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Out-of-this-World Experiments

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I. Introduction

Have you ever thought about where you were when certain events have happened that have dramatically impacted lives throughout the world? Certainly, I will always remember the day that J.F.K. was assassinated in Dallas, the afternoon that the USA Hockey Team won the Olympic Gold Medal, and the morning that Christy McAuliffe and her fellow astronauts died in the Challenger explosion. I can still see their proud, smiling faces as they walked past the television cameras towards the lunar module, soon to die in the fiery explosion due to "O" ring malfunctions.

It seems like just yesterday but, in fact, it's been many years since we've witnessed these occurrences, burning indelible impressions upon our minds. Likewise, it's been decades since the beginnings of space exploration.

When I was a kid, the space program was in its infancy stages. People were wondering if it was ever going to be possible to send animals, no less humans, to the moon. And, in just a few short years, we were witness to Neil Armstrong's voice echoing throughout the universe: "One small step for man; one giant leap for mankind."

Today, we are on the verge of launching and manning space station laboratories which will enable space scientists to conduct experiments in "weight-less" environments for governmental, commercial and industrial applications. These stations and other orbiting space platforms will allow scientists to observe and record phenomena from perspectives previously unattainable. New frontiers of knowledge will continue to be explored and this will facilitate a greater understanding of our existence as it relates to the Universe as a whole.

Within our curriculum unit, students will be introduced to the marvelous history of our space program; they will have opportunities to read about experiments which are conducted in "weight-less" conditions; they will gain hands-on knowledge of space-related experiments in our science laboratories; they will utilize our Yale-New Haven Teachers Institute computer system to gain access to current data concerning shuttle missions, and they will focus some time on the latest images from the Hubble Space Telescope.

Hopefully, they will develop an appreciation for the diligent efforts of our space scientists and engineers, and they will share in the strong tradition of nationalistic pride in a program designed to observe and explore the boundless limits of the Universe. It is my hope that our students will have the opportunity to gain a richer understanding of the American commitment to space exploration.

II. Goals, Objectives, and Strategies

Over the past twelve years, I have participated in several wonderful seminars developing innovative curriculum units to supplement my teachings. These projects have motivated my students and myself to investigate new and exciting areas of learning. In recent years, we have explored African-American studies in art, literature and poetry, highlighting the contributions of Jacob Lawrence, Langston Hughes, Gwendolyn Brooks and Paul Laurence Dunbar. In the sciences, we have created marvelous units which focused on the Wright Brothers and their aerodynamic discoveries and inventions.

This year I am developing a unit entitled “Out-of-this-World Experiments” which will introduce our students to the early years of our space program allow them the opportunity to share in the excitement of going to and landing on the Moon, and help them to understand the scientific achievements that are being accomplished on the Space Shuttle voyages.

As my unit develops, we will focus on numerous scientific research experiments which have been conducted on space shuttles dating back to the early 1980’s, especially as to those which were related to micro-gravity sciences Other experiments will be discussed such as astrophysics, space plasma physics and Earth and planetary observations.

Our unit will conclude with a discussion of future space exploration and research; that is, we will examine the design, development, operation and utilization of the International Space Station, its current cost factor and future growth expenditures, and the positive and negative rationales of this most expensive proposition. The ultimate question remains... Is this project worth $100 billion dollars plus and could the appropriated monies be better spent serving science and mankind in some other capacity.

My curriculum unit will assist me, in many ways in my classroom. At Clemente school, our comprehensive school plan strongly emphasizes reading, writing and cognitive skill development. Students will be challenged with oral and silent readings, especially as they relate to individual space shuttle missions. To date, ninety such missions have been flown, each with a payload variety of experiments being conducted. Each student will be charged with researching specific data as it relates to individual missions. Launch dates crew members, time duration, and payload experiments would number among their responsibilities.

As I have previously noted, our curriculum will be taught utilizing an interdisciplinary approach. Students will monitor NASA and Soviet press releases in our computer labs, Daily logs will be recorded, with critical information to be disseminated to our students weekly by our designated lab technicians. In Language Arts, students will be encouraged to correspond with students from the fifteen other countries who are collaboratively developing the International Space Station. Responses from these “fellow junior scientists” will be shared as well. In Social Studies, chronological time lines will be developed, citing critical accomplishments to date. In Science classes, our students will gain hands-on experience as they participate in “Free Fall” experiments which will help to explain micro-gravity concepts. This understanding will help them to comprehend the challenges facing our astronauts and our space scientists as they go about their daily business in outer space. Hopefully, our students will develop a richer understanding of the heroic accomplishments of these people and, in turn, applaud their perseverance.

III. Theory of Quest

Throughout recorded history, men have attempted to make sense of their lives, to give it meaning through external means. These may be physical, philosophical or religious in nature. Many are the tales of adventures in search of stones of magical ability, fountains of youth, golden amulets of fantastic power, the grail supposedly possessing spiritual and life-giving properties, and thousands of other objects that have fired man's imagination and desire. Even in our own time, men continue to search for these same things. These quests are about mankind's search for itself, the immortality of the flesh and spirit.

There may be no profound and grand relationship relating the grail, gold, quests, and the characters and themes found in our space exploration program today. Yet I think that a connection exists; a common thread running through each. The knights who quested after the grail, the many adventurers who have searched for treasure and magical things, and the explorer Columbus and his crew sailing across the Dark Sea in search of the West Indies and Japan. All these people have essentially been looking for similar things. For some of these men, these things would simply be on the level of material acquisition, such as wealth or power. For a few, these things would transcend material wealth and ascend to a level where the search becomes, as for some of the knights, a "journey of the soul" and for some of the characters "a quest for identity, dignity, and individual freedom."

