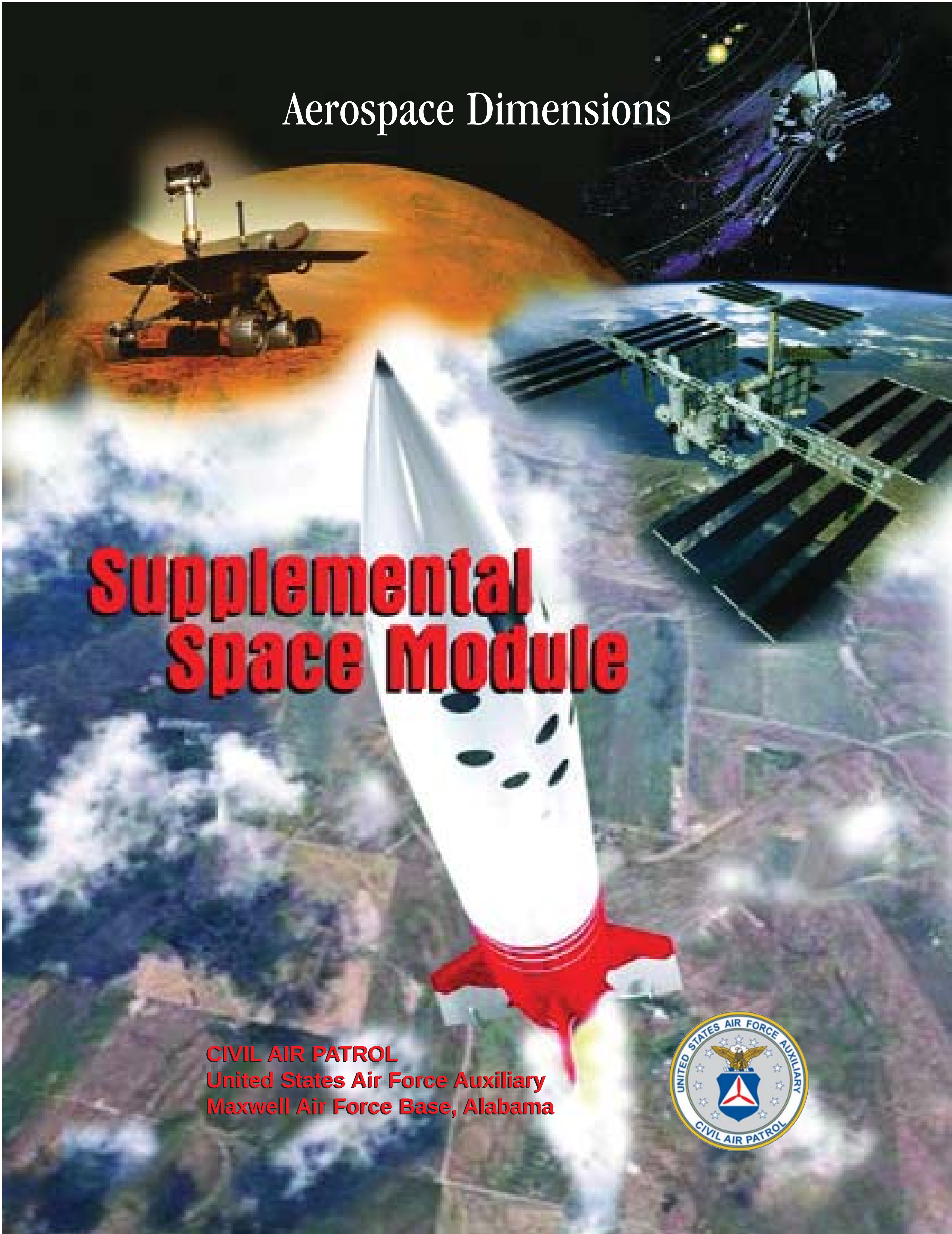
Aerospace Dimensions

Supplemental Space Module



CIVIL AIR PATROL
United States Air Force Auxiliary
Maxwell Air Force Base, Alabama

Acknowledgments

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I want to sincerely thank the X PRIZE Foundation, Analytical Graphics, Inc., and National Aeronautics and Space Administration (NASA) for all of the support they give CAP and aerospace education. These organizations are leading the way into the future, a future that includes space.

Thanks also go to Col Mike McNeely and CAP Col Drew Alexa for their expertise and dedication to CAP and to ensuring STK being properly included in this module. A special thanks goes to CAP C/COL Andrew Shepherd for dedicating his time and considerable talents to this project.

Finally, I want to thank the leadership team at National Headquarters CAP for their vision and support. For this project that team consisted of Judy Rice, Deputy Director of Aerospace Education; Jim Mallett, Director, Leadership Development and Membership Services; and Colonel Al Allenback, Executive Director, CAP. Without their talents, understanding, and dedication to aerospace education this module could not have been produced.

Jeff Montgomery
Project Manager

Introduction

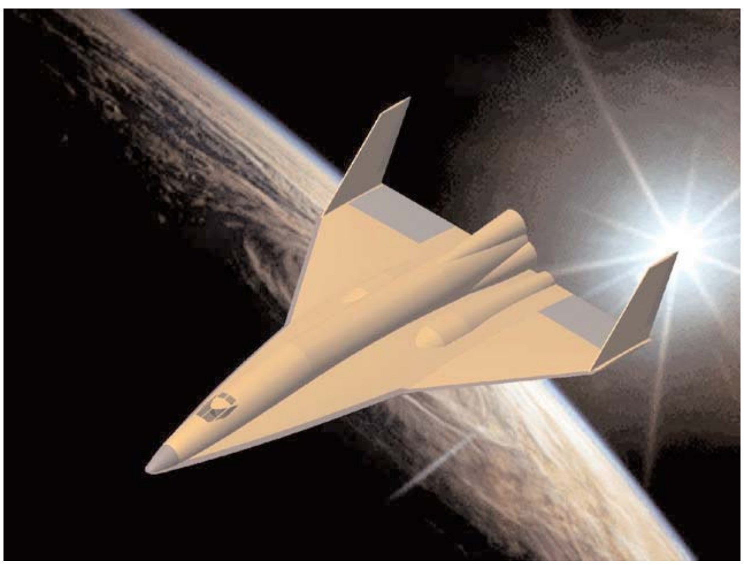
This module discusses current space information and is designed to be a supplement to the six modules of Aerospace Dimensions. This module provides the reader with an up-to-date look at some intriguing topics that are very relevant in today's discussions of space. In a few cases, this module elaborates on subjects mentioned in Aerospace Dimensions modules 5 and 6. At other times, this module covers new and exciting topics that we hope you will enjoy. Studying this supplemental module is not required for promotion within the cadet ranks of CAP. This module simply consists of some of the hottest topics relating to space and provides some of the latest information available.

The module is divided into five chapters covering five main subjects. We begin with X PRIZE, which is a $10 million space-travel competition to boost space tourism. Next, we discuss satellites and Satellite Tool Kit (STK). We devote time to orbits and trajectories and the wonderful technology of STK. Then we discuss the history and current status of the International Space Station. We approach the Mars chapter in a similar way, including discussing the very latest explorations to Mars. Finally, we conclude with a look at astronomy and the latest scientific discoveries in space. It is our hope that these diverse subjects will give the reader a current and accurate perception of where America is today with regard to space, and a glimpse of where we might be headed in the future.

We included some hands-on activities, which we hope you will enjoy and also find stimulating and educational. They are listed in the back of each chapter. We also included some links to web sites that provide more in-depth knowledge and sophistication.

Whether you study all five chapters or only a few, we hope you find this module to be informative, interesting, educational, and worthy of your time.

Contents



Learning Outcomes

Chapter 1 - X PRIZE

After completing this chapter, you should be able to:
- Define X PRIZE.
- Describe the mission of X PRIZE.
- State some reasons for why X PRIZE was created.
- Identify some of the teams that are competing.
- Explain how the prize can be won.
- Describe some of the benefits to be derived from X PRIZE.

Chapter 2 - Satellites and Satellite Tool Kit

After completing this chapter, you should be able to:
- Define an orbit.
- Describe different orbits.
- Discuss the Hubble Telescope's contributions.
- Define STK.
- Describe how STK can be used.
- Apply STK technology to predict satellites passes.

Chapter 3 - International Space Station (ISS)

After completing this chapter, you should be able to:
- Explain some of the research to be conducted on the ISS.
- Describe the living conditions on ISS.
- Name the nations involved with ISS.
- State the purpose of ISS.
- Describe the current status of ISS.
- Estimate a timetable for completion.
- Identify some uses for the ISS.

Learning Outcomes

(Continued)

Chapter 4 - Mars

After completing this chapter, you should be able to:

- State facts about Mars' environment.
- Describe reasons for scientists' interest in Mars.
- Identify earlier missions to Mars and what they accomplished.
- Describe future missions to Mars.

Chapter 5 - Astronomy

After completing this chapter, you should be able to:

- Identify some of the latest space discoveries.
- Discuss any new planetary discoveries.
- Discuss latest findings concerning stars.

National Science Standards

Chapter 1 - X PRIZE

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Unifying Concepts and Processes
- Evidence, models, and explanation
- Form and function

Chapter 2 - Satellites and Satellite Tool Kit

Content Standard B: Physical Science
- Motions and forces
- Interactions of energy and matter

Content Standard D: Earth and Space Science
- Energy in the earth system
- Origin and evolution of the earth system
- Origin and evolution of the universe

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

Unifying Concepts and Processes

- Evidence, models, and explanation
- Constancy, change, and measurement
- Form and function

Chapter 3 - International Space Station

English Language Arts

1. Reading for Perspective
3. Evaluation Strategies
4. Communication Skills
5. Communication Strategies
6. Applying Knowledge
8. Developing Research Skills
12.. Applying Language Skills

Science

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Life Science

- Behavior of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Science as a human endeavor

National Science Standards

Social Studies
3. People, Places, and Environment
4. Individual Development and Identity
8. Science, Technology, and Society
9. Global Connections

Technology
Standard 8: Students will develop an understanding of the attributes of design.
Standard 11: Students will develop abilities to apply the design process.

Chapter 4 - Mars

Science
Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Nature of scientific knowledge
- Unifying Concepts and Processes
- Evidence, models, and explanation

Chapter 5 - Astronomy

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Structure and properties of matter
- Interactions of energy and matter

National Science Standards

Content Standard D: Earth and Space Science
- Energy in the earth system
- Origin and evolution of the earth system
- Origin and evolution of the universe

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

Unifying Concepts and Processes
- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium

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LEARNING OUTCOMES

After completing this chapter, you should be able to:

- Define X PRIZE.
- Describe the mission of X PRIZE.
- State some reasons for why X PRIZE was created.
- Identify some of the teams that are competing.
- Explain how the prize can be won.
- Describe some of the benefits to be derived from X PRIZE.

The X PRIZE Board of Trustees

X PRIZE

The excitement is building! The X PRIZE could be won in a few months! This chapter will discuss what the X PRIZE is all about and describe a few of the leading candidates to capture the prize. Much of this information comes from the X PRIZE website.

MISSION AND PURPOSE

In 1995, Dr. Peter Diamandis established the X PRIZE Foundation with the assistance of Byron Lichtenberg, Colette Bevis, and Gregg Maryniak. The Foundation was initially headquartered in Rockville, Maryland but moved to St. Louis, Missouri in 1996.

The X PRIZE is a $10 million prize to jumpstart the space tourism industry through competition between the most talented entrepreneurs and rocket experts in the world. The $10 million cash prize will be awarded to the first team that: a) privately finances, builds and launches a spaceship, able to carry three people to 62.5 miles (100 kilometers)(the edge of space); b) returns safely to Earth; c) repeats the launch with the same ship within 2 weeks.

The X PRIZE competition follows in the footsteps of more than 100 aviation incentive prizes offered between 1905 and 1935, which created today's multibillion-dollar air transport industry. The X PRIZE was inspired by the early aviation prizes of the 20th Century, primarily the spectacular trans-Atlantic flight of Charles Lindbergh in The Spirit of St. Louis, which captured the $25,000 Orteig prize in 1927. Through a smaller, faster, better approach to aviation, Lindbergh and his financial supporters, demonstrated that a small professional team could outperform a large, government-style effort.

Vice President and one of the trustees of the X PRIZE Foundation is Erik Lindbergh, a grandson of Charles Lindbergh. To help support X PRIZE and to commemorate the 75th anniversary of his grandfather's flight, Erik recreated that famous flight over the Atlantic Ocean in May 2002. Erik successfully flew nonstop from New York to Paris in 17 hours, 7 minutes in a Lancair Columbia 300. Upon his arrival in Paris, the press asked him what he would do next, and Erik replied that he looked forward to flying into space with X PRIZE.

Dr. Peter Diamandis and Erik Lindbergh

Ever since man landed on the moon, the general public has waited for an opportunity to enjoy the space frontier on a first-hand basis. The X PRIZE Foundation is working to make space travel possible for all. The spaceships that compete for the X PRIZE are designed to carry passengers. Some of the benefits from X PRIZE include:

- creation of a new generation of heroes;
- inspiring and education students;
- focusing public attention and investment capital on this new business frontier;
- challenging explorers and rocket scientists around the world; and
- vehicles built for the X PRIZE will eventually serve four different industries; space tourism, low-cost satellite launching, same-day package delivery, and rapid point-to-point passenger travel.

The mission of the X PRIZE Foundation is to create a future in which the general public will personally participate in space travel and its benefits. The foundation seeks to do this by: organizing and implementing competitions to accelerate the development of low-cost spaceships for travel, tourism and commerce; creating programs which allow the public to understand the benefits of low-cost space travel; and providing the public with the opportunity to directly experience the adventure of space travel.

X PRIZE believes that space flights should be open to everyone, not just the ultra-rich. They believe that commercial forces will bring space flights into a publicly affordable range. The Foundation believes that the resources of space are the key to enhancing the wealth of all nations while preserving the environment of Earth.

They also believe that the risks involved in human space flight are far outweighed by the benefits to the participant and to humanity. X PRIZE will use the utmost efforts to foster safety for participants, observers and the public in all X PRIZE activities.

In October 2002, a report published by the U.S. Department of Commerce's Office of Space Commercialization stated that X PRIZE was a potent catalyst for the sub-orbital commercial space transportation industry. The report goes on to say that commercial space transportation entrepreneurs were shifting their focus to the sub-orbital market, which is the exact market X PRIZE is working to develop.

As of March 2004, 27 teams, from seven different countries, have entered the competition for the X PRIZE. Here is a closer look at some of those teams and their innovative ideas for winning the competition.

COMPETITION

Scaled Composites

This team, headed by Burt Rutan, was the first team to register for the X PRIZE. Rutan is known principally for designing and flying the Voyager, the first plane to fly around the world without refueling. Scaled Composites is located in Mojave, California.

Recently Rutan unveiled his future manned spacecraft, a space-faring vehicle called SpaceShipOne and the airborne launcher, the White Knight. This research vehicle was designed to investigate the feasibility of low cost sub-orbital space flight. The team's goal is to demonstrate that non-government manned space flight can be done at very low costs. Safety is of the utmost importance, but low cost is also critical. This team looks forward to a future where ordinary people, for the cost of a luxury cruise, can rocket into the sky above the earth's atmosphere. Rutan believes that the X PRIZE competition has the ability to help make private space flight and space tourism a reality.

Rutan's plan involves flight in a spaceship, initially attached to a turbojet launch aircraft while climbing for an hour to 50,000 feet, above 85% of the atmosphere. The spaceship then drops into gliding flight and fires its rocket motor while climbing steeply for more than a minute, reaching a speed of 2,500 mph. The ship coasts up to 62 miles altitude then falls back into the atmosphere. The coast and fall are under weightless conditions for more than three minutes. During weightless flight, the spaceship converts to a high-drag configuration to allow a safe stable atmospheric entry. After the entry deceleration, which takes more than a minute, the ship converts back to a conventional glider, allowing a leisurely 17-minute glide from 80,000 feet altitude down to a runway where the landing is made at light plane speeds.

SpaceShipOne Aboard the White Knight Launcher

On December 17, 2003, Scaled Composites took a major step forward in the competition. They flew the first manned supersonic flight by an aircraft developed by a private, non-government effort. SpaceShipOne test pilot Brian Binnie flew to an altitude of 68,000 feet. During the landing, the left landing gear received minor damage, but no one was hurt.

To learn more about Scaled Composites click on ***www.scaled.com.***

Starchaser Industries

Steve Bennett, Director of the Space Technology Laboratory, Salford University, England, began Starchaser as an experimental rocket test program in 1992. In 1996, the team successfully launched the largest private civilian rocket (21 ft) ever built and flown in Europe. In 1997, they entered the X PRIZE competition.

In 1999, Bennett unveiled his next generation rocket and X PRIZE entry, Thunderbird. This was a full-scale mockup at the time, but he has since performed many tests. The flight sequence for the Thunderbird begins with an ascent in a vertical orientation using solid boosters and liquid rocket engines. At higher altitudes the main liquid oxygen/kerosene rocket engine will take over, becoming the major propulsive force in the now rarefied atmosphere. Acceleration will be kept below 3G's for the comfort of the passengers. Following main engine cutoff the vehicle will continue to coast on up to an apogee exceeding 62 miles where the occupants will experience several minutes of microgravity.

Starchaser believes the space frontier is about to open up. Experts are predicting that a global space tourism industry worth $10 billion will be the big business of the early 21st century. The operation of low cost launchers for micro satellite applications and the concept of space tourism, in the form of short sub-orbital pleasure flights are certainly possible, and Starchaser thinks quite viable.

Thunderbird

On December 12, 2003, Starchaser unveiled its new Thunderstar X PRIZE competition vehicle design.

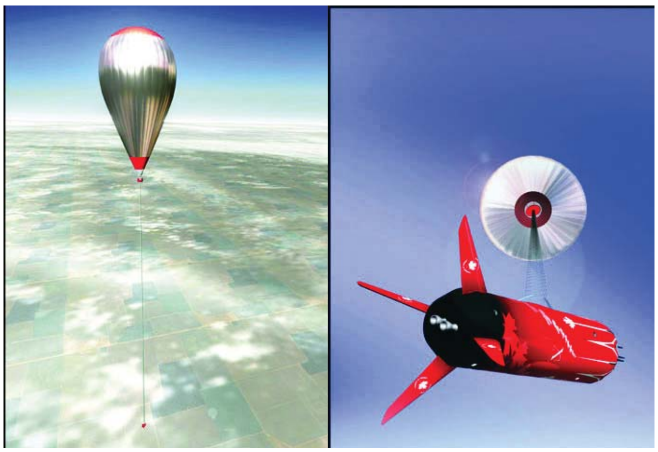
To learn more about Starchaser Industries click on ***www.starchaser.co.uk.***

The da Vinci Project

The da Vinci Project is located in Toronto, Ontario, Canada and is a team of about 30 volunteers from Canada's aerospace industry, led by Brian Feeney. It is Canada's first entry in the X PRIZE competition.

The da Vinci Project will launch its spacecraft (Wild Fire) from the world's largest helium balloon.

The 3,270 kg rocket will be tethered 720 meters below the balloon and lifted over the course of an hour to an altitude of 80,000 feet. The 10, 000 pound thrust, liquid oxygen, and kerosene engines will fire the first stage and the rocket will fly an initial angular trajectory to clear the balloon. The spacecraft then will transition to vertical flight to its apogee of 120 km in space. The rocket's maximum speed on both its ascent and re-entry is Mach 4, or 4,250 kph, or 2650 mph. An innovative ballute will protect and stabilize the rocket on re-entry. A flyable parachute will be deployed at 25,000 feet and the rocket will descend under control, probably guided by GPS, to a predetermined landing zone.



Wild Fire **Spacecraft, right, will be launched by the world's largest helium balloon, left.**

The Wildfire rocket's structure is a combination of a 6-point truss work integrated to a carbon fiber aeroshell. The spherical crew capsule is pressurized to one atmosphere and oval windows wrap around it for a spectacular view. The pilot's seat is centered with the two remaining seats angled to the side. Flight control is achieved through a programmable FAA approved autopilot from a turbine class of aircraft.

To learn more about The da Vinci Project click on ***www.davinciproject.com.***

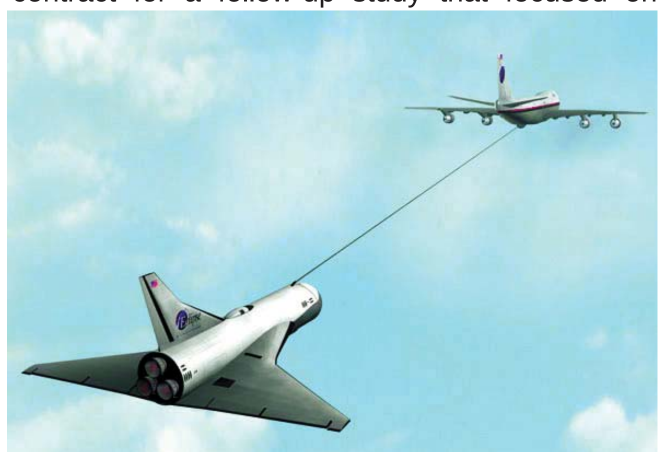
Kelly Space & Technology (KST)

KST is an engineering design and technology development company located in San Bernardino, California. KST joined with Vought Aircraft Industries for the purpose of developing a family of low cost, reusable, commercial sub-orbital and orbital launch vehicles.

KST named their spacecraft Astroliner, and they believe it will provide low-cost, reliable access to space. Astroliner will be tow-launched by a Boeing 747 from a conventional runway to its launch altitude. The Astroliner is reusable. It has a fully reusable first stage, which is the most expensive part of the vehicle.

Then, the Astroliner's second stage is expendable, which eliminates the weight of reentry insulation and recovery systems.

In the last few years, NASA has awarded KST several million dollars. KST was awarded a contract to perform a space transportation architecture study, and the following year was awarded a contract for a follow-up study that focused on developing space transportation through the year 2030.



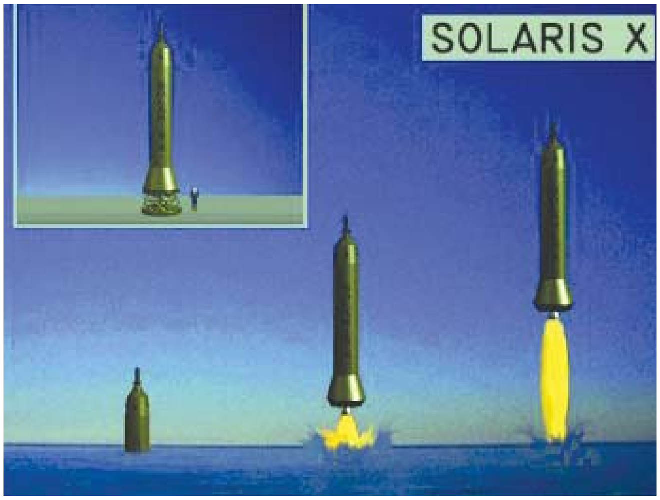
The Astroliner **is towed by a Boeing 747.**

To learn more about Kelly Space & Technology click on ***www.kellyspace.com.***

Interorbital Systems (IOS)

Interorbital is a privately funded aerospace corporation based in Mojave, California, that develops, manufactures, and tests liquid rocket engines, space launch vehicles, and spacecraft. IOS brings the first woman-owned team and first woman pilot into the X PRIZE competition. Wally Funk, one of the original "Mercury 13" female astronaut trainees in the early 1960s will pilot the SOLARIS X in the X PRIZE competition.

