation and ESA seem to be very exclusive when it comes to who they let into the programs. Countries that don't fund projects seem to be excluded from sharing in the results.

In 2003 ESA operated with a budget of 2.7 billion Euros or roughly 3.3 billion US dollars. It can be expected that their 2005 budget will be similar. Future programs within ESA include a new launcher to replace the Arian 4, a global navigation system, advanced telecommunications, and even manned space programs.

Based on WPI case studies, the Russians are somewhat interested in unmanned exploration of space. Space scientists have not influenced Russia that much, and there is great military involvement. China is active in the unmanned launch market. It wants to get to the moon. Like Russia, there is high military involvement, and little influence from the space scientists. Both Russia and China should seriously consider making a move towards unmanned flight if they want to be players in the next few decades.

Russia's space budget is much smaller than that of NASA. For 2005, the Russian Federal Space Agency has announced that its budget will be $860 million. However, only $620 million will be put towards space program expenditures, the rest going to pay off other expenses. It has been difficult for Russia to get anything done on the International Space Station because of the tight budget.

The Chinese first sent a manned mission into space in October 2003. Their next planned mission is in late 2005. China is also developing a craft that will explore the moon. Its launch date is scheduled before 2007. The craft is being designed to orbit the moon for at least a year. A later mission, which will be unmanned, is scheduled to launch before 2010.

Background Research

European Space Agency

History

In 1962 France, Germany, Belgium, Italy, Netherlands, United Kingdom and Australia combined to form ELDO, European Launcher Development Organization. The goal of ELDO was to develop a launching system. That same year, Spain, Denmark, Sweden and Switzerland joined with the ELDO member countries to form the European Space Research Organization or ESRO.

Within ELDO Britain designed the first stage of the launch vehicle, with France designing the second stage, Germany designed the third stage. Italy designed the satellite that was to be launched. The Netherlands, and Belgium concentrated on tracking and telemetry systems while all Australia did was provide a launch site.

There were ten planned launches broken up into three phases. The three phases consisted were: phase one where the first stage was launched, the second phase consisting of the entire launch vehicle with a satellite and the third phase where the satellite would be put into orbit, however the satellite failed to orbit at any point. It was soon realized that the Woomera launch site was not suitable for putting satellites into geosynchronous orbit so in 1970, the site was moved to Kourou in French Guiana, South America.

In 1974 ELDO and ESRO merged to form the European Space Agency. Eleven countries were initially involved in the ESA those countries were Spain, Portugal, Great Britain, Netherlands, Belgium, Germany, France, Sweden and Switzerland.

The ESA's first mission was called COS-8 and provided the first detailed maps of Gamma Ray emissions across the universe. Three years later the ESA launched the first major high-earth orbit satellite called IUE which was a astronomical satellite which made observations of Halley's Comet, the first Supernova visible from the Naked Eye in 300 years, and the atmospheric disturbances of Jupiter after it was hit by a comet in 1994.

It was at this point when the Ariane 1 was developed. The first launch was in 1979 and ran through 1986 with nine successes out of eleven launch attempts which is a success rate of approximately 82 percent. Ariane 1 had a height of 47 meters, a liftoff mass of 210 tons and a max payload of 1.83 tons.

Ariane 2 was developed in 1987 and made five successful flights out of six attempts. Ariane 2 had a height of 49 meters and a max payload mass of 2.27 tons. Ariane 3 which was in use at the same time as Ariane 2 made ten successful launches out of eleven attempts for a success rate of 91 percent.

Ariane 3 had a height of 49 meters and a max payload of 2.65 tons. The main difference between Ariane 2 and Ariane 3 was the strap on boosters. These boosters allowed Ariane 3 to have a fifteen percent larger payload then Ariane 2.

Figure 1 Ariane 1-3 Family

The best known Ariane launch system, the Ariane 4 was developed for use in 1988 and was used through 2003. The Ariane 4 made 116 attempts with 113 launches being successful for an amazing success rate of 97 percent. Ariane 4 is justly known as the 'workhorse' of the Ariane family. The Ariane 4 proved ideal for launching communications and Earth observation satellites as well as those for scientific research. This launcher is extremely versatile. The first stage could hold two or four strap-on boosters, or none at all. This allowed the Ariane 4 to boost up to 4.3 tons of payload or approximately 40 percent more then Ariane 3.

Figure 2 Ariane 4 Family

In 1980 Arianespace SA was founded. Arianespace undertakes the production, operation and marketing of all Ariane rockets. As of 2002 Arianespace held more then 50 percent of the world market for boosting satellites into geostationary transfer orbit. However, due to the recent poor performance of the Ariane 5 launch vehicle Arianespace has been losing a little bit of ground to the Russians and Chinese. The information in this section was found through the ESA, All Time Launch Results and through Wikipedia.

Launch Sites

The ESA's spaceport is the Guiana space centre in Kourou, French Guiana. Kourou was chosen due to the fact that it is close to the equator, allowing for easier access to commercially important orbits such as geosynchronous orbit. The easier access amounts to less fuel per given mass. Also due to the spaceport being close to the equator gives it better weather for the long stretches of the year. The spaceport was moved to Kourou in 1970, from Australia because since Australia is so far from the equator it requires more fuel to launch and is harder to get vehicles into geosynchronous orbit. The newest pad at the spaceport, the ELA-3 launch complex, was started in 1988 and took 8 years to build. The launch complex can handle up to five launches per year with a launch campaign lasting approximately 20 days. The Kourou spaceport has such optimal placement that the ESA plans on maintaining it for use throughout the foreseeable future. The ESA has plans on the table to build a launching pad for the Soyuz launch system, and also more launch pads for the Ariane 5 as business increases. This information is from Wikipedia, and Space-Technology.com.

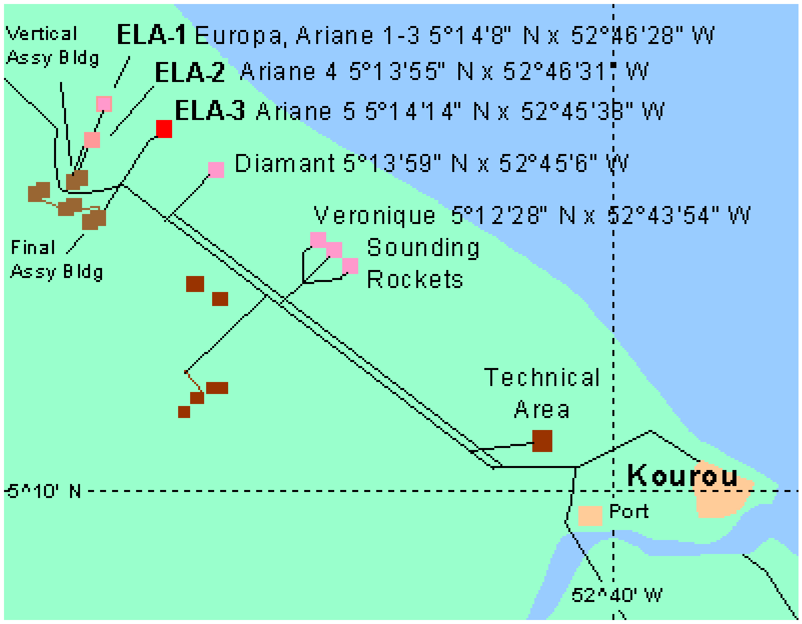


Figure 3 Layout of Kourou

The ESA's mission control is based in Darmstadt, Germany. The ESOC was founded in 1967 and has operated or worked with 59 various spacecraft including several non-ESA craft. This information is from the ESA webpage.

Launch Vehicles

The main launch vehicle for the ESA and Arianespace right now is the Ariane 5. The first launch was on June 6th of 1996. This launch was a complete and utter failure with the rocket self-destructing approximately 40 seconds after launch due to a simple conversion error in the control software. The following test flights on October 30th, 1997 and October 21, 1998 were both successful. The first commercial launch occurred on December 10th, 1999 and was a success.

Development for the Ariane 5 took approximately 10 years and cost about 12 billion US dollars. The Ariane 5 has a current payload capability to deliver 6,200 kilograms to geosynchronous orbit which is equivalent to 13,700 pounds. There are currently plans under development to increase that number up to 12,000 kilograms which would be 26,000 pounds.

The Ariane 5 uses a liquid oxygen and liquid hydrogen mix to power the main Vulcan engine which provides 180.000 pounds of thrust. It has a pair of solid propellant boosters to help the rocket reach orbital speeds which provide 1,430,000 pounds of thrust each. A small upper stage is used to boost the final satellites into geosynchronous orbit. This upper stage burns nitrogen tetroxide and monomethylhdrazine which provides a thrust of 6,140 pounds. The estimated launch price for one Ariane 5 rocket is 120 million US dollars.