There seems to be a parallel in all these quests throughout history. Those who believed in amulets and sun gods, those who searched for the wondrous grail, those who prospected their entire lives looking for gold, and those who plundered across Central America and the Caribbean were all caught up in this desire to find treasure; a treasure that surely transcended mere material wealth and became a passion of dreams. This quest is what elevates the man or destroys him forever.

IV. History of Flight

There have been many individuals, who have through an advancement of some technical skill or through the sheer inspiration of their personality, progressed the science of flight. Actually, too many to include in this discussion. Therefore, only a few representative individuals and their achievements will be noted. Each is a representative of their own particular time, and each evokes the spirit and essence of the "magic" of flight.

4.1 The Quest

As far back as 1480's, Leonardo da Vinci had a curiosity and eye for life and its complexity. Flying was one of his strongest interests. Though never to fly himself nor to create a workable flying machine, da Vinci sensed the science behind flight. He writes, "A bird is an instrument working according to mathematical law, which instrument it is within the capacity of man to reproduce with all its movements but not with a corresponding degree of strength, though it is deficient only in the power of maintaining equilibrium (1)." Leonardo da Vinci obviously felt that man could reproduce the mechanics of flight by mutating the birds. That he was wrong, and in fact constructed models that could never fly misses the point. His inquisitive mind and probing spirit acted as a catalyst for others after him. That those who followed da Vinci refined and in many cases discarded his ideas on flight only serves to illustrate that invention is very often an evolutionary process. We build as much on inspiration as we do on technically correct formulas. Probably the first aerial voyage of any kind that man attempted successfully was in a balloon. In 1783 two gentlemen, Messrs. Rozier and Marquis d' Arlandes, using the technology supplied by two brothers, Joseph and Etienne Montgolfier, set sail in a balloon for a brief trip across Paris. The technology behind this balloon trip was simple; heat causes expansion and consequently reduces the weight of air. This balloon was in reality a "floating chimney" powered by burning straw (1). Though this flight lasted only 25 minutes over a distance of about five miles, it did serve as a springboard for the imagination, and as a focus for the competitive, inventive spirit.

In 1785 Jean-Pierre Blanchard and Dr. John Jeffries crossed the English Channel for the first time by air, using an improved balloon design.

Balloon designs (lighter than air) reached their peak in the form of the dirigibles. These were used for exhibition and warfare. More importantly, regular transatlantic traffic had been carried out for years. Had it not been for the horrible tragedy of the Hindenburg in 1937, both dirigibles and zeppelins may have enjoyed a greater success, even into our own time.

In 1896, the Langley Aerodrome Model No. 5 had demonstrated the possibility of mechanical flight. Designed by Professor Samuel Pierpont Langley, this model was powered by a small steam engine. This unmanned model made the first significant flight of any engine driven heavier-than aircraft. It flew twice on the afternoon of May 6, 1896, launched from a houseboat on the Potomac River. Professor Langley's later attempts at manned flight in a full-sized version of the Aerodrome were unsuccessful. Also launched from a houseboat anchored in the Potomac, the larger craft hit the water almost immediately after launch in October 1903. A second attempt in early December ended in similar fashion.

As a parallel to these powered attempts at manned flights, there was considerable energy being spent in flying using gliders. The most successful of these was the glider constructed by Otto Lilienthal in 1894.

Basically, gliders had a pilot hang between the wings by bars that passed beneath his arms. Lilienthal made glides of up to 1,150 feet in machines of this type, Despite his faith in the safety of his invention, Lilienthal was killed following a crash in one of Ws hang gliders.

Apparently, Lilienthal's death was not in vain. It is reported that the aviation pioneers, Orville and Wilbur Wright had read about and were much impressed with Lilienthal's experiments. These attempts at flight by Lilienthal had obviously acted as a strong incentive to the brothers Wright, to try their own flight with engine powered heavier-than-air flights. Another great influence upon the Wrights was Octave Chanute. Chanute, a successful engineer, was himself very interested in gliders and powered flight. His knowledge of previous aerodynamic experiments and his encouragement acted as a strong motivation to Orville and Wilbur.

4.2 Mastery of Flight

Apparently, though mankind had dreamed of powered flight, and had worked hard at it for many years, interest in this being accomplished was slowly but surely fading. All previous attempts had ended in failure. As it is with many experiments that appear solvable but continually end in failure over many years and many attempts, the invention of the airplane by the Wright brothers was from a design almost uniquely their own. The Wright brothers using the inspiration of Lilienthal, together with his awareness of the curved wing as superior to the flat wing, perfected the correct curvature of the wing, thereby removing any impediment to successful powered flight that had previously been little understood.

After much experimentation and reading, after much discussion and application of the laws of aerodynamics, as they themselves had investigated and solved, the Wright Brothers were on the doorstep of an event that would change the course of the world forever.