SOLARIS X is a liquid-propelled, vertical take-off/horizontal landing vehicle that will become the flagship of IOS' future sub-orbital space tourism operations. IOS is presently engaged in the



development of its Neptune-Solaris Orbital Spaceliner, a two-stage manned reusable orbital launcher. The orbiter upper stage in this configuration is the SOLARIS X rocket plane.

Randa Milliron, CEO and co-founder of IOS is confident of the revenue potential of their enterprise and has started to sell advance purchase tickets for the sub-orbital flights on eBay, under the search title of "Ride a Rocket."

To learn more about Interorbital Systems click on ***www.interorbital.com***.

Vanguard Spacecraft

Vanguard is located in Bridgewater, Massachusetts. The ship's name is Eagle. The Vanguard series launch vehicle, the Vanguard Eagle, consists of two booster stages and spacecraft. The booster stages include fuel tank housing and solid fuel booster housings. The Vanguard Eagle follows a traditional vertical take-off and ballistic reentry mission plan. The flight begins with a vertical launch and a crew of four. The first stage will provide a primary lift-off thrust

Vanguard *Eagle*

for the first 50 kilometers. The second stage will carry the Eagle to an altitude of 75 kilometers where the spacecraft will separate stages and return to Earth via parachute. After the booster fuel is exhausted, the booster stages separate, and the capsule coasts to an altitude of 100 kilometers.

No web site is available at this time.

IL Aerospace Technologies (ILAT)

IL Aerospace is located in Zichron Ya'akov, Israel. Their spacecraft is called the Negev 5, and it is a self-sufficient reusable sub-orbital space

Negev 5

vehicle capable of being launched and recovered anywhere in the world from land or sea without the need of runways, assist aircraft, costly installations or complicated procedures. The vehicle will be a pressurized 3-person habitat equipped with all the essential instrumentation for flight, navigation, communications and life-support. The vehicle will be constructed employing lightweight aircraft-grade alloys and composite materials, while the propulsion system will utilize the latest hybrid rocket technology. The Negev 5 will be launched from ground level using ILAT's own fully reusable

High Altitude Launch Platform. The concept allows the vehicle a free ride on a large stratospheric balloon filled with helium to its intended rocket launch altitude of 82,000 feet above mean sea level. Most of the atmospheric drag will be overcome while saving precious fuel.

No web site is available at this time.

Suborbital Corporation

Suborbital is the only Russian team in competition for the X PRIZE. Suborbital is located in Moscow, Russia. The name of the spaceship is Cosmopolis XXI. This spaceship is a rocket-powered ship, which rides to a high altitude on a M55 altitude aircraft. Separation occurs at 17 kilometers. Suborbital plans to initially rent the M55 aircraft for prototype and testing flights and then eventually buy a copy for regular sub-orbital flight operations.

Cosmopolis XXI

The interior of the spaceship is pressurized, but the passengers are expected to wear pressure suites as a backup. Suborbital plans to operate in Russia, but once the system is proven, they hope to operate around the world.

The team leader is Sergey Kostenko, and his reason for founding the corporation was to open the space tourism market utilizing Russian talent and technology.

No web site is available at this time.

These are just a few of the teams competing for the X PRIZE. I hope this gives you an awareness of how some of the teams are striving to achieve the X PRIZE. To find out more about the teams click on ***www.xprize.org.*** Some of the teams are being secretive, and it may be hard to find more information on them, but all of the teams are listed on the X PRIZE web site.

A 2002 report published by the U.S. Department of Commerce's Office of Space Commercialization called the X PRIZE a potential catalyst for the sub-orbital commercial space transportation industry. Certainly the team that wins the X PRIZE will be providing a major step toward an orbital reusable launch industry.

The momentum is progressing. Some of the teams' tests have gone very well, and experts believe a team will win the X PRIZE in 2004. Space travel for the average citizen may not be far off. Click on the X PRIZE website frequently to keep current on the latest developments.

Activity Section

Activity One

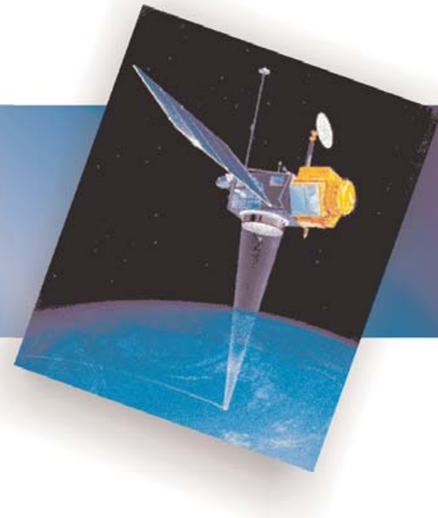
THE CLASSIC "EGG-DROP" ACTIVITY

You've probably heard all about this classic egg activity -- or seen it in action! The idea behind the "Egg Drop" is to create a "package" that will protect a raw egg when it's dropped from a height of 8 feet (or whatever height you decide).

You can use many different materials in fashioning a protective cushion for your egg. You can work individually or with someone to create your egg containers. Students will use everything from bubble wrap and foam peanuts to peanut butter. I heard of a student who packed an egg in peanut butter. It survived the fall, but it broke apart when the student tried to pry it out of jar. Some students might even attach parachutes to the packaging if you let them.

Once constructed, you are ready to "drop" your egg from the appointed height. (Want a real test? Drop your egg from a third-story window!) One helpful hint, Spread a plastic tarp over the spot where eggs will land to protect the floor or ground. Of course you can experiment as often as you want with different protective cushions.

Satellites and Satellite Tool Kit



LEARNING OUTCOMES

After completing this chapter, you should be able to:

- Define an orbit.
- Describe different orbits.
- Discuss the Hubble Telescope's contributions.
- Define STK.
- Describe how STK can be used.
- Apply STK technology to predict satellite passes.

In 1957, the Russians launched Sputnik, the first artificial (manmade) satellite. Since then, scientists have used the term satellite for any object that orbits the Earth, natural or artificial. The moon is the Earth's only natural satellite. So, all the rest of the satellites are manmade. In this chapter, we will only discuss artificial satellites and their orbits.

Sputnik (1957)

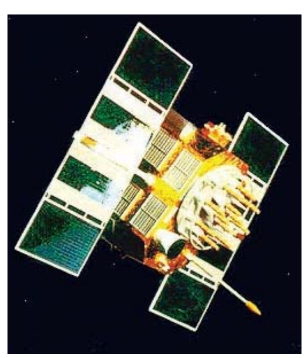
A few months after Sputnik, the United States launched *Explorer* 1, America's first satellite. Now, 45 years later, thousands of satellites are orbiting Earth. Satellites are designed with a purpose. They have a mission to perform. For instance, their purpose might be communication, navigation, observation or scientific. These are four broad categories of purposes, which all involve satellites collecting information and relaying it back to Earth.

***Explorer I* (1958)**

Satellites are gathering and transmitting amazing information. Technology has become so sophisticated. Communications satellites (COMSATs) have been around since 1958, and their uses have grown tremendously. COMSATs still transmit for radios and televisions, but they also transmit for the internet and cellular phones. Additionally, they provide command and control for military forces, and they provide links to other spacecraft.

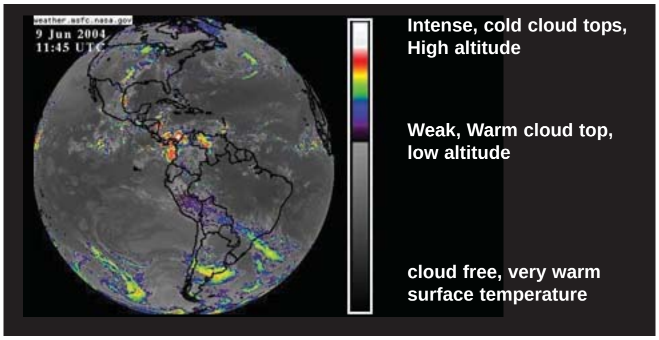
Artists rendering of an Advanced Communication Technology Satellite

About thirty years ago, the US Air Force, in association with the other branches of service, created a new global navigation system called NAVSTAR Global Positioning System (GPS). This system provides navigation and timing information to both civilian and military users worldwide. Position,

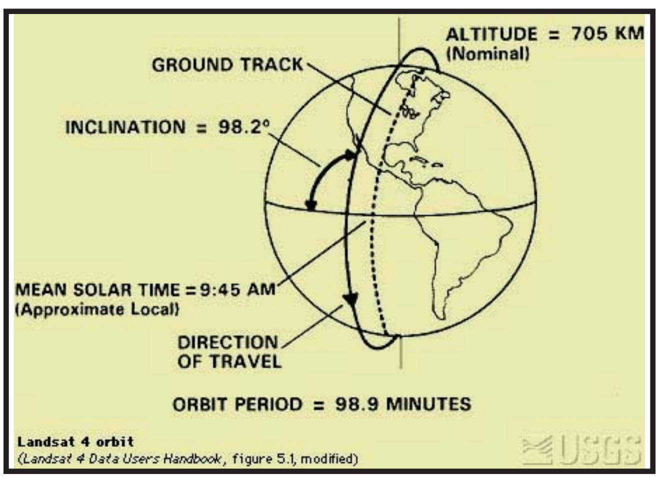


Navstar

satellites give precise reference points and continuously broadcast position and time data. The GPS satellites calculate a three-dimensional position, which is given in latitude, longitude, and altitude. GPS is rapidly replacing all other navigational systems. Virtually all ships and airlines use GPS technology and trucking fleets and law enforcement agencies use it. Search and rescue teams, military, and even hunters and hikers use GPS.



A type of observation satellite is the weather satellite. Weather satellites have become very im-portant. They aid tremendously to the accuracy of weather forecasts. Every weather station uses satellites. Turn on any news channel weather report and they will mention what the satellites are depicting. Of course, the weather satellites are particularly helpful with severe storms and hurricanes.



Landsats Orbit

Another type of observation satellite is the multi-spectrum-imaging satellite; an example of this is the Landsat series. Landsats locate natural resources and monitor other conditions on the Earth's surface.

Scientific satellites orbit to gain information, and there are literally hundreds of examples we

The Hubble Space Telescope

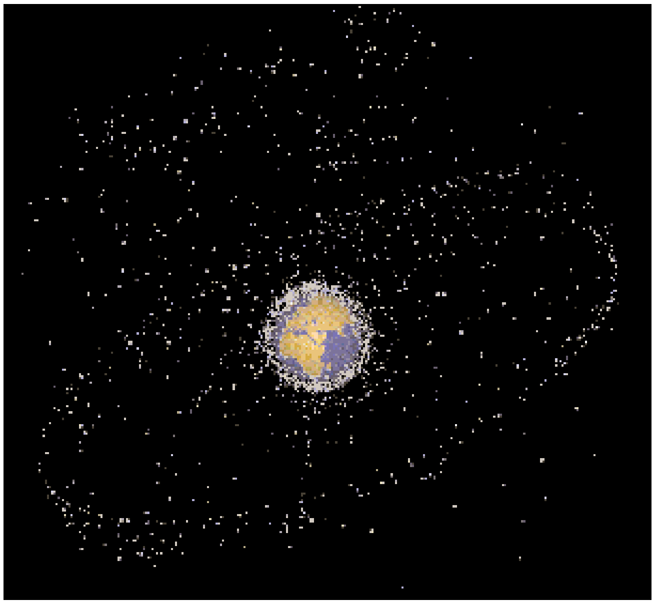
could discuss, but I want to mention only one more before going into a discussion of orbits. This last example is the Hubble Space Telescope. Hubble was launched in 1990, and thanks to over 90 hours of on-orbit service calls by Space Shuttle astronauts, Hubble continues to be a state-of-the-art model.

Hubble orbits at 600 kilometers or 375 miles above Earth, working around the clock to unlock the secrets of the universe. It uses excellent pointing precision, powerful optics, and modern, up to date instruments to provide stunning views of the universe that cannot be duplicated using ground-based telescopes or other satellites.

Hubble travels at 5 miles per second or 18,000 miles per hour. A trip from Los Angeles to New York takes 10 minutes. Hubble completes one full orbit every 97 minutes. In an average orbit, Hubble uses about the same amount of energy as twenty-four 100-watt light bulbs. To locate Hubble click on: **www.hubble.nasa.gov** and go to Hubble Operations and get an instantaneous reading.

Hubble was designed to last 20 years, so it only has a few years left. However, Hubble has given scientists the best pictures ever received about space. Hubble has taken over 300,000 separate observations and has observed more than 25,000 astronomical targets. The latest astronomical findings are discussed in Chapter 5, and in most cases those discoveries can be credited to the Hubble telescope.

So, we have thousands of satellites in space. What is keeping them from bumping into each other? Well, first of all space is a very vast place,



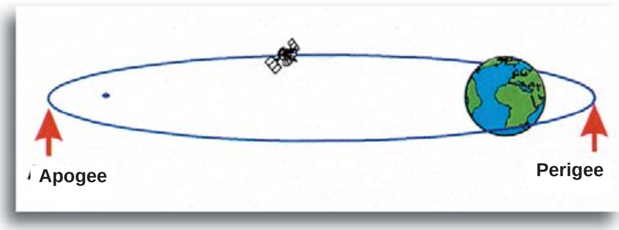
Space debris

and there is plenty of open space where satellites haven't gone yet. And secondly, these thousands of satellites are on different orbits around the Earth. An orbit is defined as a path described by one body in its revolution about another body.

Ancient astronomers determined that the motion of celestial bodies was not random. They studied the motion and measured the movement of planets. In 1611, German astronomer Johannes Kepler discovered several objects moving around Jupiter. From this, Kepler created rules of motion for planets, but all celestial bodies, including artificial satellites obey them.

Kepler's First Law states: The orbit of each planet is an ellipse, with the sun at the focus. In an elliptical orbit, the satellite's altitude, velocity and speed are not constant. Therefore, the shape varies. When orbital variations in speed are small, the orbit shape is nearly circular, but when the speed variations increase, the orbit becomes more elliptical.

During an orbit, the orbiting object reaches a high point and a low point. Its highest point is called the apogee, and its lowest point is called its perigee. The apogee represents the point where the object is the farthest away from the body being orbited. The perigee represents the point where the object is the closest to the body being orbited.



Gravity gives the orbit its shape. An example of a bullet fired from a gun helps to explain this. As the bullet is traveling in a straight line, gravity pulls the bullet toward the center of the earth. The combination of the bullet's speed and gravity create a curved flight path. The curvature of the bullet's path can be changed by adjusting the bullet's speed. Matching the curve of the flight path to the curve of a planet is the basic concept of an orbit.

Orbits have different ranges of altitudes: low, high, and medium. Low earth orbits are below 300 miles. The International Space Station moves in a low earth orbit at about 250 miles above Earth, and the Space Shuttle flies in low earth orbit. A high earth orbit is above 23,000 miles. Geostationary or geosynchronous orbits are high earth orbits. Most communication satellites and some weather satellites are found here. Also some astronomy satellites are found in high earth orbit. Medium orbits are in between the low and high orbits. This category ranges from orbits of a few hundred miles to a few thousand miles. Some communication and telecommunication satellites operate in medium earth orbit. Also, the Hubble Space Telescope moves in a medium orbit at about 375 miles above Earth.

Types of Orbits

Sunsynchronous

This orbit synchronizes the satellite's orbit with the Earth's orbit around the sun. The light from the sun forms an angle with the satellite's orbital plane. In this orbit, this plane turns as the Earth moves around the sun. The turning maintains a constant angle between the light from the sun and the orbit plane creating the same lighting conditions for the satellite to view year around. Sunsynchronous orbits are used by earth observation and weather satellites.

Geosynchronous

In this orbit, the rotation of the satellite is synchronous with the rotation of the Earth. The satellite's period is 23 hours and 56 minutes, the same time as one revolution of the Earth. When the inclination of a geosynchronous orbit is zero degrees, the satellite appears to remain over the same spot on the equator for the entire orbit and is refered to as a geostationary orbit. Remember, both the satellite and the spot on the equator are revolving around the axis of the Earth. From the ground, a satellite in this orbit appears stationary in the sky. The high altitude of this orbit gives a satellite a large field of view, and the stationary appearance makes it easy to find and aim a radio antenna at the satellite. These two features make the geostationary orbit very useful to communication satellites.

Molniya

This is a highly elliptical and highly inclined orbit. Molniya is the Russian word for orbit and the former Soviet Union first used this type of orbit as an alternative to a geosynchronous orbit for communication satellites. The satellite in a highly elliptical orbit moves slowly at apogee and then speeds up near perigee. From the ground, the satellite appears to dwell around the apogee making it easier to locate and track the satellite. The high inclination also gives the satellite a good field of view of the polar regions of the Earth.

Circular - an orbit that maintains a virtually constant altitude above the Earth's surface.

Elliptical - any closed orbit that is not circular. All elliptical orbits around Earth have an apogee and a perigee.

Equatorial - The satellite travels from west to east over the Earth's equator. Some satellite orbits incline to the Equator a certain number of degrees.

Now, let's put some of this information you have learned to more practical use. Let's talk about Satellite Tool Kit and some of the amazing applications it provides.

SATELLITE TOOL KIT (STK)

Satellite Tool Kit, developed by Analytical Graphics, Inc. (AGI), is the leading commercial off-the-shelf software solution for the aerospace industry. As the industry standard, AGI's software supports end-to-end satellite systems from mission planning through operations. Basic applications include tracking satellite locations, determining when they have access to certain areas, and analyzing what satellites can see at any point in time.

STK makes it easy to analyze complex land, sea, air, and space scenarios and determine optimal solutions. It provides the ability to present results in graphical and text formats for easy interpretation and analysis. It is used by tens of thousands of professionals worldwide. STK is used by over 70 major universities, including the U.S. Air Force Academy, NASA, CIA, and all branches of the military, government and commercial operations working in space.

STK provides the analytical engine to calculate data and display multiple 2-D maps that visualize various time-dependent information for satellites and other space-related objects such as launch vehicles, missiles, and aircraft. STK's core capabilities include generation of position and attitude data, acquisition times, and sensor coverage analysis for any of the objects modeled in the STK environment. The integrated STK software provides tools to support all aspects of the aerospace community, ranging from system design and concept to real-time operations.

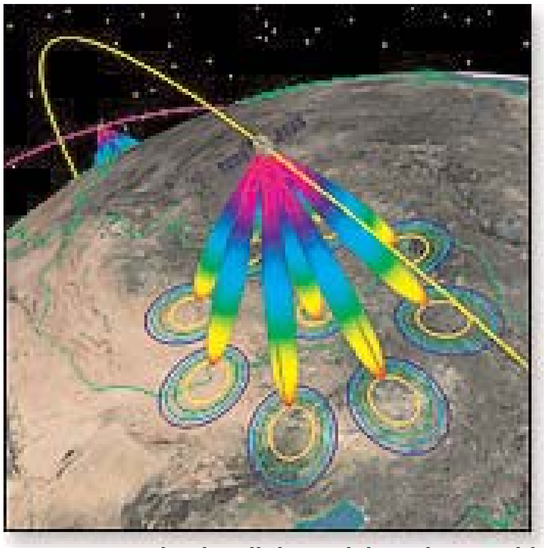
For learning more about STK and AGI go to **www.stk.com** or **www.agi.com.**

To pique your interest a little we have included a couple of exercises to demonstrate some of STK's basic capabilities. We hope you will enjoy the exercises and visit the STK website. In order to perform these STK scenarios and activities, you you will need a STK 5.0 disk. A copy of this disk can be obtained from your CAP wing Director of Aerospace Education (DAE).Your wing DAE has a few copies that are available to borrow. Please use the disk, learn about STK, and then return it to your DAE so others can also benefit from the software program.

STK

Scenario One

An important part of Orbital Mechanics is orbital geometry. Included in this section are four activities describing different concepts in



Laser communication link model analyses wide-band satellite crosslinks in visible near-infrared, and infrared wavelengths.

orbital geometry: semi-major axis, eccentricity, inclination and perigee. STK can help you understand these concepts. We hope you enjoy the following scenarios.

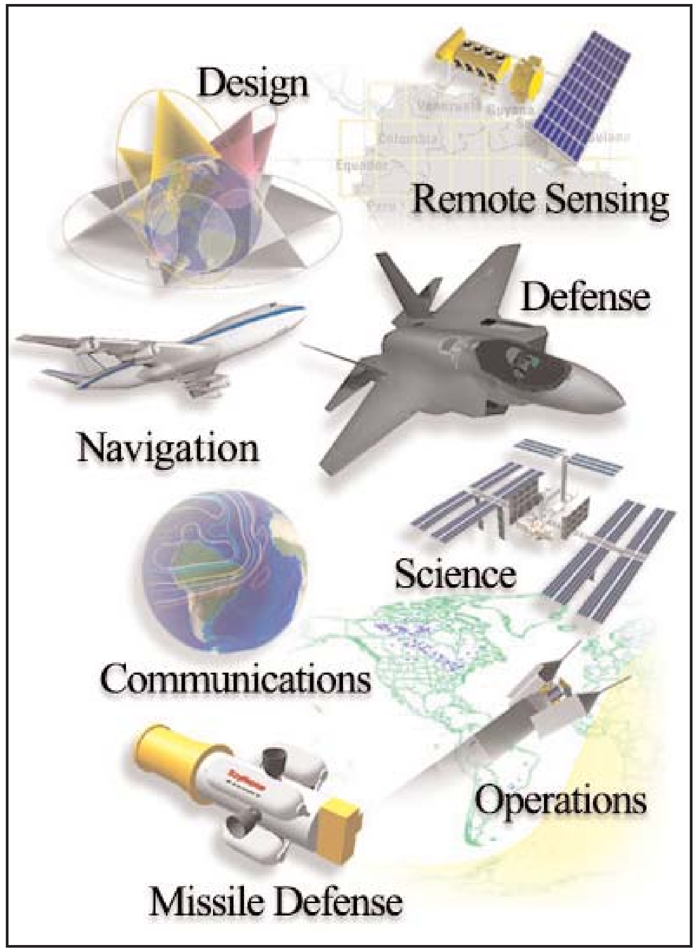
This activity helps you visualize the semi-major axis influences on an orbit. Specifically: **(1)** changes in the semi-major axis change the altitude of an orbit, **(2)** changes in the semi-major axis alter the satellite's field of view, **(3)** changes in the semi-major axis alter the satellite's geographic point location on a flat map.

