INTRODUCTION TO AEROSPACE ENGINEERING

Early Flight to World War I

Overview

- Early Uses of Lighter-than-Air Flying Machines
- Heavier-than-Air Flying Machines
  - The US Army's Reaction to the Wright Brothers' Invention
  - The Army's Requirements for the First Military Aircraft
- Early Uses of Airpower

Early Years of Flight Introduction

- Man first flew aloft in a balloon in 1783
- Airpower did not have an immediate impact
- Flying machines were not readily accepted by land oriented officers
- Airpower’s first major impact was not until World War I

Balloons

- Mongolier Brothers flew first hot-air balloon in 1783
- Ben Franklin saw first balloon flight and immediately saw the military potential
- First used for military purposes by the French in 1794 at Maubege
- Union and Confederate forces employed balloons during the American Civil War

Balloons (Cont)

- Adolphus V. Greely, the grandfather of military aviation in US, revived interest in military capability of balloons in 1891
  - 1892 -- Greely balloon used to direct artillery fire during the Battle of San Juan Hill
- Interest in balloons dropped quickly with the development of heavier-than-air vehicles

Dirigibles

- Steerable balloons -- often called “Airships”
- 1884 -- first successful flight in a dirigible
- Ferdinand Von Zeppelin -- person most readily identified with dirigibles
  - Zeppelins first flown in 1900
  - Germans used to bomb England in WW I
  - Germans used to fly observation cover for their surface fleet in WW I
- Vulnerable to winds and ground fire

The Early Years of Flight

- Uses of Balloons and Dirigibles
  - Reconnaissance
  - Artillery spotting
  - Bombing (extremely limited prior to WW I)
  - Morale Booster/Mail/Escape Means
  - Air transport of supplies

Early Pioneers of Flight

- Otto Lilienthal -- studied gliders and first to explain the superiority of curved surfaces
- Percy Pilcher -- built airplane chassis
- Octave Chanute -- Developed a double winged-glider/wrote history of flight to1900
- Samuel P. Langley -- First to secure government support to develop an airplane
  - Failed twice to fly from houseboat in 1903
  - Congress withdrew monetary support

Orville and Wilbur Wright

- First to fly a heavier-than-air, power-driven machine -- 17 December 1903
  - Flight traveled 120 feet and lasted 12 seconds
- Approached flying scientifically and systematically
- Used experience of Lilienthal, Pilcher and Chanute
- Built a glider in Dayton in 1899
  - Moved to Kitty Hawk, N. Carolina in 1900

Reactions to the Wright's Invention

- US government was very skeptical at first
  - Not interested because of the Langley's failures
- Britain and France were very enthusiastic
- President Roosevelt directed the Secretary of War, W. H. Taft, to investigate the Wright Brothers' invention in 1906
- Dec.1907 -- Chief Signal Officer, BG James Allen, issued Specification # 486 calling for bids to build the first military aircraft

Signal Corps Specification # 486

- Established the requirements for the first military aircraft. Aircraft must be able to:
  - Carry 2 persons
  - Reach speed of 40 mph
  - Carry sufficient fuel for 125 mile nonstop flight
  - Be controllable in flight in any direction
  - Fly at least one hour
  - Land at take-off point, without damage
  - Be taken apart and reassembled in one hour
  - No Military Operational Requirements Specified

Specification # 486 (Cont)

- 41 proposals were received, only 3 complied with specifications
- US Army signed contract with Wright Brothers on 10 Feb 1908
- Wright Brothers delivered the first military aircraft on 20 Aug 1908
- US Army accepted the first operational aircraft on 2 Aug 1909

The Early Years of Flight
Closing Remarks

- Until WW I balloons, dirigibles and aircraft were primarily <u>reconnaissance</u> vehicles
- Early on, the flying machines were not seen as weapons of war
- Few believed the flying service was ready to be a separate air force
- The potential uses of the airplane would evolve considerably during WW I

Summary

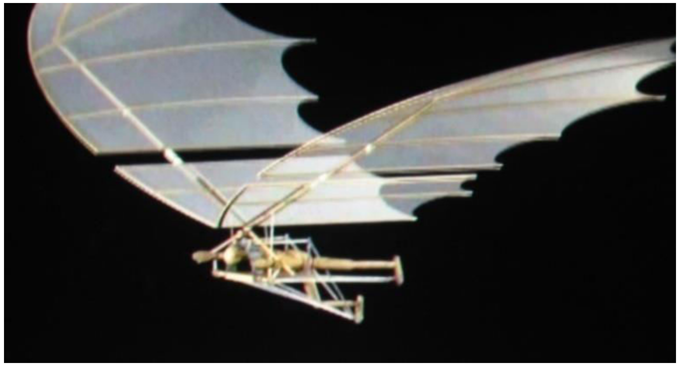
- Early Uses of Lighter-than-Air Flying Machines
- Heavier-than-Air Flying Machines
  - The US Army's Reaction to the Wright Brothers' Invention
  - The Army's Requirements for the First Military Aircraft
- Early Uses of Airpower