The ESA also recently entered into a 453 million dollar venture with the Russian Federal Space Agency in order to use the Soyuz launcher. Under the agreement Russia will manufacture Soyuz parts for the ESA, which will then be assembled in French Guiana. This will give ESA a medium payload launcher and save on development costs while Russia will be able to use the Kourou launch site and almost double the Soyuz's payload carrying ability due to Kourou's close proximity to the equator. This information was found through the Federation of American Scientists, the ESA and Space and Technology Database.

Platforms

The ESA originally had an a plan for a platform, based off of the Hermes capsule. Originally proposed in 1986, the Columbus Man-Tended Free Flyer was put forward but at the time it was unsure whether the Columbus would be part of the International Space Station or an independent European venture. Eventually as the International Space Station gained support the idea of the Man Tended European venture was pushed back as a concept. It was pushed back to 1999 after the unification of Germany forced a 15-20% cut in expenditure on ESA. Several years later the concept was pushed back even farther due to the rising cost of the International Space Station. The information in this section is from European Space Stations on Astronautix.

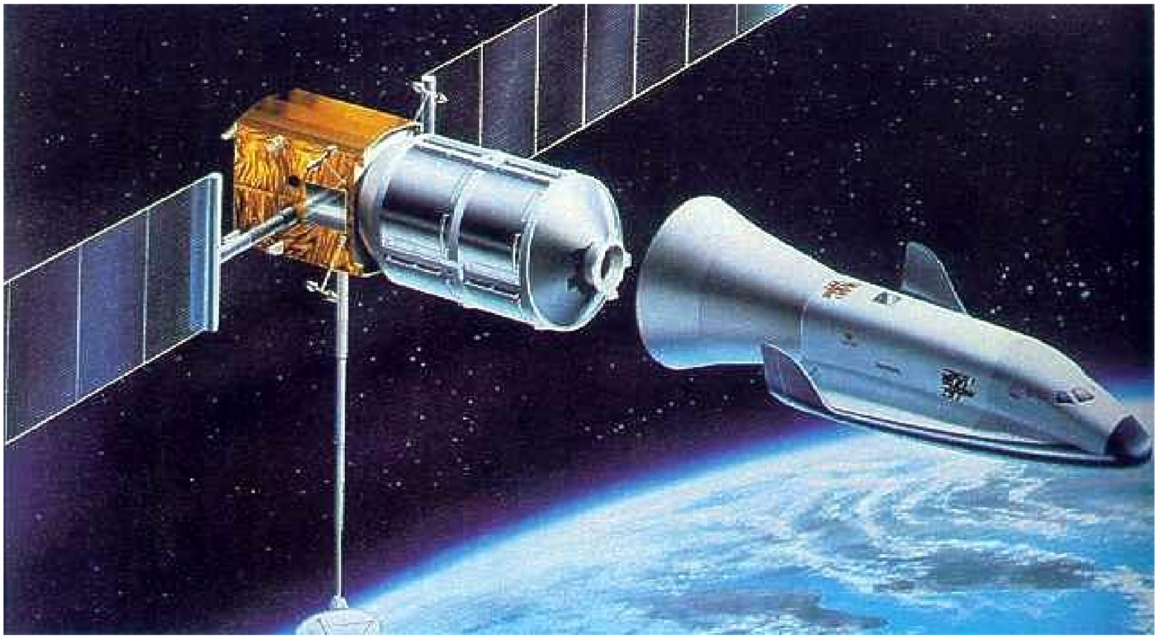


Figure 4 Concept Drawing of the Columbus MTFF

Recent Activity

Arianespace has established relationships with satellite operators, telecommunications providers and spacecraft manufacturers around the world. They have worked with a wide variety of customers including AT&T, Boeing, NASA, Hughes, JAXA, Fairchild, Lockheed Martin, Indian Space Research Organization, and British Aerospace. This list of customers includes several other national Space Organizations showing how much the world depends on Arianespace for launches.

2003-2004 saw seven launches take place with an average of three months between each launch. These launches all took place without any failures for a wide variety of customers.

Figure 5 July 17th, 2004 Ariane 5 Launch

Russia

History

The following information comes from the Internet site, *"Origin of the Test Range in Tyuratam."*" In the 1950s, Soviet designers raced to develop ICBMs, such as the R-7 and the winged Burya. Both of these needed a new test site, because the site located in Kapustin Yar was unable to meet the launch requirements of these new missiles.

Korolev hoped to have a significant influence on where this new test site would be. He told his deputies to start searching for this new test site. They began by surveying an 8,000-km trajectory originating at Kapustin Yar and moving east towards Kamchatka. However, they realized this wouldn't work. The booster stages would end up falling into populated areas, and one of the radio control stations would actually be in the Caspian Sea or Iran. They then searched west of the Caspian in the Stavropol Region. Now the boosters would fall into the sea, but the radio control stations would be in the mountains.

The Soviet of Ministers U.S.S.R. ordered the Ministry of Defense, the Ministry of Medium Machine Building, the Ministry of Defense Industry, the Ministry of Radiotechnical Industry and the Ministry of Aviation Industry to find a test site, because the sites that Korolev proposed were not going to work.

Launch Sites

The following comes from the site "*Russia's Space Centers*." Russia now has four major launch sites. One of their major sites for satellites is the Baikonur Cosmodrome, which is near Tyuratam and Leninsk in Kazakhstan. It is actually about 370 kilometers away from the town of Baikonur.

A second launch site is near Plesetsk, in the arctic, north of Moscow. It is primarily a military site, but is also used for navigation, communication, and weather satellites.

The third launch site is near Kapustin Yar on the Volga River, south of what was formerly known as Stalingrad. This site launches vertical probes such as White Sands, and small orbital payloads like Wallops Island in the U.S.

Svobodny, the fourth launch site, came into being in 1997 to replace the Baikonur Cosmodrome because Kazakhstan became an independent nation. Svobodny is much further east than the other three.

Launch Vehicles

The following comes from the site, "*YaKhR-2*." Russia had a nuclear powered launch vehicle that was capable of delivering 40 tons to low-earth orbit.

It used ammonia as a propellant. This vehicle, the YaKhR-2, was scrapped because the engineers wanted to pursue traditional chemical propulsion instead.

The next several paragraphs take information presented in the site, "*Russian Rockets*." The Russian Space Agency got its launch vehicles from the former Soviet Union Space Program. The Proton, Zenit and Soyuz are all being used to launch parts of the Space Station. The Russian launch vehicles include the A-class, the Soyuz, the Zenit and the Proton.

The A-class vehicles are based on the Soviet SS-6 ICBM. These include the Vostok, Soyuz and Molniya launchers. These three vehicles use the same core stage and all use four strap-on boosters that are propelled by liquid oxygen and kerosene.

Soyuz is Russia's main launcher for manned space flights. However, nearly half of all of Russia's space missions begin with the Soyuz vehicle. Soyuz is also used to deploy low-altitude reconnaissance satellites. It was first launched in 1963, and is a 2-stage rocket that can deliver a 15,000 pound payload into low earth orbit at a 51.6 degree inclination.

Zenit was introduced in 1985. Like the A-class rockets, it is propelled by liquid oxygen and kerosene. It is able to deliver over 30,000 pounds of payload into low-earth orbit at 51.6 degrees. The Zenit that will be used to deliver Space Station parts into orbit is a two-stage rocket. A three-stage version is under development. It will be used for geostationary missions. The Zenit is launched from the Baikonur Cosmodrome.

The Proton was first introduced in 1965. This was the first Russian launch vehicle that was not based on a ballistic missile prototype. There are both 3- and 4-stage versions of the Proton, with the 4-stage version being used mostly for geostationary satellite missions. The first stage has six strap-on boosters and puts out more than two million pounds of thrust. The 3-stage version can put over 44,000 pounds into low-earth orbit and is to be used for the largest components of the Space Station.

The AUOS Bus

Information on the AUOS bus comes from the site, "*AUOS Science Platform*." AUOS stands for "Automatic Universal Orbital Station" in Russian. It is a space platform, designed to perform a multitude of tasks. The Coronas-type spacecraft is based on this platform. The AUOS has been under development since the early 1970s, at which time the KB Yuzhnoe design team in Dnepropetrovsk took up the job. This team developed the AUOS because it had previous experience with the DS-U satellites. KB Yuzhnoe conducted a study in 1971 that showed that this concept of a space platform was indeed feasible, producing three basic designs: KAM-I, KAM-II and KAM-III. "KAM" in Russian stands for "Multipurpose Space Apparatus" in English.

KAM-I became the basis for two variations of the AUOS. The first, called the AUOS-Z, went under development in 1973. The AUOS-Z had a cylindrical service module which had eight solar panels, attached to the upper end of the module and deploying at 30 degrees when it reached orbit. A special boom for gravitational stabilization would position itself on the top of the service module.

The payload module would dock to the service module through a standard interface. Ten satellites based on the AUOS-Z platform were sent into orbit. Most of them were for the benefit of space scientists from the Soviet Union and countries of the Warsaw Pact. The other satellite bus based on KAM-I was the AUOS-SM, which went under development in 1987. The first AUOS-SM spacecraft, launched in 1994, was the Coronas-I.

