Chapter 1

SPACE HISTORY

Few events in our history have been more significant than the dawn of the space age. This chapter will discuss early space pioneers, the space race, the manned space programs, the formation of NASA and some of the first satellites ever launched into orbit above the earth.

EARLY DEVELOPMENTS IN ROCKETRY

No one really knows when the first rocket was created; however, most historians agree that the Chinese were the first to produce a rocket around 1212 AD. This first rocket was essentially a solid fuel arrow powered by gunpowder, which was also invented by the Chinese sometime around 800 AD. These very early rockets contained black powder, or something similar, as the propellant (fuel). According to legend, a man named Wan Hu made the first attempt to build a rocket powered vehicle in the early 1500s. He attached 47 rockets to a cart and at a given signal, 47 workers simultaneously lit all of the rockets. In the ensuing explosion, the entire vehicle disappeared in a cloud of smoke and Wan Hu was never seen in this world again.

The principles by which rockets operated were not understood until the late 1800s when man began thinking about using rockets for the transportation of people. Up to this point, rockets had been used in warfare in a limited capacity. For example, rockets were used by the British during the War of 1812 shelling of Fort McHenry (i.e., "the rockets' red glare"). Yet even in warfare, the rockets' potential was not fully realized. Major advances in rocket technology did not occur until the early 1900s.

Events in America: 1909-1929

Dr. Robert Goddard, commonly referred to as "The Father of Modern Rocketry," is responsible for the advent of space exploration in the United States. He achieved most of the American accomplishments in rocket science in a somewhat autonomous effort. In 1909, he began his study of liquid propellant rockets and in 1912, he proved that rockets would work in a vacuum such as exists in space. The year 1919 brought the end of World War I as well as the publication of Dr. Goddard's book, *A Method of Attaining Extreme Altitude*. This document laid the theoretical foundation for future American rocket developments.

On 16 March 1926 in Auburn, Massachusetts, Dr. Goddard made history as the first person to launch a liquid-fueled rocket. The strange looking vehicle covered a ground distance of 184 feet in 2.5 seconds and rose to an altitude of 41 feet while achieving a speed of 60 mph. In 1929, Goddard launched an improved version that was the first rocket to contain weather instruments. This vehicle rose to a maximum altitude of 90 feet and provided some of the earliest weather readings from "on-board" sensors.

Dr. Goddard and Rocket Technology in New Mexico

In 1930, with financial backing from Charles Lindbergh and the Guggenheim Foundation, Dr. Goddard moved his operation to New Mexico where he continued his work until his death in 1945. His work centered on a number of improvements to his rockets, which resulted in a number of "firsts" in rocket science and technology. For example, Dr. Goddard was the first to develop a gyro-control guidance system, gimbaled nozzles, small high speed centrifugal pumps and variable thrust rocket engines. All of these technologies are used on modern rockets today.

Dr. Goddard's rocket project was a privately funded effort with absolutely no government funding, aid of any sort or interest in his work. Notwithstanding, his accomplishments in rocketry were truly extraordinary. Meanwhile, a team of German scientists were also interested in rocket development and their advances would prove to have a devastating effect upon the world.

Events in Germany

The German rocket development effort can be divided into two phases. Phase I occurred between 1923 and 1931 and involved Herman Oberth, Walter Hohmann, Johannes Winkler and the Society for Space Travel. Phase II occurred between 1932 and 1945 and involved only one man, Wernher Von Braun.

Phase I

Although he never actually built any rockets, Herman Oberth inspired others in both Germany as well as abroad to do so (e.g., Dr. Goddard). He accomplished this through his 1923 publications on space and upper atmosphere exploration. His book "*The Rocket into Planetary Space*" laid the foundation for the German rocket development effort. Oberth suggested that if a rocket could develop enough thrust it could deliver a payload into orbit. Many people thought this impossible, but a man named Johannes Winkler was so inspired by Oberth's work that in 1927 he formed the Society for Space Travel, of which Oberth later became president. Also known in German as the "Verein fur Raumschiffahrt," this society became the spawning ground for the most significant breakthroughs in space technology. Members of the organization would later include rocket pioneers such as Dr. Von Braun.

In 1925, Walter Hohmann published his book "*The Attainability of Celestial Bodies*," in which he defined the principles of rocket travel in space (to include how to get into geosynchronous orbit). In recognition of Hohmann and his work in rocketry, the orbital transfer technique used to place payloads into geosynchronous orbit is called the "Hohmann Transfer."

Johannes Winkler invented the first liquid propellant rocket, the HW-1. The first launch attempt was a failure but the second launch was successful in 1931, achieving an altitude of 295 feet.

Phase II

In 1932, the National Socialist dictator Adolf Hitler rose to power in Germany and directed the German Army to pressure Dr. Von Braun to develop rockets which could be employed in warfare. Hitler used the resulting rocket technology to terrorize London during World War II. Ironically, the rocket technology which resulted from Dr. Von Braun's early work would eventually enable the United States to send a man to the moon.

Under direction of the German Army, Dr. Von Braun began experimenting with liquid fuel rockets, leading to the development of the "A" series. The A-1, which did not appear promising, was abandoned after a number of launch failures. The A-2 subsequently emerged and was successfully launched in 1934, thus opening the door for development of even larger rockets.

In 1937, General Dornberger, the head of the German Army's rocket development effort, Dr. Von Braun and their development team moved to Peenemunde (a peninsula in northern Germany). From this installation

(**Fig. 1-1**) would come the vengeance weapon, the V-2 (**Fig. 1-2**), which Hitler

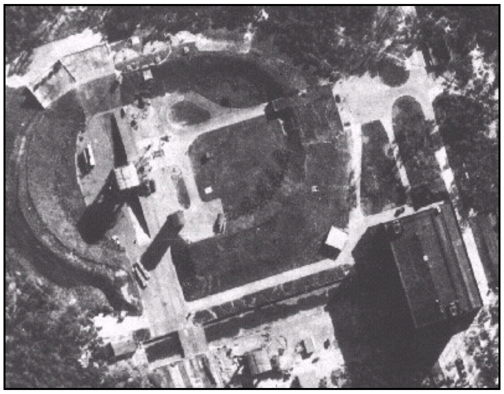

Fig. 1-1. Peenemunde

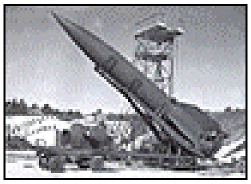

Fig. 1-2. V-2 Rocket

would unleash against England. By 1942, the A-4 test rocket had been successfully launched. Research and development continued until 7 September 1944, when the first V-2 rocket boosted a 2000 lb. warhead to 3,500 mph and burned out with the warhead continuing on a ballistic trajectory to a range of 200 miles, literally "falling" on London.