History of Flight

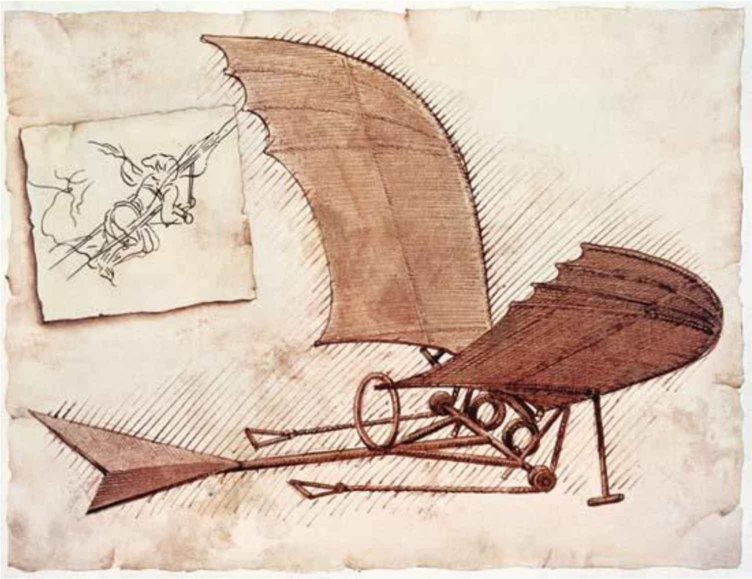
Aviation Through the Ages 1000B.C to 1250A.D

- Man's observations of the earth around him aroused his curiosity and often inspired him to attempt the impossible. How did man's lack of knowledge of the physical laws of nature sometimes bring him tragedy?
- **The Greek myth of Daedalus and his son Icarus was written around 1000 B.C. The myth states that after Daedalus built the labyrinth the king of Crete threw him in it to test it. He and his son Icarus escaped by building wings of wax and flying away. However Icarus flew too high and the wax in his wings began to melt. His wings collapsed and he plunged to his death in the sea.**
- **Kites flown around the year 400 B.C. in China were ancestors of modern aviation and the airplane. In the year 1020 A.D. Oliver of Malmesbury put on a pair of wings and leapt from the top of an abbey. He landed very hard and broke his legs. Luckily he survived the crash. Many others attempted to fly with "wings" but all failed, sometimes fatally.**

Aviation Through the Ages
1250 to 1750



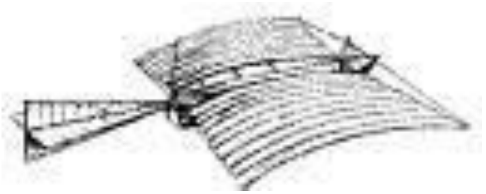
- I was one of the first to experiment with the science of flying. Unfortunately my writings and sketches weren't discovered until three hundred years after my death.
- **Leonardo da Vinci spent most of his life exploring flight and left the world about 160 documents of sketches and observations about flight. He made important discoveries about the center of gravity, the center of pressure, and streamlining. But like so many people of his time he was obsessed with learning to fly like a bird. What is the difference between simply gliding and really flying like a bird?**