Since 1976, there have been 12 launches based on the AUOS-SM and AUOS-3. All of them have been launched from the Plesetsk Cosmodrome.

Recent Activity

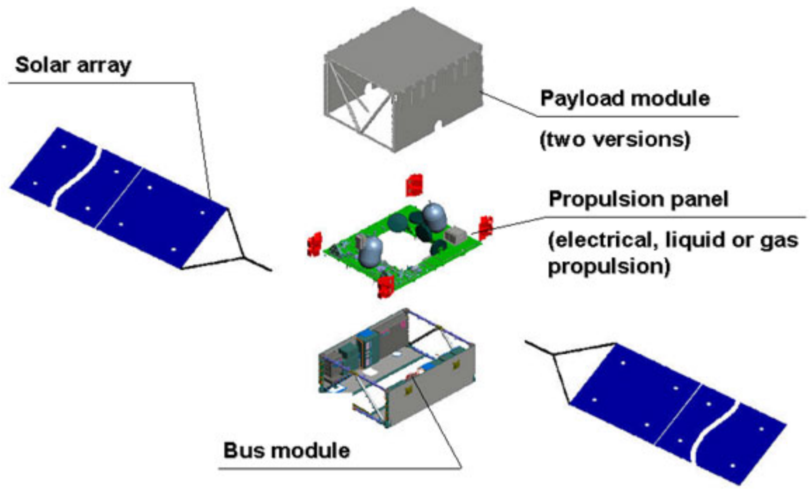
In July 2001, Russia and Ukraine launched a cooperative mission to study sun-earth interactions. The Coronas-F platform was launched on July 31, 2001 at midnight Moscow time from the Plesetsk Cosmodrome. It had a mass of 2,260 kilograms and was equipped with 15 scientific instruments that will be used by space scientists in Russia, the United States, Georgia, Slovakia, Germany, Great Britain and Poland. A 3-stage Tsyklon-3 rocket put the platform into orbit 500 kilometers above the earth with an 82.5-degree inclination towards the equator. The craft separated from stage 3 after just under an hour after the other two firings of the stage's engine.

As of 2001, the Coronas-F was expected to spend at least a year studying dynamic processes of solar activity. This activity includes active regions of the sun, solar flares and mass ejections in the wide range of the electromagnetic spectrum, the interaction between solar winds and the Earth's magnetosphere, and the interior of the sun. The Coronas-F is the successor of the Coronas-I, launched seven years earlier.

Universal Space Platform

Information on this section comes from the site, "*Universal Space Platform*." The S.P. Korolev RSC Energia Corporation developed the Universal Space Platform within the Yamal project. It went under flight qualification as a part of the Yamal-100 satellite which was launched on September 6, 1999. This platform provides RSC Energia with a firm and flexible base from which to conduct space activities. These activities include the development and launching of satellites with different purposes, and it allows other space vehicle developers to adapt to the standards set by the RSC.

The multi-purpose satellite bus has several important features. There are no pressurized compartments, which are typically used in satellites. It has compartments, solar panels, and on-board antennas which are made of "sandwiched honeycomb structures based on composite materials." The power comes from solar panels and Ni-H batteries. The electrical propulsion unit is currently using xenon. It has a motion control system that is based on optical sensors, momentum wheels and extremely accurate angular rate meters.

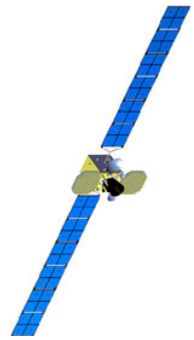


Drawing of the Multi-purpose Satellite Bus
Courtesy S.P. Korolev RSC Energia

The Universal Space Platform is capable of low, middle and high earth orbit, sun-synchronous orbit, and geostationary orbit. It weighs between 950 and 1,200 kg, and can carry a payload of 250-1,000 kg depending on orbit. The platform puts out up to 3,000 watts of power at 28.5 volts. In low, middle and high-elliptical orbits, the service life is no less than 7 years; for geostationary orbit the service life is as long as 12.5 years.

S.P. Korolev RSC Energia has invented many different advanced spacecraft, which are to be sent into orbit by different launch vehicles. These vehicles are the Proton LV, the Zenit-3SL LV, the Aurora LV and the Soyuz LV. They are launched out of the Plesetsk and Baikonur Cosmodromes, as well as the Odyssey launch platform. Odyssey is located near Christmas Island.

The heavy-class spacecraft weigh nearly 3,000 kg and can carry a payload of up to 800 kg. They are launched by the Aurora LV and the Proton LV. The lighter class craft weighs less (1,600 kg) but carries less payload and puts out less power (up to 4.5 kW rather than the 12 put out by the heavy-class craft). The light-class is launched exclusively by the Aurora LV. Both types have a flight life of 12-15 years.

Heavy-class spacecraft   Light- class spacecraft

(Courtesy S.P. Korolev RSC Energia)

Energia has also developed two earth resources satellites, a light model and a heavy one. Both put out the same power, 450 watts, and have the same flight life of 5-7 years. They have the same altitude control accuracy of 3 minutes of arc, and the same stabilization accuracy of 0.001 degrees per second. The heavy ERS can carry a slightly greater payload (680 kg) than the light ERS (580 kg).


Small ERS   Large ERS

Courtesy S.P. Korolev RSC Energia

These advanced spacecraft can be used both publicly and privately for communications, earth remote sensing, relay spacecraft for low-orbit users, navigation, and unmanned servicing and repair of expensive vehicles.

Currently, Russia is proposing building a new orbital platform. This information comes from the site, "*Russia to Build New Orbital Platform*." Roskosmos Chief Anatoly Perminov said at the International Space Congress on October 14, 2004 that Russia would design a new platform for its cosmonauts. This new platform would enhance the research at the International Space Station and would combine the advantages of manned and unmanned technology. Perminov said that the platform will be used for development of "interplanetary complexes" and new transport and hardware systems. Russia has been working on the problem of launching spacecraft from another stationary spacecraft since the 1960s, and the country will benefit from this platform. Perminov said that the exact date is still tentative, and depends upon international cooperation and financial, industrial and technological reserves.

Launch Costs and Budget

Energia's EUS launch vehicle costs $120 million in 1994 U.S. dollars. (*International Launch Vehicle Data*) Using a conversion factor of 0.793, this converts to approximately $152 million in 2004 U.S. dollars. (*CPI Conversion Factors*) Russia's expendable budget for 2005 is a mere $620 million, (*Center for Defense Information, Space Security Updates*) so it appears that Russia would be able to make about four launches using the EUS vehicle.

China

Platforms

This information comes from the site, "*Large Geostationary Satellite Platform*." China is considering developing a similar technology to that which is on the Russian's drawing board. This will be a next-generation large geostationary satellite platform, which will be used heavily in the communications satellite market. The platform will house many communications satellites and will meet the demands of the customers who put up the satellites. The heavy satellites--which are for communication, broadcasting, tracking and data relay and military purposes--have very high power requirements.

The development of the platform is coming in three phases. Initially, the platform will be able to put out 6,000 to 8,000 watts, carry a payload of over 450 kilograms, and will require maintenance every 15 years, according to China's market demand and technology status. The second phase will introduce a greater power output (more than 10,000 watts). In the third phase, an electric thruster will be used for orbit control, thus heightening the performance of the platform. It has been predicted that, by 2010, the platform's payload will be over 800 kilograms, in which case it will be ready to meet the demands of the consumers.

Recent activity

This information comes from the site, "*China to Put 10 Satellites Into Orbit in 2004*." As of January of 2004, China had plans to put ten satellites into orbit over the course of the coming year. This was a record number for China. The new satellite platform will help the nation take its place in the demanding space community. In 2003, China put six satellites into orbit and joined the former Soviet Union and the United States in putting a man into space. In January of 2004, China had 16 satellites working, which cannot meet the demands of economic growth and communications systems. So over 30 satellite launches were planned for 2001-2005. The ten for this year were planned for meteorological, natural resources, and marine observation and geospace exploration. One of them, the first, carries small scientific instruments and blasted off from the Xichang Satellite Launch Center in the Sichuan Province.

By 2010, environmental monitoring and disaster forecasting satellites will be in orbit, according to Yuan Jiajun, president of the Chinese Academy of Space Technology. He also said that China is planning on cooperating with foreign countries to deliver satellites, in orbit, to customers.

Up through 2004, China has not made its own satellites, but rather parts for them to be made elsewhere. This is because of an agreement Yuan's school made with Alcatel Space of France.

China's latest satellite, the Dongfanghong III, puts out a mere 3,000 watts and has a life of eight years.

Investment into China's new platform is $156 million as of January of 2004.

Track Record

Below is a list of China's track record since 1970 for launches using the Long March rocket, courtesy of the site, "*Long March Track Record*."