Events in the Soviet Union

If it could be agreed upon that the space age was born in one place, most historians would say that it would have been in the home of Russian schoolmaster Konstantin Eduardovich Tsiolkovsky. In 1883, he first explained how it would be possible for a rocket to fly in space. This was a time when most people believed it was not possible for man to fly. Consequently, Tsiolkovsky was thought to be eccentric by his fellow Russians. In 1895, he published "*Dream of the Earth and Sky*" in which he initially postulated the feasibility of an artificial earth satellite. In 1903, he began publishing parts of another book describing the theory of rocket flight and the prospects of space travel.

Tsiolkovsky had a unique depth of understanding. He was the first to recommend the use of liquid propellants because they performed better and were easier to control than solid propellants. His notebooks contain many ideas and concepts that are used by rocket engineers today. His works also include detailed sketches of spaceship fuel tanks containing liquid oxygen and hydrogen (the same fuel used in the Saturn V moon rocket). Tsiolkovsky further recommended controlling a rocket's flight by inserting rudders in the exhaust or by tilting the exhaust nozzle, just as Dr. Goddard would suggest some thirty years later.

Tsiolkovsky determined a way of controlling the flow of liquid propellants with mixing valves and advocated cooling the combustion chamber by flowing one of the liquids around it in a double-walled jacket, as seen in the space shuttle engines of today. His spaceship cabin designs included life support systems for absorption of carbon dioxide and proposed reclining the crew with their backs to the engines throughout the acceleration phase, also as is currently done. Tsiolkovsky further suggested building the outer wall of spaceships with a double layer to provide better protection against meteors and increased temperature. Tsiolkovsky foresaw the use of an airlock for space-suited men to leave their ship and suggested that gyro-stabilization as well as multiple-stage boosters were the only way to attain the velocities required for space flight. Finally, he anticipated the assembly of space stations in orbit with food and oxygen supplied by vegetation growing within.

Tsiolkovsky designed extensive calculations to ensure all his proposals were mathematically possible, but without funding, he was unable to perform any meaningful experimentation. Because of his considerable technical foresight and realistic approach to space problems, he is now known as the "Father of Space Travel."

ROCKET DEVELOPMENT AFTER WORLD WAR II

This section will address booster and missile development in the Soviet Union and the U.S. between 1945 and the early 1960s.

Soviet Efforts

When the Red Army captured Peenemunde in May 1945, they found that most of the important personnel and documents were gone. The Soviets learned of the American effort to seize important German space technology and began a similar program of their own. They ended up with a majority of the hardware and a few remaining scientists and technicians.

In 1946, Stalin was not satisfied with the progress of the Soviet rocket effort at Peenemunde so he moved it to the Soviet Union. There, like in America, the expatriated German scientists and technicians worked with Soviet rocket scientists in an effort to improve the basic V-2 design. However, the Soviet team decided to strike out on their own, thus relegating the German team to a support role. By the end of 1953, all the expatriated German rocket team members had been returned to Germany.

Decision to Build the Intercontinental Ballistic Missile (ICBM)

The U.S. was well ahead of the Soviet Union in nuclear technology and possessed the most powerful bomber force in the world. This unnerved the Russians and forced them to probe for an equalizer. In their search for this weapon, the Soviets began to realize the potential of the ICBM for striking over long distances. The Soviets envisioned a missile capable of striking the U.S. from the Soviet Union. This thinking dominated all of Soviet rocket research and by the end of 1947, the consensus in the Soviet Union was to build an ICBM with this capability. In their quest to build an ICBM, a whole family of short and medium range ballistic missiles were developed, the most important of which was the Shyster Medium Range Ballistic Missile (MRBM), which became the world's first operational MRBM in 1955.

In 1951, biological experiments with dogs convinced Soviet scientists that manned rocket flights were possible. They were also convinced that they would soon have the capability to place large payloads into orbit. Thus, along with the development of the ICBM, emerged the idea of space flight, which included the beginning of research into space suits, life support systems and emergency escape systems for manned flights.

While Soviet scientists contemplated putting things into space, the vehicles required to accomplish this were developing at an astonishing rate. The Soviet missile program was well on its way to becoming reality. In 1953, two more missiles entered the development phase: the SS-4 Sandal and the SS-6 Sapwood.

SS-4 Sandal

The SS-4 was required to carry a one megaton (MT) warhead across more than 1,118 miles. It used storable propellants which improved its launch rate capability. The SS-4 became operational in 1959 and remained in use for two decades. The SS-4 was the weapon at the heart of the Cuban Missile Crisis, when the Soviet Union deployed ICBM missiles to the island of Cuba in 1962.

SS-6 Sapwood

The SS-6 was still under development in 1956, but the Soviets were so sure of its success that they began discussing its use as a launcher for an artificial satellite. The Soviets announced to the world that they would launch a satellite into earth orbit as part of International Geophysical Year (IGY) activities. The western world did not take this proclamation seriously, oblivious to the great strides that the Soviets had made in rocketry.

The SS-6 (**Fig. 1-3**) was ready for its first test launch in May 1957. The Soviets traded off stylish design for brute strength. They did not yet have powerful rocket engines built so they used more engines to compensate for the lack of powerful engines.

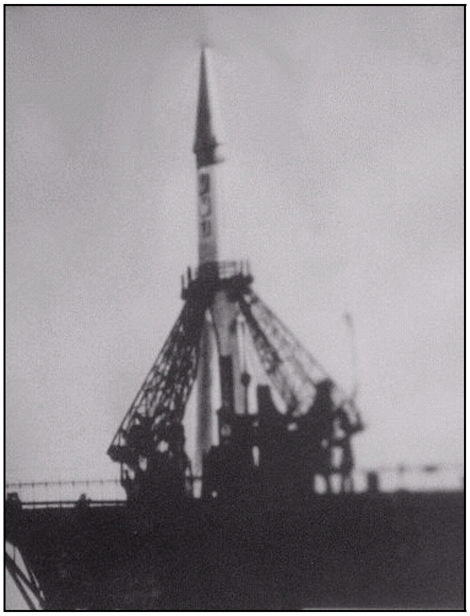

Fig. 1-3. SS-6 Sapwood

The SS-6 was a single stage missile with clustered engines and had twice the power of the U.S. Atlas or Titan ICBMs. To avoid making the missile in several stages, the Soviets opted to go with a centralized cluster of motors. These clusters would be ejected after they had used up their fuel, while the central core motor continued to burn. By October 1957, the Soviets were ready to prove to the West that their missile capabilities were more than just a proclamation.

