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46

THE FUTURE OF SPACE EXPLORATION

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by

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Abstract:

The current study is part of the forecasting phase of a proposed technology assessment. This report represents the literature review phase of an effort to predict what the moon and near space would look like thirty years from now if the USA and People's Republic of China (PRC) had a space race to the moon. Another objective of the project is to assess the likelihood that competition rather cooperation in space will prevail. The following is a review of the past and present activities of the USA, Russia and Chinese space programs.

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Introduction:

This literature research report is meant to provide the necessary information for doing the forecasting aspect of a technology assessment. Specifically, the goal of this project is to set the stage for a follow up group to estimate the social and technical implications on planet Earth of a moon race to create a moon base between China and the US. I describe the past and present events in China, the United States and Russia that involve near space and the moon. The goal is for us to have a discussion of the important historical and present events, and based on that information make a forecast thirty years out focusing on activities in near space specifically with relation to the moon.

Our approach to the problem is to make predictions on the likely outcome of any new race by comparing the current situation with what happened in the past, where the past refers to the previous space race between the Soviet Union and United States. After some research into the relationship between The United States of America and People's Republic of China this group has decided to assume a competition between US and China, rather than cooperation or forming coalitions with other space agencies. Another focus of this project is to describe what the interests of each country are in a space race, and how they are likely to pursue these interests. Also, we will consider whether either country will have more trouble than the other in getting the support of its citizens for a space project, and why.

This project will involve analyzing reports and doing our own investigation into the Chinese space program today, NASA today , and the previous space race between the Soviet Union and the United States by means of existing books (such as Hanford's Biography on *Korolev*) journals, periodicals, multimedia, and online sources. From these sources we hope to obtain the necessary information to understand the previous capabilities of NASA and where they stand today. Furthermore, getting information on the Russian space program and China's relationship with countries ranging from Russia to Brazil is important because it is necessary to know what technology the Chinese may have access to on the open world market.

From this literature research the next group will compare what happened in the previous space race with what is happening in the present to assess the current relative capabilities of China and US. Finally, based on this information, the concurrent group will make a projection about what will probably happen in the next thirty years if there is a Moon race, how, when, and why. The concurrent or follow up group will make an assumption that there will be no huge space technology technological breakthroughs in next thirty years. However, since we have limited time we will not be able to discuss the full social implications of this technology buildup on the future of planet Earth.

To be able to achieve these goals it is important for our group to look deeply into technological capabilities as well as, economical, political, and cultural dynamics of both United States and China. With this information our group will compare the differences between each society and find out if/how the differences will be an advantage or a disadvantage to each country. Since we are making a prediction thirty years into the future knowing what happened in past events can greatly assist us in comparing them with present events to give us a better understanding of each country and the way they deal with certain situations. The Soviet Union's and United States' previous race is very important because it is an example of how each country approached the race how they justified it, and where they left off. Also, the equipment the Russians used will likely be available to the Chinese and knowing what technology they have at the outset will be important to consider predicting where this race will take us in thirty more years of rapid incremental development.

One of the things the group will try to find out and describe is the technical capabilities of the Chinese space program. To assess China's technical capacities, we will compare current known technology that China has to that of other countries (e.g. Russia) at various points in time to determine how fast they developed their own technology. This will be necessary to determine how far Chinese technology is likely to evolve in the next thirty years if it is developed internally in isolation or openly purchased. We will also try to account for the Chinese political, social, and overall cultural aspects to explore possible motivations behind the moon project and any further space aspirations to see which strategy they will follow. Any information may that gives us insight into the organization and dynamics of the CNSA is also highly sought after. We want to know how it compares with respect to the existing NASA program and technological capability.

The next subject our group will research is the Soviet Union politics and achievements in space. We will observe how close the Soviets came to winning the space race back in the 1960s. This group will research into Korolev, who was a very important figure in the Russian space program. We will emphasize him because of his great contributions in the Cold War race of United States and Russia. Research on politics will also contribute greatly to the project since China also has a Communist regime that operates in secrecy and links its space program with its military ICBM production systems. We will be able to reflect this on the project and try to decide if communism which claims to be a technocracy, was an obstacle or a boost to the space program, as compared to the open democratic system of NASA which answers to congress.

We will also research the technical abilities of NASA. One focus will be on the technology developed in the Apollo program and how long it took to develop it, lessons learned by the program, and a look at current technology. With this information we will try to determine what it would take to rebuild NASA into the agency it was in the Apollo years, and what NASA might be capable of in the next thirty years if that were done. Lastly our group will research into the political and bureaucratic aspects of the NASA during the past space race between USA and USSR and will try to figure out how NASA was managed during this period. Also the effect of the support of the American public on the past space race and the level of enthusiasm of the American public during the past space race will be researched. Keeping this in mind we will try to predict whether Americans currently have enough public support to engage in such a race and what Americans need to be willing to do in order to get enough public support to gather the resources needed to beat the Chinese in a possible moon race.

As a follow up to our project, we suggest either a study looking into the possible future of what would happen if there was cooperation between China and US or if the possibility of having each agency form competing coalitions with other space agencies were to emerge. Another good project would be to look into the social and political implications of our technical prediction for the whole of planet Earth. In short, this project is expected to raise and frame more questions than it answers, but should get things off to a good start on the proposed technology assessment.

Background:

United States:

Though humans have dreamed for centuries of space travel and exploration, only in the mid-20th century did this become technologically possible. The technology that made it possible was the rocket propulsion device, which was developed for military use in the form of the ballistic missile (Booker 2). Scientists soon realized that it could be used for another purpose and by the late 1950's, descendants of the V2 rocket were being used by the United States to send satellites into orbit. However, this was just the beginning.

In the late 1950's, speculation about whether it would be possible to put a man on the moon in the near future was building, and in fact there was already some planning going on. The National Aeronautics and Space Agency, NASA, was formed, and they began the Mercury program to test the effects of zero gravity on humans. Alan Shepherd was sent into space on what was essentially a double-size V2 rocket, and then later Mercury missions used a modified Atlas ballistic missile (Booker 5). The Mercury program proved that humans could survive in zero gravity. This was a very important step, but it was also a small one.

It takes a lot more power to get to the moon than it does to simply get into orbit, and, at the time, NASA didn't have a rocket capable of supplying this amount of power (Booker 20). Dr. Werner von Braun, director of the George C. Marshall Space Flight Center at Huntsville, Alabama had designed the Saturn I rocket, which was the largest one we had at the time, but it soon became apparent that even it wasn't up to the task of putting a man on the moon. Because of this, the Rocketdyne Division of North American

Aviation, Inc. created the F-1 rocket, which was eight times as powerful as the rockets NASA was using at that time.

At the time, scientists saw three different possibilities for getting to the moon and back. The first idea was to make a rocket device large enough to carry everything including fuel to return home to the moon and back. They actually began planning to use this technique with a theoretical vehicle called Project Nova. However, it quickly became apparent that they couldn't design and build such a device within the timeline of the Apollo program, so this idea was scrapped.

The second possibility involved blasting off into Earth's orbit, and then refueling to go to the moon. This would have been feasible, but because it might have been difficult to get two large vehicles to rendezvous in orbit, it too was abandoned. The third possibility was the one NASA ultimately went with: lunar orbit rendezvous. This technique involved leaving the fuel they would need to return to earth and anything else they wouldn't actually use on the surface of the moon in lunar orbit and descending to the moon on a separate landing module.

Using the new F-1 rocket technology and his past rocket designing experience, Von Braun began designing the largest rocket that could be developed in the Apollo timeframe. It was known as the Saturn V, and it used five F-1 rocket engines. This was the device that ultimately became our vehicle to the moon, launching the Command Module which would remain in lunar orbit, and the Lunar Module which would actually land on the moon.

The Mercury program was followed up by the Gemini program, which featured a two-man spacecraft. The Gemini program was also used to test orbital rendezvous techniques. This experience would be necessary given the new plan for the Apollo mission, which was the lunar orbital rendezvous. The Gemini program also featured the first-ever space walk.

The launch vehicle used for the Gemini program was the Titan II intercontinental ballistic missile. The actual spacecraft itself was considerably more complex than that of the Mercury program as well, having various independent sections. The McDonnell Aircraft Corporation was the primary contractor of Gemini equipment. There were some difficulties encountered during various Gemini missions, but overall they were a great success and many successful dockings were completed (Booker 31).

At the same time as the Gemini program, which featured manned missions in Earth's orbit, NASA began sending unmanned probes into lunar orbit and to the lunar surface. This was necessary to gain more knowledge about the moon itself, in order to know what to prepare for in the actual Apollo missions. There were three series of probes sent: the Rangers, Surveyors, and Orbiters.

The Rangers were by far the most primitive. They were simply satellites with a video camera, and a "survival pack" consisting of equipment to measure surface conditions. The probes would crash themselves into the surface of the moon, returning video footage of the crash to scientists on Earth, and hopefully leave the survival pack on the surface to collect additional data. Ranger 7 was the first successful Ranger probe due to many difficulties.

The Surveyors were significantly more advanced. This probe was to be soft-landed rather than crashed. The video cameras on it could be controlled from Earth to focus on desired areas after landing. The Surveyors were also used to determine the effects of rocket engines being fired on the moon, when one of them took off and landed elsewhere. Based on this information, it was determined that the Lunar Module would be capable of landing on the moon and then returning to orbit.

The Orbiters were launched concurrently with the Surveyor probes. They were designed to orbit the moon and take detailed pictures of possible landing sites for the Apollo mission, in order for scientists to choose the most desirable sites. They selected five (Booker 35).

After gaining all this new information, NASA was ready to develop the equipment necessary for the Apollo missions. The spacecraft was designed modularly, just like Gemini. The Command Module was the first stage, and the Service Module which held the rocket engines and their fuel was the second stage. The third stage was the lunar module.

The first few Apollo missions (missions 4 and 5, for some reason) were used as unmanned tests for the Command Module and Lunar Module, respectively. These tests were both successful. Apollo 7 put a 3-man crew into Earth's orbit for 11 days, showing that men could survive inside the Apollo spacecraft. Then Apollo 8 featured a 3-man crew orbiting the moon; the first time humans had left the Earth's gravitational field. Apollo 9 was a manned test of the Lunar Module in Earth's atmosphere, followed by Apollo 10, a test of the Lunar Module in the Moon's gravitational field. After Apollo 10, everything had been successfully tested.