1. Execute scenario one by following the **STARTING AND USING SATELLITE TOOL KIT** instructions and loading **Scenario\ Lesson3\ axisR\semi- major_axisR.sc**
   - Select the **VO** map and rotate the earth until Korea is centered on the earth.
   - Depicted in **blue** is a **LEO** satellite with a 6700 km semi-major axis.

2. Select **START**
   - Observe the speed of the satellite. The semi-major axis determines the altitude, which in turn determines how long it takes the satellite to complete an orbit.

3. Select **PAUSE**
   - The next few steps will enable you to change the semi-major axis and observe the effects.
4. Select the **Satellite Tool Kit** window.

5. Highlight **LEO.** Be sure the + **(plus)** symbol is



indicated. Thus, this action will enable all linking files to be copied in the next step. If the **- (minus)** symbol is displayed, click once **ON** the minus sign to get the plus sign back.

6. Select **EDIT,** and **COPY**.

7. Highlight **semi-major_axisR.**

8. Select **EDIT** and **PASTE.**

9. A **LEO1** file will appear. Change the name to **MEO.**
   - To change the name
   - Click **ONCE** on the center of the name. **LEO1** will be highlighted in **blue** and cursor will flash.
   - Type in **MEO,** then point to the icon before the name and click once.
10. Select **PROPERTIES** and then **GRAPHICS.**
11. Change the **blue** color to **magenta.**

12. Select **APPLY and OK.**

13. At the **MEO** icon, click on the +. A **Sensor1** icon appears.
14. Highlight **Sensor1**.

15. Select **PROPERTIES** and then **BASIC**.

16. Change the outer half angle parameter to15.0 degrees. This action is required to ensure the satellite's **FOV** (field of view) is an appropriate size for the visual representation.

17. Select **APPLY** and **OK**.

18. Once again, highlight **MEO**.

19. Select **PROPERTIES** and then **BASIC**.
    - Displayed are all the basic orbital elements necessary to define an orbit. Currently the **MEO** orbital elements are a carbon copy of the **LEO** orbital data.

20. Now change the semi-major axis to **20372 km**. This value reflects an appropriate **MEO** altitude.

21. Select **APPLY** and **OK**.

22. Toggle to the **VO** map and select **RESET**.

23. Select **START**.
    - In addition to the **LEO**, the **MEO** is depicted in **magenta**. Compare the relative speeds of each orbit. The **LEO** satellite travels faster than the **MEO** satellite because the **LEO** semi-major axis is smaller. Consequently, the smaller the semi-major axis, the lower the altitude and the shorter orbital period.

24. At time **15:03**, select **PAUSE**.
    - Also note that the semi-major axis (altitude) influences the field of view size (FOV). The **MEO** satellite FOV is comparatively larger than the **LEO** satellite FOV. Again, as described in lesson 1, the greater the altitude or semi-major axis, the larger the satellite's FOV.

25. Select the **2D** map.
    - The **2D** map view is a mercator projection map. Basically it is the globe projected on a flat map. The unique characteristic of a mercator projection is that the distance between latitude lines is equal, making it easy to perform any calculations. Earth view map 1 is used to show the satellite's orbit projected over geographic areas. The semi-major axis affects the ground track in a few ways. First, it shows the speed of a satellite. Note how quickly the **LEO** satellite, depicted in **blue**, moves across its track compared to the **MEO** satellite. Second, it determines the ground track repeating pattern. Note the **LEO** satellite moves slightly west with each pass, giving the appearance of successive ground tracks.

26. Select **PAUSE.**

27. Review the scenario as often as necessary. Repeat steps 4-25 to change the value of the semi-major axis again to different altitudes. Once complete with the scenario, select **PAUSE**.

28. View the scenario as often as needed. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**
    Do not save the file. Saving the file causes problems for the next user.

STK

Scenario Two

Scenario two helps you visualize how eccentricity affects the shape of the orbit. Specifically: (**1**) changes to the eccentricity value from zero to one changes an orbit from circular to eccentric; (**2**) the eccentricity values describes the symmetry of the orbit. To initiate the scenario, complete the following steps:

1. Load **Scenario\Lesson3\eccentricityR \eccentricityR.sc**

2. Select the **VO** map. Now select **RESET**.
3. Orient the globe so the African continent is at the nine o'clock position. Then select **START**.

    - Depicted in **red** is the **MEO1** orbit. The eccentricity value is 0.01, representing a cir cular orbit. Because the orbit is circular, the earth is at the center of the orbit.

4. The next few steps will enable you to change the eccentricity value to a **0.5** value.

5. Select the **Satellite Tool Kit** window.

6. Highlight **MEO_1**.

7. Select **EDIT** and **COPY**.

8. Select **EDIT** and **PASTE**. A **MEO_11** file will appear. Change the name to **MEO_2**. Refer to step9 of Scenario One if you need instructions on how to do this.

9. Select **PROPERTIES** and **GRAPHICS**. Change the color **red** to **magenta**.

10. Select **APPLY** and **OK**.

11. Select **PROPERTIES** and **BASIC**.
    - Displayed are all the basic orbital elements necessary to define an orbit. Currently, the **ME0_2** orbit has the same orbital data as **MEO_1**.

12. Change the eccentricity value to **0.5.**

13. Select **APPLY** and then **OK**.

14. Toggle to the **VO** map.

15. Select **RESET**, then **START**.
    - The **magenta** orbit depicting an eccentricity value of .5 represents an elongated orbit. Compare the two orbits. For the **MEO_2** orbit, the earth is no longer in the center of the orbit, illustrating its elongated orbit.

16. The remaining steps will change the eccentricity value form **.5** to **.65**.

17. Select the **Satellite Tool Kit** window.

18. Select the **MEO_1** icon.

19. Select **EDIT** and **COPY**. A **MEO_11** will appear.

20. Change the **MEO_11** name to **MEO_3**.

21. Select PROPERTIES and then **GRAPHICS**. Change the color **red** to **Dark Sea Green**.

22. Select **APPLY** and then **OK**.

23. Select **PROPERTIES** and then **BASIC**.

24. Change the Eccentricity value from **0.0** to **0.65**.

25. Select **APPLY** and then **OK**.

26. Toggle to the **VO** map and select **RESET**.
    - The Dark Sea Green orbit represents the highly eccentric orbit. Observe how elongated the orbit is compared to the previous orbits.

27. Select the **2D** map and select **RESET**.
    - Eccentricity determines a ground track's symmetry. In turn, it defines how much ground will be covered in a period of time throughout the orbit. For example, if the eccentricity parameter equals zero, a satellite will sweep over equal areas in equal time. In contrast, if the eccentricity parameter is close to one, the satellite will dwell over the apogee point. Thus, the area covered in this portion of the orbit is small. Conversely, the satellite will move through its perigee point rapidly and cover more surface area in an equal amount of time.

28. Select **START**.

29. At time **2 Jan 00:10**, all three satellites will be in view.
    - The earth map shows each satellite's ground track for one complete pass, specifically, pass number three. The **MEO_1** orbit will sweep out an equal area in equal time. However, **MEO_3**, representing the highly eccentric orbit will initially move out quickly until its apogee point, where it dwells for a long time over one geographic spot, approximately 20 degrees longitude.
    - At time **2 Jan 08:05** select **PAUSE**.
    - All satellites have completed one pass and are in the same approximate position to each other. Each orbit completes its pass in

the same amount of time. Only the speed during the orbit varies for the more eccentric orbit.

30. Review the scenario as often as needed. **Close out** according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**

Do not save the file.

STK

Scenario Three

Scenario three helps you visualize how the inclination affects the orientation of the orbit. Specifically: (**1**) changes to the inclination value changes the tilt of an orbit from the equatorial plane; (**2**) from a flat perspective, the extreme northern and southern latitudes a satellite will cover equates to the inclination value. For example, if a satellite's inclination is 28.5 degrees, it will travel no further north than 28.5 degrees north latitude and no further south than 28.5 degrees south latitude.

This scenario will illustrate these concepts by having you make changes to the inclination value. To initiate the activity, complete the following steps.

1. Load **Scenario\Lesson3\inclinationR\inclinationR.sc**
2. Select the **VO** map and maximize the window.
3. Select **RESET.**
4. Orient the globe so that the African continent is a nine o'clock position.
5. Zoom in on the globe until the word **LEO_1** is visible.
   - You are viewing a **LEO** orbit at a zero inclination.
   - Observe its relation to an imaginary equatorial line. The **LEO_1** satellite, having a zero inclination, parallels the equator. It does not tilt away from the equator.
6. The next few steps will enable you to change the inclination value.
7. Select the **Satellite Tool Kit** window.
8. Highlight the **LEO_1** icon. Ensure the **+ sign** appears before you do the next step.
9. Select **EDIT** and then **COPY**.
10. Select **EDIT** and then **PASTE**. **LEO_11** will appear. Change the name to **LEO_35**.
11. Select **PROPERTIES** and **GRAPHICS**. Change the color **red** to **magenta.**
12. Select **APPLY** and **OK**.
13. Select **PROPERTIES** and **BASIC**. This orbit tab represents all the parameters required to define the orbit. Currently, the **LEO_35** parameters are the same as **LEO_1**.
14. Change the inclination value to **35.0** degrees.
15. Select **APPLY**, then **OK**.
16. From the **LEO_1** icon, click on the **+**. **Sensor1** will appear.
17. Highlight **Sensor1**.
18. Select **PROPERTIES** and **GRAPHIC**. Change the color from **red** to **Medium Orchid.**
19. Select **APPLY** and **OK**.
20. Toggle to the **VO** map.
21. Select **RESET**, then **START**.
   - By observation, you can view the 35-degree tilt of the orbit with respect to the imaginary equatorial line or the **LEO_1** orbit. As **LEO_35** travels in its orbit, it is able to view 35 degrees above and below the **LEO_1** orbit.
22. Select **PAUSE**.
23. The next few steps will enable you to compare a highly inclined orbit to the previous two orbits.
24. Select the **Satellite Tool Kit** window.

25. Highlight **LEO_35**. Ensure the **+** symbol is indicated. Thus, this action will enable all linking files to be copied in the next step.

26. Select **EDIT** and **COPY**.

27. Select **EDIT** and **PASTE**. **LEO_351** will appear. Change the name to **LEO_80**.

28. Select **PROPERTIES** and **GRAPHICS**. Change the color from **magenta** to **Dark Sea Green.**

29. Select **APPLY** and **OK**.

30. Select **PROPERTIES** and **BASIC**. The orbit tab is displayed. Presently, the orbital parameters reflect the same values as the **LEO_35**.

31. To define a highly inclined orbit, change the inclination value to 80.0 degrees.

32. Select **APPLY** and **OK**.

33. Highlight **Sensor1** under the **LEO_80** icon.

34. Select **PROPERTIES** and **GRAPHICS**. Change the color from **red** to

35. Select **APPLY** and **OK**.

36. Select the **VO** map and select **RESET**.
    - In view are all three orbits. The **LEO_80** orbit is tilted 80 degrees from the equator. It is nearly perpendicular to the equator and nearly parallels the north and south poles. The advantage to a highly inclined orbit is the satellite will travel over higher latitudes.

37. Select **START**.
    - Observe that the distance north and south of the equator that a satellite can cover is a function of orbital inclination. The greater a satellite's orbital inclination, the greater the satellite's coverage of northerly and southerly latitudes.

38. Select **PAUSE**.

39. Select the **2D** map, then select **RESET**.
    - The map illustrates the concept of how inclination bounds the satellite's ground track to its equivalent inclination value. Simply stated, it shows how much area above and below the equator the satellite views.

40. Select **START**.
    - In this scenario, **LEO_1**, depicted in red has a zero inclination. This, it will remain at the equator, at zero degrees latitude. By comparison, the **LEO_35** satellite, depicted in **magenta**, will travel north to **35** degrees and then to 35 degrees south, equivalent to it's inclination value. Finally, the **LEO_80** illustrates that the ground track will cover latitudes up to 80 degrees north and south.

41. Select **PAUSE**.

42. View the scenario as often as needed. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT**.

Do not save this file.

STK

Scenario Four

Scenario four helps you visualize the influences of argument of perigee on an orbit. Specifically, the lesson addresses the primary influence of perigee point placement. To help visualize this concept, you will make changes to a **HEO** satellite's argument of perigee. To run the scenario, complete the following steps:

1. Load **Scenario\Lesson3\argperigee\ArgperigeeR.sc.**

2. Select the **VO** map and **RESET**.

3. Orient the globe so that the North American continent is centered on your screen.

4. Zoom out until three-fourths of an orbit is in view.

5. Displayed is a **HEO** orbit. The argument of perigee value is 270 degrees, resulting in a perigee point in the southern hemisphere.

- By definition, the argument of perigee is measured from the ascending node to the perigee point in the direction of satellite motion. Now look at your display and imagine a horizontal line around the center of the earth. This line represents the equator. The point at which that line crosses the orbit is the ascending node.

From the ascending node, use a pointer and trace a movement around the orbit **270** degrees in a counter clockwise direction. Your pointer is now at the southern point in the orbit, representing the perigee point.

6. Select **START**.
   - The satellite will travel fastest at its perigee point. Thus the south pole region will have very little coverage.

7. The next few steps will have you change the argument of perigee value.

8. Select the **Satellite Tool Kit** window.

9. Highlight **HEO270**.

10. Be sure the **+** symbol is indicated. This action will allow all linking files to be copied in the next step.

11. Select **EDIT** and **COPY**.

12. Select **EDIT** and **PASTE**. A **HEO2701** will appear. Change the name to **HEO90**.

13. Select **PROPERTIES** and then **GRAPHICS**. Change the color from **red** to **magenta.**

14. Select **APPLY** and **OK**.

15. If the + symbol appears next to HEO90, click on it. Sensor1 appears. If the + symbol isn't there, Sensor1 will already be visible.

16. Highlight **Sensor1.**

17. Select **PROPERTIES** and then **GRAPHICS**.

18. Change the color to **Hot Pink**.

19. Highlight **HEO90**.

20. Select **PROPERTIES** and then **BASIC**. The orbit tab displays all the parameters defining this orbit. However the HEO90 orbit is a duplicate of the **HEO270**. Observe the effects when you change the argument of perigee.

21. Change the Argument of Perigee value to 90 degrees.

22. Select **APPLY** and **OK**.

23. Toggle to the **VO** map.

24. Select **START**.
   - In comparing the two orbits, the perigee points are directly opposite from each other. The magenta orbit represents a satellite with a 90 degree argument of perigee. The majority of its coverage will be in the southern latitudes as it approaches apogee.

25. Select **PAUSE**.

26. Toggle to **2D** map.

- Observe where the perigee points are for each satellite. The perigee point defines the point in the orbit at which the satellite will spend the least amount of time. In selecting a satellite orbit, you should consider how much time a particular point on the earth needs to be viewed. **Note:** a circular orbit does not have a defined argument of perigee. Can you explain why? **Hint**: The apogee and the perigee are equal values.

27. View as often as needed. When complete, select the **PAUSE** button. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**

Do not save this file.

Here are some additional STK activities.

Activity Five

TerraServer Directions

Before you begin you will need:

1. The basic version of STK loaded on your computer
2. An Internet connection
3. The ability to save and open a bitmap

TerraServer is a combined project of the U.S. Geological Survey and the Microsoft Corporation. Almost all of the U.S. has been mapped with aerial photographs and topographical imagery. Someday there will be high-resolution satellite images as well. TerraServer allows even remote areas to be downloaded into STK easily in the form of bitmaps. To download a TerraServer map into STK, simply follow these steps:

1. Get images and coordinates from the TerraServer website
2. Import them to a STK map
3. Repeat for higher resolution and topographical maps

Easy isn't it! Well, let's walk through it in case you need a little more help. First go to ***www.terraserver-usa.com***. Click on **Advanced Find** and then select the **Place Link**. Enter your **home city** to see the aerial photo or topographical map. If your town doesn't come up, don't worry. Just pick another close city. Yours is there, but at this point, all we want is to learn to download the map. Once you have learned how to download maps, you can try different ways of finding them. Now click **Aerial Photo** and choose the last bar (**64 meter resolution**). Select **Larger** in the drop down menu, click **Print** in the upper right corner, change to **11x17 Print Size**, change to **Landscape**, and click **Show Gridlines**. Then select **Download** in the upper right corner and follow the directions given. **Don't close the window**! You will need to look back as you load the map into STK.

In STK, click the **Map Graphics Properties** in the map window. Do this by **highlighting your 2D map and then selecting Map Properties** (found on the toolbar). Select the **Images** Tab and click the **Add** button to select the correct image. Change the **scale** to match the **LLA bounds** in the window. Click **Change** and then **OK** to accept the new scale. You may repeat this process for multiple images. If you have an image of a large area and wish to layer the pictures, you must have the biggest image first on the image list. Although it takes longer, you will get a better picture if you piece together small, high-resolution portions instead of a single large image. This is because the earth is elliptical and big pictures will be distorted on a flat map.

Activity Six

Search and Rescue Directions

The first thing you should understand about Search and Rescue in STK is that it uses a **geodetic system** (a geodetic system is a latitude, longitude, and altitude (LLA) system that represents the elliptical nature of the earth). For this to make sense, you must realize that the earth is not flat or round, it's curved! Geodetic can be confusing and hard to work with in the small areas of most search and rescue missions, but we won't do anything too hard. If you don't remember how to download a map from Terraserver, reference the last section as we go along.

First, download a map in an area of interest or use a map you already have. Once you have loaded it into the program, create an aircraft by selecting the **Aircraft** icon in the drop down menu of **new items** found in the upper left hand corner of the tool bar. A Satellite may be visible on the tool bar, so you need to click on the **small triangle** next to it to see the aircraft. Once added, **right click on the Aircraft** icon in the **Objects Browse**r and click **Properties**. Expand the window so you can see and check the box labeled **"Clicking on map changes current point"**. You may also need to input the first set of latitude and longitude before you can click on the map. Do this by clicking **Insert Point** and typing the coordinates from some part of your downloaded image. Make sure you verify the "**+**" and "**-**"in the numbers or your aircraft will be on the wrong side of the globe.

Zoom into your loaded map by clicking the "**+**" **Magnifying Glass** in the toolbar and **click and drag a box over the area of your map**. This should allow you to zoom in enough to see your map. Continue the process until you have reached the desired level of magnification. Right click on the **Aircraft** and select the **Properties Browser**. Under **Basic**, select **Route** and click **Insert Point** for as many points as you wish to incorporate. Then click somewhere on the map in your **2D Graphics Window.** This should position the Aircraft on the map (if it's not already there). Continue to click for new points until you have created a search grid of your choosing on the map.

Next you will need to add a **Sensor** to your aircraft by **highlighting the Aircraft** in the **Object Browser** and selecting a new **Sensor** from the same dropdown menu as the Aircraft. Now you may create a view area for your Sensor. To do this, simply right click on the **Sensor** and choose Properties Browser. Once there, verify that "**Simple Conic**" is selected as your Sensor type and **15 degrees** as your **view cone**. Close the properties page and right click on the **Sensor** again. Go to **Sensor Tools** and select **Access** to indicate when you find the **Target**. In the **Properties Browser** for the **Sensor**, scroll down to **Constraints**, select **Basic**, and limit the range to 2 kilometers. Allow the **Pointing** (found at the top of the list under Basic) to be **targeted** instead of **fixed.**

Make a Target somewhere on your map. To do this, simply **create it** as you have the Aircraft and Sensor. You will need to input its location in its **Properties Browser**. It can be hidden or unhidden at this point. Now have your search aircraft fly a grid over the area and look for the **Target** to be visible to the **Aircraft**. Next **rewind the scenario** back to the beginning and add a **Ground Vehicle** the same way you did the Aircraft. Add a **Sensor** with a 1- kilometer range to the **Ground Vehicle**. Have it drive down roads on the map (you can click on the map like you did for the aircraft to pick a new point). After you have finished a search with one Aircraft and Ground Vehicle, add multiple air and ground units. Try to have as little overlap as possible as you search while not missing a part of the search area. Remember to experiment with the program. Try different things to learn what it can do. This may be the free version, but anything you learn here can easily transfer to the full CAP version.

Activity Seven

Before you begin: STK Free Version should be installed on your computer. Close other programs on your computer to help it run faster.

Consider looking at the orbit descriptions in *Module 6 of Aerospace Dimensions* and Chapter 23 of *Aerospace: The Journey of Flight*.

In this section, we will learn how to create a satellite in STK and have that satellite orbit in each of the eight options given. Open the program and select a new scenario by clicking on the New Scenario button found in the upper left hand corner of the tool bar (it looks like a mountain with the sun rising over it). Select a new satellite by clicking on the Satellite symbol found in the dropdown window. The Satellite should be the picture already shown on the toolbar. This will open the **Orbit Wizard**, which will give you several options including what type of orbit you would like to create. Start by selecting Molniya (Note that a description of the satellite orbit selected is given). Continue clicking **Next** until you are out of the Orbit Wizard. Although you may change the numbers you are passing through, wait until you have seen what each orbit should look like before you change its characteristics.

You should see a ground trace area on your **2D Graphics Window**. Press the Play button (it works like a normal VCR) to set the animation in motion. Any other options will be provided just as they would on a normal VCR. After you have examined the ground trace of the orbit in your 2D window, remove the satellite by right-clicking on the **Satellite** icon in the **Object Browser** and pressing **Delete.** Repeat this process for each of the eight orbital patterns until you have an idea of what each one does and looks like. After you have created each of the satellites once, feel free to go back and experiment with the numbers that were preset in the Orbital Wizard and to create more than one satellite at a time.

3

International Space Station

LEARNING OUTCOMES

After completing this chapter, you should be able to:

- Explain some of the research to be conducted on the ISS.
- Describe the living conditions on ISS.
- Name the nations involved with ISS.
- State the purpose of ISS.
- Describe the current status of ISS.
- Know the estimated timetable for completion.
- Identify some uses for the ISS.
- Locate when the ISS is travel ing over your house.

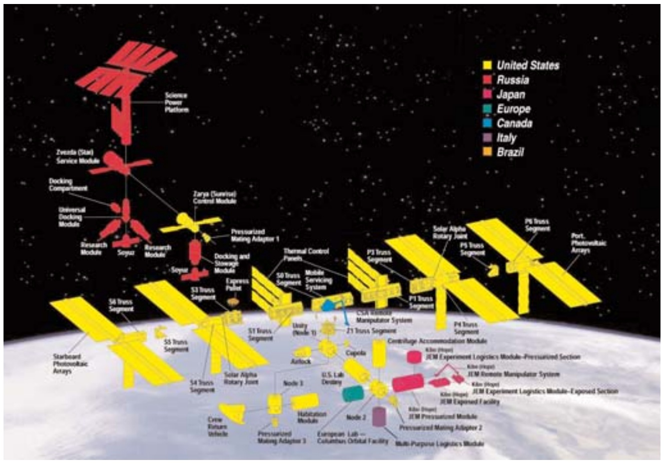
Background

In November 1998, a Russian rocket placed the Zarya module in orbit. This was the first flight toward the assembly of the ISS. In December of the same year, the United States launched the Space Shuttle Endeavor, which attached the Unity Module to Zarya, thus initiating the first ISS assembly sequence. Since then, twenty flights have traveled to the ISS. America's space shuttle and two Russian rockets will continue to deliver the various components to the space station. It will take approximately 45 space flights, and several years to complete the assembly. The latest estimate projects a completion date of 2006.