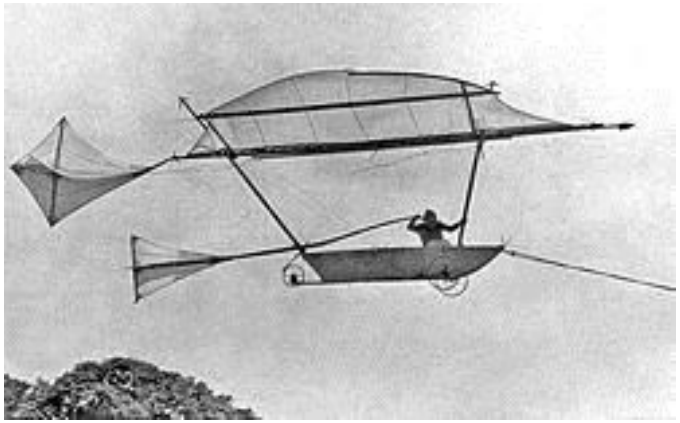
Aviation Through the Ages 1750 to 1850

- What forces cause smoke to rise in a fireplace? This was what sparked Montgolfier's curiosity.
- **Joseph and Etienne Montgolfier designed the first successful flying craft. Their observations led them to believe that burning created a gas, which they called "Montgolfier's gas," causing a craft to rise. They constructed a balloon made of cloth and paper. The first aviators were a duck, rooster, and a sheep. Then in 1783 a crowd in Paris watched as a Montgolfier balloon carried two French men. The way the balloons worked is hot air and gases filled the balloon causing it to lift. Once it was in the air it simply went wherever the wind took it. To counter this problem Henri Giffard designed a round oval shaped balloon called a [blimp] and combined it with a steam engine to make it steerable. When gasoline engines were invented they became a major source of transportation across the Atlantic Ocean. The Hindenburg [zeppelin] disaster in 1937 caused the end for these large [airships].**

Aviation Through the Ages 1850 to 1900



- Sir George Cayley set in motion the future study of aerodynamics in a single sentence. "The whole problem is confined within these limits, namely to make a surface support a given weight by the application of power to the resistance of air."
- **Sir George Cayley experimented with gliders at his home in Yorkshire. He was the first to discover how wings work. Cayley discovered that wings are lifted on the air. He also constructed the first aircraft that was heavier than air. He is now recognized as the father of aviation. He came up with many principles of heavier-than-air flight.**



Aviation Through the Ages 1850 to 1900

- **In 1896, the German engineer, Otto Lilienthal, tested several monoplane and biplane gliders. He built and flew the first glider capable of carrying a person, but died when he crashed in a sudden gust of wind before he could finish his powered plane.**
- **The structure of an airplane as we know it today was in its formative years. What are the parts of a plane and how does each function?**

AIRPLANE

- An **airplane** is a vehicle heavier than air, powered by an engine, which travels through the air by the reaction of air passing over its wings.
- **FUSELAGE**
  The **fuselage** is the central body portion of an airplane which accommodates the crew and passengers or cargo.
- **COCKPIT**
  In general aviation airplanes, the **cockpit** is usually the space in the fuselage for the pilot and the passengers: in some aircrafts it is just the pilot's compartment.
- **LANDING GEAR**
  The **landing gear**, located underneath the airplane, supports it while on the ground.
- **WINGS**
  Wings are the parts of airplanes which provide lift and support the entire weight of the aircraft and its contents while in flight.

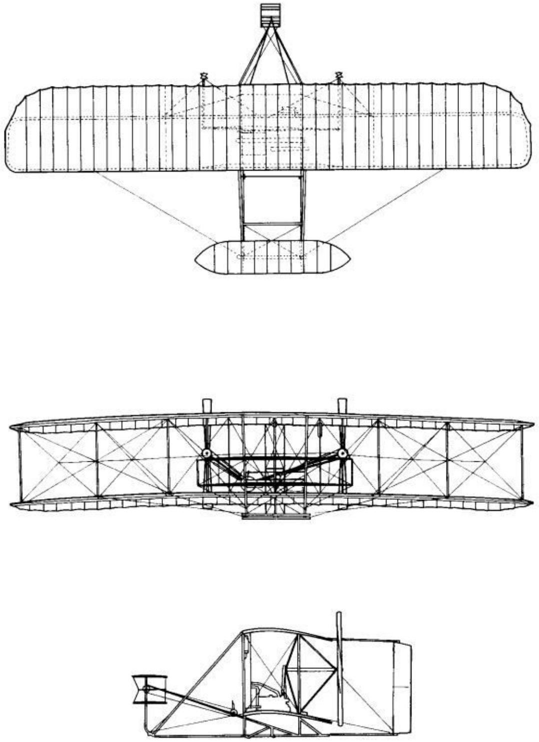
EXPERIMENT 2
Equipment:

- 2 sheets of notebook paper
- Hold two sheets of notebook paper about four inches apart. Blow between them. Instead of flying apart they come together. The air moving rapidly between the two pieces of paper has less pressure than the air pressing on the outer sides of the paper.