Apollo 11 was the culmination of the project: the lunar landing mission. It was also highly successful, although the Lunar Module landed about 4 miles away from where it was expected to land. Neil Armstrong and Buzz Aldrin walked on the moon, performed some experiments, and successfully re-docked with the command module. The mission's goals had been achieved.

However, things have changed since the so-called Golden Age of NASA. The organizational culture of the employees has changed completely. In the Golden Age, space travel was new and exciting; it's now routine and boring. Risks were seen as necessary for advances, and the failures that went along with taking those risks were seen as acceptable. Nowadays, failure is deemed unacceptable, and thus they don't take the same risks that they used to. This obviously helps to perpetuate the lack of new and exciting missions. (McCurdy 155).

During the Mercury, Gemini, and Apollo programs, NASA officials took pride in knowing exactly how everything worked. They outsourced as little as possible and kept tight control on what they did outsource. Today, much more work is outsourced to other companies, and not nearly as much work is hands-on. Additionally, all of the flight testing that went on in the early days is now seen as costly and unnecessary, however recent mistakes should have shown how it could be helpful. (McCurdy 134).

Recently, President George W. Bush announced plans for a major change in direction of our space program. The new plans will shift NASA's focus from low orbit projects such as the space shuttle and the international space station to more ambitious projects such as returning to lunar missions, building a lunar base, and ultimately going to Mars. The timeline he suggests has the technology for the missions developed by 2008, manned test flights by 2014, and the United States putting a man back on the moon by the year 2020. (Bush)

The technology to be used for these missions will be revolutionary. Different versions of the spacecraft, known as the Crew Exploration Vehicle, will be capable of low-orbit missions, moon missions, Mars missions, and even deeper space missions (Morris). Actual details of what technology will be used are currently being worked out, but it seems as if it will likely be based on the modular technology used for the Apollo missions, rather than another space plane like the space shuttle. NASA has contracted both Boeing and Lockheed Martin to design the spacecraft, and it will select the better design and put it into practice (Sietzen).

One question on many minds is, without the Saturn V launch vehicle, what will be capable of lifting the CEV into orbit? Each company seems to have different plans. Boeing is planning to use a launch vehicle based on the Delta rocket (CES – Delta IV Heavy Launch Vehicle). Lockheed seems to be planning to use the Atlas rocket (Crew Exploration Image Gallery).

Experts are divided on how feasible all of this actually will be. Some think this is the push that will be necessary to return NASA to the frontier mentality of the Golden Age, and the technical advantages that come along with it. Others are worried that NASA is too set in its current ways to change. Still others are concerned that either the budget is too small for the project to be successful, or that the dates are too far off in the future to build the excitement needed to reinvigorate NASA (Bush's Space Vision Thing).

NASA came into existence with the National Aeronautics and Space Act of 1958 after the public and political outcry due to Sputnik. The purposes and policies of American space activities were:

- the expansion of human knowledge
- improvement of aircraft and space vehicles
- development of craft to carry instruments and living organisms into space
- separation of military and civil space activities to show peaceful intentions
- preservation of the United States as a leader in space science and applications
- cooperation with other nations
- optimal utilization of American scientific and engineering resources

The principles of NASA have changed little since 1958. The program had its highs and lows throughout its existence of 46 years. But it seems that NASA is turning back to its early days when there was a big emphasis on manned exploration. An example of this is George W. Bush's announcement of his new Vision for manned US Space Exploration including a manned mission to Mars. This is a bold long-range plan that needs big commitments both politically and financially.

A Discussion on the New Vision of George W. Bush

It is debatable whether to take this new vision seriously, because in the past a former president, George H.W. Bush, proposed a similar program in 1989. His OMB director estimated its 30-year cost to be about $590 billion on a 2003 dollar basis. However, after the Reagan and Bush administrations, in the fiscal year 1992, the yearly deficit hit a record $290 billion out of a federal budget of $1.38 trillion (21% of the total) and the national debt was mounting. Congress and the administration began cutting the budgets of 'less-high-priority' programs. NASA was not exempted from the budget cuts.

NASA's budget decreased during the 1990s; on the other hand it had increased during the 1980s in inflation-adjusted dollars.

Currently, the US is again facing an increasing deficit close to $500 billion. Bush claimed that the projected increase in NASA's budget over the next few years will not affect his fiscal policy to contain discretionary spending at a 4 percent growth rate and to cut the deficit in half within five years.

During a U.S. House of Representatives hearing on Feb 12, 2004, there was a lot of skepticism, curiosity, and even some positive attitudes toward the President's new plan. The witnesses were NASA administrator Sean O'Keefe and the President's science advisor John Marburger. During the hearing a few Congressmen questioned the necessity of such a costly program "at this time of record-high deficit spending" and asked the possibility of postponing the spending. On the other hand, one Congressman claimed that the U.S. is in desperate need of more young people to go into careers in science, math and engineering. President Bush added that this program will serve that purpose by inspiring young people. O'Keefe supported the new plan and reminded the Congress that in August 26, 2003, the Columbia accident investigation board observed the absence of strategy and national goals as being contributing factors in the space policy drift over the past three decades.

Neither Bush nor O'Keefe has yet put a price on the new space objectives and there are already many skeptical views on the new program. A Washington Post article, on Feb 11. 2004, stated that Norman Augustine, the retired chairman of Lockheed Martin, made a comment that NASA doesn't have enough money or bright young stars to achieve President Bush's goal of returning astronauts to the moon and flying from there to Mars. Augustine said, "it would be a grave mistake to undertake a major new space objective on the cheap", he said. "To do so in my opinion would be an invitation to disaster."

Political History

Presidents since NASA was established:
Eisenhower, Dwight 1953-61
Kennedy, John F. - 1961-63
Johnson, Lyndon - 1963-69
Nixon, Richard - 1969-74
Ford, Gerald - 1974-77
Carter, Jimmy - 1977-81
Reagan, Ronald - 1981-89
Bush, George H.W. - 1989-93
Clinton, William J. - 1993-2001
Bush, George W. - 2001-present(may 2004)

NASA Administrators:
Dr. T. Keith Glennan, August 19, 1958-January 20, 1961
James E. Webb, February 14, 1961-October 7, 1968
Dr. Thomas O. Paine, March 21, 1969-September 15, 1970
Dr. James C. Fletcher, April 27, 1971-May 1, 1977
Dr. Robert A. Frosch, June 21, 1977-January 20, 1981
James M. Beggs, July 10, 1981-December 4, 1985
Dr. William R. Graham, December 4, 1985-May 11, 1986 (Acting)
Dr. James C. Fletcher, May 12, 1986-April 8, 1989
Richard H. Truly,May 14, 1989-March 31, 1992
Daniel S. Goldin,April 1, 1992-November 17, 2001
Daniel R. Mulville, November 19, 2001 - December 21, 2001 (Acting)
Sean O'Keefe, December 21, 2001- present(may 2004)

Accomplishments of Daniel Saul Goldin - NASA Administrator, April 1, 1992 - November 17, 2001

Despite lower budgets, his "faster, better, cheaper" approach has enabled the Agency to deliver programs of high value to the American public without sacrificing safety. When Goldin became Administrator in the spring of 1992, outside observers perceived the Agency to be a bloated bureaucracy pursuing missions that were too expensive, took too long to develop and flew too infrequently. NASA also was criticized for an imbalance between human and robotic missions.

Through Goldin's aggressive management reforms, annual budgets have been reduced, producing a $40 billion reduction from prior budget plans. He implemented a more balanced aeronautics and space program by reducing human space flight funding from 48 percent of NASA's total budget to 38 percent and increasing funding for science and aerospace technology from 31 to 43 percent. During his tenure, the Agency's civil service workforce was reduced by about a third, while the Headquarters' civil service and contractor workforce was reduced by more than half. These reductions were accomplished without resorting to forced layoffs by using attrition and other methods. At the same time, NASA's productivity gains climbed 40 percent.

Goldin also cut the time required to develop Earth and space-science spacecraft by 40 percent and reduced the cost of these by two-thirds, while increasing the average number of missions launched per year about four times. During the same time, space shuttle costs were reduced by about a third, while all safety indicators and mission capabilities have achieved significant improvements.

Management Problems in NASA

The middle managers and the bottom workforces of NASA are reluctant to speak up. People are afraid of being moved to different and ineffective jobs when they speak up.

After the challenger disaster, NASA's managers were speculated to regard it as a failure when a launch is held up. On the contrary, they should regard it as a success not to go on with risky launches.

NASA lacks an environment where people can speak up without the fear of retribution. NASA's top managers say they are trying to encourage their employees to go out and seek opposition views if there isn't any to what their idea is about a particular situation. NASA is currently doing a reorganization of some of its space centers such as Kennedy to shake up ingrained inertia.

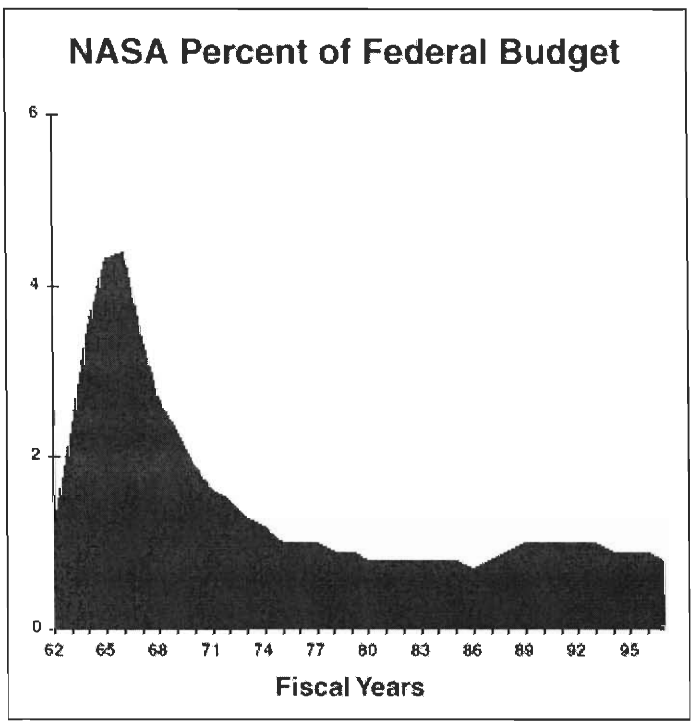
The leaders in NASA are criticized for not being accountable. The feedback loop between the leaders and their subordinates is not rapid enough and needs to be improved. There are people saying communication is an issue at NASA. Recently less than half of the workforce, the civil servant workforce, responded to a survey.