Sixteen nations formed a global partnership to build the ISS. The United States and Russia have taken the lead, but the completion of the ISS will draw upon the scientific and technological resources of all sixteen countries. The other fourteen countries are: Belgium, Brazil, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. This cooperative agreement represents one of the largest non-military joint efforts in history.

Facts

This project is an engineering and scientific wonder ushering in a new era of human space exploration. More than 100 ISS elements will be assembled during the 45 missions with a mass of almost one million pounds (almost 500 tons). The ISS will measure 356 feet across and 290 feet long, and that doesn't count almost an acre (over 43,000 square feet) of solar panels. It will take approximately 160 space walks to assist in assembling the ISS. Plus, the astronauts will use a 58-foot robotic arm for moving large elements of the



assembly. A smaller robot arm, about 12 feet long, will also be used for more precise work and replacing smaller parts.

Fully assembled, the ISS will house a crew of up to seven. Depending on the size of the crew, the station will have one or two sleeping modules and six or seven laboratories for research. The space station will have four windows for conducting Earth observations, experiments, and other applications. There are also 11 external payload locations for mounting experiments.

The ISS is orbiting at about 250 miles above Earth at a speed of 17,500 mph. The ISS completes one orbit every 90 minutes; that's sixteen times a day. The altitude allows for launch vehicles from all of the international partners to provide to delivery of crews and supplies, and also provides for excellent Earth observations. The space station can view 85 percent of the globe and 95 percent of the population of Earth. In the activity portion of this chapter, you can use **J-TRACK** to locate the ISS and even discover when it travels over your house. Additionally, in the Satellite chapter of this book, you can use Satellite Tool Kit (STK) technology to locate the ISS. Be sure to visit chapter 2 to see the amazing things you can do with STK.

First ISS Crew: Cosmonaut Sergei Krikalev, Astronaut Bill Shepherd, and Cosmonaut Yuri Gidzenko.

Expedition 1 took the first crew to live onboard the space station in October 2000. That crew spent more than 138 days at the station. Since then, there have been several expeditions to the space station. As of this writing, the last mission-completed aboard the ISS was Expedition 8.

Expedition 8 conducted the first ever two-man spacewalk without a crewmwmber inside. The spacewalkhad been scheduled for five and a half hours, but there was a malfunction with the Russian astronaut's space suit, so they returned inside after three hours. Before the spacewalk was over, the astronauts were able to install a device that will provide data on radiation exposure to the human body during space flight.

Russia's greenhouse experiment investigates plant development and genetics.

Expedition 9 is conducting many science experiments and plans on two spacewalks that will perform modifications on the ISS exterior. Expedition 9 is scheduled to stay at the International Space Station for six months.

Life on the space station takes time to adjust to, but the ISS is designed to keep the astronauts comfortable. The modules are bright, roomy and are kept at 70° Fahrenheit at all times. In a typical workday, crewmembers spend 14 hours working and exercising, 1½ hours preparing and eating meals, and 8 ½ hours sleeping.

Space food has gotten much better over the years. The astronauts now have microwave ovens and refrigerators. Now they can eat more fruits

Crewmembers Malenchenko and Lu share a meal in the Zvezda Service Module.

and vegetables, and their diets are designed to supply each astronaut with 100 percent of the daily value of vitamins and minerals necessary for the environment of space.

Each crewmember has a private sleeping room. Because of no gravity, their beds are bolted down so they won't float away. Astronauts claim it is a great way to sleep. While in the space station, the astronauts can wear regular clothing and exer-

Crewmembers of the ISS must exercise daily.

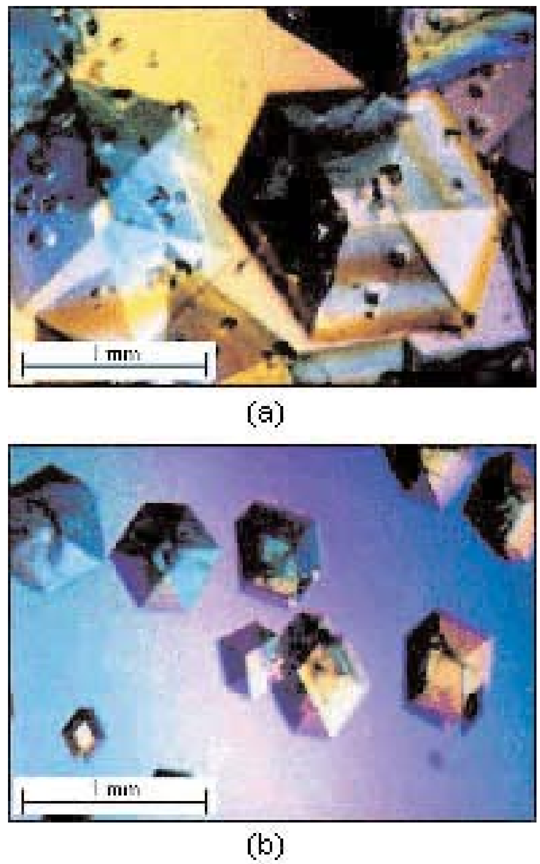
cise daily to keep their muscles and bones from getting too weak.

Potential Benefits

The international partners believe that the benefits from ISS research far outweigh the enormous costs of building the space station. For instance, ISS allows humans to live and study for long periods in microgravity, or a weightless environment. Since gravity influences almost every biological, physical, and chemical process on Earth, the space station gives us the unique opportunity to study a world without gravity. This will help us better understand gravity's effects on plants, animals, and humans.

Without gravity, chemical reactions behave differently than they do on Earth. This means that molecules can be blended and substances created that would be impossible on Earth. These experiments may lead to possible treatments for diabetes, AIDS, cancer, and organ transplants. Watching the long-term effects of gravity in space will teach us about biological processes on Earth, such as aging and osteoporosis.

More pure protein crystals may be grown in



Crystals of insulin grown in microgravity, figure (a) were extremely well ordered and unusually large (many >2 mm) compared to those grown under identical conditions on the ground, figure (b).

space than on Earth. Analysis of these crystals helps scientists better understand the nature of proteins, enzymes and viruses, perhaps leading to the development of new drugs and a better understanding of the fundamental building blocks of life. This type of research could lead to the study of possible treatments for cancer, diabetes, emphysema, and immune system disorders, among other research. According to Astronaut Dan Bursch, "The National Institute of Health has said that protein crystal growth is the number one research tool that we'll be using in the next century….".

Living cells can be grown in a laboratory environment in space where they are not distorted by gravity. Growing cultures for long periods aboard the station will further advance this research. Such cultures can be used to test new treatments for cancer without risking harm to patients, among other uses.

Fluids, flames and molten metal and other materials will be the subject of basic research on the station. Flames burn differently without gravity. Reduced gravity reduces convection currents, and the absence of convection alters the shape of the flame in orbit. This allows for studying the combustion process in a way that is impossible on Earth. The absence of convection allows molten metals or other materials to be mixed more thoroughly in orbit than on Earth. Scientists plan to study this to create better metal alloys and more perfect materials for applications such as computer chips.

Observations of the Earth from orbit help study large-scale, long-term changes in the environment. These studies can increase our understanding of forests, oceans and mountains. These studies can also perceive atmospheric trends, climate changes and even view the effects of hurricanes, typhoons, and volcanoes. Also, air pollution, water pollution, deforestation, and how we use our land, mineral, and food resources can be seen and analyzed from space and can be captured in images that provide a global perspective unavailable from the ground.

In the field of biology, the scientists of the ISS will assist in answering some basic scientific questions in a different environment. For example, what is the role of gravity in the processes of biological evolution? Also, how does chronic exposure to altered gravity and other space related factors affect normal physiology, metabolism and function of mature organisms? These are just two of many theories in biological research.

Tropical Storm Claudette was seen from the ISS as it turned into a hurricane that hit Houston and other areas in Texas July 15, 2003.

Many of the new engineering technologies being developed on the ISS will lead to improved commercial space communication systems for personal phone, computer, and video use. They will also lead to improvements in energy efficiencies, air and water capabilities and new lower-cost building construction techniques. Advancements in space technology will significantly enhance the quality of life on Earth.

Expedition Five flight engineer Peggy Whitson is shown with the Microgravity Science Glovebox following its installation in the Destiny

A very recent development is the Microgravity Science Glovebox, which Expedition 7 brought to the ISS. The glovebox is a sealed container that allows astronauts to perform hands-on experiments in a sealed environment. It works very well with certain fluids and materials that otherwise might be hazardous.

Research on the commercialization of space will also occur. Industries will participate in research by conducting experiments aimed at creating new products and services. The results may benefit us by providing innovative new products and creating new jobs to make the products.

Additionally, the space station is thought of as a stepping-stone to the stars. The ISS gives astronauts a much better opportunity to explore our solar system, as well as other distant galaxies. If humans are ever going to travel to other planets, such as Mars, we must understand the effects of such long journeys on the human body. We already know that living in microgravity leads to the weakening of bones and muscles. The space station will allow scientists to understand these effects and study solutions for long-term space travel.

NASA continues to conduct space research to improve life on Earth. The benefits of space continue to provide advancements in science and technology. More than 150 companies are partners with NASA in 15 research centers in developing meaningful, beneficial research.

Activity Section

Activity One

ENGLISH LANGUAGE ARTS (CAREERS) AND SCIENCE

Objective:
Explore certain careers associated with the International Space Station.

Materials:
Computer with Internet access, task cards, pencil/pen.

Estimated Time: 60 minutes

Background

There is a wide scope of opportunities in the field of aerospace. Many of these professions try to provide technologies that will add value to improve people's quality of life by strengthening the nation's economy, improving the environment, increasing our mobility and safety, and ensuring the continued national security. Many organizations work together to accomplish these goals including NASA, the Federal Aviation Administration, U.S. industry, the Department of Defense, and the university community.

The crews of the International Space Station (ISS) and the Space Shuttle have inspired many people to pursue careers as astronauts. However, the astronauts will tell you that their jobs would be impossible without the support people that work hard to make astronauts' jobs easier.

Many thousands of support staff provide skill and dedication to successful missions. Many are classified as aerospace technology workers, and their work falls into roles that include physical, life, and social scientists, pilots, mathematicians, engineers, technicians, designers, and quality control inspectors. Many of these careers require a college degree with an emphasis on mathematics and science, but there are plenty of positions available to anyone with general knowledge and a desire to achieve.

Procedure/Activity:
1. Divide students/cadets into groups of three people - "engineers", "astronauts", and "scientists" - and provide each with a description of the job and some questions that relate to that job.
2. Students should research and answer questions; then share the answers with the rest of the group.

Rationale:
This lesson will provide a better understanding of some aerospace career fields.

Assessment:
Use a rubric to evaluate research skills and career knowledge.

Additional Information:
- ESL students should research someone involved in the aerospace industry from their part of the world.
- Have special needs students work with a group that will be supportive and assist with the information. These students can also research one question about one career or do a web graphic organizer.

Helpful web sites:
- **http://www.jsc.nasa.gov/news/factsheets/food.pdf** (food in space)
- **http://ltp.arc.nasa.gov/space/team/leljackson.html** (reliability engineer for ISS bio)
- **http://jsc-web-pub.jsc.nasa.gov/fpd/food.asp** (space food systems laboratory)

- **http://nasajobs.nasa.gov/astronauts/** (astronaut selection information)
- **www.spaceflight.nasa.gov/outreach/jobsinfo/astronaut.html** (how to become an astronaut)
- **http://www.scipoc.msfc.nasa.gov/** (ISS science operation news)
- **http://www.nasaexplores.com/lessons/01-044/9-12_article.pdf** (article containing the physical aspects of microgravity)
- **http://quest.arc.nasa.gov/projects/astrobiology/astroventure/teachers/fact_sheets.html#generic** (generic career fact sheets)







Student Information

Task Cards for Careers

Engineer Task Card

Your responsibility is to investigate the design and construction of ISS components that will support astronauts living and working in space. Think about what materials you will need, and work with scientists and astronauts to determine priorities of power, life support and other requirements. Report on what international partners are currently doing to prepare for ISS.

- What does it take to become an engineer for the ISS?
- How are ISS engineers currently training for the missions?
- What role might you play in how meals are determined for Space Station?

Internet Resource
Space Station Home Page
http://spaceflight.nasa.gov/station

Scientist Task Card

Your responsibility is to investigate the types of research proposed for the Space Station. Report on how microgravity will benefit this research, and how this research will benefit life on earth. Work with engineers and astronauts to investigate how research will be conducted differently on ISS, considering weight, size, and power restrictions, as well as, the human interaction required.

- What does it take to become a scientist for the ISS?
- How are ISS scientists currently planning for the missions?
- What role might you play in how meals are determined for Space Station?
- What effects does microgravity have on the body?

Internet Resource:
Space Station Science
http://spaceflight.nasa.gov/station/science/index.html

Scientist Task Card

Your responsibility is to investigate the types of research proposed for the Space Station. Report on how microgravity will benefit this research, and how this research will benefit life on earth. Work with engineers and astronauts to investigate how research will be conducted differently on ISS, considering weight, size, and power restrictions, as well as, the human interaction required.

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- How are ISS scientists currently planning for the missions?
- What role might you play in how meals are determined for Space Station?
- What effects does microgravity have on the body?

Internet Resource:
Space Station Science
http://spaceflight.nasa.gov/station/science/index.html

Activity Two

SOCIAL STUDIES

Objective:
Practice reading longitude and latitude as well as exploring sighting days and times for the ISS at specific locations.

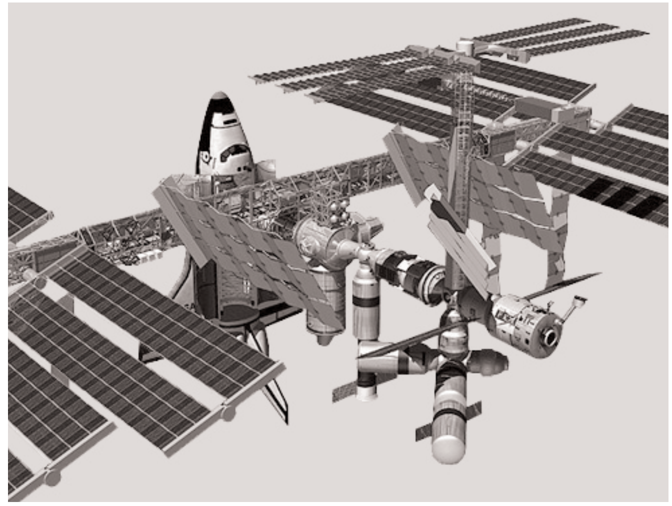
Materials:
Computer with Internet access, world map or atlas, pencil, and chart to fill in.

Estimated Time:
60 minutes

Background

If you look in the sky at the right time and right place, you can see the International Space Station. Except for the Moon, it's the brightest object in the nighttime sky. The Space Station is in orbit at about 250 miles above the Earth's surface, and moves at about 17,000 miles an hour. Moving at that speed results in the ISS making about 16 complete trips around the Earth each day. The Space Station remains visible in any given section of the sky for 10 minutes or less. If it's not moving it's not the ISS. It moves at approximately the same rate as an airplane, but an airplane blinks. And a plane follows a linear path. The Space Station follows an arc. If you live in the 60 to -60 degree latitudes, you've got the best circumstances to view the ISS and that's just about everyone in America. For sighting information, go to: **http://spaceflight.nasa.gov/realdata/sightings/index.html.**

Procedure/Activity:

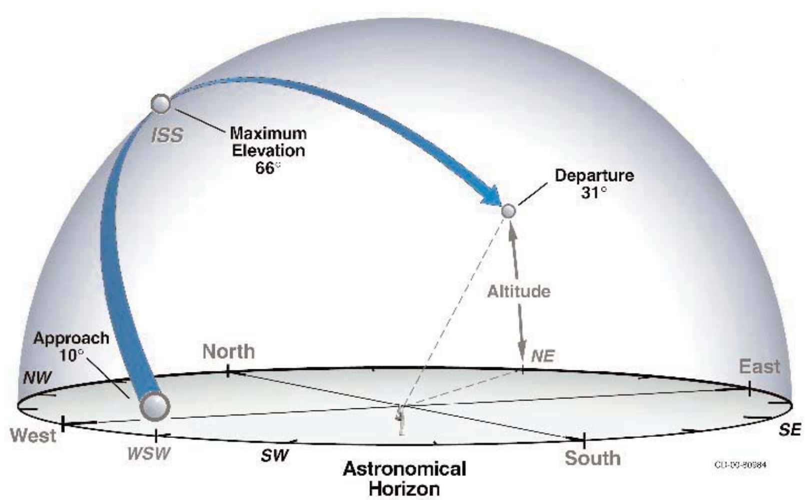


1. Review latitude and longitude and how to use an atlas.
2. Give students the chart to locate places and fill in the name of the city for each longitude and latitude.
3. Next, have students go to the j-track web site: **http://spaceflight.nasa.gov/realdata/sightings/index.html** and find the day and time the Space Station can be seen at this location (have them choose three days - the same three days - for all locations.)
4. **Extension:** Students can create a graph showing the times and days for each location (locations can be color coded).

Rationale:
This lesson will strengthen latitude and longitude skill as well as create interest in locating the ISS in the sky.

Assessment:
Students will be evaluated according to accuracy in identifying and labeling the cities from the chart.

Additional Information:
- ESL students can locate places with the help of the ESL teacher or another student.
- Special Education students can locate fewer places (half of the chart).
- Website:**http://liftoff.msfc.nasa.gov/realtime/jtrack/spacecraft.html** (Skywatch - see satellite paths over the Earth).
- Website concerning longitude and latitude - **http://www.infoplease.com/homework/latlongfaq.html**
- Website for maps:**http://www.eduplace.com/ss/maps/index.html**



Student/Cadet Information

Materials:
Computer with Internet access, world map or atlas, pencil, and chart to fill in.

Directions:
1. Review latitude and longitude and how to use an atlas with your teacher.
2. Get the chart to locate places and fill in the name of the city for each longitude and latitude. Place a mark on the map for each location.
3. Go to the j-track web site: http://spaceflight.nasa.gov/realdata/sightings/index.html and find the day and time the Space Station can be seen at each location (choose three days - the same three days - for all locations.)
4. Extension: Create a graph showing the times and days for each location (locations can be color coded).

Name: ____ Date:______________

Web site: http://spaceflight.nasa.gov/realdata/sightings/index.html

Latitude	Longitude	Location	**Date(s)**	Corresponding Time(s)
57:12:00 N	**2:12:00 W**			
33:45:46 N	**84:25:21 W**			
39:55:00 N	**116:23:00 E**			
33:31:40 N	**86:47:57 W**			
42:20:10 N	**71:01:04 W**			
42:53:23 N	**78:51:35 W**			
53:30:00 N	**113:30:00 W**			
53:34:00 N	**10:02:00 E**			
58:23:19 N	**134:08:00 W**			
38:42:00 N	**9:05:00 W**			
36:36:05 N	**121:52:54 W**			
40:46:38 N	**111:55:48 W**			
30:18:21 N	**97:45:02 W**			
18:58:00 N	**72:50:00 E**			
34:20:00 S	**58:30:00 W**			
30:00:00 N	**31:17:00 E**			
21:02:00 N	**105:51:00 E**			
41:02:00 N	**29:00:00 E**			
37:52:00 S	**145:08:00 E**			
48:13:00 N	**16:22:00 E**			

On a world map, place an X on the cities in this chart.

Activity Three

A SIGN OF THE TIMES

Procedure:

Develop a time line from the list of important events below. Review your CAP aerospace education products to remind yourself of many of these events. Use the internet or other textbooks to learn more about the events that are not included in your CAP books.

Develop your time line. Of course, it is your time line, so if you want to add or subtract events you certainly can. For easy reference, consider hanging the time line on a wall, a shelf or place it on a table.

Important Events:

- 1870 American writer Edward Everett Hale published a science fiction tale called "The Brick Moon" in the Atlantic Monthly.
- 1903 Konstantin Tsiolkovsky wrote *Beyond the Planet Earth.*
- 1923 Hermann Oberth coined the term "Space Station."
- 1927 Robert Goddard launched the first liquid-fueled rocket.
- 1928 Herman Noordung published the first Space Station blueprint.
- 1942 German V-2 rocket developed and used.
- 1945 Wernher von Braun came to the US to build rockets for the US Army.
- 1952 In Collier's magazine articles, Wernher von Braun described a wheel-shaped Space Station reached by reusable winged spacecraft.
- 1955 Work began on the Baikonur launch site in central Asia.
- 1956 The world's first intercontinental ballistic missile lifted off from Baikonur.
- 1957 *Sputnik* 1 launched from Baikonur.
- 1961 Yuri Gagarin launched in the *Vostok* 1 capsule, becoming the first human in space.
- 1969 Neil Armstrong and Buzz Aldrin became the first humans to walk on the moon.
- 1971 The first Space Station in history, the Russian *Salyut* 1, reached orbit atop a Proton rocket.
- 1973 The US launched the *Skylab* Space Station atop a *Saturn* V rocket.
- 1974-1977 *Salyut* 3, 4 are launched (also known as *Almaz* Station).
- 1977 *Salyut* 6 launched.
- 1982 *Salyut* 7 launched.
- 1984 President Ronald Reagan called for a Space Station that includes participation by US allies.
- 1985 Japan, Canada and the European Space Agency each signed a bilateral memorandum of understanding with the US for participation in the Space Station project.
- 1986 Space Station *Mir* initial element launched.
- 1988 Formal agreements were signed between the US and its Space Station partners.
- 1992 Russia joined the US and its partners in the International Space Station Program.
- 1995 The Shuttle-*Mir* Program, the first phase of the ISS, began.
- 1998 The first two elements of the ISS, *Zarya* and *Unity*, launched from Russia and the US.

Activity Four

WHERE IS THE ISS?

Go to **www.liftoff.msfc.nasa.gov** for J-Track. This site will track the ISS.

Activity Five
BUILDING THE ISS

OBJECTIVE

To introduce students/cadets to the International Space Station as a topic of study. The secondary objective is to build a model of the ISS that will hang in a classroom, or meeting site, in the form of a mobile.