On December 17, 1903, the Wright Brothers successfully flew the first powered heavier-than-air craft. Their plane was an innovative combination of lightness and strength. The plane flew a distance of 120 feet on the first trial and their last flight covered 852 feet and lasted 59 seconds. The Wrights had worked almost continuously for over five years, solving problems, difficult and minor, theoretical and technical. They labored over problems as diverse and complicated as wing warping control, integrated wing warp and rudder control, construction of their own aircraft engines and propellers, and of course their experiments in aerodynamics. As stated previously, the Wrights alone were able to test and understand the profound significance of an accurate airfoil. The Wright brothers were two creative geniuses who mastered the theory and the practical application of aviation. Their gliders and powered flying machines were of superior design and construction. Their methods and materials were thoroughly tested and re-tested. Their scientific data was constantly being reevaluated. They mastered the construction and utilization of propellers and engines. Their wind-tunnel experiments provided accurate measurements for lift which proved to be one of the great turning points of attempts at human flight. Their mastery of flight control with the discovery and implementation of ailerons, wing warping techniques, front elevators and flexible rear tails or rudders stabilized lateral and longitudinal balance. These and other achievements enabled the Wrights to be the first to fly.

4.3 Extending the Mastery of Flight

On May 20-21, 1927, twenty-five year old Charles Lindbergh made the first solo, nonstop transatlantic flight in his specially constructed plane, “The Spirit of St. Louis.” The flight took 33 1/2 hours. Lindbergh took off from Roosevelt Field, Long Island on the morning of May 20, 1927 and 33 1/2 hours later landed at Le Bourget Field near Paris, France to a hero’s welcome. One hundred thousand people were there to greet him.

His plane was constructed in such a fashion, that Lindbergh to see forward, had to either turn the plane or use a periscope; a gas tank was installed where the windshield normally would have been.

Lindbergh, not even counting the significant technical feats involved in his aircraft, epitomized the true and adventurous spirit of the men who took the next step in advancing the art and skill of flying. Lindbergh’s feat was accomplished a mere 24 years after the first successful flight of the Wright Brothers.

4.4 Breaking The Sound Barrier

On October 14, 1947, a little more than 20 years after Lindbergh’s historic crossing the Atlantic Ocean, another milestone was reached in aviation history. Captain Charles “Chuck” Yeager, U.S. Air Force, flying his rocket powered craft, the Bell X-1, became the first person to fly faster than the speed of sound in a sustained, level flight.

Remember, the speed of sound is 670 miles per hour! Only 44 years before, Orville and Wilbur Wright had managed to soar for the first time ever at a more modest speed of 35 miles per hour. Amazing!

4.5 Man's Countdown to the Moon

Looking back now to the early days of spaceflight, the first trips into outer space are modest by comparisons. However, at the time, those events were incredible. Individual men were strapped into tiny capsules and they flew sub-orbital flights around the earth hoping to return home safely. Starting with Vostok I, Yuri Gagarin was the first man to fly in space. He hurled around earth at over 17,000 miles per hour and after 89 minutes, he reentered earth's atmosphere and parachuted to Earth .... a Russian national hero. The Space Race had begun.

Within a month, the Americans responded with astronaut Alan Shepard in Shepard's capsule, which he had named Freedom 7, sped through space at over 5,100 miles per hour, at an altitude of 115 miles. The total trip took l5 minutes, landing in the Atlantic Ocean, 300 miles from Cape Canaveral. Two months later Gus Grissom flew almost an identical flight on Mercury 4. However, his capsule, the "Liberty Bell", sunk just after splash down and it never was recovered.

The second manned Soviet craft, Vostok 2, orbited the earth 17 times, recording 25 hours in space. His orbital patterns crisscrossed most of the earth, creating world-wide alarm as to the military implications of space dominance. The United States answered with John Glenn and "Friendship 7" on February 20, 1962. This was the first American orbital flight and Glenn circled the earth three times. Upon his return, he received a hero's welcome with parades in New York and Washington D.C. Scott Carpenter's trip in Mercury 7 was similar to Glenn's in orbital distance; however, faulty instrumental readings, low fuel and over-heated flight suit troubled his voyage. Upon reentry, his rockets failed to fire properly, and when they did, his cabin filled with smoked. Fortunately for Scott, he landed safely.

Two Soviet pilots were launched 24 hours apart on August 11th and 12th, 1962. They were the first to "fly in formation" aboard the Vostok 3 and Vostok 4. After Andrian Nikolayer orbited the earth 16 times, Pavel Popovich was launched almost into an identical orbit; he was able to bring his craft within 4 miles of his fellow cosmonaut where they could see each other and correspond by radio. Three days later, they both landed safely in central Russia.

In October, Walter Schiarra and the "Sigma 7" circled the earth nearly six times in three hours. The Mercury 8 expedition was nearly trouble-free and it marked the final mission of 1962. In May, 1963, Mercury 9 was launched, the last in the Mercury series. Gordon Cooper piloted his "Faith 7" capsule around the earth 22 times in 34 hours. The first color photographs and movies of earth were recorded by Cooper and transmitted from his spacecraft.

A month later, Soviet cosmonaut Valery Bykovsky spent nearly 5 days in space studying the long term effects of weightlessness. During that time, he orbited the earth 81 times, parachuting to Earth after reentry of Vostok 5. During that same flight time period, the first woman to fly in space, Valentina Tereshkova, was launched 48 hours later. She stayed in orbit for three days, communicating by radio with the other spacecraft. She too ejected from her capsule and parachuted to safety shortly after reentry. Vostok 6 was successful.