Equipment:
Ping-pong ball

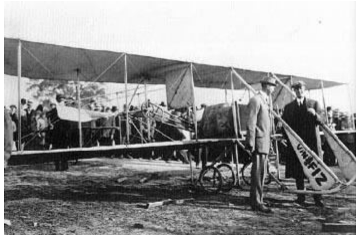
- Tank-type vacuum cleaner
- Connect the hose to the blower rather than to the suction end of the vacuum cleaner. Turn the switch on. Hold the hose vertically so the stream of air goes straight up. Release the ping-pong ball into the stream of air about a foot from the nozzle. Slowly tip the nose so that air shoots at an angle. The ball will stay suspended in the airstream. The force of gravity upon the ball tends to make it drop out of the airstream. However, the fast moving airstream lessens the air pressure on the portion of the ball remaining in the airstream, overcoming the force of gravity, which results in the ball remaining suspended.

Aviation Through the Ages
1900 to 1935



- "Only those who are acquainted with practical aeronautics can appreciate the difficulties of attempting the first trials of a flying machine in a 25-mile gale. . . but. . . we were determined. . . to know whether the machine possessed sufficient power to fly."
- That was Wilbur Wright's statement to *The Associated Press,* January 5, 1904.
- **At 10:35 a.m. on December 17, 1903 the world's first successful airplane known as the *Flyer I* accelerated along its launching rail and flew through the air. Twelve seconds later it landed 100 yards away on the soft sand at Kill Devil Hills near Kitty Hawk, North Carolina. The pilot Orville and his brother Wilbur had experimented for four years with kites and engines to make the first successful flight ever.**
- **The brothers had made their own engine that weighed 200 pounds and had four cylinders. It could make 12 horse power, a sixth of the engine power of a small car. It had no seat and the pilot had to lay in a cradle in the bottom wing.**

Aviation Through the Ages
1900 A.D to 1935 A.D



- **The Wright brothers continued to perfect their plane and it was in a Wright biplane that the first transcontinental flight was made by Calbraith P. Rodgers, in 1911.**

  The key to their success was to learn how to control the plane. How were they able to accomplish this task?

- **In 1914 World War I broke out. At first planes were used mostly for reconnaissance, but later planes developed into biplane and triplane fighters and bombers. Experiments were done with even more sets of wings, but most failed. The main fighters of the war were the British Sopwith "Camel," its cousin, "The Snipe," and the famous German Fokker Df.I which was flown by the infamous Red Baron. Aerial tactics and strategies were developed during the middle of the war. Germany developed many fighter tactics that are still in modified use today. The compass was an important instrument to these early fighters. How do they work? How has the technology changed over the decades?**

Aviation Through the Ages 1900 to 1935

- After the war General Billy Mitchell became an advocate for military aviation. He and his pilots achieved many firsts in the field of aviation during these golden years. But the Europeans were leading the race in commercial flight. It wasn't until Ralph Pulitzer offered a trophy to promote high-speed flight and began a national craze for air races that the American public began to take notice.
- In 1918, the Post Office Department started airmail service in the United States. The first Mailwing was built by Pitcairn Aviation, Inc. In 1926, Congress passed the Air Commerce Act. This established an Aeronautics Branch within the Department of Commerce. They were authorized to license planes and pilots and provide standards for commercial flight. And in 1927, Charles Lindbergh completed the first transatlantic flight. He instantly became a world hero.
- Amelia Earhart was the first woman to fly solo across the Atlantic in 1928.

Aviation Through the Ages

1935 A.D to 1950 A.D

- New technologies developed throughout the course of World War II. The motto was if you commanded the skies you could win the war.
- **World War II implemented almost exclusively monoplanes. Both sides of the war manufactured literally thousands of fighters and bombers. The main Allied planes included the British Supermarine Spitfire Mk.IV, the American P-51 Mustang, the American C-4U Corsair, the American B-17, and the American B-29 Superfortress. The Grumann F6F Hellcat was first used in 1943 and became the premier carrier fighter plane. The main Axis planes were the Bf109, the Junkers Ju-22, and the Stuka dive-bomber. The mainstay of the Japanese forces was the feared Mitsubishi Zero-sen. Our hangar also includes the North American T28 B and the AT-6 Texan, other planes from this period.**

Aviation Through the Ages 1935 A.D to 1950 A.D

- **The major air battle of WW II was the Battle of Britain. For days the much larger German Luftwaffe attacked the British Isles, but the small number of British Spitfires always seemed to know exactly where and when the German bombers would be attacking and how large of a force.
The reason for this was a relatively new technology called radar allowed the British ground stations to detect and identify the size, speed, distance, and trajectory of the German bombers and send their Spitfires on perfect intercept missions.**