NO.	Launcher	L.Date	Payload / SC	Orbit	L.Site	Result	Remark
1	LM-1 F01	24 Apr. 1970	DFH-1	LEO	JSLC	Success	
2	LM-1 F02	3 Mar. 1971	SJ-1	LEO	JSLC	Success	
3	LM-2 F01	5 Nov. 1974	FHW-1	LEO	JSLC	Failure (1)	
4	LM-2C F01	26 Nov. 1975	FHW-1	LEO	JSLC	Success	
5	LM-2C F02	7 Dec. 1976	FHW-1	LEO	JSLC	Success	
6	LM-2C F03	26 Jan. 1978	FHW-1	LEO	JSLC	Success	
7	LM-2C F04	9 Sept. 1982	FHW-1	LEO	JSLC	Success	
8	LM-2C F05	19 Aug. 1983	FHW-1	LEO	JSLC	Success	
9	LM-3 F01	29 Jan. 1984	DFH-2	GTO	XSLC	Failure (2)	
10	LM-3 F02	8 Apr. 1984	DFH-2	GTO	XSLC	Success	
11	LM-2C F06	12 Sept. 1984	FHW-1	LEO	JSLC	Success	
12	LM-2C F07	21 Oct. 1985	FHW-1	LEO	JSLC	Success	
13	LM-3 F03	1 Feb.1986	DFH-2	GTO	XSLC	Success	
14	LM-2C F08	6 Oct.1986	FHW-1	LEO	JSLC	Success	
15	LM-2C F09	5 Aug.1987	FHW-1/Pigybck	LEO	JSLC	Success	No.1 PS
16	LM-2C F10	9 Sept.1987	FHW-2	LEO	JSLC	Success	
17	LM-3 F04	7 Mar.1988	DFH-2A	GTO	XSLC	Success	
18	LM-2C F11	5 Aug.1988	FHW-2/Pigybck	LEO	JSLC	Success	No.2 PS
19	LM-4 F01	7 Sept.1988	FY-1	SSO	TSLC	Success	
20	LM-3 F05	22 Dec.1988	DFH-2A	GTO	XSLC	Success	
21	LM-3 F06	4 Feb.1990	DFH-2A	GTO	XSLC	Success	
22	LM-3 F07	7 Apr. 1990	AsiaSat-1	GTO	XSLC	Success	No. 1 DLS
23	LM-2E F01	16-Jul-90	BADR-A/DP	LEO	XSLC	Success	No.3 PS
24	LM-4 F02	3 Sept.1990	FY-1/A-1,2	SSO	TSLC	Success	

25	LM-2C F12	5 Oct.1990	FHW-2	LEO	JSLC	Success	
26	LM-3 F08	28 Dec.1991	DFH-2A	GTO	XSLC	Failure (3)	
27	LM-2D F01	9 Aug.1992	FHW-3	LEO	JSLC	Success	
28	LM-2E F02	14 Aug. 1992	Aussat-B1	LEO	XSLC	Success	No.2 DLS
29	LM-2C F13	6 Oct.1992	Freja/FHW-2	LEO	JSLC	Success	No.4 PS
30	LM-2E F03	21 Dec.1992	Optus-B2	LEO	XSLC	Failure (4)	No.3 DLS
31	LM-2C F14	8 Oct. 1993	FHW-2	LEO	JSLC	Success	
32	LM-3A F01	8 Feb. 1994	SJ-4/DP2	GTO	XSLC	Success	
33	LM-2D F02	3-Jul-94	FHW-3	LEO	JSLC	Success	
34	LM-3 F09	21-Jul-94	APSTAR-I	GTO	XSLC	Success	No.4 DLS
35	LM-2E F04	28 Aug. 1994	Optus-B3	LEO	XSLC	Success	No.5 DLS
36	LM-3A F02	30 Nov. 1994	DFH-3	GTO	XSLC	Success	
37	LM-2E F05	26 Jan. 1995	APSTAR-II	LEO	XSLC	Failure (5)	No.6 DLS
38	LM-2E F06	28 Nov.1995	AsiaSat-2	LEO	XSLC	Success	No.7 DLS
39	LM-2E F07	28 Dec.1995	EchoStar-1	LEO	XSLC	Success	No.8 DLS
40	LM-3B F01	15 Feb. 1996	INTELSAT-7A	GTO	XSLC	Failure (6)	No.9 DLS
41	LM-3 F10	3-Jul-96	APSTAR-IA	GTO	XSLC	Success	No.10 DLS
42	LM-3 F11	18 Aug. 1996	ChinaSat-7	GTO	XSLC	Failure (7)	No.11 DLS
43	LM-2D F03	20 Oct. 1996	FHW-3/pigybck	LEO	JSLC	Success	No.5 PS
44	LM-3A F03	12-May-97	DFH-3	GTO	XSLC	Success	
45	LM-3 F12	10-Jun-97	FY-2	GTO	XSLC	Success	
46	LM-3B F02	20 Aug.1997	MabuhaySat	GTO	XSLC	Success	No.12 DLS
47	LM-2C/SD F15	1 Sept. 1997	Motorola MFS	LEO	TSLC	Success	
48	LM-3B F03	17 Oct. 1997	APSTAR-IIR	GTO	XSLC	Success	No.13 DLS
49	LM-2C/SD F16	8 Dec.1997	Motorola	LEO	TSLC	Success	No.1 MLS
50	LM-2C/SD F17	26 Mar.1998	Motorola	LEO	TSLC	Success	No.2 MLS

51	LM-2C/SD F18	2-May-98	Motorola	LEO	TSLC	Success	No.3 MLS
52	LM-3B F04	30-May-98	ChinaStar-1	GTO	XSLC	Success	No.14 DLS
53	LM-3B F05	18 July.1998	SinoSat-1	GTO	XSLC	Success	No.15 DLS
54	LM-2C/SD F19	20 Aug.1998	Motorola	LEO	TSLC	Success	No.4 MLS
55	LM-2C/SD F20	19 Dec.1998	Motorola	LEO	TSLC	Success	No.5 MLS
56	LM-4 F03	10-May-99	FY-1	SSO	TSLC	Success	
57	LM-2C/SD F21	10-Jun-99	Motorola	LEO	TSLC	Success	No.6 MLS
58	LM-4 F04	14 Oct. 1999	CBERS/Pigybck	SSO	TSLC	Success	No.7 MLS
59	LM-2F F01	20 Nov. 1999	First manned spacecraft test flight	LEO	JSLC	Success	
60	LM-3A F04	26 Jan. 2000	ChinaSat-22	GTO	XSLC	Success	
61	LM-3 F13	25-Jun-00	FY-2	GTO	XSLC	Success	
62	LM-3 F05	1 Sept. 2000	ZY-2	SSO	TSLC	Success	
63	LM-3A F05	31 Oct. 2000	BD-1	GTO	XSLC	Success	
64	LM-3A F06	21 Dec.2000	BD-2	GTO	XSLC	Success	
65	LM-2F F02	10 Jan.2001	Second manned spacecraft test flight	LEO	JSLC	Success	
66	LM-2F F03	25 Mar. 2002	Third manned spacecraft test flight	LEO	JSLC	Success	
67	LM-4 F06	15 May. 2002	FY-1D/Ocean-1	SSO	TSLJ	Success	
68	LM-4 F07	27 Oct. 2002	ZY-2	SSO	TSLJ	Success	
69	LM-2F F04	30 Dec. 2002	Forth manned spacecraft test flight	LEO	JSLC	Success	
70	LM-3A F07	25 May.2003	BD-3	GTO	XSLC	Success	

Long March International Commercial Launch Record

NO.	Payload/SC	Launcher	Customer	L.Date	Ref.
1*	Micro-gravity Test Instrument	LM-2C F09	Martra Maconi France	Aug.5,1987	Piggyback
2*	Micro-gravity Test Instrument	LM-2C F11	Intospace Germany	Aug.5,1988	Piggyback
3	AsiaSat-1 Communications	LM-3 F07	AsiaSat HK	April.7,1990	Single
4*	BADR-A/Dummy Payload of Aussat	LM-2E F01	SUPARCO Pakistan	July.16,1990	Piggyback
5	Aussat-B1	LM-2E F02	Aussat Australia	Aug.14,1992	Single
6*	Freja	LM-2C F13	SSC Sweden	Oct.6,1992	Piggyback
7	Optus-B2	LM-2E F03	Aussat Australia	Dec.21,1992	Single
8	APSTAR-I Communications	LM-3 F09	APT HK	july.21,1994	Single
9	Optus-B3	LM-2E F04	Optus Australia	Aug.28,1994	Single
10	APSTAR-II Communications	LM-2E F05	APT HK	Jan.26,1995	Single
11	AsiaSat-2 Communications	LM-2E F06 (EPKM)	AsiaSat HK	Nov.28,1995	Single
12	EchoStar-1 Communications	LM-2E F07 (EPKM)	EchoStar USA	Dec.28 ,1995	Single
13	INTELSAT-7A	LM-3B F01	INTELSAT	Feb.15,1996	Single
14	APSTAR-IA Communications	LM-3 F10	APT HK	July.3,1996	Single
15	ChinaSat-7 Communications	LM-3 F11	ChinaSat China	Aug.18,1996	Single