The House recently passed NASA work force legislation to improve NASA's ability to attract and retain the best and the brightest new engineers, scientists, astronauts, etc.

<u>Budget</u>

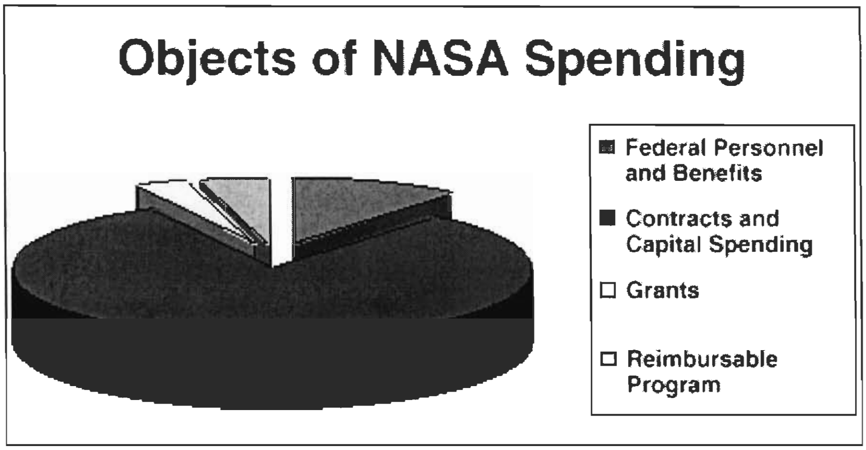
NASA Budget Trend

NASA's share of Federal spending has been declining from a high of 4.4% of the Federal Budget in 1966, at the height of the Apollo program, to about 0.7% currently. NASA continues to make significant scientific and engineering advances with fewer resources.



How NASA spends its Budget

In accomplishing its programs, NASA spends the greatest part of its resources through contracts for a wide variety of support and services, plus the acquisition of capital assets. NASA supported a Civil Service workforce of 18,973 during 1997. NASA spends the rest of its resources through grants, principally research grants with colleges and universities, and for its reimbursable program with Federal, commercial and international agency customers.



Looking into the future

The federal deficit will hit a record $477 billion this year and get worse if lawmakers cut taxes or increase spending, the Congressional Budget Office projected in a report sure to become ammunition in the election-year fight over red ink.

The budget office also estimated that deficits for the decade ending in 2013 would total nearly $2.4 trillion. The August report foresaw deficits totaling $1.4 trillion over 10 years.

In fact, U.S. government funding for research and development has been cut in half when looked at as a portion of the U.S. Gross Domestics Product. In 1965, the U.S. spent over 1.8% of its GDP on scientific funding. By 1997, that amount had dropped to a mere 0.9% of the GDP. Private industry has filled many of the funding gaps that the government left behind, but funding from the private sector creates a new problem for scientists: they are nearly forced by their funding sources to pursue only those topics in the interest of the private sector. NASA has had a mixed record on the credibility of its budgeting.

This will not be an easy year to start a major new initiative in the face of the growing deficit. The President's budget is $16.2 billion and rising in the five year plan and is well within the President's fiscal policy to contain discretionary spending at a 4 percent growth rate and to cut the deficit in half within five years. All of those actions have been accommodated in the proposal the President submitted on February 2, 2004.

The massive budget in the year 2020 according to a report would be about $22 billion. $15 billion for the development of a crew exploration vehicle is a pretty big ticket item. Mr. O'Keefe said that NASA's budget charts indicate that there won't be U.S. funding for the International Space Station beyond 2016. On the other hand O'Keefe said then that NASA will continue the operation and maintenance of the ISS consistent with the U.S. space exploration goals.

In the past, Congress has often invested so heavily in NASA programs that it seems too late to cancel a program even after it proves to be troubled. We've seen an example of that. What milestones for assessment are built into the major aspects of the expiration initiative? At what point should NASA and the Congress reexamine the initiative, particularly CEV development to determine whether it is appropriate to proceed to completion. In the period of time of 2005 to 2009 the total projected amount is $86 billion.

Public Opinion

The government surveys that came out suggest that NASA is the most desirable agency to work for in the Federal government. That is the American University survey that was released Fall 2003.

The public interest continues to support space exploration. During January 2004, the NASA web site has received 6 billion hits. That involves 47 unique different visitors. Over the span of this 40-day period that is more than twice the total number of hits NASA received all of last year. All of last year was four times that which we've ever received before.

Even at its height, the public doubted the space program. Two-thirds of people in a 1971 poll by the Roper Organization said the government spent too much money on space exploration.

But most people weren't aware the budgets had been cut, the USA TODAY poll shows. It found only 29% of those polled believed that NASA's budget had shrunk over the past 10 years compared with the overall federal budget.

During the reign of the Apollo Project, NASA received unprecedented public support. Astronauts were heroes, and the space program moved full steam ahead toward its goals. (Byrnes)

Luckily for NASA - in a poll of 1,120 adults, approximately 80% said that the Shuttle Program should continue and 68% said that accidents were bound to happen sooner or later. 40% of those questioned believed that NASA was spending too much money, and 46% said that they would not support NASA if taxes increased for the agency's spending. However, these numbers were not much different than in April 1981, before shuttle launchings began. Americans saw Challenger as an isolated tragedy in the grand scheme of space exploration and NASA still offered hope for the American dream.

One excellent example of the way in which scientists should conduct their public relations is the recent NASA Shuttle mission that marked John Glenn's return to space. Granted, every research endeavor cannot be as exciting as the return of an old hero, but NASA saw a chance to perform a mission that yielded many scientific benefits as well as capturing the public eye. Though it yielded enormous publicity, Glenn's return to space was inarguably not a publicity stunt: his mission completed more than eighty scientific experiments and provided NASA with valuable data. Extensive research was done on the effects of aging in space, sleep patterns, and the repair of deteriorating body systems. (Bilstein)

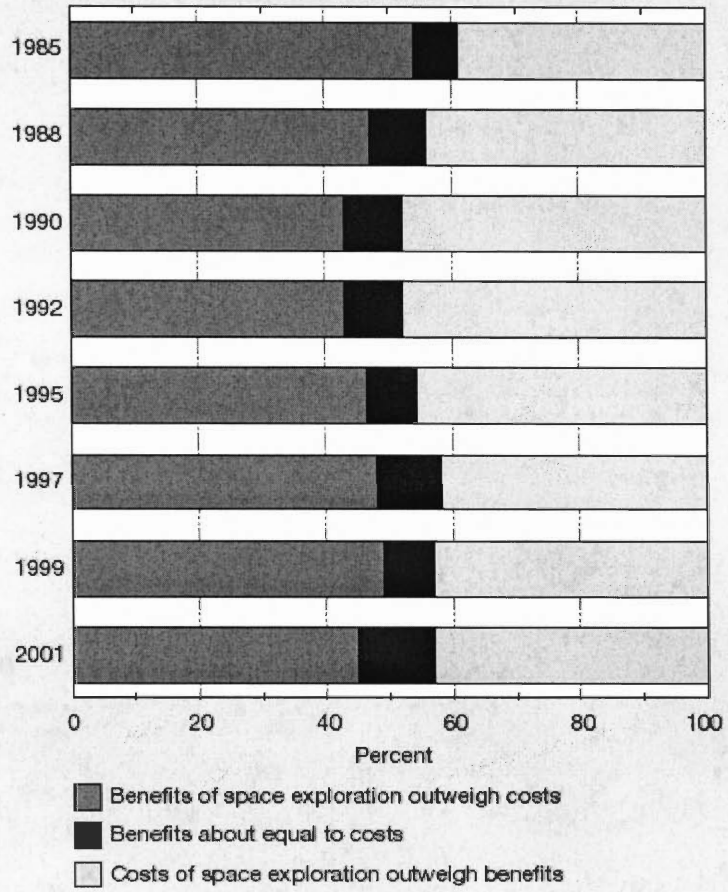
Scientists observed the biggest event in the history of the universe in the spring of 1997. At the far end of the universe, seven billion light-years away, two neutron stars collided, releasing as much energy in a few seconds as the sun will release in 10 billion years. Observations of the energy burst enabled scientists to solve a mystery that had been plaguing physicists since the dawn of the Cold War-where do gamma rays come from? Across the country, few newspapers carried the story. The New York Times, Los Angeles Times, and Boston Globe all addressed the discovery, but smaller newspapers, as well as television and radio outlets, failed to even mention this unprecedented occurrence.

There is belief that NASA can send approximately 1,000 robots to Mars for the cost of sending one human and bringing that human back. And so, NASA has to compare what we can do with 1,000 robotic flights compared to one human flight.

Private Sector

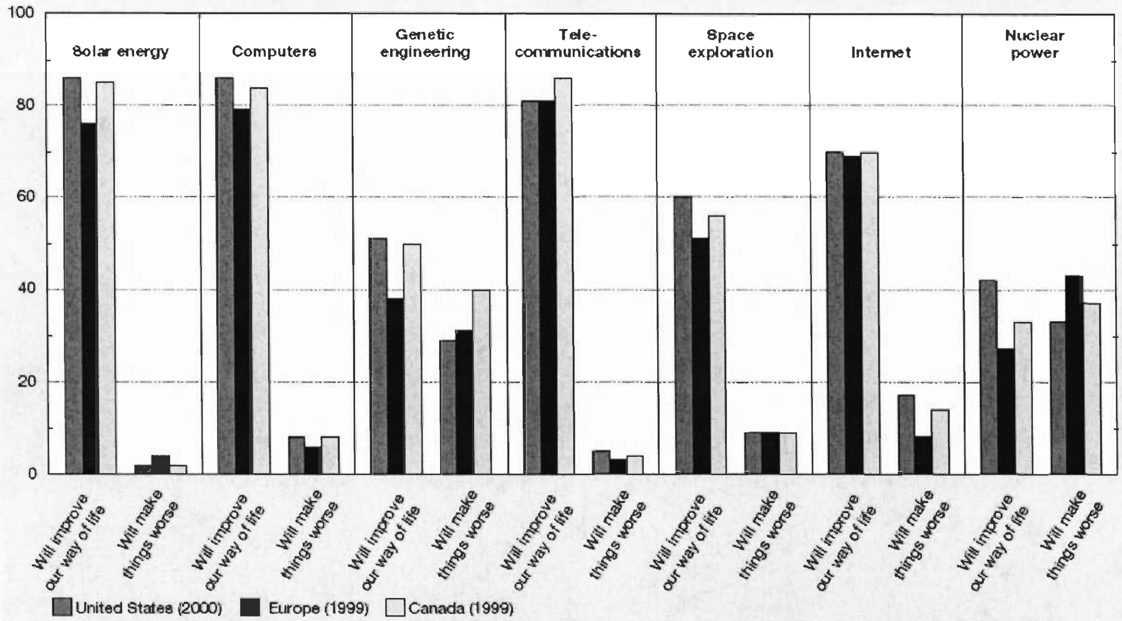
A recent survey stated that the contractors are feeling like they are being treated as second class citizens. During the 1990s, the budget cuts also affected the private aerospace industry. During this period, a European consortium, Airbus, became second in the market after Boeing and ahead of McDonnell Douglas. After this incident, NASA was criticized for allowing American dominance in the space and airlines industry to slip away.