BACKGROUND

The first module of the International Space Station, known as Zarya, was placed in orbit on the 20th of November, 1998, by a Russian Proton Launch system. On December 3, of that year, a second module, known as Unity, was put into orbit by our Space Shuttle and the two units were joined together.

This was the culmination of a long, turbulent process of funding problems and international cooperation. Actual planning began in the Eighties; however dominance of the program by the U.S. didn't set well with many of the countries scheduled to be involved in the project. Over a period of several years, projected costs forced many of the potential partner nations to withdraw support and funding. A continuous down sizing and arguments over its mission almost brought about cancellation of the project.

In 1993, President Clinton gave NASA the task of reorganizing and restructuring the ISS program. Using expertise and existing space hardware, the US and Russia were able to cut projected costs by nearly 40%. The U.S. was able to negotiate an agreement with Russia as a result of this new partnership-the former Soviet Union agreed to stop the sale of ballistic missile components to other countries and to maintain strict control over the export of strategic weapons technology. Another benefit was the expertise and technology gained by the Russians from their experience in long term manned flight aboard the MIR space station. If all goes according to plan, a fully operational Space Station will be ready by the year 2004.

MATERIALS

Build this in stages; however, it is recommended that you get all of the supplies together ahead of time. These include:

a. At least a dozen long bamboo skewer sticks. These can be purchased at grocery stores.
b. One or two large soda straws are required.
c. 6-8 foam meat trays, preferably the ones that have one side "waffled." Usually, meat markets have these available. If you will shop around, waffled trays can be found in blue and that makes the ***PV array panels*** more realistic!
d. A length of pipe foam insulation, similar to the kind used in the Goddard Rocket, will be needed to make the modules. Toilet paper or kitchen paper towel cylinders can be used for modules.
e. The tubular modules can be capped with black or gray 35mm film canister caps.
f. A roll of high-strength packaging tape will be used to hold the "station" parts together.
g. A length of nylon fish line can be used to hang the ISS from a ceiling in a classroom or CAP squadron.
h. Hot glue guns can be used to bond tubes and end caps.
i. Epoxy glue works very well to bond areas that tend to get broken easily.

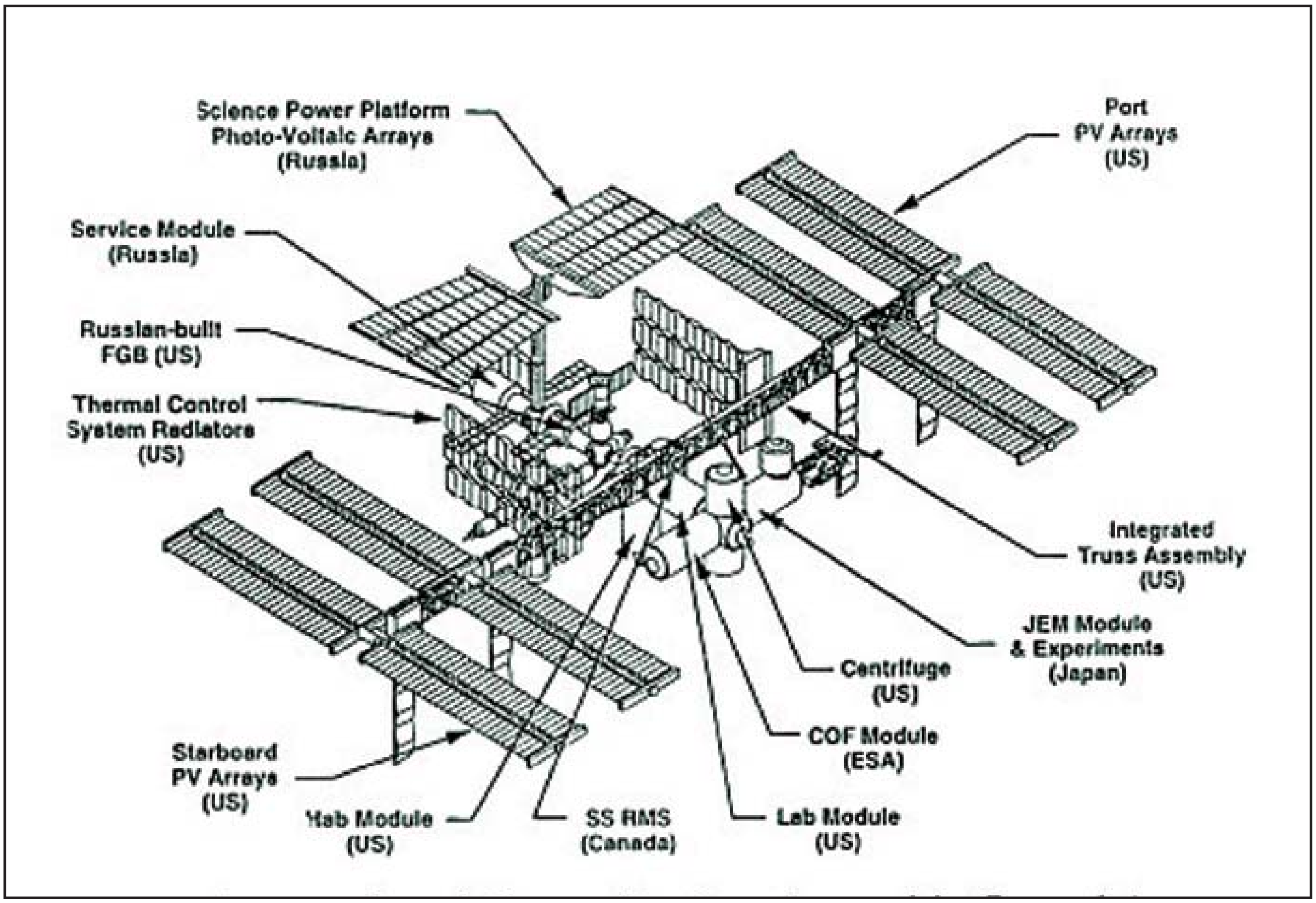
PROCEDURE

You are urged to follow this sequence of construction:

1. The bamboo skewer sticks are "stacked" together for the ***integratedtruss assem-***

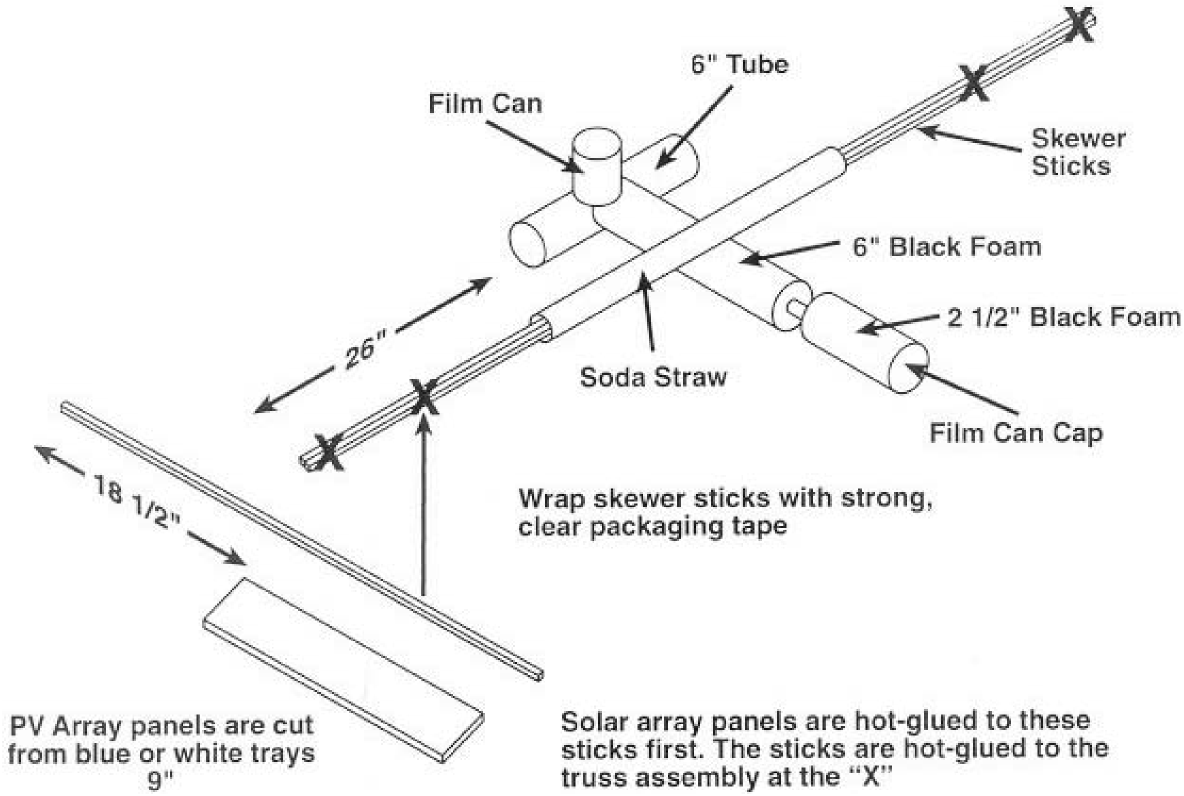
bly component shown in the "International Space Station Assembly Complete" illustration.

2. These skewer sticks (4-6) are first taped together in the center to hold them in a bundle. This is done by wrapping them with a long, single piece of packaging tape.
3. If your bundle isn't too bulky, you should be able to push a large soda straw over the bundle covering the tape. Check the illustration and you will see how it is supposed to look at this stage.
4. Using a hot glue gun, bond four skewer sticks at the positions shown on the illustration. These will be the frames for attaching the *PV Array Panels.*
5. Cut out at least 8 *PV Array Panels* from your supply of foam meat trays. These are 9 inches long and about 2 inches wide.
6. The *PV Array Panels* are bonded to the bamboo skewer sticks as shown in the illustration.
7. Lengths of pipe foam tubing are used to make the main modules. Use the illustration as a guide.
8. Film canister lids are used to "cap" the open foam tube "modules."
9. Using the ISS Assembly Complete illustration as a guide, students can make more modules and arrays to improve accuracy.
10. Once complete, nylon fish line can be used to hang this replica in a classroom.



International Space Station Illustration

This is the most current layout of the International Space Station. It should be noted that ISS assembly launches are on hold awaiting the Space Shuttle's return to flight following the Columbia's tragic loss.



This is a guide to the basic construction of the ISS. It is recommended that teachers and AEOs build the Station in stages so that students can study each module as an individual lesson. Cylinders made of cardstock or those found in paper products work quite well. Foam tubing was used because it is very light and weight is a factor in how the ISS "mobile" will look when completed. (Illustration by Seth Stewart.)

Discussion

1. By using library, or Internet sources, students can study each component as it is built into the ISS.
2. This project can be expanded using clear plastic soda pop bottles. The smaller Coke® or Pepsi ® bottles can be used instead of the foam pipe insulation material. Bamboo is very strong and will support quite a bit of weight. To keep the main Integrated Truss Assembly from bending with the additional weight, it recommended that more sticks be used.
3. Each of the larger bottles can be filled with tiny "Astronauts" and equipment so that students can see how each module is being used. The complexity depends upon the age level of students involved in the project.
4. Teachers and AEOs are urged to use the "Gallery" section of Boeing's web site to see some very dramatic images of the Space Station. This site has a tremendous amount of information about the ISS.

Activity Six

"PUFFY HEAD, BIRD LEGS"

Human Physiology In Space

OBJECTIVE

This activity will make you aware of the changes that the human body experiences in space flight.

CREDIT- Human Physiology in Space (pp 63-66) by R. J. White & B.F. Lujan, NASA Life and Biomedical Science and Applications Division, 1994. Online at: **http://www.nsbri.org/HumanPhysSpace/**

Ms. Lauren Allwein, aerospace teacher at the Nationally-acclaimed Euclid Middle School, Littleton, Colorado, attended an extensive summer course put on by the Baylor University College of Medicine. This course is known as "From Outerspace To Innerspace" and has the theme, "What can we learn in space about bodies here on Earth?" This outstanding program is highly recommended by the Civil Air Patrol's Aerospace Education Division. For more information about the National Space Biomedical Research Institute K-8 education Programs, please contact the Center for Education Outreach Baylor College of Medicine, Houston, Texas. 800-798-8244 or visit the NSBRI Web site at **www.nsbri.org.**

BACKGROUND

All astronauts and cosmonauts experience a phenomenon known as the "Puffy-Head, Bird Legs" When in a condition of microgravity, astronauts report a feeling of "stuffiness" especially in the sinuses, and a "fullness " in the head. There is also a puffiness of the face and this can be easily measured. Where aerospace medical specialists measure various parts of the body, such as face and legs, it clearly shows that changes occur in the shape of the legs. Astronauts call this condition "bird legs."

Measurements taken of the leg circumference during space flight on astronauts with larger legs show a proportionally larger decrease in leg volume than those with smaller legs. This is explained by the fact that the more muscle a person has in the his/her limbs, the more fluid and blood flow is required to nourish those muscles. The more fluid and blood there is, the more there is to lose. It has shown that a fluid shift actually begins during the launch sequence. This is due to the astronaut having been seated in the space shuttle in a reclining position with his/her legs elevated, sometimes for several hours prior to launch.

PROCEDURE

In this activity, the students will break out into teams of three. Two will be the aeromedical scientists and the other will be the astronaut. A piece of tape (like masking) and a soft tape measure (found at fabric stores) will be used to make the measurements. Data will be collected from measurements of the astronaut standing and reclining. It might be pointed out that during the early portions of the head-down orientation, a student's stroke volume increases from about 75 ml/beat to about 90 ml./beat. This is entirely expected because there is a rush of fluids to the upper part of the body and the heart then has more blood to force out during each beat. In addition, to compensate for this increase in stroke volume (to keep cardiac output relatively stable), the subject's heart rate decreases. Therefore, during the portion of this student investigation where you are determining cardiac output, don't be surprised when you obtain lower values for the subject's heart rate. This is normal.

Students are given a full briefing before beginning the activity. If they know the importance of the data gathered, they will tend to take it more seriously.

1. Student Joe Winne volunteered to become the astronaut. Teacher Lauren Allwein places a piece of masking tape on his forehead, and this will become the point where measurements are taken. This tape is left in position throughout the experiment.

2. A similar piece of tape is placed on the subject's calf muscle. This will be the point where another source of data is gathered.

3. Chelsea Frommer and Rachel Winne carefully measure Joe's forehead in a standing position. It is important to get accurate circumference measurements from the test subject's leg and forehead in millimeters. Have the person(s) doing the measuring be accurate and record the data on a data table. Be neat and make sure that numbers are accurate.

4. The next step is to get an accurate standing pulse rate. The scientists at the Baylor College of Medicine say, "…To get the test subject's STAND ING pulse, have the test subject stand up for 3 minutes, then sit down and the 'pulse taker' should take the test subject's pulse for 15 seconds. Multiply this pulse rate times 4 to get the standing pulse rate. Record this pulse on the data table in the 'standing pulse rate' box."

5. The astronaut is allowed to lie down with his feet propped up on a chair. A timer should begin timing for 5 minutes. Record the starting time. After 5 minutes have passed, while the test subject is still lying down, remeasure the calf and forehead in millimeters on the tape in exactly the same spot. Be accurate. Record this measurement in the "after 5 minutes-head down-feet up" calf and forehead boxes. While the test subject is still lying down, observe his facial characteristics and record these on the data sheet in the "facial observations after 5 minutes" box. While the test

subject is still lying down, question him about this own feelings or sensations. Record these sensations under "test subjects sensations after 5 minutes" box on the data sheet. Again, while the test subject is still lying down, take his pulse for 15 seconds. Multiply this pulse by 4 and record it on the data sheet under "pulse rate after 5 minutes.

The same procedure can be repeated for 10 minutes, 15 minutes and 20 minutes. All of the measurements are recorded and a conclusion is made regarding fluid shifts in the body during standing and reclining positions.

Mars

LEARNING OUTCOMES

After completing this chapter, you should be able to:

- State facts about Mars' environment.
- Describe reasons for scientists' interest in Mars.
- Identify earlier missions to Mars and what they accomplished.
- Describe the current missions to Mars and their status.
- Describe future missions to Mars.

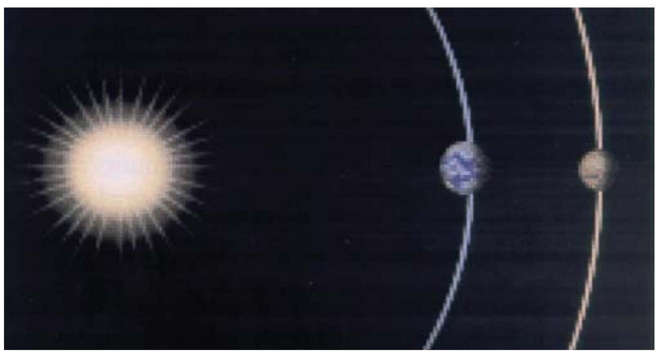
Mars has been a topic of interest and constant scrutiny lately. Not only has it been a very bright star in the evening sky but two probes recently landed on Mars and have been exploring it for a couple of months. Read on and see the latest news about the intriguing planet, Mars.

A Bright Star

In August of 2003, if you looked up into the night sky you probably noticed something a little different; perhaps there was a brighter object out there. That object would have been Mars. Mars was closer to Earth in August than it had been for 60,000 years. On August 27, 2003, Mars was actually closer than 35 million miles from Earth. Normally, Mars is 50 to 60 million miles from Earth.

Of all the planets in our solar system, probably the one that has most mystified and intrigued scientists and non-scientists, has been Mars. Probably more books have been written, movies made, and research conducted on Mars than any of our other neighboring planets. People were fascinated by H. G. Wells popular book *The War of the Worlds.* The book introduced us to Mars and its creatures, and so did the famous movie of the same name, based on Wells' book. So, why so much curiosity about Mars?

Many folks have heard Mars referred to as the angry red planet, and I think the visible redness of Mars adds to our fascination. However, not discounting any of the above, I believe that Mars intrigues us most because there is still expectation



Earth Mars Orbit (NASA Photo)

that life could exist on Mars.

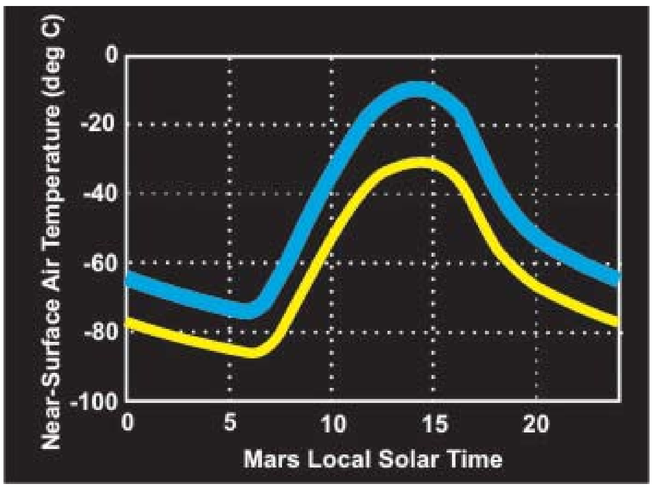
Before we discuss the latest missions to Mars, and the continuation of exploring the possibility of life on Mars, let's review some of the facts about Mars.

Mars' Facts

Mars is the fourth planet in our solar system from the sun. It appears as a reddish light when viewed with the naked eye at night. This reddish color stems from the rocks and dust covering the surface of Mars. The surface has a high iron content that gives it a rusty look. The surface of Mars is very dry and rocky and covered with this reddish dust.

Mars' atmosphere consists of 95% carbon dioxide, 3% nitrogen and traces of oxygen, carbon monoxide and water. Daytime temperatures reach 65 F, while nighttime temperatures can dip to -130 F. These temperatures were recorded from Mars' surface. One day on Mars lasts 24 hours 37 minutes. A year on Mars lasts 687 Earth days.

The characteristics of Mars are closest to Earth's of any of the planets in our solar system.



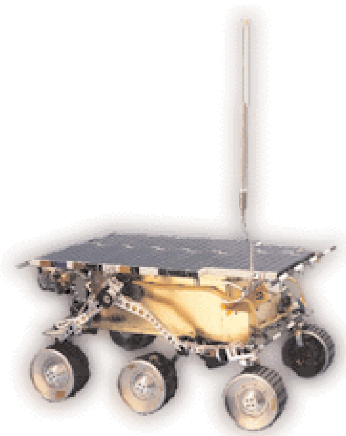
Graph shows near surface temperature on Mars.
(Information copied from NASA photo)

Some scientists believe that conditions are right for life on Mars. Some scientists think that pools of frozen or liquid water may be hidden underground. The North and South Poles of Mars are covered with permanent ice caps that are made mostly of carbon dioxide (dry ice) and water ice. In summer, much of the carbon dioxide sublimes, leaving a residual layer of water ice.

Past Expeditions

In the 1960s, Mariner spacecraft made flybys and took lots of photos of Mars. Then, in the 1970s, *Viking* 1 touched down on Mars. Unfortunately, the experiments were inconclusive even though more water was found on Mars than had been expected.

In July 1997, the space probe, Mars Pathfinder, landed on Mars. The Pathfinder's rover, Sojourner (two feet long and one foot tall) explored the planet. The Sojourner studied the surface, analyzed the soil and rocks and conducted scientific experiments on Mars.



***The* Sojourner.** (NASA photo)

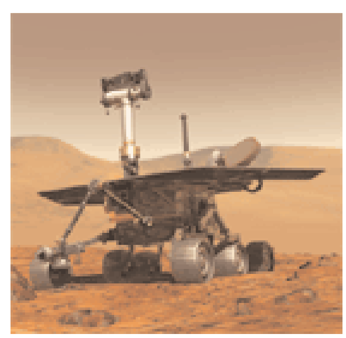
In September 1997, Mars Global Surveyor arrived at Mars and began studying Mars' climate and geology. The Surveyor has been highly successful and has sent back great pictures and information about Mars. In fact, it is still operating on Mars.

From 1998-2000 the Mars Program experienced engineering problems and funding shortages. The Mars Polar Lander and the Mars Climate Orbiter failed to achieve their missions, and the Mars program was restructured. Then in 2001 the Mars Odyssey orbiter was launched.