16*	Micro-gravity Test Instrument	LM-2D F03	Marubeni Corp. Japan	Oct.20 1996	Piggyback
17	MabuhaySat Communications	LM-3B F02	Mabuhay The Philipines	Aug.20,1997	Single
18	APSTAR-IIR Communications	LM-3B F03	APT HK	Oct.17,1997	Single
19	Iridium	LM-2C/SD F02	Motorola USA	Dec.8,1997	Dual
20	Iridium	LM-2C/SD F03	Motorola USA	March26,1998	Dual
21	Iridium	LM-2C/SD F04	Motorola USA	May.2,1998	Dual
22	ChinaStar-1 Communnications	LM-3B F04	China Orient China	May.30,1998	Single
23	SinoSat	LM-3B F05	SinoSat China	July.18,1998	Dual
24	Iridium	LM-2C/SD F05	Motorola USA	Aug.20,1998	Dual
25	Iridium	LM-2C/SD F06	Motorola USA	Dec.19,1999	Dual
26	Iridium	LM-2C/SD F07	Motorola USA	June.12,1999	Dual
27	CBERS/PS	LM-4 F04	CAST,China INPE,Brazil	Oct.14,1999	Dual

This information comes from the site, "*China Launches Most Advanced Weather Satellite to Date*." On October 19, 2004, China launched its first geostationary orbit weather satellite. With a weight of 1.38 tons, the Fengyun-2C is capable of monitoring a third of the Earth's surface at any time. The satellite has enhanced resolution, allowing it to measure temperature and radiation levels accurately. The nation plans on using the satellite to monitor natural disasters, and has plans to launch more earth-sensing satellites in the coming years. China also has the ability to launch more advanced spy probes as well.

The budget information comes from the site, "*China Plans Space Competition*." China plans to have an unmanned lunar satellite in orbit by 2007, and this will be followed by an unmanned lunar vehicle in 2010. China's space budget is currently estimated at $2 billion. The Long March 2C, 2E and 3 cost $24 million, $47 million, and $39 million in 1994 U.S. dollars, respectively. Converting to 2004 dollars, the cost range is $30 million to $59 million per launch. (CPI Conversion Factors)

The United States

Founded in 1958 under President Eisenhower, NASA is the United States non-millitary space agency. Nasa was a response to the Soviet Union's launch of Sputnik-1, the first statelite put into orbit in 1957. After a few months of discussion, congress and the president declared that a new federal agency was needed to keep the United States from falling behind in development of an adaquate space program. With this decloration, NASA was born and the space race began.

Today NASA operates with five launch locations. The one best known to most people is Cape Canaveral Air Force Station in FL. Cape Canaveral is best know for its shuttle launches but serves to launch many other missions as well. NASA prefers this site for missions requiring east/west orbits

The next major site used by NASA is Vandenberg AFB in California. Although Vandenberg is not as widely know about to the public, it where many of the early projects for developing rockets were headed up. NASA uses Vandenberg when it wants to conduct a mission with a north/south orbit.

The other three sites are Wallops Island Flight Facility where the Goddard Space center is located, Reagan Test Site, Kwajalein Atoll, and Kodiak Island, which is NASA's premier site for missions requiring polar orbits.

Early Rockets

Before NASA, the United states had been developing rockets for space and missile systems. In 1946, after the end of WWII, the US acquired a number of German V-2 rockets. Prior to this the US efforts to build rockets had been headed by a man named Goddard. The development was initialy for Military use, and whas not a top priority project with the army until 1944, when they realized they were technologicaly behind the Germans. The capture of the V-2 rockets plus a number of German rocket scientists, set the U.S. up to become one of the front runners in space technology.

By 1958 the U.S. had developed more advanced rockets of its own. One of these was the Jupiter-C. The Juipiter C was a modified Redstone ICBM designed for testing nose cone re-emtry. The Jupiter rocket, also know as the Juno or Juno-1 was a four stage rocket, capable of carrying a 31 lb payload into low Earth orbit (LEO). Other variations of these rockets existed and could cary more payload. The Jupiter rocket was used from 1956 until 1958. Although it did have a few failures it was used to launch the first four of the Explorer satelites. Jupiter rockets were also used in the Mercury Manned Space program, along with the Atlas-Mercury rocket, as they had similar capablities.

Saturn V and Saturn Family

"The original Saturn design originated with a concept developed by Wernher von Braun in 1957. He submitted a proposal to the United States Department of Defense, outlining a need to develop a heavy booster with thrust in the 1.5 million lbf range." To get such a large amount of thrust, two main ideas were put forth. One was to bundle many rocket engines together, the other was to build a rocket engine larger then anyone had concieved before. To advise NASA on how to proceed with the project the Saturn Vehicle Evaluation Committee or Silverstein Committee was formed. They proposed three main types of Saturn rockets, with a total of eight configurations; Saturn A (A-1, A-2), Saturn B (B-1), and Saturn C (C-1 to C-5). The A series, B series, C-1 and C-2

Saturns used the idea of clustering many engines together to work as one. C-3, C-4, and C-5 used a singe new F-1 engine for the lower stage developed by Rocketdyne. In 1957 when the Saturn idea was first purposed, it was origonaly called JunoV, to follow in the path of the Jupiter Juno series. However in 1959 Von Braun proposed the name be changed to "Saturn", to indicate that it was infact, an improvement on the Jupiter Juno series. The most Famous of the Saturn rockets was the SaturnV. The SaturnV is comonly known as the moon rocket as it was the rocket used for the Apollo program. With 1.5 million pounds of thrust, Saturn can launch 10 to 20 tons into earth orbit or 2 to 6 tons into deeper space. Today Saturn is out of service, yet its size and power are still greatly unmatched world wide.

Current NASA/US Launch Vehicles

Pegasus

Pegasus is a small three stage rocket developed by a U.S. company called Orbital Sciences. With its three stages, Pegasus comes in two variations, standard and XL, and can launch 1000 lbs into LEO. It is used by government, civilian, military and international customers. At about $25 million per rocket, the Pegasus is making LOE launches more cost effective. Orbital debuted the Pegasus rocket on April 5, 1990. It has flown 35 missions with a 94% success rate. A unique feature of the Pegasus is the way its launched. Unlike conventional rockets, the Pegasus is launched by a Lockeed Martin L-1011 jet. The rocket rides on the belly of the plane as it is carried up to 40,000 feet. Once released it freefalls for 5 seconds then the first rocket engine fires. From here it takes the Pegasus about 10 minutes to reach orbit. The unique launch system employed by Orbital gives the Pegasus rocket an advantage over the rest of the market. Not being bound by launch pads, the Pegasus can be launched from almost anywhere in the world. This feature along with its low cost and good success rate, has already helped the Pegasus secure a place in the global launch market.

*Pegasus rocket onboard Lockheed L-1011

Taurus

Taurus is yet another launcher by Orbital Sciences. It is a larger variation of the Pegasus, designed to fill the small payload market. Taurus had four stages. It can put 3000 lb into LEO and smaller payloads into Geostationary Orbit (GTO). There are two fairing sizes to help increase flexibility for customers. Either size can easily be modified to carry more then one payload, helping to cut costs for customers. Unlike Pegasus it is ground launched, but still offers flexibility and is certified to launch in four locations in the U.S. alone. A unique feature offered by Taurus is the payload mounting process. The payload is mounted in the capsule, and the upper stages are configured horizontally, or “off –line”, then delivered to the launch site and mounted on the first stage. This gives companies the ability to test the hardware on the ground without needing the entire rocket to do so. Since its first flight in 1994, Taurus has completed nine of ten missions giving it an90% success rating. At about $20 million per launch the Taurus is also an attractive option for agencies, governments, and the private sector.

Atlas

Originally designed as a ICBM by Lockheed Martin, the first atlas rocket was a 1.5 stage, 3 engine rocket. Developed in the early 1950’s it had its first test flight in 1959. By the mid 1960’s the military lost interest in atlas, choosing the Minuteman rocket to serve their ICBM needs instead. Since then, there have been some major developments to the Atlas, producing 3 major lines; Atlas II, Atlas III, and Atlas V. All three versions of the Atlas are in service, with the Atlas V being the newest. The Atlas two family can carry payloads up to 8200 lbs. The Atlas III family can carry just under 10,000 lbs and the Atlas V can carry 19,114 lbs. All three families can reach GTO with these payloads.