Figure 7-12.
Public assessment of space exploration: 1985–2001



See appendix table 7-25. *Science & Engineering Indicators – 2002*

Figure 7-11.
Public attitudes toward selected technologies in the United States, Europe, and Canada



SOURCES: Gaskell, G., and Bauer, M.W. (editors) *Biotechnology 1996–2000*, National Museum of Science and Industry (U.K.) and Michigan State University Press. The 1999 and 2000 surveys were conducted by George Gaskell, Martin Bauer, and Nick Alum for the European Commission; Susanna Priest, Texas A&M University; and Edna Einsiedel, University of Calgary.

Science & Engineering Indicators – 2002

Russia:

Korolev and his engineers had a dream, they were to create the world's first artificial Soviet satellite. They had certain goals, they set certain characteristics. The most important characteristic of this first mission was simplicity. They did not desire a complex satellite. It was to have a radio system, an antenna, and it was designed to be spherical. Sputnik 1 was constructed for delivery by an R-7 rocket, it weighed 83.6 kg. R-7 was a strong rocket capable of carrying much heavier payloads so the light weight of Sputnik1 was the main source of confidence for Korolev in this project. This satellite was launched on October 4, 1957. At this date the space race commenced. The reaction of the Soviet Union was not as expected.

The launch of the first man-made satellite did not even make it to the front page on October 5, 1957. It was the next day when Soviets were aware of what they had accomplished and acknowledged the response of the rest of the world. They celebrated this accomplishment with great joy, it was right after than Sergei Nikita Khrushchev ordered Korolev "to send something new in space" for the celebration of the revolution. Korolev and his team had one month to prepare until the celebration. He had no time for a test flight, yet he still managed to create Sputnik 2. It weighed 508 kilograms, Sputnik 2 carried the world's first space passenger, a dog named Laika. Sputnik 3 was launched on February 1958 but this launch resulted in failure. This was because of a rocket engine failure. The rocket went up about 13 kilometers and then parted with the satellite. On May 15, 1958 a second launch of Sputnik 3 was conducted which resulted in success. Sputnik 3 was 1.3 tons and was more complex than the first two kinds of Sputnik. Sputnik 3 also removed any doubts regarding the launch of an ICBM from the Soviet Union to the United States. The launch of Sputnik 3 forced the United States to spend more on manned satellites and rocket motors with greater thrusts.

First Manned Missions (Vostok)

Korolev had in mind the creation of a manned space craft as early as 1948. However, the design of Vostok which would carry Cosmonaut Yuri Gagarin into space did not begin until 1958. Just like Sputnik, its shape would be spherical. Korolev thought that the spherical shape would be better since it would be symmetrical. Vostok was supposed to have two components. The shape of the first component was spherical. It was in this component in which the cosmonaut would continue his journey. The second component was under the rocket system. The weight of Vostok was 4.73 tons. Vostok was designed in such a way that very little margin was given to the human factor. Everything was operated by six simple buttons, these buttons were coded and had to be punched three at a time. They did not want any failures resulting from human factors therefore they simplified and automated the whole operation. The codes for these buttons were given in envelopes to Cosmonauts right before the launch.

It was not only the system which was simple but the spacecraft. It lacked the instrument for a soft land which would force the cosmonaut to use another method to get out of the spacecraft. An ejection seat was created, the cosmonaut would have to eject during his flight on Earth. He would later be recovered. Since there was little margin for the intellectual ability of the cosmonauts, perfect health was the priority when selecting among twenty pilots. Finally two cosmonauts were selected, Yuri Gagarin and Gherman Titov. On April 12, 1961 Yuri Gagarin achieved a magnificent victory for the Soviet Union in the space race. He was the first man to be in space. The duration of the mission was 108 minutes. After Vostok 1 on August 1961, Vostok 2 was launched. This time the cosmonaut was different, his name was Gherman Titov. Vostok 2 was a much longer mission than Vostok 1, it was 25 hours. As the duration of flights increased, the confidence in the spacecraft and the mission also increased accordingly. There were many more launches of Vostok but among these the Vostok 6 was very important because it was on this mission Valentina Tereshkova was sent to space. It was another first for the Soviet Union; she was the first woman who traveled to space. After this flight the Vostok project was finally complete. The project Soyuz would now take the place of Vostok.

Soyuz Missions

This spacecraft was thought to be a descendent from the Vostok mission but actually it was a total redesign for a new mission. Korolev saw this spacecraft as a lunar flyby but his main goal was to send a manned spacecraft to orbit, then land on the moon. There were nine missions conducted from 1967-1970. The spacecraft (Soyuz A) was composed of three modules. They were orbital, descent and instrument. Soyuz A was designed as a manned craft. Soyuz B was an unmanned supply craft and Soyuz-V was an unmanned tanker. Our main concern is Soyuz A "the manned craft." This was the main spacecraft on which the whole hope of Korolev and his group rested. Soyuz 1 was supposed to be the first manned spacecraft which belonged to the Soyuz family. Unfortunately Soyuz 1 resulted in a great catastrophe on April 24, 1967. Soyuz landed with such great velocity that it was impossible for the cosmonaut "Vladimir Komarov" to survive. Korolev died in 1965 and it was obvious that Soviet Union was suffering the loss of this man greatly. It was on October 25 1968, Soyuz 2 was sent to space but as a precaution it was sent unmanned. After the success of Soyuz 2, enough confidence was gathered to launch Soyuz 3. This time it was a manned spacecraft which carried Gyorgi Beregovoi. Soyuz 2 and Soyuz 3 had a rendezvous and came very close to one another. This mission was a success and a great confidence boost for the Soviet Union.

After this mission, Soyuz spacecraft was the official vehicle of Soviet space industry. On January 14-15 1969 "the world's first orbiting space station" was created. The successful docking of two manned spacecraft was a spectacular accomplishment for the Soviet Union. Soyuz 4 carried cosmonaut Vladimir Shatalov and Soyuz 5 carried cosmonauts Yevgeni Khrunov, Alexei Yeliseev and Boris Volynov. Soyuz 6, 7 and 8 were launched in October, the main goal of these launches was research and data gathering. Soyuz 7 and 8 were aimed to dock with one another but this was never accomplished. Soyuz 9 was launched in June 1970, the goal of this project was also scientific research. After this era, there will be a new endeavor and goal for the Soviet space industry, the rise of space stations

Salyut Space Stations

The Salyut space stations comprise two eras. The Salyut 1-5 space stations represent the beginning of space stations. Salyut 6 and 7 are second generation space stations which led to the creation of a great space station MIR. Salyut 1 had four components, the first one allowed the transfer of cosmonauts into and out of the space station. This eliminated the spacewalk which was a major design problem for the Soviets. The first component was used as a docking system. The second component was designed for the propulsion system. The propulsion system of Salyut 1 was similar to the Soyuz propulsion system but contained certain modifications. The third compartment was designed for working. In this work compartment optimum living conditions were desired. A dinner table, sleeping bags, medical units, a library and other accommodations for the life conditions of cosmonauts were included. There was also another compartment designed for scientific research and data gathering. There were labs in this compartment which possessed scientific research equipment. Two launches were made to Salyut 1, both of these launches resulted in failure. Soyuz 10 docked with Salyut 1 yet cosmonauts failed to enter Salyut 1. Soyuz 11 docked with Salyut 1, this time cosmonauts did manage to enter Salyut 1 and conducted experiments, but this mission resulted in tragedy because the crew of Salyut 11 was found dead upon the return to Earth. Salyut 1 was discarded and Salyut 2 was next sent, but this space station was also a failure because two unmanned flights resulted in failure. These space stations served two purposes, military and civilian. Salyuts 2, 3 and 5 were designed to serve military purposes, Salyut 4 which had a similar design with Salyut 1 served civilian purposes.

Salyut 3 was the first successful space station in Soviet space history. Soyuz 14 had a successful mission with this space station and some medical experiments were conducted. Salyut 4 took the place of Salyut 3 and this space station which served civilian purposes was also successful.

Second Generation Space Stations

The first generation space stations created many problems for the Soviets. They had many failures as they acquired the necessary experience to create the second generation of space stations. Salyut 6 and 7 are the second generation space stations which marked a new era for the Soviets. Salyut-6 was similar to Salyut-4 and they both were designed to serve civilian purposes. The only difference Salyut 6 had from Salyut 4 was it had an extra docking system which enabled the docking of two spacecraft and it also had three solar panels for energy production. It also had certain modifications in the mounted accessories, a topographical camera and a resource camera were installed for mining and map making uses. There was also a telescope used for planetary observation.

Soyuz 25's mission was to dock with Salyut 6 but this mission resulted in failure because of a docking problem. There were always problems regarding the docking system, this last problem raised the question of a major engineering and production flaw in the docking system of Salyut. Soyuz 26 made all those doubts go away because the mission was a success. Cosmonauts docked with Salyut 6 and inspected the space station for certain flaws. Many more Soyuz missions were conducted on Salyut 6 (Soyuz 28, 29, 36, 35, 40). In those missions cosmonauts stayed in Salyut 6 for 96 days. Salyut 6 missions had 95 percent success rate in contrast with the first generation space stations which had a much lower success rate than Salyut 6.

The positive results of Salyut 6 brought confidence for Salyut 7. There were great expectations from this station. Salyut 7 did have additional improvements like more solar panels which made it more durable and efficient. The station offered a more comfortable environment for cosmonauts. Manned Soyuz-T missions were conducted to Salyut 7. These missions brought great success and there even was a great Cosmonaut endurance record of eight months. The Soviets now had sufficient experience and confidence to create a great space station which would enable them to continuously man a space station. This would be the famous MIR space station.