Aviation Through the Ages
1935 A.D to 1950 A.D

- **Instrumentation was crude in comparison to today's technology. In the early days pilots relied on landmarks and sometimes even pre-set bonfires to guide them along their way. What were the early instruments like and what were their functions? How has instrumentation evolved through the ages?**
- **In the late 1940's, the military had developed the jet engine and began changing over to jet fighters. This resulted in faster and better performing craft. New aviation records were set. In 1947, Chuck Yeager broke the sound barrier.**

Aviation Through the Ages 1950 A.D to 1975 A.D

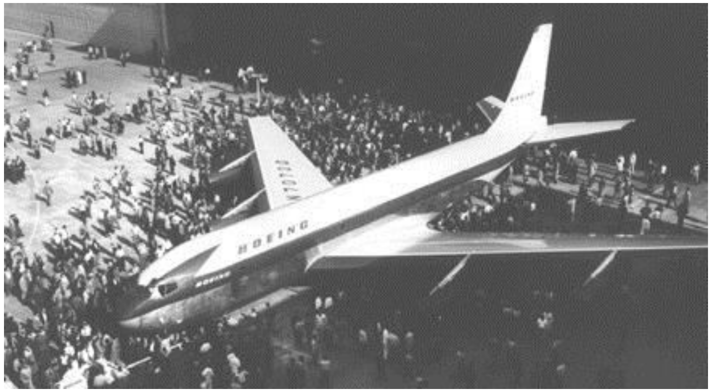
- After Chuck Yeager's supersonic flight in 1947, aviation entered a new era dominated by jets.
- **The years following the war saw the aviation industry grow in leaps and bounds. The military airforce developed more effective planes to address the arms race with Russia. The B-47 and B-52 bombers were built to be used to deliver nuclear bombs. They were the world's heaviest bombers and could hold up to 99,206 pounds of bombs. Early bombers flew so high that the crew had to wear pressure suits but later they were used at low altitude because they were harder to locate with radar.**

Aviation Through the Ages
1950 A.D to 1975 A.D

- **In September, 1955, a contract was awarded to North American Aviation for the X-15 plane which could fly at 4,500 miles per hour at an altitude of at least 70,000 feet. 54 percent of its total weight was its fuel (18,000 pounds). The total weight of the X-15 was 33,000 pounds. Though only three of this type of plane were built they flew a total of over 200 times. The highest speed ever reached was about 4,525 miles per hour or Mach 6.72.**

Aviation Through the Ages
1950 A.D to 1975 A.D

- **In 1958, the first American commercial jet, the 707, was put into service by the Boeing Company. The commercial liners were an instant hit with passengers who appreciated the faster flying time. Again new records were set. By 1966 both Lockheed and Douglas Aircraft Corporations had entered the commercial industry giving rise to competition and the development of new technologies.**
- **During the Vietnam War the use of military air power was somewhat limited by policy in Washington. President Nixon launched the only strategic bombing campaign of the war. Many fliers were shot down over Southeast Asia. They were recently honored in a ceremony dedicating the Missing Man Monument at Randolph Air Force Base, in Texas.**



Aviation Through the Ages

1975A.D to 2000A.D

- Aviation has changed much since the beginning of time.
- **The world's first supersonic commercial passenger aircraft operating regular scheduled flights was the Concorde. It was developed jointly by Great Britain and France during the 1960s and 1970s when the Comet 4, the DC-3, and the Constellation were in regular service. No other supersonic aircraft can fly as fast and as far as the Concorde without needing mid-flight refueling. Some military aircraft can fly faster, but need in-flight refueling. The Concorde flies literally on the edge of space, high through the atmosphere. Passengers are even capable of seeing the earth's surface.**

- **The Nighthawk (F-117A) first flew in 1981 and began combat in 1989. This jet was designed to avoid detection and mount precision attacks. It is the first stealth combat aircraft in the world. It has a top speed of 593 mph (955 kph) and is loaded with 5,000 lbs. of weapons. The choice of weaponry varies from laser-guided bombs, air-to-air missiles, or air-to-surface missiles. Two types of weapons can be carried at one time. The outside of the Nighthawk is coated with a special material that absorbs some of the radar signals that strike it. It is protected by 24 hour security with armed guards all around it. Authorized personnel must pass a palm print test to get near the aircraft.**