In October 1964, the first flight of the Voskhod series took three men into space for 24 hours. Vladimir Komarov piloted the craft while Space Doctor Boris Yegorov and Space Scientist Konstantin Feoktistov conducted experiments. This flight marked the first time that the capsule was pressurized and air-conditioned, allowing the cosmonauts the luxury of light-weight clothing instead of those bulky, inflated suits.

The following year, in March, Voshkod 2 lifted off. Aleksei Leonov became the first man to actually walk in space. As his ship sped around earth at 17,500 miles per hour, Leonov stepped out of the double air lock for ten minutes. At the end of their 17 orbit flight, Leonov and his pilot Pavel Belyayev overshot their targeted area and landed in snow in the Ural Mountains. It took rescuers two days to reach them.

Gemini 3 was the first in a long series of two-man flights powered by the new Titan 11 rocket. Gus Grissom and John Young orbited the earth three times, changing the capsule's orbit on three different occasions. This changing of direction was the first time that a manned spacecraft had altered direction. Remembering that his first capsule had sunk, Grissom named this one the "Unsinkable Molly Brown" and it floated just fine.

Two months later, aboard Gemini 4, Ed White became the first American to "walk' in space as pilot James McDivitt navigated the third orbit of the ffight. White maneuvered outside the spacecraft for 20 minutes, attached to the capsule by a 25 foot-long tether which supplied oxygen and communications. In August, Gemini 5 took astronauts Charles Conrad and Gordon Cooper through an 8-day test of endurance in outer space. During that time, they circled the earth 120 times and traveled three million miles. The astronauts practiced rendezvous navigation techniques with an imaginary target but problems with their thrust rockets precluded other experiments. Gemini 7 and 6 were the last flights of 1965. Gemini 7 launched first, sending Frank Borman and James Lovell on a two week endurance mission which would take them around the world 206 times. Towards the middle of the voyage, Gemini 6 with Walter Schirra and Tom Stafford lifted off aiming to rendezvous with Gemini 7. The two spacecrafts flew in tight formation for almost six hours, coming as close as four feet from each other.

In 1966, Gemini 8 almost ended catastrophically. Early in the mission, one of the tiny maneuvering thrusters began firing uncontrollably, causing Armstrong's capsule and the 26 foot Agena target rocket which had been previously coupled together to tumble over and over again. Fortunately, Neil Armstrong and co-pilot David Scott were able to pull away from the rocket and then shut down the malfunctioning thruster. Subsequently, the remainder of the mission was canceled.

Tom Stafford and Eugene Cernan were the next American astronauts to attempt to dock their spacecraft to another unmanned target rocket but, unfortunately, a protective covering on the 11 foot rocket prevented them from doing so. Cernan later stepped outside for a two-hour space walk, returning quite tired to his Gemini 9 space capsule.

On the Gemini 10 space flight, the capsule quickly located the targeted rocket and docked perfectly. While Commander John Young piloted the vehicle, Mike Collins walked twice in space, recovering a detachable measuring device from the docked Agena rocket. In September, Pete Conrad and Richard Gordon were able to dock with an Agena rocket during their first orbit. Later, Gordon walked outside of Gemini 11 and attached a 100 foot rope between the rocket and the capsule. This connection allowed the spacecraft and the Agena to spin around each other, creating a temporary gravity in weightless space. The last flight in the Gemini series included several successful dockings with an Agena rocket and a series of open-door maneuvers by Buss Aldrin., While James Lovell kept Gemini 12 steady, Aldrin took pictures from the opened capsule door. Later in the flight, Aldrin left the capsule completely for over two hours, working at the end of a 25 foot tether. He avoided fatigue suffered by other astronauts by taking regular rest periods.

On January 27, 1967, America's space program suffered a major setback as three astronauts died in a sealed capsule fire as they were simulating a flight. Gus Grissom Ed White and Roger Chafee all died quickly. This tragedy, believed to have been started by faulty wiring, brought the United States space program to a tragic halt. Future capsules underwent substantial redesigned constructs.

The first flight, of the Soviet Soyuz 1 also ended in death. Pilot Vladimir Komarov had trouble controlling the vehicle which began tumbling after several orbits. Four miles above earth the parachute lines snarled and the capsule crashed to the ground, killing Kamarov.

The first American manned flight after the fire tragedy was Apollo 7. Walter Schiarra, Don Eisele, and Walter Cunningham circled the earth 163 times in 11 days. The crew made several complicated rendezvous maneuvers and broadcast live on television.

On October 26, 1968, Georgi Beregovoi twice rendezvoused his Soyuz 3 with an unmanned Soyuz capsule which had preceded him into space. After 64 orbits, he returned to earth. At the age of 47, he was the oldest man to fly in space up until that time. Two months later, Apollo 8 lifted off with Frank Borman, James Lovell and William Anders abroad. This expedition was designed to test the technology that would enable us to get to the Moon and to return to earth. It was also the initial test of the Saturn V rocket with its 7 1/2 million pounds of lift-off thrust. The spacecraft left earth's atmosphere and reached the moon three days later. They circled the moon ten times, later returning to earth safely.

The Soviets continued their space exploration early the next year sending Soyuz 4 and Soyuz 5, into orbit on January 14th and January 15th. Pilot Vladmir Shatalov was already orbiting the earth in Soyuz 4 when Soyuz 5 was launched. After several maneuvers, the two capsules docked in space and Alesksie Yeliseyev and Yevgeni Khrunov walked from Soyuz 5 to Soyuz 4, wearing pressurized suits. The two capsules then separated and pilots Shataov and Volynov flew their vehicles back to earth, having successfully exchanged passengers in outer space.