Third Generation Space Station (MIR)

The launch of the third generation space station was conducted on February 19, 1986. This space station was a modified version of the second generation Salyut. The reason second generation Salyut's were selected is that these stations were a proven, reliable entity. Their great reliability built confidence in these space stations. Therefore the Soviets modified this series to create MIR. The modifications on MIR were numerous. MIR had the ability to dock up to six spacecraft. The energy problems which were common in Salyut space stations did not exist in MIR because the solar panels on MIR were larger that the solar panels in Salyut models. MIR was a great creation; in this space station the Soviets reached the peak of their expertise in space stations. Two cosmonauts spent a year on MIR, which was the greatest record of endurance in a manned space station.

The space shuttle Buran was created specially for MIR. This space shuttle would have made the journey easier if it had ever been used for manned flight, but it was not. Buran was similar to the space shuttle of the United States in shape but was launched on a liquid rather than a solid rocket booster. The Soviets did not want to risk any failures, therefore they built the shuttle very similar to the model of United States, but later decided the shuttle was not a good design and far too expensive. However, MIR was a great space station without any equal in its day. Only the current International Space Station is larger and more elaborate. MIR was a testament to the great expertise of Soviet space stations at its high point.

Korolev

When we started working on this project the first source offered to me by my professor was James Harford's book on Korolev. He told me to read this book carefully and advised me that if there ever was a great man scenario in space history this would be it. As I read the book I could not agree more with my professor and the author. This book is a testament to show the world how a great man could change the fate of one nation. He was the chief director of the Soviet space program. He coordinated the missions of Sputnik, Vostok and Voskhod. All of these missions brought great success to the Soviet Union. Under the direction of Korolev, the Soviet Union achieved many victories from the world's first satellite to the first man in space.

Korolev was born in the Ukraine on December 30, 1906. He was a very smart child who grew up in a broken family. His parents were divorced so he did not grow up in a happy environment. He lived with his mother and did not see his father. His mother was also taking classes. This made things difficult for little Korolev since he grew up without a father. The frequent absence of his mother pushed him into a lonely existence. This forced him to show initiative and improve his inventiveness so that he was not bored because of his lonely environment. Korolev was an excellent student, his teachers said he had brilliant memory and he was very good at arithmetic. He studied at Kiev Polytech, and then he was accepted to the Moscow Higher Technical School.

In Moscow, he would have the privilege of working with the great scientists and was later recruited by Tukhachevsky after proving to himself that he had great potential. Tukhachvesky was a very important figure not only in the Soviet Union, but also in Korolev's life. He funded the research of rocket engines and was the main supporter of Korolev and his group. Tukhachvesky founded RNII, this was a Reaction Propulsion Institute. Korolev was assigned there to achieve the goal of "high velocity stratospheric flight ". The use of rockets in military weapons would also be researched at this institute. Since RNII was founded by Tukhachvesky, a very powerful military general working under Stalin, Korolev was now officially working for the military. The creation of ballistic missiles was going at full gallop under the supervision of Korolev.

Korolev was very successful. Because of his good work, he was promoted to chief designer and coordinator of RNII. This promotion unfortunately did not bring luck to Korolev. Soon after this promotion he was arrested by the NVKD, the military intelligence unit of the Soviet Union. He was arrested on June 27 1938. At that time Korolev was thirty one years old. Although he was twenty years younger than the great

American rocket scientist Robert Goddard, his achievements in rocket science nearly matched those of Goddard.

The great question is why would such a successful scientist be arrested? Korolev would soon find the answer to this question. He would learn this answer in the Lefortovo prison in which he was tortured during his interrogation. He was accused of collaborating with the Germans and deliberately holding the liquid rocket project back. This accusation however was based on a larger one. This whole incident was caused by the arrest of General Tukhachvesky. This General was seen as a German spy. This accusation was made by the NKVD. The interesting part is that the NKVD got this information from the Germans. However, NKVD was not aware of the fact that this was false information supplied by the Nazis. The Stalin era was so paranoid that any information was taken very seriously and actions were taken rashly. Therefore there was never a thorough investigation. The Nazis had a great victory since Tukhachvesky was more than a mere general. He was the one man who modernized the Soviet army. He was the founder of RNII in which great weapons such as ballistic missiles were created. The arrest of Tukhachvesky not only brought the demise of modernization of the Soviet army, but also brought the demise of Korolev and other scientists working under Tukhachvesky's RNII. Since Tukhachvesky was seen as a German spy, paranoid minions of Stalin thought that everyone working for Tukhachvesky was a conspirator and therefore they were all arrested along with Korolev. Since they did not have proof for everyone, a fair trial was out of the question. The method of the NKVD was to torture the accused until he accepted the accusations. During the Stalin era, 5 million people were arrested and subjected to the method mentioned above. The main goal of Stalin was to evoke terror, he tried to terrify people in such a way that no one would ever dare to conspire against him. In this method however many innocent people suffered unnecessarily. One of them was Korolev.

After torture and a quick trial in Lefortovo, Korolev was sentenced to 10 years of hard labor and sent to Kolyma gulag. In this gulag there was a gold mine and the prisoners were ordered to work in this mine. This was a very difficult chore which required great strength. The conditions of the gulag were terrible, it differed very little from the Nazi concentration camps. Korolev stayed in Kolyma for one year, he was than moved to a Sharaga. Sharaga was a different penal institution. When Stalin arrested most of the scientists and engineers out of paranoia; he realized that the improvements in technology suffered greatly. He therefore gathered all the scientists and engineers in one prison and forced them to work on military technology. Tupolev, who was the professor of Korolev in Moscow Higher Technical Institute, intervened and brought Korolev to the Sharaga where he was working. Unlike gulags life in Sharaga was not that terrible. Decent food was given out and they did not do any exhausting work. They had time for rest and their health was an important issue for the NKVD so the health care was much better than the care in the gulags.

Korolev worked under the team of Tupolev and they started working on Tu-2 light bomber. He than continued to work on the use of rockets in planes and weapons. He worked on the four chamber RD-1 rocket engine which was used on Pe-2 dive bomber. He continued to work in Tupolev's sharaga until the end of World War II. During his captivity he achieved magnificent successes. He made a lot of contributions to aviation and rocket science. At the end the war he went to Germany to learn more about the V-2 rockets. It was in Germany that the Russians captured German scientists who worked under Von Braun. These scientists gave very helpful tips to Korolev and his group about ballistic missiles.

After these tips Korolev created the R-7 rocket which was the world's first Intercontinental Ballistic Missile (ICBM). The R-7 rocket could also carry heavier payload than V-2 rockets so R-7 was used in Sputnik missions. In Sputnik missions Korolev achieved marvelous things but the most astonishing one was the preparation of Sputnik II which was completed in one month. After the Sputnik missions came Vostok and Voskhod missions which brought great fame and honor to the Soviet Union. Korolev was the mastermind of all three of these missions.

At the time of his death Korolev was trying to build a moon rocket called the N-1. The handicap that he faced compared to the Americans was the lack of a booster comparable in power to that of the F-1. Without it had had to use 3 or 4 times as many smaller rocket engines and find a way to coordinate and balance them if one of the rockets failed, and 2 or 3 were expected to do so on any given launch. This problem was not solved at the time of his death, and indeed there was a spectacular explosion associated with the last attempt to get the N-1 moon rocket to work. The decision to turn off the rocket opposite to any one that failed was the probable basis for this failure. If more than 3 failed the system would be done more than 6 rockets and the great Moon rocket would never get off of the launch pad. Given this failure, the Soviet Government denied that there ever was a policy to try to reach the moon in a manned flight before the Americans. The Russians went to the moon and collected samples in an unmanned mission instead, using the proven Proton booster.

After the death of Korolev, the Soviet's accomplishments in space declined. It is interesting that the political leadership completely lost faith in the space science and technology community and decided that without this great mastermind as "Chief Designer" they could not achieve the goal of getting to the moon. Actually they had lost more than their space designer, his team an NPO Energyia had designed their land-based and submarine launched ICBM's as well. They gave up rather quickly on the Moon after a huge investment and turned to cover-up very soon after his death. The space program did not stop, as they turned to unmanned missions and perfecting their space stations, but with their booster expert gone they lowered their sights to what could be done with the booster technology they had. At least in the eyes of the Communits leadership, Korolev was a great mind who really made a difference. He was irreplaceable and in a sense he was the only one who had such stature that he could force the various units in the far flung space industry to cooperate or else, and enforce his design concepts on everyone. The whole success of the Soviet program rested on the shoulders of Korolev and his students not because they were brilliant, but because they have the complete confidence of the leadership, and that meant power over others and a discretionary budget under the control of just one man who answered only to the top leader, or his designated representative.

Communism

Communism had many effects on the USSR, not only in the space race. This regime affected every branch of Soviet activity. Communism had pros and cons, but before we get into the benefits and harms of this ruling system, we will first see what communism is all about.

Communism began with the ideas of Karl Marx. Marx believed that the strength of workers whose only resource was a majority in the population and physical labor would surpass capitalist states and shoulder Russia into a better and a more just future. Tsarist Russia was in turmoil, peasants and workers were unhappy due to the unjust rule of the tsar. This triggered the uprising of Bolsheviks and the era of Nicholas II was over. This time Lenin took over. He first signed a peace treaty with the Germans took Russia out of World War I. Lenin achieved this at the expense of great territorial loss but certain reforms were more vital than land for Lenin. In order to achieve these reforms, he needed a state of peace because Russia was about to enter an era of change which would shake the country both economically and socially.

Lenin first seized the estates of landlords and gave them to the control of peasants. The factories were now being controlled by workers. The equality of women and men was more emphasized. One of the most important changes that Lenin tried or established was free provision of health care, education, and housing. Under the rule of Lenin certain economic actions were taken, the government nationalized banks, insurance companies, railroads, and large factories, forbade most private commerce, and seized grain from the rural population, undermining peasant support for the regime. Lenin also did not allow economy, finance, transportation, heavy industry, and foreign trade run by any companies except under state rule. Domestic companies were allowed internal trade, small-scale manufacture and farming. Although the country came through a revolution, with the economic reforms Russia emerged from a financial crisis. All of these revolutions however proved how important the role of the party and the ideology of the chairman played in the formation of the USSR. After the death of Lenin we will see how the ideology of the chairman and of the party could affect the USSR.