Sputnik

On 4 October 1957, the Soviets used their SS-6 Sapwood ICBM to launch the world's first artificial satellite, Sputnik 1 (**Fig. 1-4**). On 3 November 1957, Sputnik 2 was launched with Laika, a Soviet research dog, on board. At this point, the Soviet Union had become the first nation to enter outer space with a biological life form.

Fig. 1-4. Sputnik 1

United States Efforts

While the Soviets had a well coordinated rocket program, the U.S. did not. After the Soviets exploded their first hydrogen bomb (H-bomb) on 12 August 1953, the Armed Services of the U.S. began to concentrate on missile development. Around this time, the Air Force had begun work on their Atlas ICBM.

Air Force ICBM Program

Due to the Soviet's H-bomb capability, in 1955, President Eisenhower directed that the Atlas ICBM project become the nation's number one priority. The Atlas was a one and one half stage missile with external boosters that separated after burnout. Powered by liquid oxygen and kerosene, it required fueling prior to launch. By mid-1955, Atlas test launches were being conducted and by August 1959, the system was approved. During the development of Atlas, the Air Force was also working on another ICBM called the Titan I.

The Titan I was a two-stage missile powered by oxygen and kerosene, also requiring fueling prior to launch. This fueling operation did not allow for a quick response if the U.S. were to come under attack. This deficiency led to the development of the Titan II.

The Titan II was much more powerful than the Titan I and could stand alert fully fueled and ready to launch. Although the Titan IIs stayed in the inventory until 1987, these liquid giants were expensive to build and maintain, leading to the development of the Minuteman solid-fuel ICBM.

Work on the solid-fueled Minuteman ICBM began in 1957. These missiles were lighter, smaller and more easily stored. A reduced payload capacity was offset by the fact that the system could be built in larger numbers and its warheads had improved accuracy. By 1961, the Minuteman had met all of its test objectives and was in service by 1962.

Army Missile Program

Near the end of World War II, the U.S. 7th Army captured many intact German V-2 rockets along with Dr. Von Braun and his rocket team. In 1945, the Army began moving the scientists to Fort Bliss, Texas to establish a guided missile program which began with the test firing of the captured V-2s (A-4). This effort, which began in July 1946, was called "Operation Paperclip." When asked about the design of their V-2, the Germans said it had been replicated from a rocket Dr. Goddard flew in 1939. These V-2s were converted to carry various scientific instruments. The A-4 Upper Atmosphere Research Panel was established in January 1947 to coordinate these tests. This panel later became the Upper Atmosphere Rocket Research Panel in 1948 and the Satellite Research Panel in 1957.

In 1950, the Army moved its missile development group to the Redstone Arsenal in Huntsville, Alabama. After the Korean War, the Army was looking for a missile with a range of about 500 miles, leading to the development of the Redstone missile (**Fig. 1-5**). The Redstone was first fired on 20 August 1953 and many additional test firings were conducted until 1958, when it entered service with Army units stationed in Germany.

Fig. 1-5. Redstone Missile

The Redstone was designed and developed between 1952-54, which proved critical to the history of the entire U.S. missile program, as this missile became the foundation for all future U.S. missiles. The Army also ventured into a joint missile project with the Navy, referred to as the Jupiter missile program.

The Jupiter missile made use of Redstone missile technology, thereby saving time and money. In fact, Redstone missiles were used to test Jupiter nose cones. As the project progressed, the Navy lost interest because they wanted a small solid-fuel missile for submarine use and the Jupiter was shaping up to be a large liquid-fueled missile. The Navy would break away to develop the Polaris missile. The first Jupiter launch occurred in 1957 but the range was only 60 miles. By the third flight, developments improved and its range had increased to 1,600 miles, making it the first successful American Intermediate Range Ballistic Missile (IRBM). The Army Ballistic Missile Agency delivered its first Jupiter to the Air Force in 1958 and more than sixty missiles saw active service with Air Force units based in Italy and Turkey.

Navy Efforts

The Navy's rocket development project revolved around three different missiles: the Aerobee sounding rocket, the Viking sounding rocket and the Polaris Submarine-launched Ballistic Missile (SLBM). The Aerobee project was initially designed to develop a missile capable of carrying a 100 lb. payload to an altitude of 75 miles. It consisted of two levels, the lower being solid fuel and the upper using liquid fuel. The first flight of the Aerobee took place in November 1947 and since then, has served all three branches of the military. Despite its numerous revisions, it is still used today.

The Navy began looking into a missile program where they could launch a missile to extreme altitude with enough stability to allow accurate measurements to be taken. This resulted in the development of the Viking sounding rocket, much of which was based upon the V-2 design. Engine tests began in 1947 and the first Viking was delivered for testing in 1949. In May 1949, the Viking had its successful maiden flight. One was even launched from the USS NORTON SOUND to evaluate the concept of launching rockets and missiles from ships at sea.

In September 1958, the Navy began to consider launching missiles from ships. The Polaris project was started and was to be a solid-fuel missile with a range of over 2,900 miles. At the start of the project it became apparent that a special vessel would be required to handle this missile, leading to the development of the Polaris submarine (**Fig. 1-6**). By 1958, approval for the first three Polaris submarines was granted and construction began.

Fig. 1-6. U.S. Polaris SSBN

The USS GEORGE WASHINGTON was the first such Polaris submarine to be constructed, launched (June 1959) and commissioned (December 1959). The USS GEORGE WASHINGTON participated in actual test firings of the Polaris missile in July 1960 (**Fig. 1-7**) and in November of that same year, the new weapon system became operational.