On March 3, 1969, the first space test of the lunar module, took place within earth's orbital path. While David Scott piloted the command module "Gumdrop", James McDivitt and Rusty Schweickar entered the lunar module "Spider" and flew it on its own for 6 1/2 hours. After the test, the lunar module was jettisoned away because it could not have survived the fiery reentry into earth's atmosphere.

On May 18, 1969, Apollo 10 became the final preparation test flight for the voyage to the moon. While John Young watched from the command vehicle "Charlie Brown" Thomas Stafford and Eugene Cernan made two low-level passes around the Moon aboard "Snoopy". The crew also broadcast 19 color televised transmissions. The stage was now set for Apollo 11. On July 16, 1969, Apollo 11 and its crew reached for the Moon aboard the "Eagle" and the "Columbia". The three astronauts had done the unthinkable ... they had journeyed to the Moon and back. The epic voyage having been completed, American realized that the 21st manned space flight had enabled the United States space program to "come of age." Apollo 11 was a technological triumph of the highest order, made possible only by the sustained effort during the past decade of hundreds of thousands of persons and the expenditure of some 22 billion dollars.

It involved so complex a technology that it was difficult to comprehend the components: the tons of blueprints, the 20,000 contractors; the 20,000 pages of manuals and instructions printed monthly by the Kennedy Space Center; the rocket and the spacecraft encompassing over 5,000,000 separate parts; the most powerful engines in the world, consuming 15 tons of kerosene and liquid oxygen in seconds; and the telemetry that during launch sent back to Houston enough information to fill an encyclopedia each second.

Above all, Apollo I I was a triumph of human spirit. As Buzz Aldrin noted while traveling home from the Moon, "This has been far more than three men on a voyage to the Moon .... this stands as a symbol of the insatiable curiosity of all mankind to explore the unknown."2

At the President's dinner honoring Neil Armstrong, Buzz Aldrin and Micheal Collins, Neil Armstrong brought tears to many an eye as he profoundly noted: "We hope and think ... that this is the beginning of a new era when man understands the universe around him, and the beginning of an era when man understands hirnself."3

4.6 The Next Steps In Space

As the 1960's were brought to a triumphant close, scientists were already anticipating the research and the accomplishments of the 1970's. The administrator for the NASA, Dr. Thomas Paine, ushered in the new decade with premonitions of assembling a permanently manned station in earth's orbit. Gradually enlarged, it could become the work site for perhaps a hundred scientists.

NASA had already envisioned and prioritized three goals. According to Director Paine, NASA needed to develop re-usable rocket planes, able to shuttle hundreds of times between earth and earth orbit. Second, nuclear power needed to be harnessed to power spaceflight beyond the earth's orbit and would enable scientists to conduct experiments in many fields and would also serve as a base for deep-space ventures and astronomical research.

"Designers already envisioned the reusable craft that would be needed to shuttle between earth and its orbiting space station. The shuttles would take off vertically from earth, fly to orbit, discharge their cargo, return to earth, and land horizontally, using wings, like conventional aircraft. They could carry a dozen passengers - physicists and astronomers perhaps - into space. They could haul 10 tons of supplies and deploy and recover unmanned satellites."4 Imagine!

V. Skylab Laboratories

The Skylab Space Station was launched May 14, 1973 from the Kennedy Space Station by a huge Saturn V launch vehicle. This station was designed to prove that humans could live and work in space and to expand our solar astronomy knowledge well beyond the capacity of Earth-based observatories.

Skylab's achievements are a composite representation of the accomplishments of many ground-based persons as well as its three separate crews. In Skylab, both the man-hours in space and the man-hours spent in performance of extravehicular activities under micro-gravity conditions exceeded the combined totals of all of the world's previous spaceflights up to that time.

The effectiveness of skylab crews exceeded expectations, especially in their ability to perform complex repair tasks. They demonstrated excellent mobility, showing man to be a positive asset in conducting research from space. Crewmen were instrumental in attaining high quality solar and Earth orientated data. All three crews demonstrated technical skills for scientific operational and maintenance functions. Their manual control of the space station, their painstakingly careful execution of experiments, and their reasoning and judgment throughout the excursions were highly effective.

The capacity to endure long time periods in space was conclusively demonstrated in Skylab, first by Skylab 2's crew returning from a 28 day mission, and later, by the crew of Skylab 3 and 4 returning from missions of 59 and 84 days respectively. Also, resupply of space vehicles was attempted for the first time in Skylab and was successfullly demonstrated.

During their time in space, all three crews exceeded their operational and experimental requirements and additionally, the third crew performed a number of astronomical sightings of the Comet Kohoutek which were not originally scheduled.

Skylab 1 was launched May 14, 1973 into orbit by a Saturn V booster rocket. Although it was unmanned and encountered technical difficulties almost immediately upon lift-off, the workshop was repaired and rendered manageable by the crew of Skylab 3 which was launched almost two weeks later. The crew of Skylab 2 included Commander Charles Conrad, Pilot Paul Weitz and Scientist Joseph Kerwin. They rendezvoused with Skylab on the fifth orbit, making substantial repairs which cooled inside temperatures to manageable levels. By June 4th, the work station was completely operable and the crew conducted solar astronomy and Earth resource experiments, medical studies and five student experiments. The mission included 404 orbits, and 392 hours of experimental research. Skylab 2 landed June 22, 1973.