Stalin was a different leader than Lenin although he worked with Lenin for many years, their approach was very different. Stalin used brutality more than Lenin, he used extreme force on his opponents, and an example of this would be the treatment of Trotsky. Trotsky was assassinated in 1940 while in exile in Mexico. People who opposed his policies were also punished severely. People were sent to the "gulag" for the reason of an opposite opinion. The era of Stalin was total terror; many people were shot or sent to death in forced labor camps because of the paranoia of Stalin. After Stalin came Khrushchev, he worked very closely with Stalin but when he came to power he tried to change everything created by Stalin. Gulags were closed, the severities of the punishments were reduced and even the past actions of Stalin were criticized. Khrushchev had other ideas. Therefore he tried to change everything Stalin stood for. He tried to do this by bringing the ideologies of the forefather Lenin. He was however unsuccessful because going back to Lenin's ideology and single party rule was too much to accept. Khrushchev was therefore replaced by Brezhnev. During the era of Brezhnev, the Soviet Union entered a term of tranquility and in this term the economy started to shrink, the budget for the space industry also had a great reduction because of this fact. Brezhnev did not want drastic changes, he wanted to contain the current situation of the Soviet Union. This result was very negative since the economy declined because of this status-quo policy. After Brezhnev, Gorbachev took the reins. However because of his policy the whole system collapsed. When we observe all the leaders, we can make out a fact related with communism. The party leader's ideology decides the success or failure of his era. The whole nation's path and destination is drawn by the party leader. The problem with this method is that no stability could be achieved in a system such a system. Lenin's work was changed by Stalin; Stalin's work was changed by Khrushchev, and so on. The space industry was also affected by this problem.

Korolev was first sent to the gulag because of his ideologies. When Stalin realized that he had killed nearly every valuable space scientist, his only option was to release the few he had left, especially Korolev. Therefore he took Korolev out of the gulag. The Zek, became the state secret "Chief Designer" with near total control over all aspects of the space and missile program, as he no longer had any peers in his field. He would have to train a whole new generation of experts.

This action is also a good example to show how unbalanced the system was showing how Korolev was a very valuable man. He first mastered the V-2 rockets by closely observing the German scientists, but all Russian team was also formed and given all the same assignments. They were allowed to question the German's until they could surpass them. He then created R-7 rockets which would be used in the Sputnik mission. He was really the mastermind behind the Soviet space program. There is no comparable figure in the NASA Apollo program, not even the highly respected Von Braun.

Korolev and his team was such that he sent Sputnik 2 out in one month and this mission was a great success for the Soviet Union. However, much time was lost in dealing with the unreasonable demands of the politicians who were his patrons. In one case they complained to him that the Americans had a 3 man spacecraft and the Soviets was designed for 2. Months were lost as they reconfigured the 2 man space craft to carry three people just once, for purely political reasons.

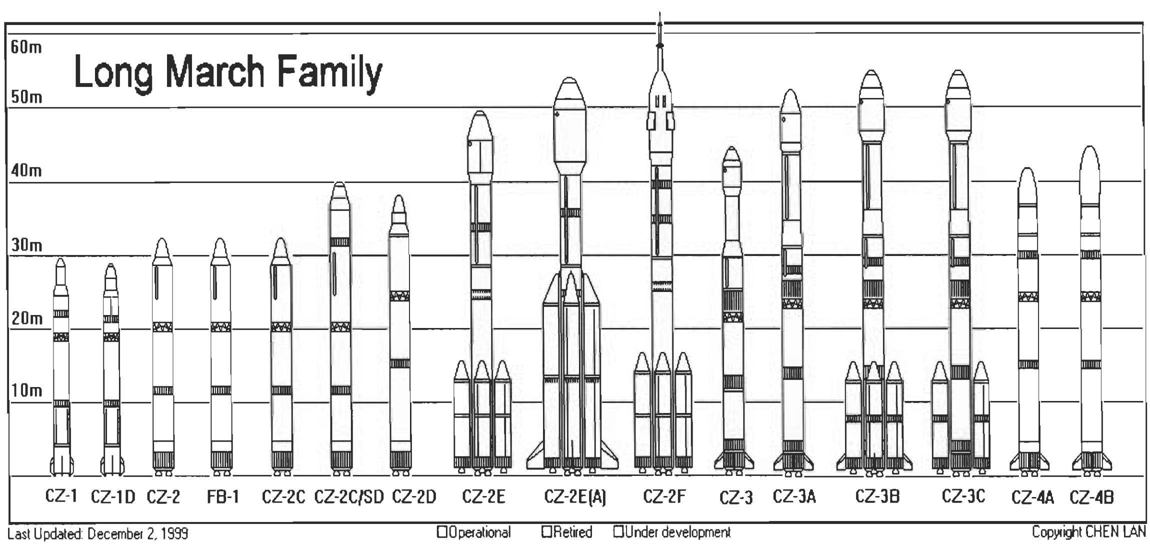
Korolev worked with Khrushchev and in this era he was very well supported and thus the Soviet Union had many victories. The Sputnik and Vostok missions brought great success both to Korolev and the Soviet Union. Korolev died in 1965 and after the death of this great man the Soviet space program declined dramatically. The Soyuz mission had great failures as in Soyuz I which resulted in loss of life. At the era of the Brezhnev era, the economy declined and the funding for the space industry was cut back. Brezhnev's status quo policy was the main reason for economic crises.

Communism had positive and negative contributions to the Soviet space endeavor. The possibility of cheap slave labor was the most important factor of communism. Workers were not given much money yet Korolev could reward his favorites and punish slacking with a phone call or two. He controlled access to privileges in a command economy so people could be rewarded by other means than salary increases. Those privileges could be very important, such as a more comfortable house than the ones other citizens had access to or use of a car. For a young engineer, being moved to the top of the apartment waiting list over 2 years long could mean the chance to marry and start a family. Since this was an authoritarian regime, people could be forced to focus more in one area or to physically work more.

The negative side of the system is the unstable environment. A long standing policy could very quickly change. This spontaneous environmental change had a very negative effect on the space industry. Also a general lack of funds and small number of contractors caused many problems for Korolev and his team. They were the underdogs in this race, but while he lived, they ran neck and neck with the better funded Americans who had 3 times as much money, twice the manpower and much better computer facilities.

China:

Since Russia and China share technological information, knowing Russia's past technology will be important in describing China's technical capabilities. In evaluating the technical ability of the Chinese it is important to know the history of China's delivery rocket the Long March (LM) in English and Chang Zheng (CZ) in Chinese. A brief history will describe the skill and speed in which the Chinese have evolved their rocketry. This will give us a better understanding of China's current abilities in rocketry and how far the Chinese will likely get in thirty years.



(Go Taikonauts, geocities.com)

LM-1 and LM-1D

The LM-1 was used to launch the first two Chinese satellites, the Dong Feng Hong (DFH) 1 and 2 into space. (tbs-statellite) The DFH 1 supposedly broadcast their national anthem "The East is Red". The LM-1 can carry a 300 kilogram payload to 400 km with 70% incline. It launched on April 1970 (DFH 1) and March 1971 (DFH 2). The LM-1 had one failure in November 1969. The LM-1D is an enhanced version on the LM-1 that can carry heavier payloads. The LM-1D can carry 900 kg into a Lower Earth Orbit (LEO). It had its first launch in 1991.

LM-2 series

The LM-2 was launched in 1970, but was a failure because the vehicle lost altitude after liftoff and was destroyed. The LM-2 was quickly replaced by the LM-2C which had a successful launch on November 26, 1975 carrying the DFH 4. The LM-2C is China's oldest operational rocket and has a reported 100% success rate. It can carry a payload up to 2,640 kg into LEO and had Motorola IRIDIUM as an anchor customer with seven launches of communication satellites from the Taiyuan Satellite Launch Center (TSLC). To handle Motorola's double launch schedule the LM-2C was modified to the LM-2C/SD with a new upper stage called, a Smart Dispenser (SD), which allowed two satellites to be launched at once. (fas.org) The LM-2E started development in 1988 and is the first rocket in the LM-2 series designed to reach a geo-stationary orbit (GTO). It is an upgraded version of the LM-2C and one of the most powerful rockets that the Chinese have developed. It is capable of carrying approximately 9,200 kg into LEO and 3,500 kg to GTO. (Go Taikonauts, geocities.com) This new stage, the perigee kick motor (PKM), was used to carry payloads from LEO to GTO. In 1990 the LM-2E had its first test flight and successfully delivered a 50 kg Pakistani piggy-back satellite, but failed to carry the Optus dummy cargo to GTO. The next mission on August 13th 1992 was successful in carrying Optus B1 into GTO. On January 25, 1995 the LM-2E exploded on the pad killing seven workers and injuring another twenty-seven with debris. Though it has faced some troubles the LM-2E is still a cornerstone of Chinese satellite launches. Lastly is the LM-2F, which is much like the LM-2E with four strap-on stages and 2 core stages. However, the LM-2F is specifically designed to support manned space and has been the rocket for all the Shenzhou program missions. The LM-2F has two unique systems: its fault monitoring system and its escape system to ensure the safety of the Taikonaut. (Space daily)

LM-3 series

The LM-3 was introduced in 1984 with a new third upper stage able to reach a geostationary orbit (GTO) from a low earth orbit (LEO) with up to 1, 500 kg payload. It is a three stage rocket; the first two stages are identical to the LM-2C, but the third stage is a restart-able liquid hydrogen and liquid oxygen engine. With launches from 1984 – 2000 the LM-3 has a lot of history in China. In 1984 on its first flight its 3rd stage failed to ignite, but the next six missions were a success. On June 10, 1997 the LM-3 was used to launch China's first geosynchronous weather satellite the Dong Fang Hong 45, which was replaced by a newer meteorological satellite on June 25, 2000, the DFH 49. (tbs-statellite) In 1994 a LM-3 was joined with an upgraded version the LM-3A capable of bringing a 7,200 kg payload to LEO and a 2,600 kg payload to GTO. The next rocket in the LM-3 series is the LM-3B which is the most powerful rocket to date that the Chinese have tested. It is actually a hybrid between the LM-3A and LM-2E because it uses the LM-2A 3 core stages with the LM-2E four strap-on boosters. (fas.org) Its payload is said to be 13,500 kg to LEO and 4,000 kg to GTO, which is more than any other rocket to date. Its first mission on February 14, 1996 carrying the Intelsat 708 satellite, which failed due to an electrical failure, hit an apartment complex killing six people and injuring 57. However, the rest of its missions which ended in 1998 were all successful.