The first commercial Atlas launch was an Atlas II in 1990. Since then the Atlas II and the Atlas III have performed with 100% mission success. Also since 1990, Lockheed has had seven debut flights of all three Atlas families, with 100% success. The Atlas plays the roll of a heavy lifting vehicle, or launch of multiple, small satellites. With three families to choose from, and several variations on each family, the Atlas rocket offers the consumer a fair bit of flexibility. However the Atlas does suffer one major draw back and that is price.

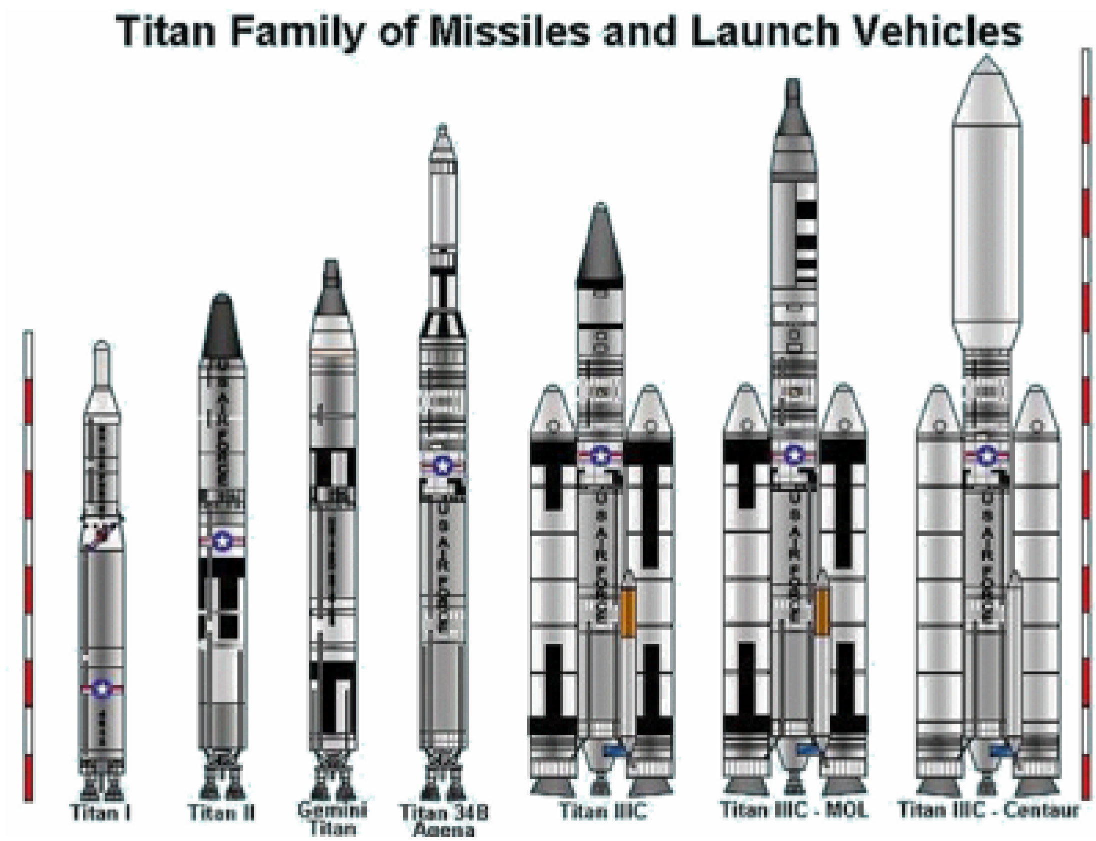
*Current Atlas rockets.

Titan

Another one of Lockheed Martin's designs the original Titan rockets go back as far as the Atlas series. The first two versions of the Titan, initially served as ICBMs, until 1982 when the military began to fade them out. By 1987 all Titan ICBMs were out of military service being refurbished for civil missions.

Today the U.S. relies heavily on the Titan III and IV. The Titan III program began in 1962 and produced several variants of the Titan III. Being one of the larger rockets out there the Titan III can put 28,700 lbs into low Earth orbit, or 7500lbs into geosynchronous orbit. The titan also has the ability to deliver some 2650 lbs to Mars.

The newest Titan is the Titan 4. First flown in the late 1990's the Titan 4 is considered to be the "Heavy lifter" now that the Shuttle is out of service. With a success rate of higher then 95%, the Titan IV can put 47,800 lbs into LEO, 12,700 into geosynchronous, and can even cary 12,470 lbs at escape velocity. However all this power comes at a cost. Like the Atlas rocket, the Titans come with a large price tag.



Delta/ Thor Rocket

One of the staples in the American launch service is the Delta rocket. Designed by Boeing, today two forms remain in service. The first one is the

Delta II. The Delta II entered service in 1989 and has launched 115 successful missions. It offers the ability to put up to 4723 lbs into GTO and 13281 into LEO. With the ability to launch multiple payloads at once the Delta rocket has proven itself a worthy competitor in the commercial launch market. In fact the Delta has been so successful that the design was given to Japan under contract where it was re-named the H-1.

The newest version of the Delta is the Delta IV. There was a Delta III before it, but only 3 have ever flown, and two of them failed. The Delta 4 is a much larger version of the Delta II, with twice the payload. A Delta IV rocket can put 9285 lbs into GTO orbit or 28,950 lbs into LEO

Japan

After WWII Japan was not able develop its own space technology due to restrictions placed on them by the U.S. It was not until 1955 when the restrictions were dropped that Japan was able to start testing rockets and developing its own space program. Despite this Japan still managed to be the 4^{th} country in the world to reach space.

Originally Japan's space program was split into three agencies; Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA). Each agency was separate from the others and was responsible for a different aspect of Japan's space program.

ISAS began in 1964 with the launch of the first Japanese satellite. Within ISAS there are two groups; space scientists and R&D engineers. The space scientists are the ones who do studies on our solar system, other planets, and all other aspects of space. The R&D engineers are responsible for providing designs and technology to help enable the space scientists to do their jobs.

NAL was the first of the three agencies, forming in 1955, although what was not formally referred to as NAL until 1962. As suggested by their name, NAL is responsible for Aerospace technology required in space travel. They research and design rockets, aircraft, engines, and anything else that has to do with space flight.

The last agency, NASDA, was formed in 1969. NASDA was originally the central group, (somewhat like NASA) responsible for overall development and managing of the Japanese space program. Their two primary missions are "Development of satellites (including space experiments and the space station) and launch vehicles, launching and tracking the craft.", and "Development of methods, facilities and equipment required for the above.". Another interesting aspect of NASADA is the are reasonable to making sure that the space program is "beneficial to people's actual lives." This is an interesting aspect because in other countries, such as the U.S., most people don't know what their space agencies do on a year to year basis. This sort of attitude helps keep NASDA in the eye of the public a little bit more then some other space agencies.

JAXA

In 2003, Japan's three space agencies, (ISAS, NAL, and NASDA) merged to form The Japan Aerospace Exploration Agency, or JAXA. This merger allows the three agencies to work together as on things such as joint research and development and use of their resources. It also makes the Japanese space program a more modern and powerful competitor against the more western space agencies. In 2004 JAXA operated with a budget of 273.2 billion yen or about 2.7 billion U.S. dollars. This was down from the year before leaving some of JAXA's projects hurting for money.

Launch Sites

Japan has two main launch sites, Kagoshima and Tanegashima. Kagoshima is located on Kyushu island, off Japan's Pacific coast. The first satellite launched by Japan was launched from Kagoshima, and soon after that a full scale space station was construction o handle the would be needs of the Japanese space program. Originally it was used mostly for sounding rockets, today it launches most of Japan's space missions, including satellites.

Tanegashima is located on Tanegashima Island and is controlled by NASDA. It sits 650 miles southwest of Tokyo. Tanegashima is more of a testing facility then Kagoshima. It has many test facilities for H-2 liquid and solid boosters, and other rocket engines. However Tanegashima does have the ability to launch J-1, H-1 and H-2 rockets, like Kagoshima does, and it also had a range for sounding rockets.

Early Rockets

Japan's first major rocket was the N-1 which had its maiden flight in 1975. However this rocket was not developed by Japan. The N-1 was simply a Boeing Delta rocket, with a few modifications to suit the Japanese's needs. Soon after the N-1 came the N-2 which was first launched in 1981. Like the N-1 it still bore many similarities to its US counter-part. The "N" series served for a little over 20 years, finally being retired for good in 1987.

The next rocket to come along was the H-1, which was first launched in 1986. Like the N series it was still heavily based on the American Delta rocket.

Able to lift 1100kg (2245lbs) into GTO, the H-1 was retired in 1992. By the end of its short service it had completed nine out of nine missions with no failures.

Modern Rockets

H-2

When the Japanese built the "N" series rockets and the H-1, they were built under a licensing agreement with the U.S. Part of this licensing agreement said that Japan could not use the H-1 for commercial launches. This essentially kept Japan out of the commercial launch business. To get around this issues Japan built the H-2. This was the first time Japan had a rocket that used 100% Japanese design. The first H-2 launched in 1994, giving Japan its first big step into the commercial launch market. Being much larger and more powerful then the H-1, the H-2 can lift ten metric tons (22,046 lbs) into LEO or four metric tons (8,818 lbs) into GTO. One draw back to the H-2 was its success rate. At about $190 million per launch the H-2 only had about 71% success.