Fig. 1-7. Polaris Missile Test

Military aspects of rocket development were not all that was being considered during this time period. In order to support President Eisenhower's "Space for Peace" policy, the government was also investigating booster development to send satellites into orbit.

U.S. Booster Development and the International Geophysical Year (IGY)

The original U.S. military services appraisals concerning the possibility of developing an effective ICBM were rather discouraging, as nuclear weapons of the day were large and bulky. At the time, it was felt that U.S. nuclear deterrence would rest on the back of the bomber force, since bomber aircraft were the only delivery systems which could carry these large weapons. However, the situation soon changed because:

- the Soviets demonstrated that they were serious about missile development,
- the Atomic Energy Commission announced the development of the hydrogen bomb,
- nuclear weapons were getting smaller,
- the Soviets obtained a hydrogen bomb of their own
- and the Sputnik satellites were launched.

This series of events was enough to alert the U.S. government to turn its efforts towards large scale rocket development. The hope of closing the gap in the missile race lay in the development of military missiles. However, President Eisenhower was determined to separate the military programs from the IGY program in order to support his peaceful intentions for space policy. The Redstone, Jupiter C and Atlas missiles were ready to launch as early as September 1956, but a different decision was made. Our non-military satellite program for IGY would be the Vanguard project.

The Vanguard Project

Vanguard was designed to have as few links to the military as possible. Although an honorable idea, it was not practical because the military had the money, scientists and hardware to get the job done. Funding for the project came from the National Science Foundation. The program was plagued with problems from the start, such as inexperienced contractors, tensions of the space race and trying to get a configuration that worked. But President Eisenhower insisted that Vanguard become the space launch vehicle for U.S. satellites.

The Vanguard launch attempted on 6 December 1957 was a disaster. After lifting several feet off the ground, the booster lost power and fell back, bursting into flames. Five days later, President Eisenhower approved a satellite launch using a modified Jupiter rocket, now called the Juno (Project Orbiter).

The Juno booster/lift vehicle was launched and the first U.S. satellite, Explorer I (**Fig. 1-8**), a 30-lb. cylinder, went into orbit on 31 January 1958. Although the U.S. did not launch the world's first artificial satellite, the nation did discover the Van Allen Radiation Belts, which may have been the most important discovery of the IGY. Explorer transmitted until 23 May 1958. Vanguard finally did succeed in getting off the ground on 17 March 1958, but this success was short lived, as only 2 of the 11 total launch attempts between December 1957 and September 1959 were successful.

Fig. 1-8. Dr. Pickering, Dr. Van Allen And Dr. Von Braun Holding Up A Model Of Explorer 1.

Early U.S. booster types were based on IRBM first stages instead of ICBM first stages. These new boosters were known as the Juno 2, Thor Able, Thor Delta, Thor Epsilon and Thor Agena. The Thor boosters later evolved into the successful Delta boosters. For the larger payloads, boosters began to be developed from the larger successful ICBMs and these were based upon the first stages of Atlas and Titan II development. The Atlas and Titan II-derived boosters have launched many U.S. satellites. With all of this space activity, the government decided a civilian agency was needed to coordinate and give direction to the U.S. space effort.

The National Aeronautics and Space Administration (NASA)

President Eisenhower's administration came up with the concept of a coherent space effort. In order to help support this concept, Eisenhower appointed James R.

Killian, president of the Massachusetts Institute of Technology, to be his scientific advisor. The military lobbied to maintain control of managing the national space effort, but Dr. Killian was a wise man and carefully weighed all the arguments against the President's aspirations. President Eisenhower was committed to his "Space for Peace" policy and civilian control of the space program was concordant to that concept. This civilian agency would handle all aspects of research and development, with scientists playing the leading role in guiding the space program.

While plans for this new agency were tied up in red tape, the President could not let time and events override our space program. He then established the Advanced Research Projects Agency (ARPA), whose plans for space exploration were soon approved by the President. Although short-lived, ARPA was essentially the first official U.S. space agency.

At this time, much maneuvering was occurring in Congress by various agencies who aspired to take control of the space program. One of these agencies, and the leading contender, was the National Advisory Committee on Aeronautics (NACA). At the time, there was no other agency which could rival NACA's expertise in the field of aeronautics and NACA felt that space would be a logical extension of its duties. Eisenhower was against this idea because he felt the NACA was, at times, too autonomous. Dr. Killian came to the rescue by proposing the National Aeronautics and Space Act, which was adopted on 1 October 1958. Under this plan, a broad charter for *civilian* aeronautical and space research was created, allowing the administration to absorb NACA. The core of NASA's facilities came from NACA and in a few years, NASA became organized and equipped to carry out the nation's space program.

SATELLITE PROGRAMS

This section will address some of the early satellite programs, broken down into four types: communication, weather, data collection and exploration.

Communication Satellites

One of the most important and profound aspects of space utilization has been in the area of communication satellites. The use of communication satellites has brought the world's nations closer together.

In May 1945, Arthur C. Clarke proposed that satellites could be placed in a position over the Earth's equator at a distance of approximately 22,000 miles. The satellite would maintain a constant position over the earth and three satellites would give total communication coverage. This position is called a geosynchronous, geostationary or Clarke's orbit. Today, most of the world's communication satellites are placed in this type of orbit.

Project Score

The first voice returned from space was President Eisenhower's in 1958 under Project Score. The satellite was placed in orbit by an Atlas ICBM with a tape-recorded Christmas message from the President to the world. It was the first prototype military communications satellite.

Echo

Echo was a NASA project consisting of a 100 ft diameter plastic balloon with an aluminum coating which passively reflected radio signals transmitted from a huge earth antenna. A number of projects were attempted using balloons, but this proved to be somewhat impractical and a better solution was needed.

Telstar

Telstar was the free world's first commercially funded communication satellite. AT&T financed the project and it was launched on 10 July 1962. Telstar's orbit was low earth, but when in sight of its ground station, it did provide communications between the U.S., the U.K. and France. Telstar proved that satellites could be used as communications devices across vast distances.

Syncom

Syncom, another NASA project launched in 1963, was the first communications satellite in geosynchronous orbit. It was used for many experiments and transmitted television of the Tokyo Olympic Games in 1964.

Molniya

Launched in 1968, this was the first of many Soviet communication satellites using high altitude, elliptical orbits which positioned the satellite over the entire Soviet Union during the day.