LM-4 series

The LM-4 also called LM-4A is a 3 stage rocket designed for carrying payloads to a sun-synchronous orbit and is also capable of carrying multiple payloads. The LM-4 has only had 2 launches, with its first launch on September 06, 1988 carrying China's first sun-synchronous weather satellite. The second launch occurred on September 03, 1990 and carried three meteorological satellites into sun-synchronous orbit for studying the upper atmosphere. The LM-4B is the most popular of the LM-4 rockets and has had a 100 % success rate with six successful launches since 1999. Its first launch was in May 10, 1999 and carried two satellites, the first was a meteorological satellite and the second was a military telecommunications satellite.

The Shenzhou

The Shenzhou, China's manned spacecraft successfully brought China's first Taikonaut, Yang Liwei, through space on October 15, 2003 in the Shenzhou V. The Shenzhou capsule was built by China Aerospace Science and Technology (CAST) and is said to be a precursor to a space station. (SpaceToday) The Shenzhou V orbited the Earth 14 times for a total distance of around 600,000 kilometers and each orbit took about 90 minutes to circle the Earth. As mentioned before the Long March 2F was used to carry the Shenzhou into space. The Shenzhou capsule is 8.86 meters in length, weighs 7,790 kg, and has 52 engines for complete control of the spacecraft. The capsule is made up of three sections: a descent module, and orbital module, and a propulsion module. (chinapage)

The orbital module is where the Taikonauts live and work, but it can also be used as a payload storage area. The module is 2.8 meters long with a 2.25 meter diameter and has two access hatches at either end. One is for access to the descent module and the other end is equipped with a docking system to dock with a space station. Also the orbital module holds most of the science experiments that will be conducted in space. The orbital module stays in space an extra six months after descent module returns to Earth. (spacedaily)

The middle section of the craft is the descent or re-entry module. It is 2.059 meters long, is 2.5 meters in diameter, and has three seats to carry three Taikonauts into space. The outer surface of the module is covered with an ablation material, which is the heat shielding structure for the spacecraft. The final module, the propulsion or service module has two deployable solar panels, which are closely monitored to analyze their power supply network.

The most promising technology that the Shenzhou has that was mentioned early is the docking system at the end of the orbital module. This technology gives China the potential to dock in space with another capsule or even a space station such as the International Space Station (ISS) and shows where their technology is headed. Another interesting technology that the Shenzhou V is said to be equipped with is an alarm system for avoiding chunks of floating debris. (space.com)

Pace

To make a grounded speculation on the future it is important to know about the pace of the program in the past and at present. From data it seems that since 1970 the program has averaged 2.3 launches every year with a total of 76 launches of the Long

March rocket, but does not include the FB-1 with 11 launches. For China to be a competitor in a global race this pace doesn't seem promising. However, 55 of the 76 launches have occurred since 1990 and from 1990 to 2003 the average launch per year is 4.23 launches. Clearly the majority of China's total launches have occurred in the last fourteen years out of the thirty-four years of the program's existence. Only one launch has occurred so far in 2004 and it was a LM-2C launched on April 18, 2004.

Looking directly at the manned space program, the program averages one Shenzhou every year on average with five launches in five years. Clearly China's rocket technology is picking up with more commercial launches and no failures since 1996. However, the manned space program still has not sped up and will need to, to be able to meet some of their forecasted goals. Having a successful space program will depend on getting experienced Taikonauts and with only one launch per year this could take a long time.

Technology

One criticism of China's technology is the Shenzhou spacecraft and how it looks just like the Russian Soyuz. Critics claim China copied the Soyuz. This is true. Even the Chinese admit that the Shenzhou was modeled after the Soyuz rocket, but they claim that it was designed and built on their own. There are many factual differences from the Soyuz to back this up. For example the boosters on the Shenzhou are different than the Soyuz. The first is the Chinese escape system which is much better than the Russian's. The Chinese escape system allows for an escape from a failing launch at high altitudes where Russians can only escape at lift off. (space.com) The Shenzhou is also a bigger spacecraft than the Soyuz. Lastly the orbital module of the Shenzhou is very different from the Soyuz; it is released from the re-entry module before descent and can be controlled separately from Earth to stay in orbit for an additional six months. With all of the upgraded features of the Shenzhou it seems even safer than the Soyuz. Due to these reasons, the Shenzhou is not just a copy of the Soyuz.

Failures

The biggest disaster that struck the Chinese space program as mentioned earlier was on February 14, 1996 after an LM-3B carrying an Intelsat 708 communication satellite had an electrical failure and crashed into an apartment complex. According to Chinese officials six people were killed and fifty-seven people were injured. However, a video taken of the wreckage makes it seem likely that the death toll was probably larger than announced, unless residents of the apartment were extremely lucky. (CNN.com). The other major disaster that China endured was on January 25, 1995 when an LM-2E exploded on the launch pad killing seven workers and injuring another twenty-seven with debris. Out of all 76 Long March launches there have been 8 failures giving the Long March approximately a 90% success rate from its beginning, which is a pretty impressive success rate. Social motivation for going into space is the driving force for the Chinese space program. Therefore, to fully understand the space program one most also look at the social and political structure of China.

Social

One needs at least two areas of knowledge to attempt a reasonable forecast of the Chinese capability to execute a successful manned moon mission, then to compare it to NASA's capability. These areas are the technical feasibility, and the social dynamics. To merely know that the Chinese National Space Agency (CNSA) has or will have the technical potential to go to the moon is inadequate and an empty statement. The decision to go to the moon needs to have a logical foundation and strong political and public support, i.e. motivation. Why and how the giant of the Far East chooses to justify the moon mission on a social, political, and economic basis is just as important as the question of whether they can actually do it. Understanding the motivations behind such an ambitious project is unlikely unless one has some idea about their economics, politics, and general culture. This equates to the relevant recent history of the Peoples Republic and the roots of the actual space agency.

With over five thousand years of tradition, China has the oldest and richest culture in the world. However, since most of it is irrelevant to the topic at hand, only the time period starting from the communist revolution (1949) will be examined. Yet approaching this study and omitting the foundation of China, which is considered to be the religion of Confucianism, would be foolish. Even though Confucianism is not as dominant in people's lives as it was in pre-revolutionary China, it still remains influential in government policy and in many geographical and cultural areas. Hence, a brief introduction to this body of belief must take place. (Johnson-Freese, 1998)

Confucianism had three core principles in the traditional sense that were adopted from the highest levels of government down to the family units. The first principle advised to not look progressively forward but to seek present harmony, which basically means to be distrustful and skeptical of anything new. Secondly, Confucianism favors hierarchical political and social organization, and thirdly, the core of Confucianism is a requisite understanding of "correct" conduct by all members of the population; the governing of the hierarchical relationships is by rules and standards. Aside from outside invasions, the first core principle is an influential factor behind China's desire for isolation, disinterest, secrecy, and "closed doors" policy to foreign nations. The third principle limits the individual, designating one's obligation only towards his personal "web" of responsibilities. The goal of Confucius was social harmony and inner stability, both of which are things that the Chinese people have historically pursued but always struggled to accomplish. (Johnson-Freese, 1998)

1949 was the year of victory for Mao Zedong and the Communist party. Mao and the communists had won the hearts of the majority of the public through their defeat of both the Japanese incursion and the regional Nationalist-supporting warlords. After centuries of imperialistic occupation and a shaky independence, Mao had restored a much-needed sense of community, pride, and strong nationalism into the hearts of the people.

Mao had claimed leadership over a nation of peasants, and so naturally his goals were industrialization, modernization, and national defense. It was this period in Chinese history when strong ties with the Soviet Union existed and the first exchanges of space and military related information took place. After hundreds of years of occupations and attempted incursions by foreign nations, Mao wanted to develop a nuclear bomb to prevent history from repeating itself and to gain respect for its military strength. He was able to acquire support and assistance from the Soviets in the development of nuclear capability for the aim of national defense. As part of the national defense agenda, a space program was started around this time as well. In 1956, China opened its first institute on missile and rocket research, the No. 5 Research Institute attached to the Ministry of National Defense, with Qian Xuesen, a Chinese scientist who returned from the United

States, as the first director. This was mainly a response to U.S. threats of attack, a situation that was related to the defense of Taiwan. From the very beginning the space program and nuclear projects were symbiotic because they were both critical to national defense and national prestige.

In the late 1950's Mao pressed on with his agenda to the extreme with the Great Leap forward. This was a program designed to speed up industrialization by taking the peasants out of their regular farming schedule and forcing them to work on industrial type tasks, such as metal production. The result of the Great Leap Forward was one of the worst famines in human history.

In 1960 Maoist China had broken off relations with the Soviet Union, and China was once again technologically on its own. In 1966 Mao became concerned about his image, the Great Leap Forward had put a dent in his reputation and people were questioning him and communism in general. Certain party officials and a significant part of the public became vulnerable to western ideology. As an effort to consolidate his power, purify the party, and to restore unity between people and his idealized vision of China, Mao launched what is known as the Cultural Revolution. During this decade amidst Mao's appeals to the public, especially students and military personnel, widespread fighting and destruction in universities and cities took place between cultural revolutionists and counter-revolutionists. These were the most ideologically radical years of recent Chinese history, often expressed as the ten wasted years because the revolution had set the nation even further behind developed countries. Schools were destroyed socially as well as politically, the country was unstable, and the economy had severely declined. The revolution had ruined any progress towards modernization and industrialization that was accomplished beforehand. (Johnson-Freese, 1998)

By the end of 1976, the young space program had felt similar impacts, many offices, labs, and personnel were situated in universities which happened to be in the eye of the storm. Before Mao had died in 1976, he announced economic reform and modernization as the number one priorities for the Chinese people. Thus, his successors have not denounced him or his legacy. To this day, economic growth, sustainability, and inner stability are still number one priorities for China.