Skylab 3 was launched July 28, 1973 to continue extensive scientific and medical experiments. The crew included Commander Alan Bean, Pilot Jack Lousina, and Scientist Pilot Owen Garriott. The mission completed 858 Earth orbits and 1,081 hours of solar observations and Earth experiments. The Skylab landed September 25, 1973.

Skylab 4 was the last of the Skylab missions. Its crew consisted of Commander Gerald Carr, Pilot William Pogue and Pilot Scientist Edward Gibson. Skylab 4 was launched November 16, 1973 and completed 1,214 Earth orbits. Astronomical observations, especially observation of the Comet Kohoutek numbered among the experimental priorities. Following the final manned phase of the Skylab missions, ground controllers performed some engineering tests that here-to-for they were unwilling to do with humans aboard. Results from these tests helped to determine causes of mission failures. Upon completion of these tests, Skylab was positioned into a stable altitude and systems were shut down. It was expected that Skylab would remain in orbit eight to ten years. However in the fall of 1977, it was determined that Skylab was no longer in a stable altitude. On July 11, 1979, Skylab crashed to Earth. The debris scattered across the Indian Ocean and parts of Western Australia.

VI. Out-of-this-World Experiments

There are many reasons for spaceflight. Spaceflight transports scientific instruments and humans into outer-space to study Earth and the solar system. It allows us the opportunity to study the interactions of the atmosphere, oceans and living things. Spaceflight allows us to travel to distant planets, stars and galaxies to investigate their compositions. It also permits scientists to investigate the fundamental states of matter and the forces that affect them in a micro -gravity environment.

To explain the state of micro-gravity, NASA scientists define the environment as “one that will impart to an object a net acceleration small compared with that produced by Earth at its surface.” In practice, such accelerations will range from about one percent of Earth’s gravitational acceleration (aboard aircraft in parabolic flight) to better than one part in a million (for example aboard Earth-orbiting free flyers)”5. Because gravitational pull diminishes with distance, micro-gravity conditions are created as space vehicles travel away from Earth.

Until the mid-20th century, gravity was an unavoidable aspect of research and technology. Initial research focused on solving spaceflight problems such as how do you get the proper amount of fuel to a rocket engine in space or water to an astronaut on a space walk. The first extended opportunities to explore the affects of micro-gravity and to conduct experiments relatively free of gravity became possible with the Apollo program and later, on board Skylab.

Since the early 1980's, NASA has sent crews and payloads into orbit on the Space Shuttle. The Shuttle has introduced new capabilities for micro-gravity research and the return to Earth of all instruments, samples and data, items that previously may have been lost in space. Use of the Shuttle for micro-gravity experiments began in 1982 and has continued today on many missions, as we will examine a variety of payloads and experiments in the next few pages.

6.1 Spacelab - I (November, 1983)

The seven crew members performed a broad range of space science experiments during their ten day flight. Research focused on micro-gravity sciences, astrophysics, Earth observations and space plasma physics. Specific experiments used the traveling heater method to grow a crystal of gallium antimonide doped with tellurium a compound useful for making electronic devices. A second investigator used molten tin to study diffusion in low gravity while a third scientist grew protein crystals that were significantly better than those that were grown on Earth using similar starting materials.

6.2 Spacelab D-1 (October, 1985)

In April 1985, NASA launched Spacelab 3, which continued to experiment with crystal and protein growth as well as a series of tests on fluid behavior. Six months later, NASA launched a Spacelab mission sponsored by the Federal Republic of German. This mission developed a significant number of sophisticated micro-gravity semi-conductor crystals which are useful in inferred detectors and lasers. Researchers also successfully measured critical properties of molten alloys, measurements which are impossible on Earth because of convection-induced disturbances.

6.3 Spacelab Life Sciences - 1 (June, 1991)

The functioning of the human body in micro-gravity conditions was the primary focus of this expedition. Ten major investigations probed autonomic cardiovascular controls and their adaptation to space environments over time duration periods, vestibular functions, pulmonary function, protein metabolism, mineral loss and fluid-electrolyte regulation. These life sciences were analyzed in space as well as the readaptation to the normal environment on Earth.

6.4 International Micro-Gravity Laboratory-I (January, 1992)

Several biotechnology experiments concerning protein crystal growth were analyzed on this International Mission. Hundreds of scientists throughout the fifteen contributing countries contributed to these experiments. Researchers were able to produce unusually high quality crystals of human serum albumin which made possible x-ray methods to determine important details of atom positions within the crystals. This work was believed to have major medical applications, especially in the development of methods for attaching therapeutic drugs to human serum albumin which could then transport a drug in the bloodstream to body sites where it was needed.

6.5 United States Micro-Gravity Laboratory - 1

In June 1992, the United States Micro-gravity Laboratory flew aboard the Space Shuttle for a fourteen day mission. The payload included 31 experiments in biotechnology, combustion science, fluid physics, materials science, and technology demonstration. The mission was successful in all areas, with the crew conducting a "dress rehearsal" for experiments to be done and living conditions to be endured on the International Space Station.

6.6 Spacelab - J (September, 1992)

This mission was the first to be shared by NASA and Japan's National Space Development Agency. NASA micro-gravity experiments focused on protein crystal growth and the evaluation of the Space Acceleration Measurement System. Japan's agency scientists focused on materials science, fluid behavior and 12 human biology experiments. Japan also introduced two devices which will be used on future excursions. These devices are the Large Isothermal Furnace and a Free-Flow Electrophoresis Unit.