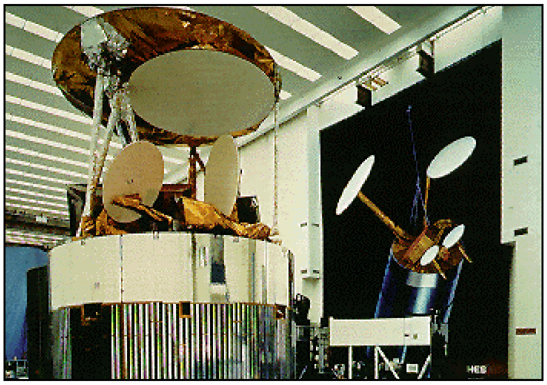

Fig. 1-9. Intelsat 2 under construction

International Telecommunications Satellite (Intelsat)

The International Telecommunications Satellite (Intelsat) Organization provided nations with a way of sharing the cost of satellite communications, based on the amount of use.

Intelsat 1, or Early Bird, was the first of the series and became operational on 28 June 1965 with 240 telephone circuits. It was designed to only last one and a half years but endured for four.

Intelsat 2 (**Fig. 1-9**) was launched in 1967 and provided an additional 240 circuits with a design life of three years.

Intelsat 3 was launched in 1968 and had an increase of 1,500 circuits with a design life of five years.

Intelsat 4 was launched in 1971 with 4,000 circuits plus two color TV channels and spot-beams to increase broadcast efficiency. The design life was advertised as seven years.

Intelsat 5 was launched in 1980 and is three axis-stabilized versus spin stabilized. It has 12,000 circuits and two TV channels.

Westar

Launched in 1974, Westar was a Western Union project and the United States' first domestic satellite.

Weather Satellites

Satellite weather photos are routinely shown on the local evening news. This section discusses some of the satellite systems which originate these pictures.

Television InfraRed Operational Satellite (TIROS)

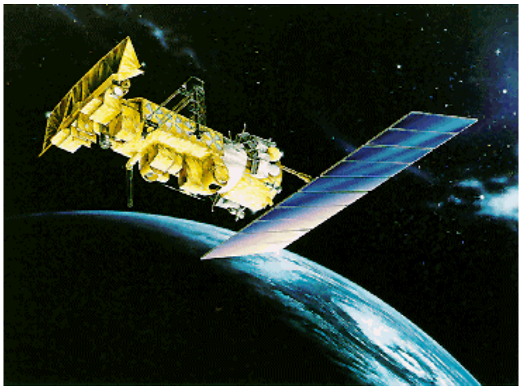

Fig. 1-10. TIROS Weather Satellite

TIROS (**Fig. 1-10**) was the first weather satellite program undertaken by the U.S. Its objective was to test the feasibility of obtaining weather observations from space. TIROS-1 was launched in April 1960, achieving all of its objectives. Nine additional TIROs were launched.

ESSA 3

Based on the success of the TIROS program, a fully operational version of the same satellite was introduced in 1966 called TIROS Operational System (TOS). The system used a pair of Environmental Science Service Administration (ESSA) satellites and was designed to provide uninterrupted world-wide observations.

Improved TIROS Operational Satellite (ITOS)

With the launch of ITOS-1 in 1970, a second generation of meteorological satellites was introduced and proved to be very successful.

TIROS-N

Following the ITOS series of weather satellites, a third generation series was developed and provided global observation service from 1978 through 1985. These satellites employed advanced data collection instruments. Included on the payload package was a very high resolution radiometer which was used to improve sea surface temperature mapping, for the location of snow and sea ice as well as conducting night and day imaging.

Since the TIROS weather satellites proved their worth by collecting data on weather patterns and after the first astronauts made detailed observations of the Earth, scientists began to consider using satellites to collect data on the Earth's land and water resources.

Data Collection Satellites

LANDSAT

In the early 1970's, the LANDSAT series (**Fig. 1-11**) of data collection satellites were employed. This series, because of its infrared microwave and imagery capability, opened up new areas of research never before explored in such detail. The government hoped LANDSAT would aid in locating new oil and mineral deposits and allow the mapping of ocean currents and temperature to help locate schools of fish. This capability has not yet been fully realized; however, LANDSAT has aided in estimating the extent of damage from forest fires, control of timber cutting and world crop yields.

Fig. 1-11. LANDSAT

SEASAT 1

Based on the LANDSAT series, NASA launched SEASAT 1 in 1978. Using microwave instruments, SEASAT 1 measured surface temperatures to within two degrees Centigrade, wind speed and direction and provided all weather pictures of waves, ice phenomena, cloud patterns, storm surges and temperature patterns of the ocean currents.

Terrestrial and Extra-terrestrial (ET) Exploration Satellites

Explorer

The largest U.S. exploration satellite program was the Explorer series. This particular group of satellites studied a wide range of space activities from Earth radiation to solar wind. Approximately 50 satellites in this series were launched, of which, the Explorer 1 discovered the Van Allen Radiation Belts.

U.S. ET Exploration Satellites

The U.S. has launched approximately twenty-four planetary probe satellites visiting most of the planets in our solar system. The first deep space probe was launched in 1960, returning data from 22.7 million miles. Since then, six have launched to Venus, six to Mars, four to Jupiter and three to Saturn. These probes were of the Mariner, Pioneer, Viking and Voyager types. Voyager 2 flew by Uranus and Neptune and will eventually fly by Pluto.

USSR Space Probes

The Soviets, while launching more planetary probes than any other country, have confined themselves to Mars, Venus, the Moon and Sun. Most of the Soviet initial attempts to send probes to Venus and Mars failed. These probes were of the Venera, Mars, Cosmos, Zond and Vega series. An ambitious probe to Mars in 1996 weighing 7 tons failed to escape Earth orbit and is believe to have impacted in a remote area of South America.

The Future

Both the U.S. and the Russians are planning future missions back to Mars, Venus, the moons of Jupiter and other interesting places within the solar system. As time goes on, more countries have entered the space exploration business (Japan, Germany, France, etc.) by sending probes into the cosmos.

MANNED SPACE EXPLORATION BY THE U.S. AND USSR SINCE 1960

Now that *unmanned* space exploration efforts have been discussed, *manned* space efforts will be addressed.