H-2A

Japan's newest rocket is the H-2A. It was designed to be a low cost version of the H-2. The H-2A was first flown in 2001, and since then has had only one failure giving it a success rate of 85.7%. The H-2A is capable of lifting 11,730 kg (25,860 lbs) into LEO and 5000 kg (11,023 lbs) into GTO. Although the power difference between the H-2 and H-2A isn't much, the big difference is the price. Depending on the exact configuration of the rocket, the H-2A costs

$80 to $90+ million per launch, rather then the H-2's $190 million. This makes the H-2A a very affordable option for companies looking to launch satellites.

Comparative Table

Below is a table to facilitate the comparison of the five major agencies and what they are capable of in the current state.

Country or Agency	Name	Cost ($ millions)	Payload to LEO (lbs)	Payload to GTO (lbs)	Success Rate	Manned Capability?
Russia	Proton (8K82K)*	50	45320		89.66%	Yes
China	Long March	59	20240		90%	Yes
USA/Orbital	Pegasus	25	1000		94%	Yes
USA/Orbital	Taurus	20	3000	1500	90%	Yes
USA/Lockheed	Atlas III	105		10000	100%	Yes
USA/Lockheed	Atlas V	138		11023	100%	Yes
USA/Boeing	Titan III	45		7500	75%	Yes
USA/Boeing	Titan IV	400		12700	86%	Yes
USA/Lockheed	Delta IV	90		9285	98%+	Yes
Japan	H-2	190		8818	70%	Yes
Japan	H-2A	90		11023	85%	Yes
ESA	Ariane 5	120		26400	80%	No

*Statistical Data from "Proton 8K82K"

Considerations Leading to our Prediction: Our Best Case Scenarios

Europe

Currently Europe has an extremely active economy. If all of the major countries within ESA were combined then they would have a GDP that rivals the United States in a smaller, less natural resource heavy area. The countries within ESA have a broad economic base covering manufacturing, high-tech, and banking. This encourages outside financial investment within the European countries. There is no evidence that the European economy will do anything but grow for the next several years.

The best case scenario for ESA is just a continuance of the status quo. ESA has over 50% of the launch market right now, with Arianespace being able to stay in the black without any governmental support. Arianespace would benefit from a slow development of platforms because Arianespace is a little behind at this point in time with published goals to catch up within the next several years as evidenced by the purchase of the Soyuz which gives ESA and Arianespace a manned capability that was lacking before. If ESA can increase the payload of the Ariane 5 to the goal of 26,000 pounds then ESA will pull away more because there are absolutely no countries that can even come close to that. ESA will also benefit from the American private industry staying away from the Launch Service field. This is because many American companies use Arianespace however if an American company develops a consistent launch vehicle then it would be cheaper for American companies to use that then to ship to Europe. Also ESA benefits from the continued issues of the Chinese Long March 3, the issues mainly being a low payload capability and lower percentage of success. Typically, China is able to undercut Arianespace's prices however due the launch issues companies are more likely to invest in the Ariane 5 as opposed to the Long March.

Russia

Economic data and facts for both Russia and China come from the 2003 CIA World Factbook. Currently, Russia's economy is weak relative to the other nations that have been discussed. Commodities that are very sensitive to global prices, including fossil fuels, metal and timber, account for over 80 percent of Russia's exports. This makes the country vulnerable to the forces of supply and demand, and thus shifts in prices. As supplies of these commodities increase, the price decreases, so the country would not be getting the same income. The country's manufacturing base is outdated and must be modernized to compete with other nations. Weak banking systems, corruption, government intervention in the courts, and a lack of trust in institutions have all hurt the economy. Most importantly, Russia's poor business climate has deterred domestic and foreign investors. An enormous 12 percent inflation rate in 2003 undoubtedly slowed the markets as well.

However, Russia's economic growth has been on the rise since its crisis in 1998. This can be attributed to high oil prices and a weak ruble. Investments and personal incomes have increased, and the national debt has been reduced significantly.

The best-case scenario for Russia would operate under the assumption that space platforms are the wave of the future in the commercial market, since they have a bit of a monopoly on that market. Somehow Russia makes foreign and domestic investment more appealing, stimulating its weak economy. Oil prices skyrocket in the wake of declining supplies, and the Russians capitalize on that market. The ruble weakens more, making foreign businesses want to set up factories in Russia. With this sudden surplus of money, the government can afford to fund more major public projects, creating more jobs and, as a result, income. Companies give their employees raises, and people spend their augmented income on goods and services. Suddenly economic growth comes alive. This helps the problem of Russia's tight budget for its space program, since it now has more money to invest. Now the Russians can send more launchers into orbit, making it more appealing to such companies as Motorola and Intelsat to sign up. Russia agrees to cooperate with other space agencies on the platform project. The satellite companies are really attracted to the space platform. Russia can currently put just under 5,500 kg into geosynchronous orbit with its Zenit-3SL (which Russia and Ukraine built together) which is slightly less than the payload of ESA.

China

Since 1978, China has moved in the direction of a market-oriented society. The economy has moved away from government control and has been affected by individuals and non-state organizations. Since 1978, GDP has quadrupled, making China the second-largest economy in the world, only behind United States. China is often subject to bureaucracy, unemployment, unequal distribution of wealth. It has struggled to maintain jobs, lower corruption, and maintain big state-owned enterprises. China's population has become so great that it will hurt living standards. Environmental deterioration is also hurting the nation. Being a member of the World Trade Organization helps the country sustain high growth rates. Foreign investment has played a key role in China's economic growth. Unfortunately, industrial output has been limited by the lack of raw materials.

China would definitely benefit from platforms coming into the commercial market. With a stunning 9.1 percent growth rate in GDP in 2003, the country's explosive economy will continue to grow. The country could be vulnerable to increasing oil prices, since it imports more than it exports. Economic growth could be slowed down by this, which is just the opposite scenario for the Russians.

China can deliver a payload of 2,600 kg to geosynchronous orbit using the Long March 3A, which was last launched in November of 2003. ("CZ-3A") This is far short of what the Russians and the Europeans can produce. So their strength is not so much in the launch vehicles, but the service they provide on the platform will help them get customers. Chinese foreign investment is big, so that will probably help them win over customers. Their experience with Motorola and Intelsat will be a major benefit in the commercial market. Since Chinese rocketry developed from early Russian rockets, one may expect some collaboration between the two nations in the likely upcoming commercial space race.

Both the United States, and Japan are loosing out on the launch market to other countries such as Russia and Europe's *Arianespace*. Both countries have several advantages over some of their competition, and several disadvantages.

Their ability to overcome their weaknesses and exploit their strengths will greatly effect their position in the commercial launch market 25 years out.

The United States

The U.S. is currently behind in the commercial launch market. The current leader is Europe's Arian space program which is so successful it can almost support its self without government support. In contrast to the U.S., Europe's space program is more adequately funded, and more efficiently run. It resembles the early days of NASA during the moon race.

Today NASA is more of a bureaucracy then anything else. Under funded and plagued with the recent failure of the shuttle, NASA is in no position to compete in the commercial market. As it stands, NASA is not the efficient, space agency it once was. One of their major problems is their constant focus on the shuttle and other manned space programs. Many of the accomplishments made by a manned mission could have been just as easily been done with unmanned technology. For example, shortly after loosing the moon race, the Soviet Union sent an unmanned probe to the moon to retrieve samples. This mission was successful and was carried out at a fraction of the cost of one Apollo mission.

NASA's continued focus on using the shuttle is also a draw back. Although the shuttle has been very successful, and can be a useful technology to have, NASA often pushes it in cases where it is unnecessary to have a manned mission. The Space Shuttle require high amounts of costly maintenance between flights which cuts into NASA's budget. On top of that it costs around $400 million per launch, which made it one of the most expensive launch vehicles before it was grounded.

Before NASA can actively compete, they are going to up their efficiency and cut costs, by a large percentage. On top of this NASA would have to take on a newer more competitive mind set and undergo some re-organization of the agency. The chances of NASA accomplishing all of this and becoming a competitor in the commercial launch market within 25 years are slim at best.

All of this leaves the best scenario for the U.S. in the private sector. The United States clearly has the technology and the experience to run a successful, competitive space program. Right now Boeing, Lockheed Martin, and Orbital sciences all offer their own launch services. They serve both government and private needs. Within these companies the United States has a few key advantages. The first of which is reliability. The Atlas three and five series of rockets has had 100% success. Although the price can be high, it is not to unreasonable, making them good for situations when something absolutely cannot fail.