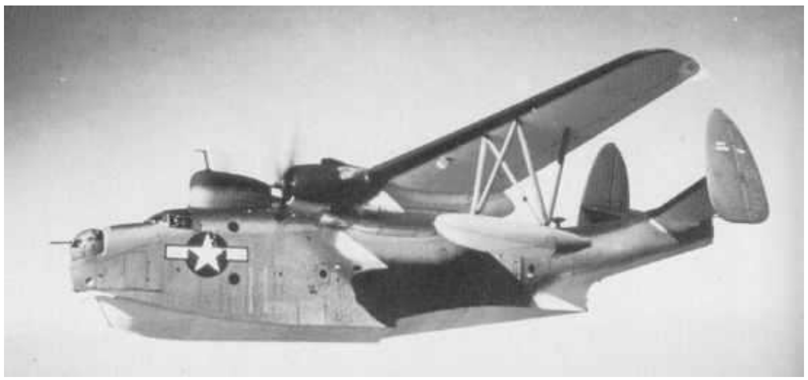
Aviation Through the Ages 1975A.D to 2000A.D

- **The CL-415, or "Firebird," is a very important aircraft. This aircraft is amphibious, which means it can be operated from land or water. It was developed by Canadair to stop raging forest fires. However, it is also useful for search and rescue missions, especially on the sea. It can search for survivors for up to seven hours before refueling. It can scoop water into its tanks. Through doors in the bottom of the aircraft it drops water on the fire.**
- **The age of computers continues to impact the aviation field. Today's technology is exciting and it seems as if "the sky's the limit" as we look into the future.**

Aviation today and tomorrow

- Boeing 787
  designed completely on the computer
- will carry 250 - 290 passengers on routes of 8,000 to 8,500 nautical miles
- The airplane will use 20 percent less fuel for comparable missions than today's similarly sized airplane. It will also travel at speeds similar to today's fastest wide bodies, Mach 0.85. Airlines will enjoy more cargo revenue capacity.

Martin Aircraft - Maryland



A PBM-3 Martin Mariner in flight

- 1937 Mini-Mariner, the flying prototype of the WWII flying boat bomber

Martin PBM-5A Mariner.
This was the only amphibious version of the Mariner.

Basic Properties of the Atmosphere

Essential Points

1. Heat, Temperature and Temperature Scales
2. The Electromagnetic Spectrum
3. Composition of the Atmosphere
4. Layers in the atmosphere are defined by temperature profiles
5. How pressure varies in the atmosphere
6. Principal weather instruments
7. Earth’s radiation budget

Heat and Temperature

- Temperature: *Average* energy of molecules or atoms in a material
- Heat: *Total* energy of molecules or atoms in a material
- Can have large amount of heat but low temperatures
- Can have high temperatures but little heat

Heat and Temperature

- The earth's outermost atmosphere is extremely "hot" but its heat content is negligible
- The surface of the moon can reach 250 F in sunlight and -200 F in shadow, but the vacuum around the Apollo astronauts contained no heat.
- It takes time for things to warm up and cool off.

Temperature Scales

- Fahrenheit
  - Water Freezes at 32 F
  - Water Boils at 212 F
- Centigrade or Celsius
  - Water Freezes at 0 C
  - Water Boils at 100 C
- Two scales exactly equal at -40

Absolute Temperature

- Once atoms stop moving, that's as cold as it can get
- Absolute Zero = -273 C = -459 F
- Kelvin scale uses Celsius degrees and starts at absolute zero
- Most formulas involving temperature use the Kelvin Scale

Electromagnetic Radiation

- Radio: cm to km wavelength
- Microwaves: 0.1 mm to cm
- Infrared: 0.001 to 0.1 mm
- Visible light 0.0004 – 0.0007 mm
- Ultraviolet 10^{-9} – 4 x 10^{-7} m
- X-rays 10^{-13} – 10^{-9} m
- Gamma Rays 10^{-15} –10^{-11} m

Composition of the Atmosphere

- Nitrogen 78.08%
- Oxygen 20.95%
- Argon 0.93% (9300 ppm)
- Carbon Dioxide 0.035% (350 ppm)
- Neon 18 ppm
- Helium 5.2 ppm
- Methane 1.4 ppm
- Ozone 0.07 ppm

Other Components of the Atmosphere

- Water Droplets
- Ice Crystals
- Sulfuric Acid Aerosols
- Volcanic Ash
- Windblown Dust
- Sea Salt
- Human Pollutants

Structure of the Atmosphere

- Defined by Temperature Profiles
- Troposphere
  – Where Weather Happens
- Stratosphere
  – Ozone Layer
- Mesosphere
- Thermosphere
  – Ionosphere

4. Layers in the atmosphere are defined by temperature profiles

Troposphere

- Heating of the Surface creates warm air at surface
- Warm air rises, but air expands as it rises and cools as it expands (Adiabatic cooling)
- Heating + Adiabatic Cooling = Warm air at surface, cooler air above
- Buoyancy = Cool air at surface, warmer air above
- Two opposing tendencies = constant turnover