Historical Overview

The U.S. had placed its prospects on project Vanguard getting into space first. However, the Russians were the first to enter orbit and this resulted in a public outcry. Senator Lyndon Johnson (later to become President) of the Armed Forces Subcommittee, recommended a national space program be established. This became a reality when NASA was formed.

National Space Program

In 1958, the consensus was that the U.S. needed a consolidated national space program to give its space efforts coordination and guidance. The program would consist of two parts; the military under the control of the Department of Defense and the civilian part under the control of NASA.

Space Race

With the launch of Sputnik, the U.S. and the Soviet Union were now firmly entrenched in the space race that was nothing other than an extension of the Cold War. The U.S. had been beaten in the unmanned race and the same would occur in the manned race. On 12 April 1961, the Soviets shocked the world again when Yuri Gagarin became the first person to orbit the earth. Public outcry wasn’t as strong as when Sputnik went up, but Presidential concern was. President Kennedy addressed Congress and committed the nation to a project that would land a man on the moon and return him safely. The President’s decision to undertake this task was endorsed virtually without dissent.

Mercury (USA) 1961 - 1963

In addition to sending a man into space, Mercury was designed to further our knowledge of man’s capabilities in space. The Soviets had already proven that man could survive reentry. Mercury had a number of objectives, the most important of which were putting a man in orbit and devising a stepping stone for an eventual journey to the moon. In the Mercury capsule, all systems were redundant, control was manual or automatic and the control system technology was new.

The main objective of the Mercury project was to investigate man's ability to function in the space environment. Mercury gained valuable information for the building and flying of more complex spacecraft, such as the Gemini and Apollo. The milestones began with the chimpanzee "Ham" flight in a capsule on 31 January 1961; followed by Alan Shepard's suborbital flight on 5 May 1961 (He rose to an altitude of 116 miles in 15 minutes and 22 seconds) and then on 20 February 1962, John Glenn became the first American to achieve earth orbit, completing three revolutions.

Vostok (USSR)

Unlike the Mercury capsule, the Vostok capsule was composed of two parts; the round shaped "manned section" and the lower equipment bay located underneath the manned section. Vostok crew recovery was also different. With Mercury, the astronaut and capsule parachuted into the ocean, while the Soviet cosmonaut was recovered on land with Vostok. Vostok led the space race by carrying the first man into space in 1961 (Yuri Gagaran), the first woman in orbit in 1963 (Valentine Tereshkova), supported the first dual flight mission and set flight endurance records.

Gemini (USA) 1962 - 1966

The Gemini capsule was designed to carry two astronauts and had two sections; the upper or manned section and a lower equipment section. Because of the greater lift needed, the Titan II ICBM was used instead of the Atlas. The objectives of the Gemini program were to develop procedures for practicing maneuvers, rendezvous, docking and Extravehicular Activity (EVA). Finally, Gemini would allow astronauts to gain experience in longer missions and perform complicated maneuvers.

All the objectives set by NASA for Gemini were met. However, some tasks turned out to be more difficult than anticipated, such as spacewalks. Gene Cernan's exertion during the space walk portion of the *Gemini IX* mission overtaxed his suit system and fogged his helmet visor. Cernan had to terminate his EVA early due to fatigue. The problem wasn't solved until the last flight, Gemini XII in November 1966. Edwin (Buzz) Aldrin used footholds, Velcro covered tools and hand grabs to work in space with ease.

The Gemini milestones were vast and diverse, they included; the first orbital plane change, the first U.S. dual flight, hard docking and one-orbit rendezvous. Gemini's success gave the U.S. confidence to press ahead with the Apollo program and in effect, placed the U.S. ahead of the Russians in the race to the Moon.

Voskhod (USSR)

The Voskhod capsule was a Vostok modified to accept three cosmonauts. A terminal thrust braking system was added to achieve a soft landing. The Voskhod program was a stopgap measure instituted by the Soviet Union to makeup for the stalled Soyuz program.

The objectives of the Voskhod program were the same as those of Gemini and resulted in some notable accomplishments, including; the first three men in orbit, the first flight without space suits and the first emergency manual reentry.

Apollo (USA)

The Apollo program was the final step to the Moon. The objective of the program was two-fold. First, the program was to gather information needed for a lunar landing. Secondly, Apollo was to actually land on the Moon.

A new "tear drop" capsule was used, thus departing from the traditional "bell" shape of the Mercury/Gemini capsules. The Apollo system consisted of three parts, the command module (or manned portion) the service module and the lunar module (as shown in **Fig. 1-12**).

Fig. 1-12. Apollo System

The booster for this program had to be designed from scratch. With the help of Dr. Von Braun, Saturn boosters were developed, which included the Saturn 1B and the Saturn V (**Fig. 1-13 and Fig. 1-14**).

Fig. 1-13. Saturn 1B

The advent of Apollo, as in the tradition of Mercury and Gemini, was a step-by-step process. However, the U.S. suffered a tragic event on 27 January 1967 when Apollo I developed a fire in the capsule which cost the lives of three astronauts: "Gus" Grissom, Ed White and Roger Chaffee. The space program was halted while NASA investigated the accident. Within 19 months, the manned portion of the Apollo program was back on track and corrections to the Apollo capsule had been made.

The program pressed ahead, testing docking maneuvers, lunar landing procedures and a slew of other experiments designed to get us to the eventual landing. Then on 20 July 1969, Apollo 11 was the first of the Apollo series to land on the moon. Six more missions to the moon followed, culminating with Apollo 17. The only mission that didn't land on the moon was the Apollo 13 moon landing which was aborted some 205,000 miles from earth when an oxygen tank exploded. An anxious world watched as NASA worked feverishly through one problem after another to bring the crew back alive. Their success in doing so was one of the agencies finer moments and inspired a 1995 feature film which ignited the interest of a new generation in the Apollo program.

The U.S. met President Kennedy's goal and proved man could react to and solve in-flight emergencies (Apollo 13). Although the Apollo Moon program concluded, an abundance of valuable scientific information had been obtained.

Fig. 1-14. Saturn V

Soyuz (USSR)

This Soviet program also began on a tragic note when in April 1967, Colonel Komarov was killed when his parachute failed to deploy properly and his capsule slammed into the ground. The Soyuz program was also halted for about 19 months. Soyuz objectives included maneuvering in group flights and dock, prolonged space flights and development of new navigation and spacecraft control systems.