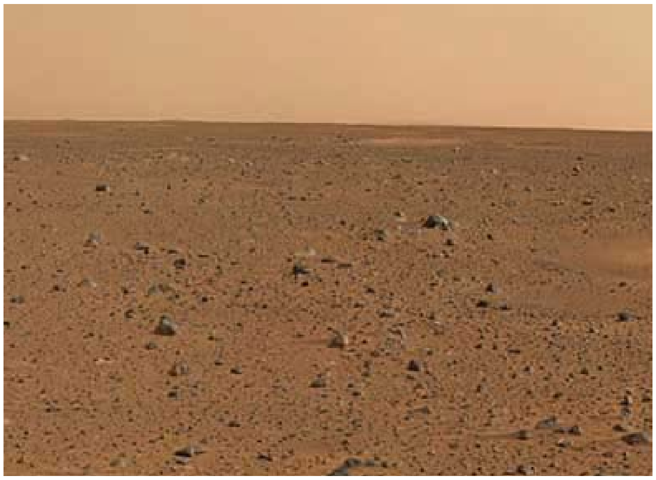
***Mars* Global Surveyor**
(NASA photo)

Current Missions

In June 2003, the European Space Agency (ESA) launched the Mars Express Orbiter and the Beagle 2 Lander, which was due to land on Mars in late December 2003. The Lander hasn't been heard from for months and an investigation is underway to find out what happened. The results should be reported soon. Once on Mars, the Beagle 2 was supposed to study the surface of Mars and collect rock samples. The Beagle 2's equipment included two cameras, two spectrometers, and a microscope. Samples were to be examined by an automated minilab and relayed back to Earth. As of the middle of March 2004, the Beagle 2's status



***Mars Rover* Opportunity**
(NASA photo)



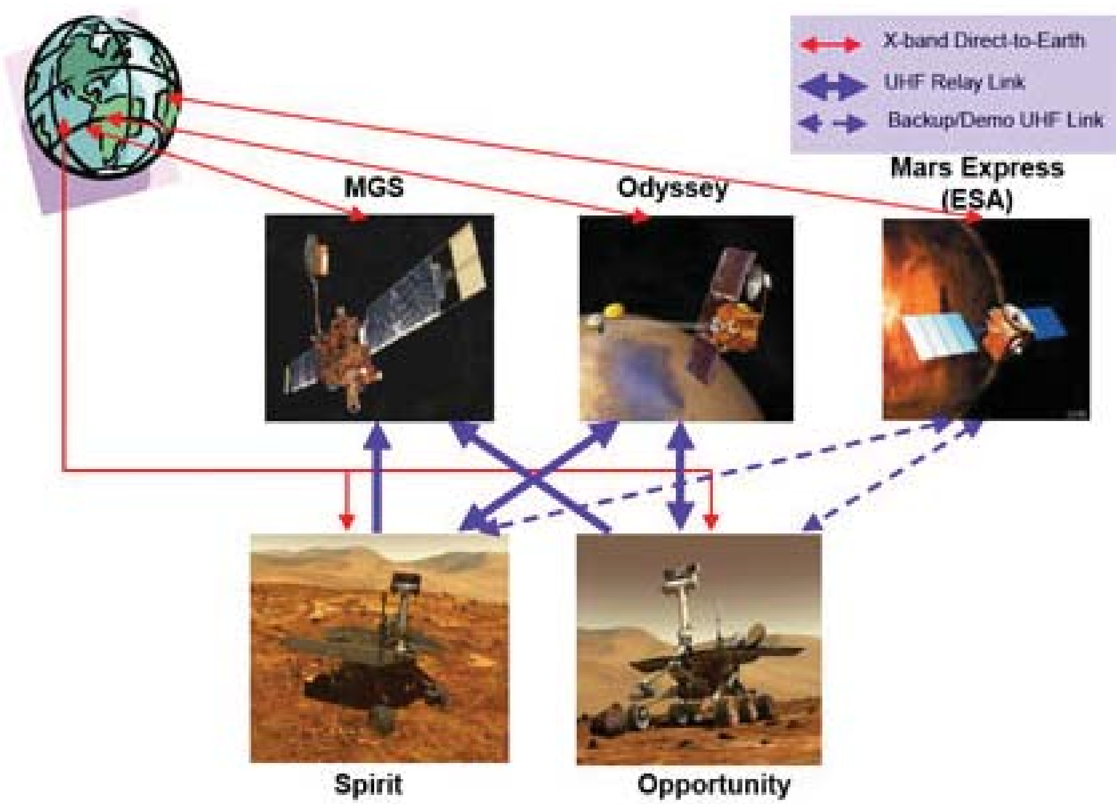
First Color Picture of Mars surfac. (NASA Photo)

is still unknown.

Also in June-July 2003, the US launched two Mars Exploration Rovers, Spirit and Opportunity. These two joined ESA's orbiter, NASA's Mars Global Surveyor and Mars Odyssey, and Japan's Nozomi in the vicinity of Mars in January 2004. Six probes all studying Mars at the same time. Together they will investigate the evolution of the planet, its internal activity, and its past and present indications of water and life. Not since the Apollo program has such an extensive effort been made to explore a heavenly body.

Spirit landed on Mars on January 4, 2004 and Opportunity landed January 25, 2004. The two rovers will try to determine if water was present on Mars and whether there are favorable conditions for the evidence of ancient life on Mars. These two rovers are designed to cover as much territory in one day as the Mars Pathfinder did during its entire mission.

This pursuit of Mars is scheduled to continue for at least a few more years. NASA announced recently that it selected the University of Arizona's Phoenix missions to launch to Mars in 2007. The university will build a spacecraft that will land on the planet's northern pole, an area rich in water ice. So, the study of Mars is not going away, until scientists can reasonably answer the questions about water and life on Mars.



How we communicate with the Mars orbiters and rovers.

Activity Section

Activity One

Build Your Own Mars Pathfinder Spacecraft Model

Download the cutouts below, print and construct the model. You will need scissors, tape and/or glue to put it together, and colored markers or pencils to finish it up.
Download Instructions:

Method 1

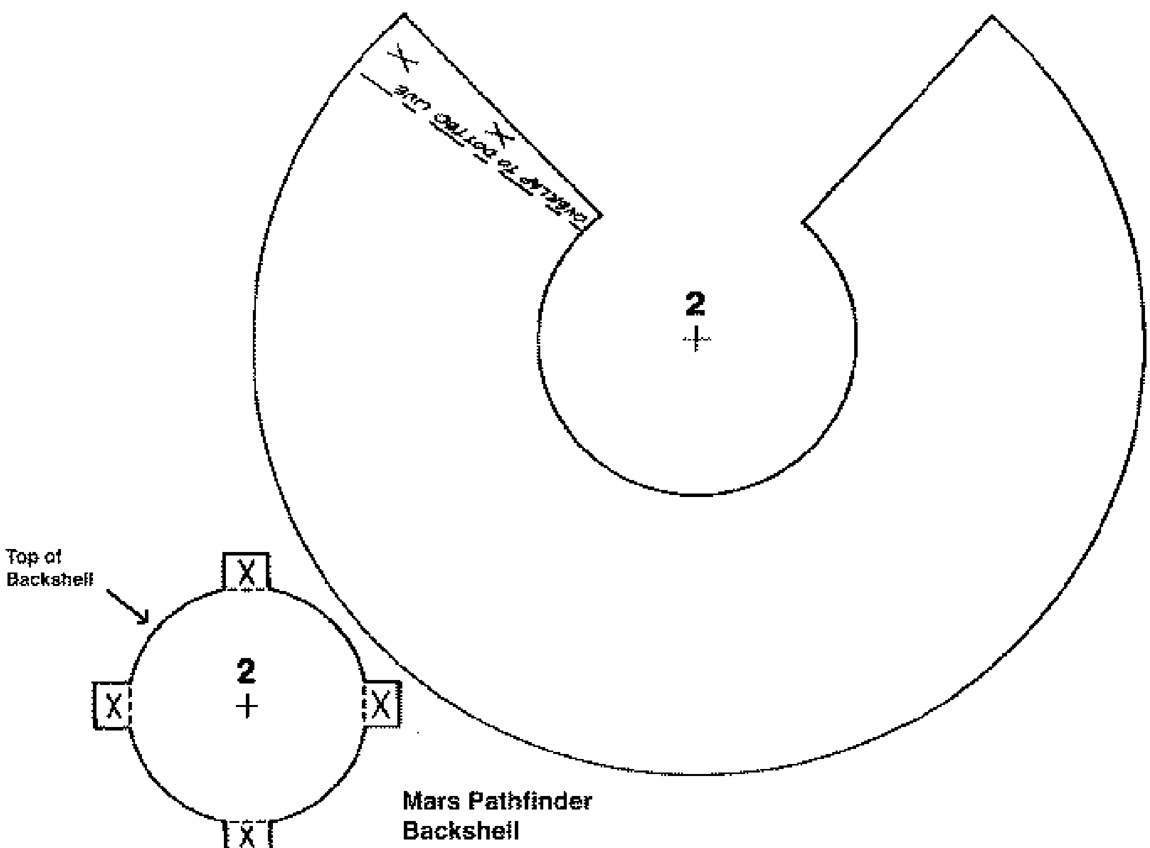
1. Click on the image.
   A larger version of the image will be displayed.
2. From your browser's menu, select **Save As**.
3. Make sure you save the page Format as **Source**.

Method 2

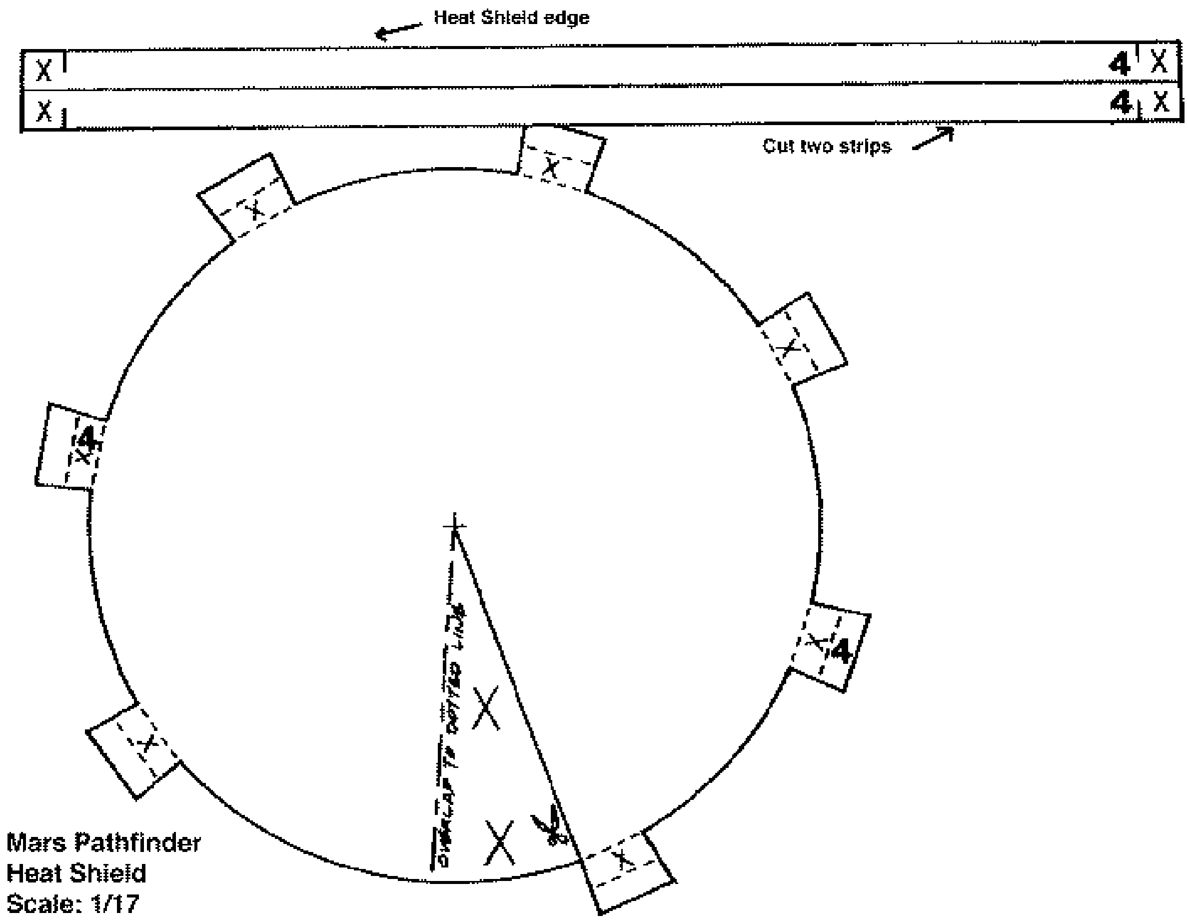
1. Click and hold your mouse button on the image (right button on a PC).
2. After a few seconds, a menu will appear.
3. Select **Save this link as**.
4. Make sure to select **source** as the save format.

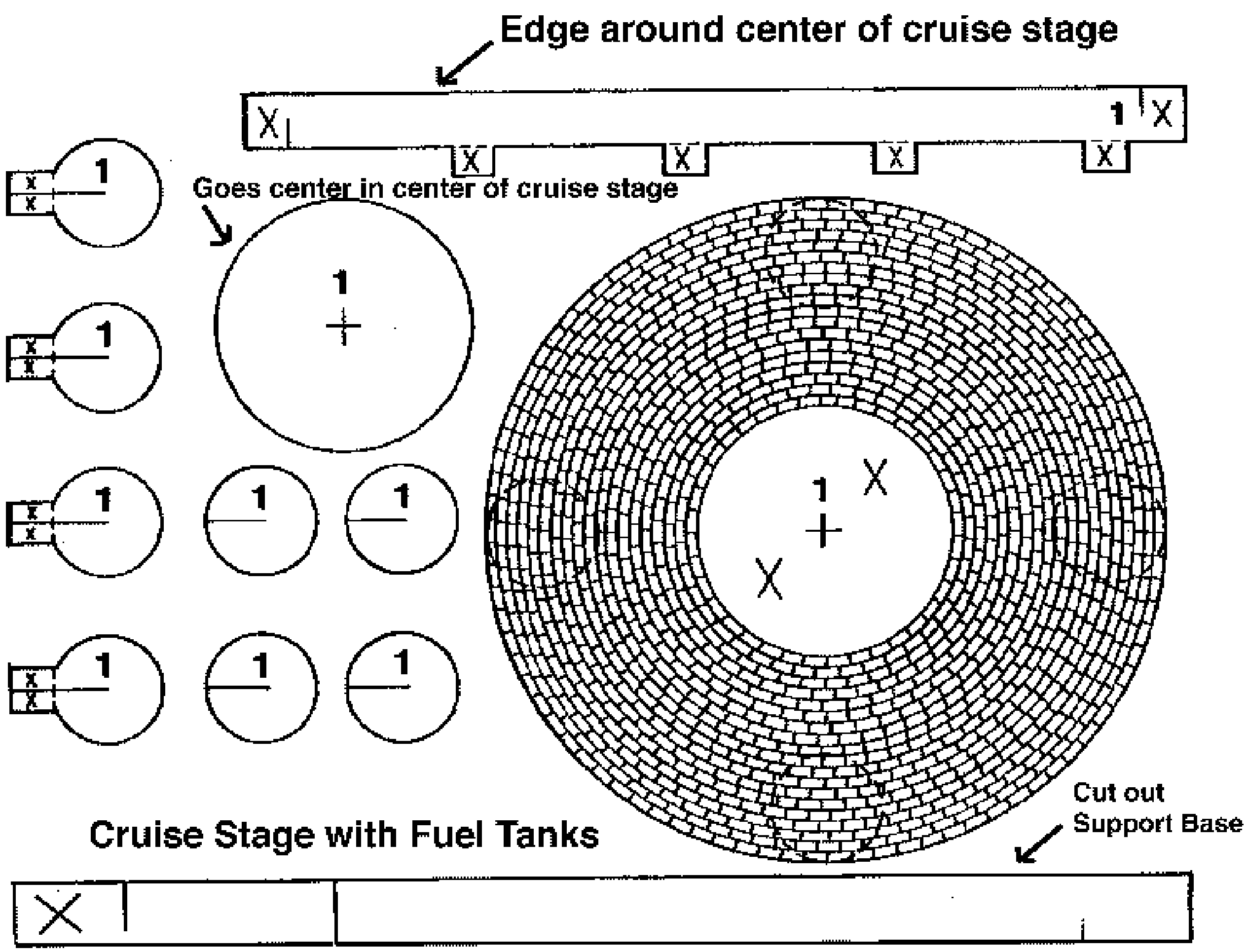
Note: The images you will be downloading are large files. Your download time will depend on the speed of your modem.
Smaller, less sharp GIF versions of the images are available below the pictured images. These smaller files will still print out on 8.5"x11" size paper but will have a lower resolution.

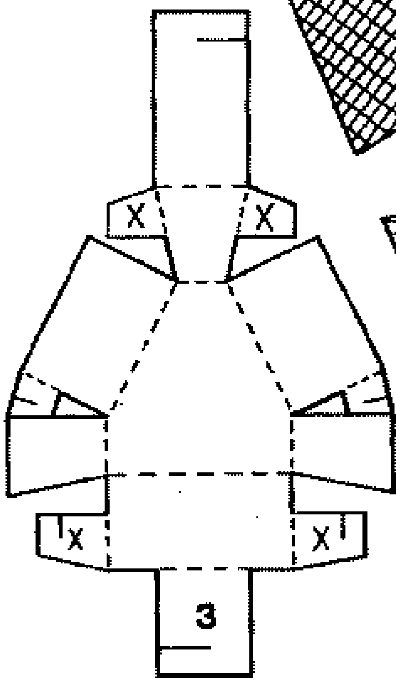
Each image is sized to print on regular 8.5"x11" paper (landscape orientation). Remember, the thicker the stock you print on, the sturdier your model will be!

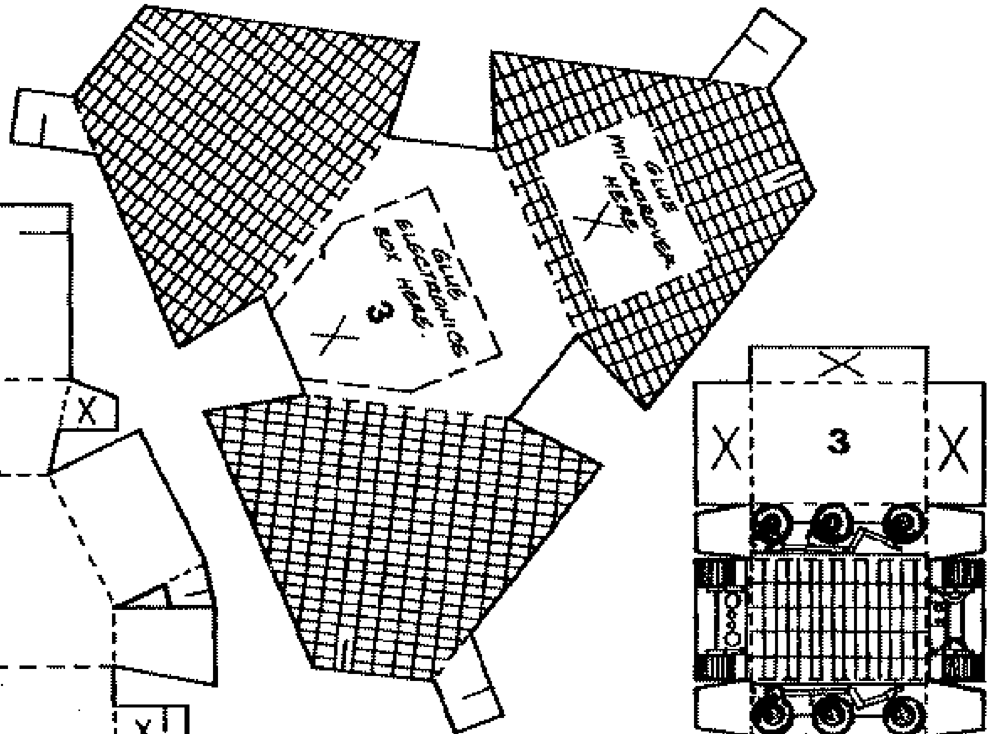


Mars Pathfinder Backshell
Scale: 1/17th


Heat Shield edge
4
4
Cut two strips
4
4
OVERLAP TO DOTTED LINE
Mars Pathfinder
Heat Shield
Scale: 1/17


Edge around center of cruise stage
1
Goes center in center of cruise stage
1
1
1
1
1
1
1
1
1
1
1
Cruise Stage with Fuel Tanks
Cut out
Support Base





Mars Pathfinder
Lander with electronics box, microrover
Scale: 1/17th

Astronomy

LEARNING OUTCOMES

After completing this chapter, you should be able to:
- Identify some of the latest space discoveries.
- Discuss any new planetary discoveries.
- Discuss latest findings con cerning stars.

Astronomers have been studying the stars for hundreds of years, and yet the fascination remains with us today. We are fascinated by the unknown, by what might be, and by the sheer beauty and wonder of space.

Many books discuss the planets within our solar system, and the other bodies existing in space. In fact, CAP's Aerospace: The Journey of Flight is a good source for reading and learning about these entities. This chapter is not going to elaborate on this already covered territory. Instead, we want to bring you up to date on the latest scientific discoveries within our universe.

I have collected and compiled several articles from various NASA websites. Sometimes, I printed the article intact, other times I took excerpts from the articles to give you the latest investigations and discoveries in space. These articles are presented chronologically beginning with 1999 - 2003. We hope you enjoy the articles and learn new information about space discoveries.

Jupiter's Composition Throws Planet-formation Theories into Disarray

By Robert Roy Britt, Senior Science Writer

Posted: 12:06 P.M. ET, 17 November 1999

Examining four-year-old data, researchers have found significantly elevated levels of certain elements in Jupiter's atmosphere that may force a rethinking of theories about how the planet, and possibly the entire solar system, formed. The work may even help explain why giant planets have been found curiously close to other stars.

The elements -- argon, krypton and xenon -- are called noble gases. They are independent characters that don't like to be trapped and strongly resist freezing except at the lowest temperatures (scientists say they are inert). Therefore, they are either rare or nonexistent in the sun, on Earth and in asteroids and comets inside the orbit of Neptune, where temperatures are relatively warm compared with the more frozen reaches of space.

So the discovery in Jupiter's atmosphere of relatively large amounts of these gases -- up to three times what exists in the sun -- has scientists puzzling over how, and possibly where, Jupiter trapped the noble gases in the first place. The puzzle will be described, though not solved, in Thursday's issue of the journal Nature.

"The implications are enormous," said Sushil Atreya, director of the Planetary Science Laboratory at the University of Michigan and part of the international team of researchers that made the discovery.

How planets formed … maybe

Prevailing theories of planetary formation hold that the sun gathered itself together in the center of a pancake-shaped disk of gas and dust, then the planets begin to take shape by cleaning up the leftovers. A developing planet trapped nearby gas and dust, and its gravitational tug reigned in comets and other icy bodies, called planetesimals.

In Jupiter's current orbit, 5 astronomical units from the sun, temperatures are too warm for the planetesimals to have trapped the noble gases, researchers say (one astronomical unit, or AU, is the distance from the sun to Earth). Only in the Kuiper belt -- a frigid region of the solar system more than 40 AU from the sun -- could planetesimals have trapped argon, krypton and xenon.

"How did they become so abundant on Jupiter?" asks lead researcher Tobias Owen of the University of Hawaii's Institute for Astronomy.