6.7 United States Micro-Gravity Payload - 1 (October, 1992)

This Space Shuttle expedition was the first to employ "telescience"; that is, micro-gravity experiments that scientists can supervise by remote control from Earth. Investigators relayed more than 5,000 commands directly to their instruments on orbit. Conducting experiments to study changes in molten metals as they solidified were made with greater exactivity because, on Earth, gravity effects would skew the conditions that develop during solidification.

6.8 Untied States Micro-Gravity Payload - 2 (March, 1994)

Building on the success of telescience in the previous Spacelab experiments, this Shuttle carried four primary experiments which were controlled by approximately 10,000 commands relayed by space scientists from the NASA Marshall Space Flight Center. An Orbital Acceleration Research Experiment in the Shuttle's cargo bay collected additional data on acceleration.

6.9 International Micro-Gravity Laboratory - 2 (July, 1994)

The second International Micro-gravity Laboratory with a payload of 82 major experiments was a world-wide enterprise comprised of scientists from the Untied States and twelve other countries. Investigations focused on materials science, biotechnology and fluid physics. Materials science studied various types of metal processing. It successfully sintered alloys of nickel, iron and tungsten. Other experiments studied the positioning of experiment samples away from the surface of a container, in effect eliminating processing effects of containers. Biotechnology experiments expanded the research production of high quality crystals of 9 proteins. High-resolution video cameras monitored these processes. A newly developed Critical Point Facility enabled researchers to study fluids at their critical points; that is, to observe the point at which the liquid and vapor conditions can coexist.

Since 1988, NASA has built on the results of previous space missions, especially in the areas of space-grown protein crystals. Medical and agricultural researchers hope to use information from these studies to improve their understandings of the complex functioning of proteins. Today the Space Product Development Program seeks to promote industrial application and facilitate the use to space for commercial products and services. Space Product Development areas include agriculture, biotechnology, combustion, electronics, laboratory automation, materials science, micro-encapsulation, protein crystal growth, robotics and zeolites. Micro-gravity research is a natural extension of traditional Earth-based laboratory sciences, in which experiments performed benefit from the stable, long-duration micro-gravity environment.

VII. Conclusion

In the past fifteen years NASA has flown a total of 22 designated missions. Although NASA has fallen far short of the anticipated space exploration goals developed by the Reagan and Bush administrations, the Skylab has been remarkably productive. In a total of 180 days in space, scientists have generated more real scientific data than 25 years of Russian research aboard Salyut and Mir except in a few limited fields. World-class scientists form MIT, the University of California and the University of Texas, along with those from Europe, Canada and Japan have participated in these excursions.

The discoveries aboard these Skylab flights have not been the kind that immediately impacted our lives. Nevertheless, these sciences have made important discoveries which have impacted other areas. Some areas of space science such as crystal growth or pharmaceuticals have not lead to industrial breakthroughs as hoped. But, in all fairness, these experiments didn't fail because of the scientists or the equipment. They were simply overtaken by superior science funded by private industry, and not subject to political appropriations.

It is currently anticipated that the International Space Station will not be operational for at least five or six years and that the current cost and then future growth expenditures will approach 100 billion dollars. And the opportunity to do rich and varied volumes of science is years beyond that.

So the question remains as to why is the International Space Station being built and at what expense. The Chabrow fiscal report notes that the program size, complexity and ambitious schedule goals were beyond what could be reasonably achieved within the $2.1 billion annual cap or the $17.4 billion total cap. It also noted that the uncertainty associated with our Russian partnership agreements and a number of critical risk elements are likely to adversely impact the scheduled completion of the International Space Station in a timely manner. Not surprisingly, many scientists have vociferously opposed the Space Station from the start, fearing that monies appropriated for this project would severely shortchange others. I personally know of one scientist who feels very strongly in a similar capacity. Such scientists hope to do away with space projects involving humans, especially the ones that orbit Earth in "tin cans".

Such opposition inevitably attends the conquest of new horizons. Explorers since the beginning of time have been unable to envision the full impact of their achievements. Often, like Columbus, they made confident assessments which time has proved wrong. It usually remained for those who followed to find the real significance of the explorer's effort and to reap benefits far greater than anticipated.

VIII. Lesson Plans

These curriculum lesson plans are designed to be taught during a time period of twenty days. The unit itself is developed in a progressive history of flight format which allows for teacher-led discussions, oral and silent readings, and a wide selection of student-planned activities.

Current research has demonstrated that learning activities which focus on hand-on lessons enables students to maximize their retention of the material being disseminated. Additionally, these lessons lend themselves nicely to creative thinking and shared enthusiasm for the experience. Many teachers may choose to devote additional time to certain areas of instruction and less time to others. These lessons have been designed to allow for flexibility and I hope that instructors will tailor the unit to fit the needs of their classrooms.

Day 1

The first day will provide a general overview of the history of flight. Teacher-led discussions will focus on our unit outline, highlighting important discoveries in flight and space flight.

Day 2

The second day will again provide an overview of our space program, focusing on the four Skylab missions and the numerous Space Shuttle missions. Teacher-led discussions on micro-gravity principles will enable our students to comprehend the working environment aboard space vehicles.

Day 3

In a Social Studies lesson, we will develop a chronological timeline for actual flight milestones and spaceflight triumphs. We will later enlarge our timeline in art class for a classroom wall display. This project will provide a daily focus outline for our unit of study.