After July 1969, the Soviets turned their emphasis towards manned space stations and away from the moon. The Soyuz would be used as a ferry to the Salyut Space Station. Today it is used to take cosmonauts to the MIR Space Station.

Follow-On Manned Programs

Skylab

Skylab (**Fig. 1-15**) was launched by a Saturn V from Kennedy Space Center on 14 May 1973. Its primary objective was to test the effects of long term weightlessness and how well humans readapt to zero gravity. Five major experiments were planned covering solar physics and astronomical observations using a solar telescope.

Fig. 1-15. Skylab

An electric furnace was used to make perfectly round ball bearings and grow large crystals. It was later discovered that major repairs could be performed in orbit (i.e., restoration of the damaged Skylab).

Due to a number of factors, such as increased solar activity and delays in getting the Shuttle off the ground (the Shuttle was to boost the satellite into a higher orbit), Skylab's orbit continued to decay until it made its final plunge on 11 July, 1979.

Salyut

The Soviet Union space station program began in 1971 with the launch of Salyut 1, which gave the USSR another first in space. The objectives of the Salyut program were virtually the same as for Skylab. However, the Salyut program was replaced by the MIR (peace) space station. Soviet Cosmonauts have set space endurance records in the MIR, with some missions lasting up to one year.

Apollo-Soyuz (July 1975)

The primary objectives of the Apollo-Soyuz program were: the development of a rescue system, rescue procedures and crew transfer between the U.S. and Soviet spacecraft. Additional objectives dealt with conducting astronomy, earth studies, radiation and biological experiments. NASA used their last remaining Apollo spacecraft for this mission. The crew consisted of Apollo veteran Tom Stafford, Vance Brand and astronaut office chief and original Mercury seven astronaut Deke Slayton medically cleared to make his first flight.

Space Transport System (STS)

The primary motivation for NASA's perseverance of the STS was to find a cost effective manned system. The current STS can trace its roots back to the lifting body research conducted at Edwards AFB. On 5 August 1975, an X-24B made a textbook landing after a powered flight to 60,000 feet. The X-24B was America's last rocket research aircraft and concluded the manned lifting body program. The X-series research developed many concepts that would eventually be incorporated into the space shuttle, such as dead stick landings, flat bottoms and others.

The actual conceptual design for the STS began in 1969 when President Nixon directed top Department of Defense and NASA scientists to devise a post-Apollo manned program. The Space Shuttle

Task Group was formed to study the problem; they recommended the STS.

Due to its design philosophy, the STS looked promising and was approved by President Nixon. The system concept included the use of reusable components, autonomous operations, large payload, relatively simple on-board operation, a cargo compartment designed for a benign launch environment, throttleable engines, on orbit retrieval and repair of satellites. This design scheme (**Fig. 1-16**) would provide the U.S. with routine access to space.

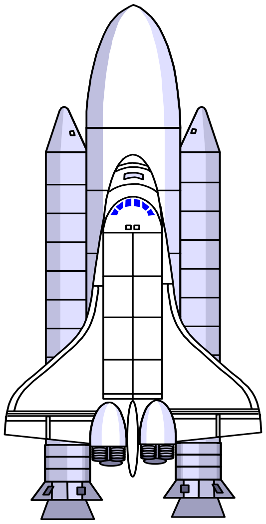

Fig. 1-16. STS

Components of the STS include orbiter, external tank and the reusable solid rocket boosters. The first STS launch occurred on 12 April 1981, with landing on 14 April. The astronauts for the mission were Robert Crippen and Gemini and Apollo veteran John Young.

After many successful missions between 1981 and 1985, tragedy struck in January 1986, when the Challenger exploded after lift-off, caused by a faulty solid rocket booster. As in 1967 with Apollo I, NASA investigated the cause and made corrections, but this time the manned space program was halted for 32 months. It was not until 29 September 1988 that America reentered space with the launch of the Discovery.

Hubble Space Telescope (HST)

The idea for the Hubble Space Telescope was conceived back in the 1940's, but work was not started on the telescope until the 1970's and 1980's. The telescope did not become operational until the 1990's. The HST program is a cooperative program between NASA and the European Space Agency (ESA). The program objective is to operate a long-lived space-based observatory which will be primarily used for astronomical observation. The HST is the largest on-orbit observatory ever built and is capable of imaging objects up to 14 billion light years away. The resolution of HST is seven to ten times greater than earth based telescopes. Ground-based telescopes can seldom provide resolution better than 1.0 arc-seconds, except momentarily under the very best observing conditions. HST's resolution is, depending on conditions, .1 arc-seconds, which is ten times better than ground based telescopes.

Originally planned for 1979, the Large Space Telescope program called for the satellite to return to Earth every five years for refurbishment and on-orbit servicing every two and one half years. Contamination as well as structural concerns negated the concept of ground return for the project. NASA then decided that a three year cycle of on-orbit servicing would work out just as well as the first plan. The three HST servicing missions in December 1993, February 1997 and mid- 1999 were enormous successes.

Future services are planned. Flights could also be added for emergency repairs. The years since the launch of HST have been momentous because of the discoveries made by the HST.

MIR

The MIR (loosely translated "peace", "world", or "commune") complex is described as a third generation space station by the Russian Space Program. The MIR (**Fig. 1-17**) is modular in

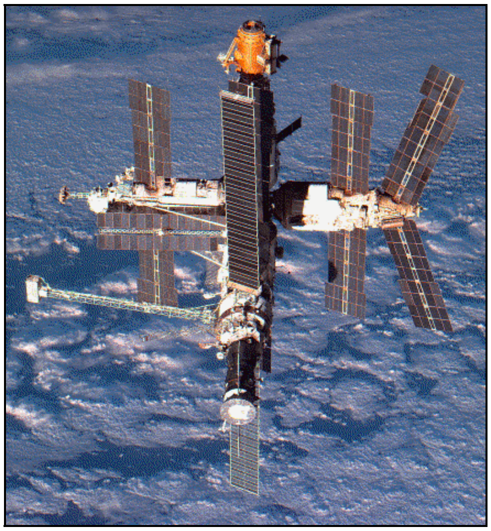

Fig. 1-17. MIR Space Station Complex

design, which allows the adding and subtracting of different modules. This also allows the modules to be moved from place to place, making the MIR very versatile. One of the most important features of MIR is that it is permanently manned, which is a giant step toward breaking earthly ties.