Another advantage the U.S. has is movable launch sites. Boeing has its Sea Launch system which is a large ship with a launch pad on the back. This system is relatively new, but so far it has had great success. The Sea launch system allows Boeing to launch a larger rocket (like a Titan) suited for heavy lift missions, from almost anywhere the ship can travel to. This system is unmatched and allows Boeing to move its launch site to the best suited area of the globe fore each mission. Orbital has the Pegasus Rocket. Like Boeing's system, the Pegasus can be moved to almost anywhere in the world for its launch. The Pegasus is fairly priced, and perfect for smaller payloads. Both systems allow for positioning a rocket to the best place possible for the kind of launch needed.

With all the technology, knowledge, and experience the U.S. has in space, the best scenario would be for the United States to continue to exploit its strengths to gradually get a firm place in the market. As business goes up, the private companies should look at how to bring their costs down. Ten years out from now the U.S. should look at having a lighter, more cost effective fleet of launch vehicles, while maintain the power and capabilities they have now. A joint venture with Japan might help them to develop a low cost, yet powerful rocket. Doing so would give the U.S. private sector the tools it needs to claim a larger chunk of the market 15 to 25 years out from now.

Japan

Japan has had a long standing relationship with the United States since the development of the N-1 rocket. The cooperation came after the Japanese had trouble designing large scale rockets of their own. Since then Japan has gone on to develop the H-2A, which is hitting the market with mixed results. Unlike other rockets its size, the H-2A is much lighter. A lighter rocket means less cost in fuel and engines to lift a payload into space. The H-2A costs $80 to $90 million per launch, making it one of the cheapest rockets designed for heavy lift missions. A major draw back however to the H-2A is that it can only carry 5000 kg into GTO, making the majority of heavy lift missions, to heavy for it to carry. To add to this the H-2A suffered several failures in the early stages of its use, temporarily grounding it, and damaging its reputation as a launch vehicle.

The best scenario for Japan would be to continue its cooperation with the U.S. to develop a more powerful, more reliable heavy lifting rocket. The ideal outcome would be a rocket with the cost and efficiency like that of the H-2A, but with enough power and reliability to compete with the Arian V and Proton rocket. To compliment this new rocket, Japan would benefit from a sea launch system like the one developed by Boeing. Right now Japan's launch capabilities are limited because of a lack of good launch sites. To overcome this mobile launch system should be developed and marketed to the rest of the world. JAXA has the right mind set for a strong completion, but operates on a smaller scale then most other space agencies. Developing their fleet of rockets, and the capabilities they have for launching them over the next 25 years are the best steps for JAXA to gain a greater competitive edge.

Conclusion: The Prediction

While we have found that all of the various space agencies have their own positives and negatives it is more then likely that one will always be ahead of the others in the unmanned space field.

Europe has the highest chance to dominate due to several reasons. First, they are on top now and will do whatever it takes to stay on top. Secondly they have an extremely strong economy which keeps European businesses putting satellites into space. Third, they have their foot in the door with platforms, and if the idea takes off ESA will be either the leader in development or close behind. Finally, the Ariane 5 has the largest payload capability and after several malfunctions it has been extremely consistent over the past several years.

China has the second highest chance because of the following reasons. First, their government is willing to spend the money to get them to the top. Secondly, their economy has been very productive as of late which allows the government the money to subsidize the Great Wall Society. Third, they have the perfect set-up in the government backed private corporation, the Great Wall Society. Finally they have plans to develop a platform within the next 10 years. The reason that China is not the best is due mainly to their low launch capabilities. The Long March 3A has a severely limited payload capability, not quite as low as the Japanese but it is significantly lower then both the Ariane 5 and the Proton.

Russia has the third highest chance because of the following reasons. First, they have the absolute most experience in unmanned space operations. Secondly, they have a well-designed launch system in the Zenit 3-SL and also in the Soyuz. Finally, they are the furthest ahead in the development of platforms and if the idea takes off they will get the most of out it. However, Russia has quite a few weaknesses. First and largest, Russia's economy is in shambles, which leaves the government close to no money to fund the Russian Space Agency. Also, the Russian government has no interest in developing a quality space agency at this point in time due to their vast problems in many other areas.

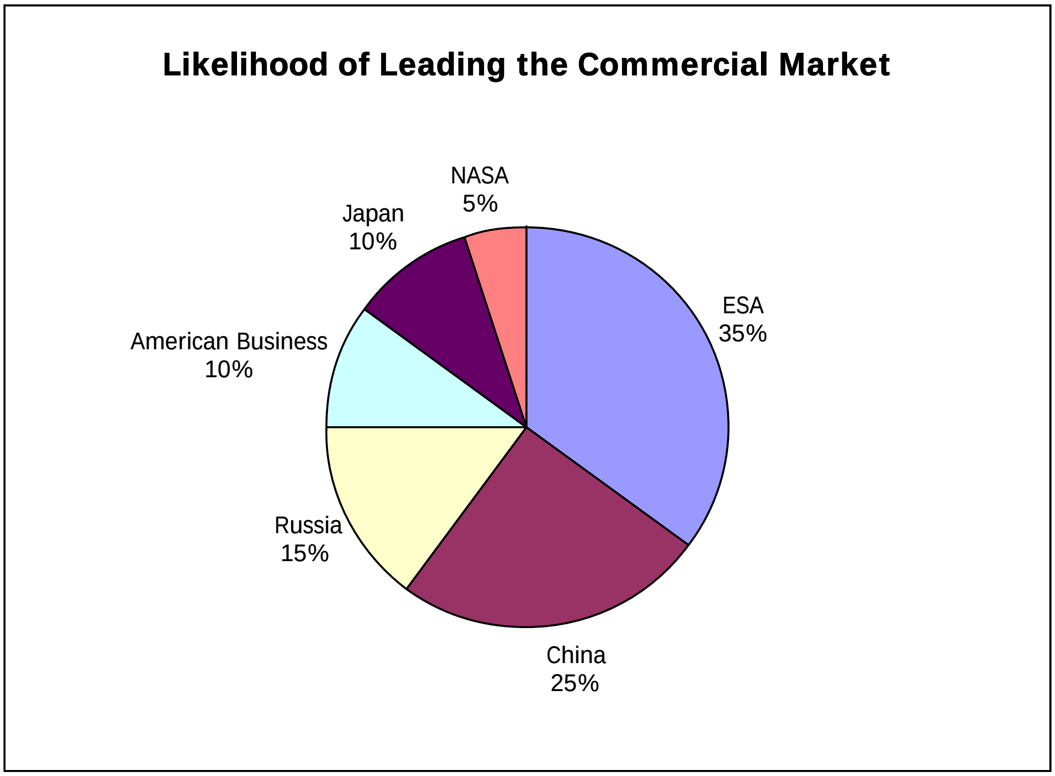
Next is American business. They have potential to become the leaders since they do everything from a business stand-point; they just involve themselves when they believe they can make a profit, and typically they have a very streamlined approach to product design, and implementation. They also have quite a bit of experience from launching Space Command's satellites over the past 20 years. They also have the potential to launch a huge amount of payload, almost as much as Europe with 12,700 pounds being able to be launched into geosynchronous orbit. However American businesses are not without their problems. First, they are not as large as most governments so the R&D money will need to come directly from the profits. Secondly, only one of them has a launch base as of right now. Third, they do not have a history of serving as a launch service aside from for the Air Force, while the Air Force is not an easy customer they usually have different requirements then commercial customers.

Next is Japan. Japan has a history of innovation which can do nothing but benefit them in the long run. They also have a manned plan in the works which can be used to service platforms. Japan has quite a few problems however. First, their launcher has the lowest Earth to Geosynchronous orbit payload out of any major countries. Secondly, Japan does not have the vast history of the ESA or

Russia or even the recent commercial success of China. Finally their economy after a strong showing during the 1980s and up through the mid 1990s has as of late hit the skids and has not been recovering lately.

NASA is the least likely to succeed. This is due to many reasons. First, NASA has close to absolutely no recent unmanned experience. Secondly, NASA is turning a completely blind eye to anything that does not have a manned element. Third, NASA's bureaucracy is completely inefficient for any attempts to become a money-making enterprise. Fourth, the American public usually has no patience or trust in a branch of government making money. When a branch begins to make money the public feels that the branch must be somehow cheating the American people and immediately stops the money making process.

The probabilities that we developed for each of the space groups being the top unmanned space option are as follows: Europe with 35%, China with 25%, Russia with 15%, American business with 10%, Japan with a 10%., and NASA with a 5% chance.



As stated earlier Europe will probably stay on top but if anyone takes over it will be either China or Russia with a slim chance that either the Japanese or American private industry can make a push for the top. NASA has close to no chance and will need a complete reorganization and a change in the American public's mindset in order to become a commercial competitor.

Future Work

As a follow-up to this project, we believe looking into the possibilities of coalitions rather than competition would be of interest. Determining real mathematical formulas for the factors we used to make our prediction would be a good project. Looking into the social and political implications of what we predicted would be of interest, also.

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