Owen and his colleagues speculate that either the developing solar nebula was far colder than current models estimate, or else Jupiter wandered into its present orbit sometime after having formed. A third possibility, and the one Owen considers the most likely, is that planetesimals began forming earlier and more rapidly, before the presolar disk had warmed up. Either answer throws current theories into disarray.

And solving the puzzle, Owen says, has implications even beyond our solar system.

"If the planetesimals really formed so early and so fast, then they could build giant planets much closer to their stars than people have thought," Owen explained in an e-mail interview. "This would help to explain why the new planetary systems that are being discovered have giant planets so close to their stars. The planets would not have to migrate inward as far as people have thought."

How the finding was made

In 1995, NASA's Galileo spacecraft dropped a probe into Jupiter's atmosphere. An onboard "mass spectrometer" measured the quantities of various gases. Researchers have been analyzing the data in recent years, but they worked on the most abundant elements first. While that research was valuable, it was the more recent work that proved most surprising.

"The excitement is all about argon, krypton and xenon," Owen said. "You are breathing tiny traces of them right now as you read this."

Owen said the three noble gases are as abundant in the jovian atmosphere as are carbon and sulfur, a "surprising" result. Jupiter's primary ingredients, like that of the sun and the stars, are hydrogen and helium.

Is Jupiter a wanderer?

While Owen does not put much stock in the idea that Jupiter might have migrated inward to its present position, other scientists on the team say the idea merits consideration. As evidence of how little we know about the possibilities, they cited recent announcements of a possible tenth planet orbiting at an incredibly far-out 25,000 AU or more, as well as the fact that planets much larger than Jupiter have been found extremely close to other stars.

But the idea of Jupiter as a wanderer still leaves significant questions about the source of the noble gases. "If Jupiter had migrated inward, it would have had to come from way out there, 40 or 50 astronomical units," said Atreya, the Planetary Science Laboratory director.

Owen said that experts on the physics controlling this kind of migration think such a scenario is "highly unlikely." Researchers add that this distant region of the solar system -- the Kuiper belt at 40 to 50 AU -- does not currently have enough mass to account for something Jupiter-sized, nor are the concentrations of heavy elements comparable to what is found in Jupiter.

"You have to characterize our understanding of how the solar system got started as sort of in a state of flux," said Thomas Donahue, also of the Planetary Science Laboratory. "There may be more to the solar system than we know about."

Where do we go from here?

Since there now seems to be much more learning to do, Owen and his colleagues are calling for more spacecraft to deploy probes into the other gaseous planets. Owen expects the probes will find similarly high levels of noble gases in Saturn, Uranus and Neptune. Hints of these gases have even been found in the thick atmosphere of Venus, another planet now begging more study.

And Owen said answers to the origin of all this argon, krypton and xenon may still be lurking out there, awaiting discovery: "Comets are probably more diverse than we think, and there may still be some of these very primitive objects left in the comet pool."

Three Extrasolar Planets Found By Telescope Down Under

posted: 07:00 am ET
12 December 2000

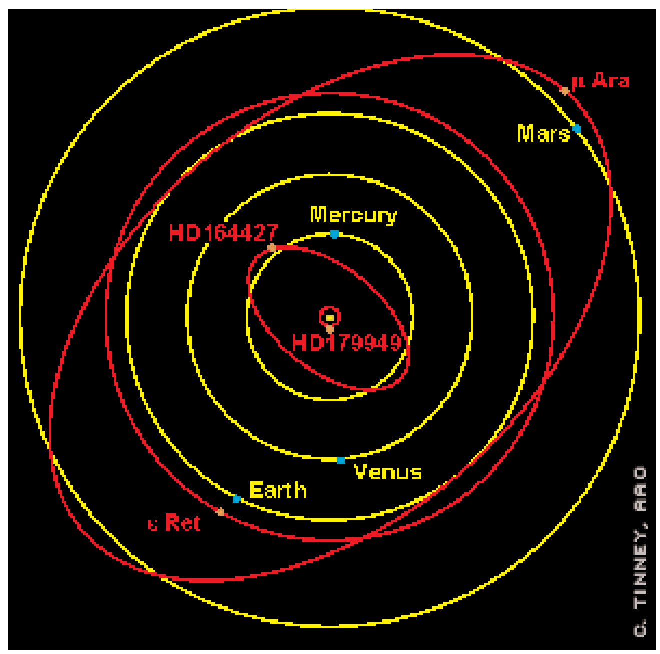
Three planets around distant stars have been found by scientists using a new high-precision system on the Anglo-Australian Telescope (AAT). The new planets were found around nearby stars within 150 light-years of Earth. Forty-six other extrasolar planets have been found since 1995, with the most recent three being the first found by a telescope "down under."

Most planet searches have detected planets more massive than Jupiter, the largest planet in our solar system.

"As a result, searches are picking up all the weird giant planets first," says team leader Chris Tinney of the Anglo-Australian Observatory.

The smallest of the new trio is a kind planet hunters call a "hot Jupiter." It has a mass at least 84 percent that of Jupiter's but lies scorchingly close to its parent star, far closer than Mercury does to the Sun. Its "year," or the time it takes to make a single revolution around its star, is a mere three Earth days.

The middleweight planet lies in an Earth-like orbit inside the "habitable zone" where liquid water could exist. The planet itself is not Earth-like: weighing at least 1.26 Jupiter masses, it is almost certainly a Jupiter-like gas giant. It takes a leisurely 426 days to complete the voyage around



This image compares the orbits of the four new planets -- each discovered around its own star -- with the orbits of our inner solar system planets. Like the planets of our own solar system, epsilon Reticulum and HD179949 have nearly circular orbits. In comparison, the brown dwarf HD164427 and mu Ara lie on very elongated orbits. If mu Ara lay in our own solar system it would swing between the orbits of the Earth and Mars once every year.

its star, epsilon Reticulum in the constellation of the Net.

The third planet is also a gas giant of at least 1.86 Jupiter masses. Its orbit extends just a bit further from its star than Mars does from the Sun. It takes 743 days to crawl around its star, mu Ara, in the constellation of the Altar.

Since 1998 the AAT search has looked at 200 nearby stars in the southern sky. There are probably more planets in the pipeline, says Tinney.
"In three years you can catch only the short-period planets," he said. "To pick up ones with longer orbits you have to observe for a few more years."
The AAT searchers also found a single brown dwarf, a small "failed-star star," in orbit around HD164427.

How it's done

The AAT search complements searches of the northern sky being done by veteran planet hunters Geoffrey Marcy, Paul Butler and Michel Mayor.

Both these and the AAT search use the "wobble" technique. As an unseen planet orbits a distant star it tugs on it, causing the star to move back and forth in space. That wobble can be detected by the Doppler shift it causes in the star's light.

"The AAT search is the most sensitive search in the Southern Hemisphere," says team member Alan Penny of Rutherford Appleton Laboratory in the United Kingdom.

The precision comes from simple glass tube containing specks of iodine, and "a bunch of clever software" written by Paul Butler, says Tinney.

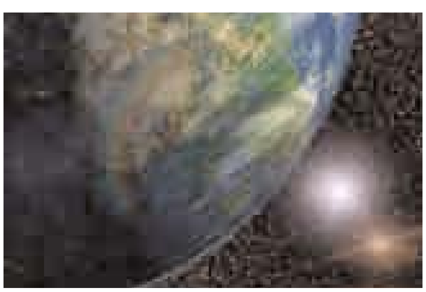
Heating the glass cell turns the iodine to a purple gas. Starlight passing through the gas has its spectrum modified. This reference spectrum is then compared with unmodified starlight. "This helps us get much of the junk out of the spectrum," Butler said.

Along with Butler, of the Carnegie Institution of Washington, and Marcy, of UC Berkeley, Tinney worked to find the three planets with researchers from Liverpool John Moores University, Rutherford Appleton Laboratory, University of Sussex, University of Colorado, University of California Santa Cruz and Tennessee State University.

Future searches

Seeing wobbling stars directly is the next step in planet hunting. That job will fall first off to the Very Large Telescope Inteferometer (VLTI) now being built in Chile and NASA's Space Interferometry Mission (SIM), due to launch in 2009. SIM will spend five years probing nearby stars for Earth-sized planets. Present-day searches will provide target lists for SIM and the VLTI.
Is it worth finding more planets? Absolutely, says Butler. "It will be at least five years before we find enough planets to even begin making sensible guesses about the whole population out there."

But the planets found to date are so different from those in the solar system that theories of planet formation have been "turned on their head," he said.



Search for Another Earth Quietly Underway

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 30 November 2000

After a five-year search that has turned up more than 40 giant, inhospitable planets around other stars, the hunt is quietly underway to discover another place like home. And while no scientist can say for sure that any such planet exists, optimism is high that another Earth will be found within the decade, possibly much sooner.

It would be a discovery of sizeable historic proportion, akin to learning that our solar system was not the center of the universe and recharging the growing expectation that we are not alone.
And it could galvanize and accelerate efforts to

explore space to a degree not seen since the U.S.-Soviet space race.

The sheer volume and variety of extrasolar planets found so far fuels a strong expectation among those involved in the search that there must be other Earth-sized planets orbiting other stars at distances suitable for supporting life.

"There are about 200 billion stars in our galaxy," said Paul Butler of the Carnegie Institution of Washington. "I would guess that Earth-like planets must exist."

Butler and a colleague, Geoffrey Marcy, pioneered the hunt for extrasolar planets, or exoplanets. They lead teams that detect small wobbles in stars caused by the gravitational pull of an orbiting planet. Along with their colleagues, they have found the majority of confirmed other worlds.

But the wobble method so far spots mostly very large planets that orbit extremely close to their host stars -- many are closer than Mercury is to our Sun -- not a place you'd want to live. And scientists have yet to see these planets directly.

Now, new methods and a handful of missions on the horizon are close to bringing another Earth within our optical reach.

Earth-sized planet discovery imminent

In recent interviews, three leading planet hunters told SPACE.com that a potentially habitable Earth-like planet might well be found within 10 years. And extrasolar planets in the "terrestrial" range -- no more than 2.5 times the size of Earth -- could be found within five years, possibly even during 2001.

Discovering one of these so-called "terrestrials" could well spur the funding, decisions and brainstorming needed to support missions that would root out truly habitable planets, scientists say.

Hans J. Deeg, a planet hunter involved in multiple searches, says if either of two planned missions gets off the drawing boards in a timely manner -- the ESA's Eddington mission or NASA's Kepler mission -- then a truly Earth-sized planet should be found in about 10 years.

Meanwhile, Deeg is currently working on COROT, a European space-based telescope due to launch in 2004.

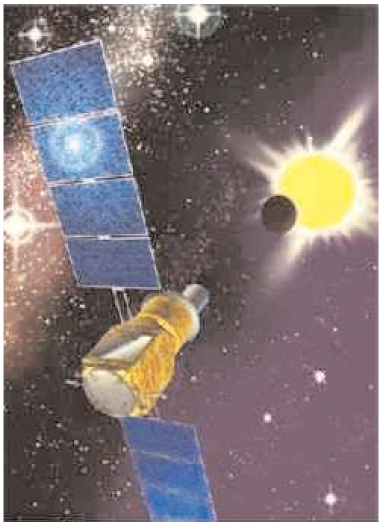
Future Missions to Search for Earth-like Planets

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 30 November 2000

Several space missions have been dreamed up to search for Earth-like planets around other stars. Some may remain dreams, others are closer to reality. Here, we detail six of the more promising candidates (though there are many others).

COROT mission

The French space agency CNES leads a group that is designing COROT (COnvection, ROtation and Transits). This small Earth-orbiting telescope will likely be the first space telescope dedicated to the search for Earth-like planets. Most other planet hunting so far has been done with ground telescopes or, when space telescopes have been use, time has been limited.



COROT would detect planets when they happen to pass in front of their host star, an event known as a transit, which causes a dip in the brightness of the star.

The telescope is only 27

centimeters (10.6 inches) in diameter. Its value would lie in the fact that it would sit above the blurring effects of Earth's atmosphere and that it would be devoted to the task of exoplanet hunting. Some stars will be studied for five months, to build strong signals that can then be picked out.

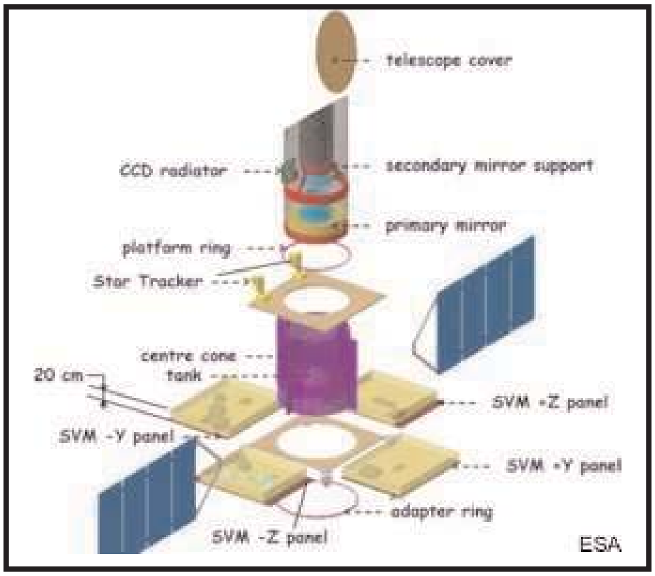
COROT participants include Spain, Austria, Belgium, ESTEC, Italy and the European Space Agency (ESA). Promoters say it will launch in 2004.

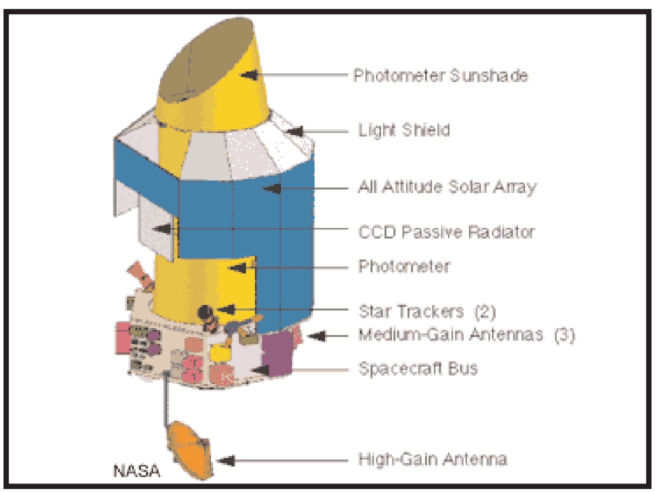
Eddington mission

The Eddington mission was proposed to the European Space Agency (ESA) in early 2000. It would search for and study potentially habitable planets around other stars using a 1.2-meter (47-inch) optical telescope.

Eddington would carry an optical photometer mounted on a three-axis stabilized platform, sitting far from Earth. The mission would also study the makeup and evolution of stars.

In October, the ESA's Science Program Committee approved Eddington as part of a larger set of initiatives to be implemented between 2008 and 2013. A workshop to discuss the mission will be held June 11-15, 2001, in Spain.





Kepler mission

The Kepler mission has been proposed as an element in NASA's Discovery Program. Its goal would be to survey relatively nearby stars to detect and characterize hundreds of terrestrial and larger planets -- if they exist -- in or near the habitable zone.

The satellite's telescope would have a 0.95-meter (37-inch) aperture. It would orbit the Sun and study some 100,000 stars for four years.

Kepler would study the size, orbit and composition of any Earth-like planets it found, and would also study the properties of stars that harbor planetary systems. The mission could get approval in December of this year, or possibly January 2001. No launch date has been projected.

Darwin mission

The European Space Agency has targeted the InfraRed Space Interferometer-Darwin for a launch in 2015 or later. Decisions about whether to go forward with the mission are expected around 2003.

The telescope, using infrared rather than optical wavelengths, would hunt for Earth-like planets around some 300 Sun-like stars within 50 light-years of Earth. Darwin would actually be an array of six small eyes, forming an effective giant that would mimic a 100-yard (91-meter) telescope. Scientists are still studying how such a system might be designed.

Unlike current space-based telescopes, Darwin would operate somewhere between Mars and Jupiter, rather than in Earth orbit. This would allow the instruments to avoid the dust between Earth and Mars that obscures the view.

The six individual telescopes would be joined either by long arms or would each be mounted on individual spacecraft. In the former case, the rigid structure would rotate to build up the image. In the latter case, the individual spacecraft would have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their own rocket motors and dance around each other to build up the image.

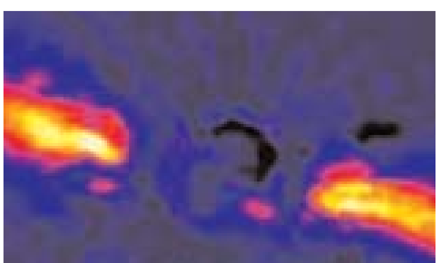
SIM mission

The Space Interferometry Mission (SIM) would hunt for Earth-sized planets around other stars and provide new insights into the origin and evolution of our galaxy.

A science team for the mission was chosen by NASA November 28, 2000, and the mission is scheduled for launch in 2009.

SIM would be placed into orbit around the Sun on a path that follows Earth's orbit. Light gathered by its multiple telescopes will be combined and processed to yield information that could normally be obtained only with a much larger telescope.

The mission would also measure the locations and distances of stars throughout our Milky Way Galaxy, and study other celestial objects.


CREDIT: ESO/CALTECH

Solar Systems Like Ours May Be Common, Study Shows

By Robert Roy Britt, Senior Science Writer
posted: 07:02 am ET, 04 January 2001

Researchers have discovered unexpected amounts of hydrogen gas, critical to the formation of giant planets like Jupiter, circling three nearby stars in dust disks previously thought to be devoid of the stuff.

While hydrogen is the most common substance inside stars and throughout the universe, the finding indicates that hydrogen remains in a dust disk, or protoplanetary disk, around a star longer than thought. This, in turn, means large gas planets have longer to form and therefore may be more prevalent than expected.

Coupled with the long-held theories that gas giants are necessary for the formation of smaller Earth-like planets, the discovery raises intriguing possibilities about the search for other planets that might harbor life.

"The new findings strengthen the likelihood that a larger fraction of stars form solar systems like our own, and that some stars near the Sun are still forming giant planets," said Jack Lissauer, a researcher at NASA's Ames Research Center who was not involved in the study.

Enough hydrogen for six Jupiters

The three stars in the study are relatively young -- between 8 million and 30 million years old (our Sun formed nearly 5 billion years ago). Each is less than 260 light-years away (our Milky Way Galaxy is roughly 100,000 light-years across).

Each of the stars was known to be encircled by a flat disk of dust. These so-called protoplanetary disks, the leftovers of star birth, are the stuff of which planets are made. But previous studies had concluded the disks contained very little hydrogen gas. Researchers assumed that hydrogen does not hang around in a dust disk for more than about 5 million years. (The interplanetary space in our own solar system is now mostly hydrogen-free.)

The new study, reported in the Jan. 4 issue of the journal Nature, found enough hydrogen gas around one of the stars to form six Jupiters. Each of the other two disks had a fraction of the hydrogen needed to make one Jupiter, but still more than expected.

Many of the stars in our neighborhood of the Milky Way are at least 10 million to 30 million years old. Until now, researchers assumed these stars could no longer form giant planets, because their disks would be depleted of hydrogen gas.

According to theories of solar system formation, giant planets are key to allowing the development of smaller planets in potentially habitable orbits -- not too hot, not too cold. Gas giants, as the theory goes, also help set up livable conditions as they use their gravity to sweep the inner solar system relatively free of life-threatening asteroids and comets.

The researchers involved with the study said their work is "good news, though indirectly, in the search for extraterrestrial life," because life as we know it needs a planet in one of these so-called "Goldilocks" orbits. Clues to our own solar system.

The findings also represent another step toward fathoming the range of ways in which solar systems, including our own, come into being and evolve.

"If indeed planet formation is still going on in these [nearby] systems, they are among the closest to the Earth," said Geoffrey Blake, a Caltech researcher who participated in the study. "They may therefore provide unique windows into how planetary systems are assembled."

Classic explanations of giant-planet formation say that a core of rock roughly 10 times the mass of Earth forms, and then the gravity of this "protoplanet" attracts gas until it becomes the size of Jupiter. But computer models have shown this would take several million years -- longer than hydrogen gas was expected to be available.

"Our new findings are important because they lengthen the time that it is possible to form Jupiter-like planets," Blake told SPACE.com.

Telescope Array to Unlock Secrets from Duplicitous Stars

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 17 July 2001

MOUNT WILSON, CALIF -- A steep and narrow road shouldered by precipitous drops into rocky canyons winds from the bright lights of the Los Angeles Basin to the top of Mount Wilson. It's an hours drive that soars up through the smog, past sturdy pine trees and, surprisingly, into some of the best telescopic "seeing" conditions in the world. It is also a paved path to the past. Some of the equipment here has sat unchanged since the 1920s when Edwin Hubble used the mountain's 100-inch telescope to discover that our universe is expanding.

Now, eight decades after Hubble ushered in a new era of cosmology, and on the heels of a complete shutdown, the Mount Wilson Observatory is alive again and being repositioned for the future by going back to basics. It is a future expected to unlock fundamental secrets about ordinary stars, objects that have lost some of their "star power" in an era of pretty pictures made by exotic space-based telescopes. Like the one named after Edwin Hubble.

Under the steady air at Mount Wilson, scientists are building an array of telescopes that will combine to work as one and effectively become among the most powerful stargazing tools ever built.

The setup is so complicated that no one person understands how it works. It is called the CHARA array, and later this month scientists plan to start normal operations as they bring the third telescope in the complex array online. The longest distance between two of the telescopes, known as the array's baseline, will be 1,148 feet (350 meters), nearly the length of four football fields. By comparison, the largest conventional optical telescopes do not exceed 36 feet (11 meters).

CHARA is expected therefore to allow astronomers to measure and weigh stars and calculate distances to them with a precision not previously possible.

Out of the age of occultations

Other telescopes -- including Hubble, Chandra, Hawaii's Keck and the European Southern Observatory's Very Large Telescope -- are better equipped to look beyond our Milky Way to explore distant galaxies or to marvel at supernovae, exoplanets and other enigmatic objects. If those are an astronomer's most elegant power tools, then CHARA could be considered a supercharged slide rule.

And unlike a handful of similar telescopes that perform diverse tasks, CHARA will be dedicated to the basic measurement of stars in visible and near-infrared light. Such measurements have until now relied heavily on lunar occultations, a moderately reliable method of studying how a star's light goes out during the seconds when the Moon chances to pass in front of it.

CHARA (Center for High Angular Resolution Astronomy) is expected to give significantly improved measurements of the mass of stars, a crucial factor in learning what the objects are made of and how they evolve.

Other research has indirectly measured the mass of stars by observing how two stars orbit around one another in what's called a binary system. But these observations have relied on noting changes in the star's light as it moves away from us, and then toward us, in its orbit.