The MIR is the central portion of the space station, and is the core module for the entire complex. MIR is currently made up of four other compartments. These compartments are the transfer, working, intermediate and assembly compartments. All compartments are pressurized except for the assembly compartment.

The usual missions begin with a launch of either two or three crew members. It usually takes about two days for the spacecraft to reach and dock with MIR. Docking always takes place on an axial port. During docking, as a precautionary measure, the crew that is already occupying MIR puts on activity suits and retreat to the resident Soyuz-TM. This is the capsule the Cosmonauts ride to and from the MIR. The Soyuz-TM stays attached so they can escape if necessary. At the time hatches are open, both crews remove their suits and begin change over procedures, which take differing amounts of time depending on what needs to be accomplished. After change over is complete, the crews put their suits back on and return to the Soyuz-TM, the crew that has been there the longest gets in the older of the two capsules, leaving the newer one for the newer crew.

The MIR has had its share of problems in recent years. Originally designed to last only five years, the Russian space station is still flying. In recent years, a NASA astronaut has been part of the crew aboard MIR. In 1997, however, there were two life-threatening incidents which almost forced abandonment of the station. In February, a fire broke out triggered by a chemical oxygen generator which filled the station with choking smoke and blocked one of the escape routes to a docked Soyuz capsule. Although no major damage ensued, it was a frightening 14 minutes for the six men on board. In June, an unmanned Progress cargo ship collided with the Spektr module and the ruptured module began to decompress. The three man crew sealed off the damaged module but the power on the station was reduced by half. In the last two years, the Russians have tried desperately to secure outside funding to keep the MIR flying concurrent with meeting their obligations to the International Space Station (ISS). So far they haven't been successful. They need $250 million to keep the station on orbit. It was reported that as of June 1999, a grass roots fundraising campaign had only yielded 80 dollars. Despite this, another MIR mission was mounted in April 2000 to tidy up the station after a prolonged period where the station was unmanned. A private corporation, MirCorp was still looking for funding to keep the station going longer. All this interest in keeping MIR on station has concerned NASA who has given the Russians large amounts of money for the new ISS modules which were running well behind schedule.

Pathfinder

The Pathfinder mission is a discovery mission being conducted by NASA. The idea behind this mission is to prove that NASA is committed to low cost planetary exploration. When describing this project, the words "faster, better and cheaper" have been commonly used. Pathfinder was developed in 3 years and cost under $150 million to construct. Overall, the project cost was $280 million, which included the launch vehicle and mission operations. Another objective of this project was to prove the utility of a micro-rover on the surface of Mars. Pathfinder was launched on 4 December 1996 and touched down on Mars 4 July 1997. The rover functioned for a short time before contact was lost and the mission ended. More bad news was in store for subsequent missions to Mars. In September 1999, contact was lost with the Mars Climate Orbiter. The likely (and highly embarrassing) cause was the orbiter burned up in the Martian atmosphere on Sept 23rd due to a failure to convert English measurements to metric units. Its companion, the Mars Polar Lander apparently suffered a design flaw problem which cut off its braking thrusters too high above the Martian surface causing it to crash on 3 December 1999. These failures contributed to much criticism of NASA's "faster, cheaper, better" credo. The whole Martian exploration program is currently being reviewed.

International Space Station

The ISS is a partnership of nations that spans the continents. Through the work of many people and organizations, preparations are being made for the launch of the most complex structure that has ever been placed in orbit. The ISS will sprawl across an area nearly the size of two football fields and will be visible to the naked eye when it passes over head. The ISS will weigh nearly one million lbs., which is five times the mass of the first U.S. space station, Skylab.

The ISS program began in 1994 and moved into the first stage in 1995. Phase one is the joint MIR/Shuttle rendezvous program. The main objective of this program is to provide operations experience to Americans. The ISS is also using the basic schematics of the MIR Space Station. Countries all over the world are responsible for different parts of the space station. The U.S. is responsible for the building of the main structure, which is 28 feet long and 14 feet wide. The U.S. is also responsible for the nearly 80,000 lbs. of hardware that go along with the station. The U.S. had many of their requirements fulfilled in 1995. This included solar array panels, rack structures, and hatch assemblies. Canada is building the Mobile Service System (MSS) which will provide external station robotics. Japan is developing the Japanese Experiment Module (JEM). ESA is developing both a pressurized laboratory called the Columbus Orbital Facility (COF) and the Automated Transfer Vehicle (ATV), which will be used for supplying logistics and propulsion. Hauling the pieces and parts of the space station will require 45 space flights on three different types of launch vehicles over a five year period. The three launch vehicles are the U.S. Space Shuttle, Russian Proton and Soyuz rockets. Launch of space station began on 20 Nov 98 (five months behind schedule) with the Russian Zarya control module. It was joined by the US Unity connecting node on 6 Dec 98. The station is in an orbit of 251 x 237 statute miles with a period of 92 minutes. The second shuttle mission to the station was in May 1999 to transfer equipment to the existing modules and perform some installation functions. The next module mated with the station was the Service Module (Zvezda) launched from Russia on July 12, 2000, well behind schedule. The first crew departed for the station aboard Atlantis on 8 Sept 2000 to turn on systems, fix problems and haul supplies to the station.

Chinese Manned Space Program

As the decade wound down the Chinese also began testing a spacecraft to carry three astronauts. They tested the first unmanned capsule, called "Shenzhou" in 1999. After incorporating several improvements to the original capsule, the Chinese were planning to attempt another unmanned launch by the end of 2000.

REFERENCES

Gatland, Kenneth. *The Illustrated Encyclopedia of Space Technology*, Harmony Books, 1981.

Interservice Space Fundamentals Students Textbook.

Ordway III, Federick and Mitchell Sharpe. *The Rocket Team*, Crowell, 1979.

Most of the updates in this chapter came from news reports (MSNBC, Florida Today, etc) off the Internet, 1998, 1999.

http://www.spacecom.af.mil/hqafspc/history/index.htm
AF Space Command History

www.patrick.af.mil/heritage/6555th/6555fram.htm
History of space launches through 1970 supported by the 6555th.

www.spacewar.com/abmdaily.html
Current space related news events.

www.spacedaily.com
Home page of the *Space Daily* newspaper.

www.flatoday.com
Florida Today home page; includes Kennedy Space Center events.

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