Stratosphere

- Altitude 11-50 km
- Temperature increases with altitude
- -60 C at base to 0 C at top
- Reason: absorption of solar energy to make ozone at upper levels (ozone layer)
- Ozone (O_3) is effective at absorbing solar ultraviolet radiation

Mesosphere

- 50 – 80 km altitude
- Temperature decreases with altitude
- 0 C at base, -95 C at top
- Top is coldest region of atmosphere

Thermosphere

- 80 km and above
- Temperature increases with altitude as atoms accelerated by solar radiation
- -95 C at base to 100 C at 120 km
- Heat content negligible
- Traces of atmosphere to 1000 km
- Formerly called Ionosphere

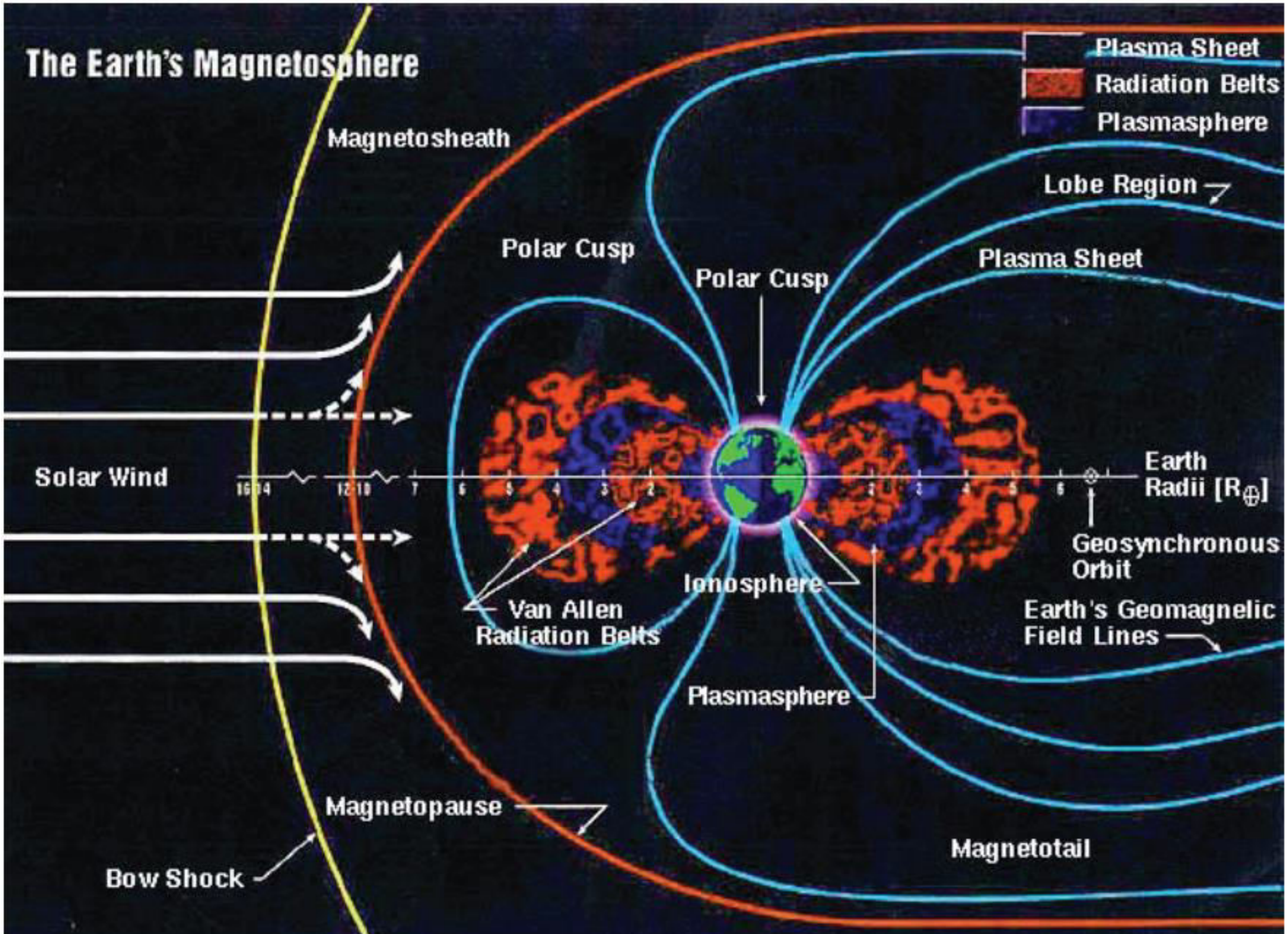
Why is the Mesosphere so Cold?