Days 4,5,6,7

Having constructed our timeline, students will be encouraged to select one of the Mercury, Gemini, Apollo, Skylab, or Shuttle missions to research independently in our computer lab. These "lab technicians" will print relevant materials to be shared with our entire class in a weekly oral discussion period. Working tangentially, the students may develop a monthly newsletter to be shared with other classes or they might seek to develop a peer tutorial program with grade level students. (Lab smocks worn by these researchers might add a nice touch and an air of curiosity to other students as these researchers walk to and from the computer labs on a daily basis.)

Day 8

"Movie Presentations" - to be introduced by the instructor and then to be followed by group discussions in the context of the computer research being done by the classroom's lab technicians. "Newton In Space". This movie introduces motions and their applications to space travel. The program explains the differences between weight and mass, balance and unbalance forces, and action and opposite reactions. Space Shuttle astronauts conduct simple force and motion demonstrations in micro-gravity conditions.

Day 9

"Space Basics" - This movie answers basic questions about space flight including: how spacecraft travel into space: how spacecraft remain in orbit; why astronauts float in space; and how spacecraft return to earth. Newton's Laws of Motion are revisited to further explain the basic science of orbiting the Earth. This movie is suitable for middle school students and is approximately 21 minutes in length.

Day 10

"Micro-gravity". This movie is available from the NASA Educational Satellite Video conference series and is approximately 60 minutes in length. NASA personnel present micro-gravity concepts, discuss scientific research and engage in hands-on activities with students and teachers who call in on conference phones and computers. This project serves to answer some of the questions that students may have about specific payloads and experiments being conducted on spacecraft missions that they are researching for their individual projects.

Day.11 12

Having developed a background of relevant information, we will encourage each student to write to NASA - c/o Goddard Space Center or the United States Space Foundation to secure additional resource materials relevant to their area of research. Students will write their first drafts from a graphic organizer of ideas and then, they will rewrite their letters, having been checked carefully by fellow classmates. This cooperative learning process continues to pay rich dividends in shared knowledge. All letters will be mailed, anticipating noteworthy responses.

Day 13

Slide Presentation on Micro-gravity - These slides are available through NASA and are suitable for grades 8-12. The 24 slides illustrate the basic concepts of micro-gravity and describes four areas of micro-gravity research, including: biotechnology, combustion science, fluid physics and materials science.

Days 14,15,16

These educational software products can be shared in our computer laboratories. The micro-gravity tutorial is designed to motivate teachers and students to study science, mathematics, and technology. Students will use inverses, squares, and ratios to calculate gravity in space and orbiting patterns.

Days 17, 18

These two days will be spent in our science laboratory conducting experiments to demonstrate that free fall eliminates the local effects of gravity. One such demonstration involves a water-filled cup which is inverted a top of a cookie sheet. Before releasing the cookie sheet, the gravitational forces or weight of the cup and water are counteracted by the cookie sheet. Upon removing the sheet, students will be asked to anticipate the results of the experiment.

Since Galileo demonstrated that all objects accelerate similarly in Earth's gravity, the cup and the water will move together. Consequently, the water will remain in the cup throughout the entire Similar experiments will be performed to amply demonstrate free fall concepts.

Days 19,20

We will bring our unit to a conclusion with the viewing of the movie "From The Earth To The Moon", a series created by HBO this past year. Students will enjoy exciting scenes detailing everything from take-off to landing during the Apollo 11 mission, reliving the amazing voyage to the Moon.

IX. Footnotes

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5. NASA. Micro-Gravity: A Teacher's Guide With Activities, December, 1995.

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2. Howard, Fred. *Wilber and Orville* . Knopf New York. 1987.
3. Reinert, M. *For All Mankind* . Weller Media Products. Science Lab Pack: 5 CD-Roms. 1996.
4. Schaaf, Fred. *Seeing The Solar System: Telescopic Projects, Activities Explorations in Astronomy.* Wiley Science Editions, 199 1.

C. Resource Centers

1. NASA Goddard Space Flight Center Teacher Resource Laboratory (I -301-286-8570)
2. NASA Greensbelt, Maryland c/o Linda Mattison (educational consultant) (1-301-286-8570)
3. U.S. Space Foundation

Educational Resource Center

2860 South Circle Drive - Suite #2301

Colorado Springs, Co. 80906-4184

XI. Appendix

A. Educational Videos

1. Reinhart, Al. For AU Mankind, Weller Media Products. 1996 (79 minutes)
2. NASA. Living in Space. Central Operations of Resources for Educators. (CORE) 1995 (IO minutes)
3. NASA. Newton In Space, IBID. (I 2 minutes)
4. NASA. Space Basics- IBID. (21 minutes)
5. NASA. Toys In Space-IBID. (21 minutes)
6. NASA. Micro-Gravity NASA Educational Satellite Video Conference Series. 1992. (15 minutes)

B. Educational Software

1. Queue. Astronomical Explorations, Discovery Educational Systems. 1997 (1-800-331-5489)
2. Reinhart, Al. For All Mankind. Weller Media Products. 1996. (Lab Pack Available)
3. NASA. Micro-Gravity NASA Educational Materials. 1995.
4. Maris. Space Station Simulator, Maris Multimedia. 1997. (computerized Lego System)

C. Educational Slides

1. NASA. Micro-Gravity Science, NASA Educational Materials. 1994 (24 slides)