This Doppler effect, identical to the change in sound as an ambulance moves toward and then away from you, is an indirect measurement tool that, again, has only provided reasonably close estimates.

What CHARA's interferometry can do that the Doppler method and conventional telescopes can't is to actually locate points around the perimeter of a star, thus providing an exact "picture" of a star's diameter. Other methods use a star's luminosity to estimate other parameters.

"If you can resolve these binary stars ... then you can directly measure the masses of the two stars as well as the distance to the stars from Earth," says Harold A. McAlister, a Georgia State University professor and director of the 14-person CHARA team. "The measure of mass is the most fundamental parameter scientists would like to know" about stars.

Duplicitous by nature

Stars are often duplicitous by nature, doubling up just to confuse observers and even, at least in the past, being perceived as evil. CHARA will help untangle stars' deceptive properties.

Roughly half of all the points of light in the night sky are actually binary star systems, in which two stars orbit around a common gravitational midpoint. Such systems give off confusing light signatures that in some cases move in the sky, sometimes sending airliners off course and generally confounding attempts to measure their size, distance, substance and movement.

One such binary system was once thought to be a single star. Its frequent winking gave the ancients the creeps, and so they gave the strange object the name Algol, meaning Eye of the Demon.

Algol, modern-day astronomers learned, has a small faint companion star that orbits around it, explains Bill Hartkopf of the U.S. Naval Observatory. Every few days the smaller star passes in front of the big star, making the system dimmer.

Hartkopf is interested in using CHARA to learn more about star systems like Algol, as well others that appear to actually move around in the sky. "Consider a star sitting out there in space all by itself, a perfect directional beacon for a jet to use to plot its course," Hartkopf said. "Unbeknownst to the pilot, however, the star slowly, imperceptibly moves -- and not even in a straight line -- enough to throw the jet off course." The moving beacon, Hartkopf explains, is a bright star accompanied by a faint star. "They're too close together to be seen as two stars," he said. "Instead we see the blended light from both. As the brighter star moves from, say, left of the fainter star to above it, then to the right of it, the center of light of that blended image appears to move in a circle."

Hartkopf says CHARA may help answer other important questions:

- Do binaries stay together forever?
- What role does a binary system play in stellar evolution?
- Do all stars form in pairs?

Recent evidence has shown that current estimates of binary systems may be incomplete. Or some stars may form in pairs and later be forced apart.

No one person understands it

The technique of combining light from multiple telescopes is called interferometry. Radio telescopes have employed it for years, but it is just emerging as a force in optical astronomy. It's all about making a big deal of small things. "When you want to see a small thing in the sky, you need a big mirror," says Mark Swain, an astronomer and technician at NASA's Jet Propulsion Laboratory who works on the Keck telescope. Keck is also an interferometer but is devoted to hunting for extrasolar planets.

"Interferometers are a cheap way to build a big mirror," he says. "A mirror the size of a football field would be tremendously expensive, if even possible." CHARA's original budget forecast put the project at $11.5 million -- a fraction of what it costs to build and launch a space-based telescope. But with the relatively cheap price tag comes a complex method of putting the light back together. Interferometry is a rapidly developing technique that requires nanometer precision. And it is a scheme that is highly complicated. So much so that nobody claims to be able to boil it down to anything resembling a lay explanation.

"No one person understands it all," says Lu Rarogiewicz, who worked on a predecessor to CHARA that was dismantled three years ago. "It takes a team of fairly specialized people in many disciplines to put it together and get it to work." McAlister, while giving a quick overview to a group of journalists visiting the observatory, called the technique a "magical process" that "involves a lot of plumbing." The magic is in the mixing.

Imagine starlight coming from a point at the left edge of a star's disk. The light will travel a slightly longer path to reach one of two telescopes. The trick in interferometry is getting those two incoming light sources to meet at one location with near-perfect precision -- to well within the length of a single light wave.

McAlister and his colleagues do this by sending the light through vacuum tubes to a central building, a long, cramped bunker where the magic mixing is done. Inside, each beam of light is bounced between mirrors and delayed as needed until they are all exactly cued up to be combined.

As the light waves are put together, they interact and produce a series of wave patterns, called fringes, that are either built up or canceled out depending on the telescope's baseline.

Instead of conventional pictures, an interferometer produces multiple fringes, mere squiggles on a computer screen, that can be combined to determine a star's size and shape. But these can be powerful squiggles.

CHARA's ability will be akin to looking from New York, across America and the Pacific Ocean, and spotting a nickel in the middle of Siberia. In astronomy-speak, that's 200 micro-arcseconds of resolution.

The array will eventually consist of six telescopes, each with a light-collecting mirror that is 1 meter in diameter (3 feet). Since 1999, two of the telescopes have been working, but useful observations require a third, which is expected to come online later this month. All six should be operational by early next year, refining accuracy and allowing for quicker observations.

Clear skies above, crud below

On a clear, shirtsleeve-warm evening in early June this year, a full Moon outshines most stars, even high atop Mount Wilson. But those that remain exhibit a characteristic prized by astronomers: They don't twinkle.

Which is precisely why the site was chosen for the CHARA array, even though it is less than 20 miles from the bright lights and heavy smog of downtown Los Angeles. It's the same reason the mountain got its first telescope in 1889.

"The prevailing winds bring in air that has been flowing across the Pacific Ocean and, except during storms, the temperature is very steady and the air becomes very uniform and flows very smoothly," McAlister explains.

"The air is not disrupted until it flows inland from Mount Wilson," he said. "When you observe stars from a sight like this, the stars don't twinkle much. The twinkling is the result of turbulent air distorting starlight."

The smooth flow of air also traps industrial and auto emissions in an inversion layer, creating the smog that snuggles against the mountains like dirty cotton.

Mount Wilson's elevation is just over 5,700 feet (1,742 meters). "And the inversion layer is typically at 3,000 to 4,000 feet," McAlister said. "So all the crud is down there."

Expect surprises

In addition to binary stars, CHARA will study some of the most massive stars, hot young objects known as O- and B-type stars. It will also take a look at some lower-mass, cooler stars that have proved particularly difficult to study by other means.

What's known about all these stars is based heavily on theory, not on observation, McAlister said. "These stars blow away a lot of their mass," he said. "They have very active winds of material that they expel out into the environment around them. And so we expect to see features of those winds as well."

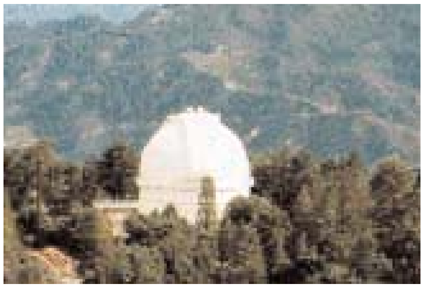
The CHARA array "should be a very good system, and it should tell us a great deal about the newer stars," said Nobel laureate Charles Townes, who operates a similar but portable interferometer, also atop Mount Wilson, and recently used it to learn that some older stars, called red giants, may be larger than thought.

McAlister said he figures that just like Townes' study of older stars, CHARA's fresh look at younger stars will yield surprises.

To a lesser extent, the array will also look for Jupiter-mass planets in binary star systems, something that is mostly ignored by current planet hunters, who typically confine their studies to single stars.

"Most of the stars in the universe are not singles, so we shouldn't be ruling out binaries ... as places for planets," McAlister said.

CHARA is funded by the National Science Foundation, the W.M. Keck Foundation, the David and Lucile Packard Foundation, and Georgia State University, which will operate it.



Astronomy Revival: New Discoveries from Historic Mount Wilson

By SPACE.com Staff, posted: 10:31 am ET, 12 June 2002

On the California mountain from which Edwin Hubble discovered that the universe was expanding, astronomers have achieved first light with a new infrared camera and made some nifty discoveries in the process.

Using the 100-inch telescope at the Mount Wilson Observatory near Pasadena, the astronomers found three previously undetected faint stars, each orbiting larger and brighter companion stars.

"This is the first time the historic Mount Wilson telescope has looked at the universe through this new infrared eye, and already it is making new discoveries," said Jian Ge, assistant professor of astronomy and astrophysics at Penn State and leader of team that developed the camera and made the discoveries.

The results do not represent a major scientific finding -- similar dim stars have been discovered from other observatories. But they "mark the beginning of a new era in the use of the 100-inch telescope for discovering very interesting faint objects in orbit around brighter stars, such as brown dwarfs, which are neither stars nor planets," said Robert Jastrow, director of the Mount Wilson Institute.

The findings will be published in the June issue of Astrophysical Journal Letters and the July issue of the Astronomical Journal.

The infrared camera, which detects electromagnetic radiation in the form of heat rather than visible light, has a specially shaped mask that covers the "pupil" of the camera's eye to allow fainter companions to be seen around bright objects.

"The image resulting from the first use of the device revealed areas of greater contrast that allowed us to find one of the faint dwarf stars," Ge said. "The technique potentially improves contrast in images by more than tenfold compared to current techniques." (Other telescopes are equipped with similar coronagraphs, as they are called.)

Future space-based telescopes will likely draw from this technology to image Earth-like planets around other stars, said David Spergel, Princeton University researcher who recommended the new approach to Ge. "Jian's work at Mount Wilson is a pathfinder for the Terrestrial Planet Finder being planned by NASA."

The dwarf stars are less than one-tenth the mass of the Sun and give off a dark-red glow that is dimmer than our hotter Sun's yellow light. One of the stars is about 50 light years from Earth, another is about 27 light years away, and the third is at a distance of about 200 light years. Astronomers consider these stars to be nearby in our solar system's corner of the galaxy.

"Our initial conservative estimate is that these are little very-dark-red dwarf stars," says Abhijit Chakraborty, a postdoctoral scholar on Ge's team. "Their mass is only about 80 to 100 times that of Jupiter, which itself is a thousand times smaller than our Sun. They have barely enough mass to burn the hydrogen in their cores, and are close to the size and luminosity of less-massive brown-dwarf objects, which don't have enough mass to ignite into stars at all."

300th Delta Rocket Launches New Window on Universe

BY WILLIAM HARWOOD
STORY WRITTEN FOR CBS NEWS "SPACE PLACE" & USED WITH PERMISSION
Posted: August 25, 2003

With a sky-lighting burst of flame and thunder, a Boeing Delta 2 rocket boosted a $1.2 billion infrared telescope into space early today, a "great observatory" designed to detect the feeble glow of infant planets, stars and galaxies in the making.

In so doing, NASA's Space Infrared Telescope Facility, or SIRTF (pronounced SIR-tiff), will complement the work of the Hubble Space Telescope and the Chandra X-ray Observatory while extending humanity's vision into a realm that, until now, has been shrouded in dusty mystery.

An artist's concept of SIRTF. Credit: NASA/JPL/Caltech

"The technical capability of SIRTF will most likely lead to discoveries that no one could predict before the start of the mission," Lia La Piana, program manager at NASA headquarters in Washington, said earlier this year. "SIRTF will significantly increase our understanding of the Universe and will probably re-write astronomy textbooks just like the Hubble Space Telescope did."

Once safely in orbit around the sun, its instruments activated, checked out and chilled to a few degrees above absolute zero - a process that will take up to three months to complete - SIRTF will be the most powerful space-based infrared observatory ever built.

So sensitive, in fact, it would be capable of detecting the pulse from a TV remote control "clicker" from a distance of 10,000 miles.

"SIRTF will be a factor of a hundred to a million times more capable than any previous facility for infrared astronomy," said Michael Werner, SIRTF project scientist at the Jet Propulsion Laboratory in Pasadena, Calif. "I'm fond of saying that SIRTF doesn't just meet our requirements, it exceeds our requirements. It's going to be very, very exciting over the next months and years."

Running four-and-a-half months late because of booster issues and the launchings of two Mars rovers this summer, SIRTF's Delta 2 finally roared to life at 1:35:39 a.m. EDT (0535:39 GMT) Monday, swiftly climbing away from pad 17B at the Cape Canaveral Air Force Station.

The fiery exhaust from the vehicle's powerful Delta 3-class solid-fuel boosters lighted up the night sky for miles around, putting on a spectacular show for area night owls. Fifty minutes later, after two firings by the Delta 2's second stage motor, SIRTF was released into an orbit around the sun designed to maximize the spacecraft's science output.

Engineers were not initially able to acquire telemetry from the spacecraft as it sailed high above Australia, causing a few tense moments following SIRTF's separation from the Delta 2's second stage. But as it turned out, all was well.

"I have no nails left," joked project manager David Gallagher. "We had a little extra delay there acquiring (telemetry) from Canberra. We have done a preliminary assessment of the subsystems of the observatory and everything looks to be good. We are pointing where we should be.

"We believe, this is very preliminary, the cause of the delay was that the signal was too strong. ... We are getting telemetry down now and everything looks good."

Launch came two full decades after the project first got underway with an official "announcement of opportunity" from NASA.

"We were all foolish enough not to notice it was actually Friday, May 13," said George Rieke, a principal investigator from the University of Arizona. "Somehow we have overcome, after two decades, the bad aura that came with that particular date."

The victim of budget cuts and resulting redesigns, SIRTF survived primarily due to the innovation and determination of the science team and the engineers charged with turning the dream into reality.

"We used to count the time to SIRTF's launch in decades," Rieke joked. "If we'd known how many decades, we probably would have quit."

The key was figuring out how to reduce the weight of the telescope to permit launch on a low-cost Delta while maintaining the same mirror size, the same orbital lifetime and the same capability to chill the observatory's instruments to within five degrees of absolute zero. The solution was as elegant as it was simple.

Instead of encapsulating the telescope in a massive liquid helium dewar, or thermos, like earlier, more modest infrared telescopes, engineers decided to launch SIRTF at room temperature. Once in space, a smaller dewar holding 95 gallons of liquid helium will begin cooling the optical system and instrument detectors.

But that alone was not enough. To achieve the ultra-low temperatures required to detect the faintest targets, SIRTF was redesigned to operate in the shade of a single fixed solar panel that will always remain pointed face on to the sun.

Finally, the SIRTF designers changed the mission profile, putting the telescope in an orbit around the sun instead of Earth, far enough away to eliminate infrared emissions from the planet or the moon that otherwise could wash out the feeble radiation from deep space.

All of that, plus the addition of the largest, most sensitive digital detectors ever built for an infrared telescope, represents "a great advancement in the state of the art for infrared observatories," Gallagher said earlier this year.

SIRTF is equipped with three science instruments: A powerful CCD camera sensitive to shorter infrared wavelengths, a light-splitting spectrograph to study the chemical composition of the telescope's targets and a multi-band photometer that will gather pictures and spectrographic data at longer wavelengths.

"The only real downside to this warm-launch architecture is it hasn't been done before," Gallagher said. "So this is a first of a kind demonstration of that. I believe after it's successful, this will become the way you do infrared missions. By not having to cool such a large volume, the mass savings, and therefore cost savings, are quite extraordinary."

Slowly falling behind Earth in a slightly longer orbit around the sun, SIRTF will focus on the faint heat emitted by stars and planets in the process of coalescing from swirling clouds of dust and gas. The 1,900-pound observatory also will probe the chemical composition of enigmatic brown dwarfs, would-be suns that lack sufficient mass to trigger nuclear ignition, and peer through intervening clouds of dust to map the hidden heart of the Milky Way.

Closer to home, SIRTF's chilled 33.5-inch mirror and a trio of sensitive detectors promise to give astronomers an unprecedented view of the outer reaches of our own solar system, where uncounted comets and icy chunks of debris slowly swarm about the faint flicker of the distant sun.

Of more cosmological significance, SIRTF will peer into the depths of space and time, capturing the faint glow of the first infant galaxies emerging in the aftermath of the big bang as well as emissions from the cooler outer regions of black hole-powered quasars.

"SIRTF will allow us to probe the young Universe in ways which compliment the work that's been done to date with Hubble and with Chandra, the other great observatories," said Garth Illingworth of the University of California-Santa Cruz. "We're looking now to try and shed light on the mystery of galaxies, when they were born, how they were assembled and how they've grown over the life of the Universe."

It's a tall order. Figuring out how galaxies evolved in the aftermath of the big bang birth of the cosmos "is really and truly one of the great quests of the next decade," Illingworth said.

SIRTF is the fourth and final member of NASA's "Great Observatories" program, following the Hubble Space Telescope, the now-defunct Compton Gamma Ray Observatory and the recently launched Chandra X-ray Observatory.

The idea was to build a fleet of space-based telescopes sensitive to different regions of the electromagnetic spectrum because "many cosmic objects produce radiation over a wide range of wavelengths," said NASA science chief Ed Weiler. "It's important to get the whole picture."

The Compton Gamma Ray Observatory, which ended its mission in 2000, was built to study extremely violent processes, catastrophic stellar detonations and collisions generating temperatures greater than 1.8 billion degrees Fahrenheit.

Chandra studies slightly less powerful million-degree X-ray processes like the enormous heating of gas and dust sucked into ravenous black holes. The Hubble Space Telescope is primarily a visible-light instrument, sensitive to the radiation emitted by stars, galaxies and interactions that generate temperatures measured in the thousands of degrees.

SIRTF is optimized to capture infrared emissions from objects and processes that generate temperatures of a few hundred degrees or less.

Barriers to Space: And Why They Should Be Overcome

By Douglas Vakoch, Special to SPACE.com

posted: 07:00 am ET,11 September 2003

"It's extremely difficult to live and work in space," says psychologist Albert Harrison, who compares a stint onboard the International Space Station to "being in a cramped house with trash piling up." While the wobbly legs of an astronaut just returned to Earth may be the most obvious side-effect of a year-long space mission, simply getting along with other astronauts for months at a time may be even harder.

According to Harrison, author of Spacefaring: The Human Dimension, "One of the things that the Russians have done with tremendous skill and daring is to build a record of increasingly long space flights. Our own astronauts gained experience on Skylab and later on Mir and the ISS." As a result, "the people that go up into space have been able to get along with one another. They work out patterns of mutual existence, living under conditions where they're cramped together." In orbit 240 miles above the Earth's surface, astronauts who tire of being in close quarters have "very little opportunity to get away."

And in their celestial home away from home, there's little room for solitude. Long gone are the days of the Mercury space capsules, with room for only one astronaut on missions measured in hours. But like their predecessors, Harrison says, today's "astronauts still have the 'Right Stuff,' it's just that it's redefined a little bit."

"The 'Right Stuff' has sort of expanded," in Harrison's view. Modern astronauts are "still highly competent and motivated and they're still cool. Today they don't have to be fighter pilots with great kill ratios ... but they do have to be able to get along with one another in ways that weren't required in the 1960s." The challenges of long-term amity can become even more difficult when astronauts come from cultures with different ways of relating to others. "Today's international crews," says Harrison, "raise the complexity. A lot of effort goes into ensuring that international crews can function comfortably."

The Greatest Obstacle

But interpersonal strife is far from the worst threat to a stable space program. Commenting on the space program in the United States, Harrison says if he had "to pick one problem which is greater than others, I think it's national will, our desire to go to space, to provide the political infrastructure and the economic support to realize that dream."

Harrison identifies three critical ingredients to a successful space program: technology, money, and commitment. "We do have the technology, and if we choose to spend it, we do have the money." But in recent years, he says, America hasn't maintained a commitment to a strong presence in space.

Though the Russians and the Chinese may have fewer resources, Harrison could well imagine either country soon surpassing the United States in space. "The Russians are a little short on cash, the Chinese are a little short on technology, but they both seem to be very determined, and it's quite possible that one day within the next five years or so-somewhere around 2007, 2008 we will see a Russian space station with tourists and a Chinese manufacturing facility."

Risky Business

"We're all happy to see the smiling faces and occasional clowning around of astronauts, on the shuttle or in the space station," Harrison says, but he warns, "We should never lose sight of exactly how dangerous and how demanding and how exacting space travel is."

Six months ago, the world was reminded of these dangers when the Columbia space shuttle exploded. Such risks, Harrison says, can never be eliminated completely. "The reality is that whenever we go where people have not gone before, wherever we try something new, there's a certain level of risk. No, we don't want people to die, they don't want to die, we do everything we can to keep them alive, they do everything they can to stay alive, but it is a cost of doing this kind of business."

Harrison was particularly struck by the unanimity of those closest to the Columbia astronauts in calling for continued exploration. "The families of the astronauts that died, the other astronauts, NASA officials, the greater Johnson space community, the greater NASA community, all came forward and said, 'This is very terrible, it's very sad, but we want space exploration to continue. This is what they would have wanted.'"

Worth the Cost

In light of all these risks, is space exploration really worth it? For some, the appeal of space is economic, though Harrison advises any potential investors to take a very long-term view. While manufacturing opportunities in zero-gravity or asteroid mining may some day be a paying proposition, Harrison warns that "it's a long way from where we are now until you start getting interest on the money that you put into this."

Harrison also emphasizes the knowledge that can be gained through space faring: "We make tremendous advances in science as a result of our exploration of space." While much of this knowledge is about outer space, some has a deeper, inner significance. After looking down on our planet from orbit, where political boundaries aren't evident, some astronauts have reported a deeper understanding of the interconnectedness of all life on Earth. As Harrison summarizes their experience, "It's one planet, one people."

Though a more holistic view of Earth may help us survive as a species, Harrison suggests it may not be enough. Instead, he says that space travel might help us insure that humankind will continue to exist, even in the face of widespread disaster on our home world: "As soon as we're able to become a two planet species, as soon as we're not limited to Planet Earth, we can protect ourselves, or we can at least protect the human future, from any global level catastrophe or extinction level event."

In spite of the obstacles to space travel, Harrison remains optimistic: "I see a long, tough road, to tell you the truth, but I think that we'll eventually get there ... that we'll get back to the Moon, we'll get to Mars."

"If we don't run out of money, if we don't lose the practical know-how that we've built up, I think that our eventual movement into space is inevitable."

Quick Bites

The Galileo spacecraft will end its mission September 21, 2003 with a planned impact into Jupiter. Launched in 1989, Galileo has been exploring Jupiter and its moons since December 1995.

NASA announced the selection of the "Phoenix" mission for launch in 2007 as what is hoped will be the first in a new line of "Scout" missions in the agency's Mars Exploration Program. Press Release from the Jet Propulsion Lab. [August 4, 2003.]

New count on planetary moons . . .

- Jupiter --- forty and counting . . . . . newest names: Autonoe, Thyone, Hermippe, Aitne, Euerydome, Euanthe, Erporie,Orthosie, Sponde, Kale, Pasithee. Two moons have not yet been named.

- Saturn --- thirty and counting . . . . . newest names: Ymir, Paaliaq, Tarvos, Ijiraq, Suttung, Kivnig, Mundilfori, Albiorix, Skadi, Erriapo, Siarnaq, Thrym

- Uranus --- twenty-one and counting . . . . . newest name: Trinculo

- Neptune --- eleven and counting . . . . . . The three newest moons have not yet been named.