Today's China is a different animal. When Deng Xiaoping succeeded Mao, he knew how important it was for China to open up its doors to the world, to cooperate economically and abolish this traditional sense of isolation. As a result, western influence spread across the People's Republic of China. Today, one finds what some consider still an underdeveloped nation in terms of economical development, while others cringe and refuse to categorize such a dynamic and growing economy as underdeveloped. The reason for this is because even though 70% of China is still rural and requires much modernization, China is slowly becoming an economic power. It has had the fast growing economy in the last 10 to 15 years and it continues to further develop at a rapid pace as a result of introducing capitalist reforms. Some critics of the political system are almost frightened by the pace at which the efficient and productive industrial sector that always eluded the Russians under Communist rule seem to be thriving in China. China has by far been the most successful in transitioning to a western influenced economic model of all the former Communist states. Presently, China's economic model is one that is highly confusing, and can be best described as a mixed economy, i.e. a hybrid between capitalism and communism. Some experts say it is so complex right now because the nation is undergoing a transitional period from communism to capitalism, and because it is undergoing this transition phase by phase, a more gradual approach than the eastern European "crash" approach where the whole economy was revamped at once. The difference in approach is probably the reason why China's recent economic history has been a study of success. However, one should not forget that China is still a Communist state politically, and the Communist party is in firm control of the nation. Also, whether China will make capitalism a goal or whether they maintain and improve the current economic model is subject to one's interpretation.

The situation that is fairly common there right now with enterprises and entrepreneurs is one where they are able to benefit from social programs that protect workers without having to pay extra for them. This is similar to the teenager who lives at home yet has a full time job. This is a byproduct of a hybrid economy, something the Chinese are happy to maintain since it gives them a competitive edge; they are hoping to sustain the best of both worlds.

However not everyone is happy, there are social problems emerging, mainly between state-owned enterprises and private business, and between coastal (rich, urban, modernized) provinces and the mainland (poor, rural, 70% of population) which need to be taken seriously. As any Chinese historian will be quick to say, almost all of the revolutions and uprisings spring from unhappy peasant groups. They cannot be left out at a disadvantage for long, or they are likely to migrate or rebel.

Social harmony is very important to the Chinese; it is the very fiber of Confucianism. Even though China is much more open than in the past it is not *that* open.

While the Communist party is in control politically, it is also much in control of many powerful state-owned corporations, the roots of Modern China and the foundation of the Peoples Republic.

As a testament to China's growing economical and political prowess, in 2003 China has become only the third nation in history to put a man in space aboard the Shenzhou. As stated earlier, the space/military program began circa 1956 as a means of national defense. In 1957, with the launch of Sputnik, the social and political effects it had for Russia were notable and surprising, hence satellite interest also began to grow in China. However, the main focus from 1958-1964 remained one of national economic growth and defense, primarily against the U.S., and Taiwan. Therefore, efforts were concentrated on long-range ballistic missiles as a warhead delivery system. The DF missile program was in effect first, and it was also at this time that the *incremental* approach to technological development was established. It was not until the DF-5 was developed that China had long-range missiles capable of reaching the U.S. Around the same time that the Soviet Union and People's Republic of China parted political company (1960-1965), the Chinese began to develop surface –to- surface (CSS) missiles without Soviet aid. It is from this project that the famous Long March rocket was derived. Currently the DF, CSS and Long March are still in service.

Meanwhile, the pursuit of commercial satellites for economic advantage and modernization (communications, remote sensing) purposes was being developed in parallel fashion. The symbiotic nature of the military and space program allowed people to work on the development of a missile and launcher for military as well as commercial aims. Remarkably, in 1970, amidst the Cultural Revolution, the biggest achievement of that time period came when China became only the fifth country in history to launch a satellite into Earth orbit. This was a scientific and experimental satellite powered by a Long March rocket. The Long March since has become a very important player, in 1985 it entered the international launch market. The Chinese hoped to offer launchings to the world as a means of generating revenue and a technological presence. However, the LM had a poor launch success rate, dipping to around 70-80% in 1996. This was nearly a 30% failure rate, which was far too high by international commercial standards. As a result, insurance rates reached 30% of the satellite value. What seemed to be the number one missile problem for the Chinese then has since that time been resolved. The success rate for Long March currently is over 90%, making it a first-rate launcher. Considering the fact that they are able to produce these rockets at about 80% of the market value, the Chinese can offer lower launching cost fees to the world market. This makes the space program potentially capable of paying for itself. The cash flow is not only positive for the economy, but important for the manned space program, as it helps to cover its costs and improve its technology.

Like its economic structure, China's space program is very involved and minimally visible. It has both a military and civil/commercial program, however unlike NASA; the programs diverge only at the applications level. Aside from these dynamics, the sheer number of organizations involved in the overall space program combined with the confusing (maybe on purpose) habit of unconventional naming and then renaming which has resulted from decades of restructuring and reform, has at least clouded the organizational structure to outsiders. There is some knowledge of the inner workings; however, much of it is still in secrecy. This is hardly surprising when one considers the symbiotic nature of it. The danger of releasing potentially sensitive information regarding national defense capabilities even though dealing with commercial equipment discourages most scientists from speaking.

It is known that the Chinese *compartmentalize* their organizations like the Soviets in their hey day. Compartmentalization is a system where each department or branch is provided with only the information it is required to maintain in order to satisfy the function they are meant to serve. This is basically what westerners call, "a need to know basis." This is perfect for the control of information flow which the Chinese are very keen on. However, such strict regulation of information flow without an understanding of how the work fits together has a strong tendency to generate communication problems between agencies and departments.

The Chinese Aerospace Science and Technology Corporation (CASC) and CNSA have the primary roles in the space program. The CASC exercises daily control over the national space program, while the CNSA serves as an interface with other national and international space agencies, basically the CNSA deals with external issues while the CASC handles internal matters. Although the operational structures of the CNSA and CASC differ, they are in effect a single organization that splits responsibilities for policy making and executive activities. The two organizations share personnel as well as responsibilities. For example, the President of CASC, Liu Jiyuan, was also the Administrator of CNSA.

Examples of CASC's activities include research, design, manufacture, and testing of various space technologies. In 1997 the CASC was composed of approximately 270,000 employees, 100,000 of which were engineers. There are many organizations under the CASC, see diagram below. The State Science and Technology Commission are responsible for macro-level policy concerning space, mainly dealing with research and academics. The rest of the agencies (at least 13) deal with either more specific or general issues, such as the Long March rocket, telecommunications, commercial related matters, national defense, and so on.

China's White Paper on Space states that the space program is intended "to meet the growing demands of economic construction, national security, science and technology development and social progress, protect China's national interests and build up the [sic] comprehensive national strength." (Lieggi, cns.miis.edu) There is no single clear motivation behind China's attempt at project Chang'e/Shenzhou. A plethora of politically, militarily, nationally and economically significant agencies support it for various reasons. From a political standpoint, the communist party is eager to show to the world (and its people) what it is capable of producing and to increase its legitimacy. In a culture where symbolism is as important as substance, China wants the international prestige, the recognition as a world power, a technological giant, and a military powerhouse. After centuries of occupation and disillusion, it is important for the Chinese people to have their "face" or pride restored. "Images of the *Shenzhou* have been placed on phone cards, water heaters, and other items as part of a marketing strategy aimed at making the *Shenzhou* program a source of national pride." (Lieggi, cns.miis.edu)

However, some of the public has growing indifference, accusing its leaders of wasting money on manned space flight while the majority of the nation still suffers from sub-standard living standards. Regardless, Chinese leadership expects a return on their large investments in space and believes the technological advancements associated with it will contribute to economic growth and stability, the two primary goals of the regime. In addition, there are certain entrepreneurs who are examining the possibilities of new industries in space. Funding has been limited for the space program in general because of higher priority Chinese issues like modernization and development. However, the political leadership does not mind committing resources to the manned space program if it is successful. Also one should not forget that commercial services of the Long March rocket launches continue to provide capital that helps cover the expenses of the manned spaced activities. (www.guardian.co)

Since there is no division between the civil and military space programs, many experts believe there is a military driven motivation as well. The Shenzhou project is overseen by the PLA's (People's Liberation Army) General Armament Department. "The Chinese have admitted that the *Shenzhou* (manned or unmanned) has reconnaissance capabilities and many analysts point out technological gains from the manned program could be used for military space programs, such as development of anti-satellite weapons." (Lieggi, cns.miis.edu) Even with probable military spin-offs, a primary military motivation is unlikely while economic growth and stability are the priorities.

Future work:

The information provided in this paper is meant to be a foundation for other research projects looking into the future of the United States, Chinese, and Russian space programs. The goal of the follow-on project is to complete this paper with a forecast on the where the Chinese and United States will be in thirty years with respect to space activities in general and the moon in particular. This paper was written with the help of my other team members Milat Sagra Berirmen, Sebastian Ziolek, Chris Elko, and Kemal Cakkol. They will be continuing this project to the point of a forecast. The follow up to this historical description will be to analyze the data presented here and determine what each country's technical capabilities and economic resources are going to be in the next period. Furthermore, they will look at the social trends within each country to estimate how the population will react to a large mission leading to a permanently manned space base on the moon. These are grounded speculations, but we are making assumptions that governments will not be overthrown, and assuming incremental technological change with no breakthroughs.

Chris Elko will be analyzing the United States technical capabilities and will be reporting about how far NASA is likely to develop in the next thirty years. Furthermore, Chris will compare technological trends and developments that happened with the United States in the previous race with Russia and give a commentary on similarities and differences from then and now.

Kemal Cakkol will be analyzing the social and economic support given to the United States manned space program at present to determine what the United States will be able to accomplish in the future depending on how much that financially increases. Kemal will also analyze the public support and funding levels devoted to the previous race and determine how that compares to the present proposal. Furthermore, within Chris's technological part they will make an estimate on the pace of the project for the next thirty years. Given all those factors, they will make a subjective estimate of where the United States will be in terms of manned space capability in thirty years.

Milat Sagra Berirmen is covering Russia, and will also work with the Chris and Kemal when determining the important events that occurred in the previous space race. This will be important as a means of comparing the past to the present situation with China and the United States to see if there are any similar events that can help make a prediction on the future. For example, important information on success and failure rates of the US and Russia during that time can be compared to China's program to better assess China's capabilities.

Sebastian Ziolek will be covering China's social and economic resources. Sebastian will make a grounded speculation on the amount of resources China is likely to be willing to dedicate to its manned space program and the likelihood of it changing its funding priorities. As mentioned before he will be assuming no major changes in the government composition. Another factor that will be discussed is the impact of public support and whether that will have any effect on the manned space program for the future. This information along with Chinese technical information will be used in predicting the overall pace of the project over the next thirty years.

As each of the county's space programs increases in accomplishments over the coming years it is likely that increased efforts will be made to compete with the other countries accomplishments. Analyzing the social and political situations of each country will be done to reveal how much each country is willing to sacrifice to put toward their manned space program.

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