- Stratosphere warmed because of ozone layer
- Thermosphere warmed by atoms being accelerated by sunlight
- Mesosphere is sandwiched between two warmer layers

How Heat Moves

- Radiation
- Conduction
- Convection

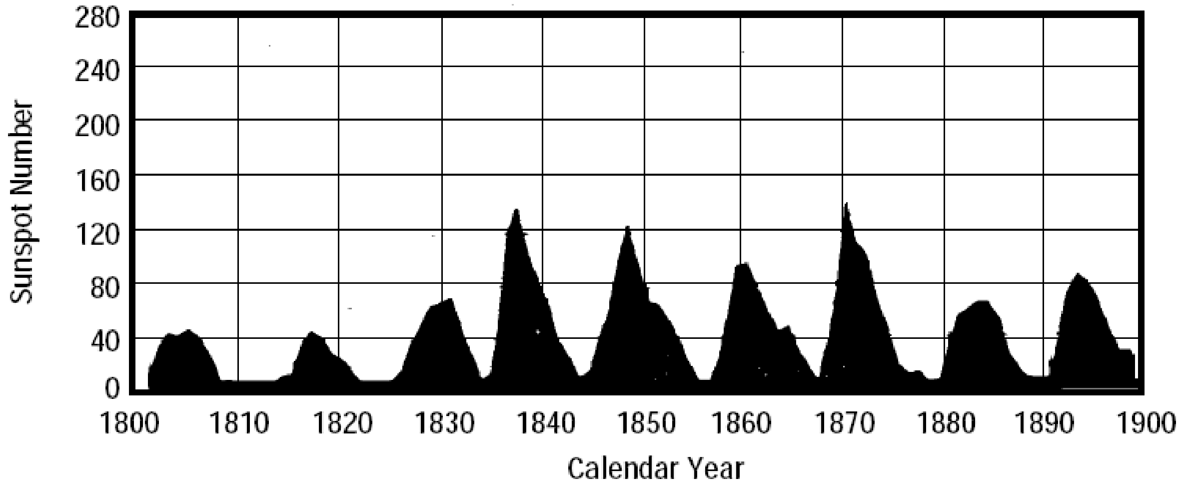
Magnetosphere

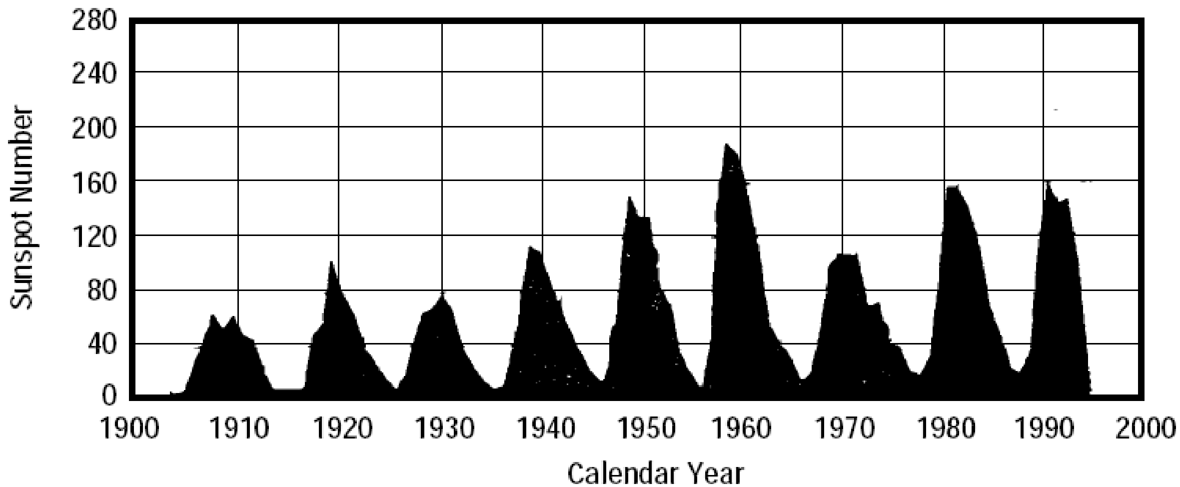


Effects of Spacecraft / Plasma Interactions

- plasma wave generation
- arcing and sputtering at significantly high negative potential relative to the plasma
- spacecraft charging at high inclination orbits
- current balance between the space vehicle and the ambient plasma
- geomagnetic field effects

Solar Environment





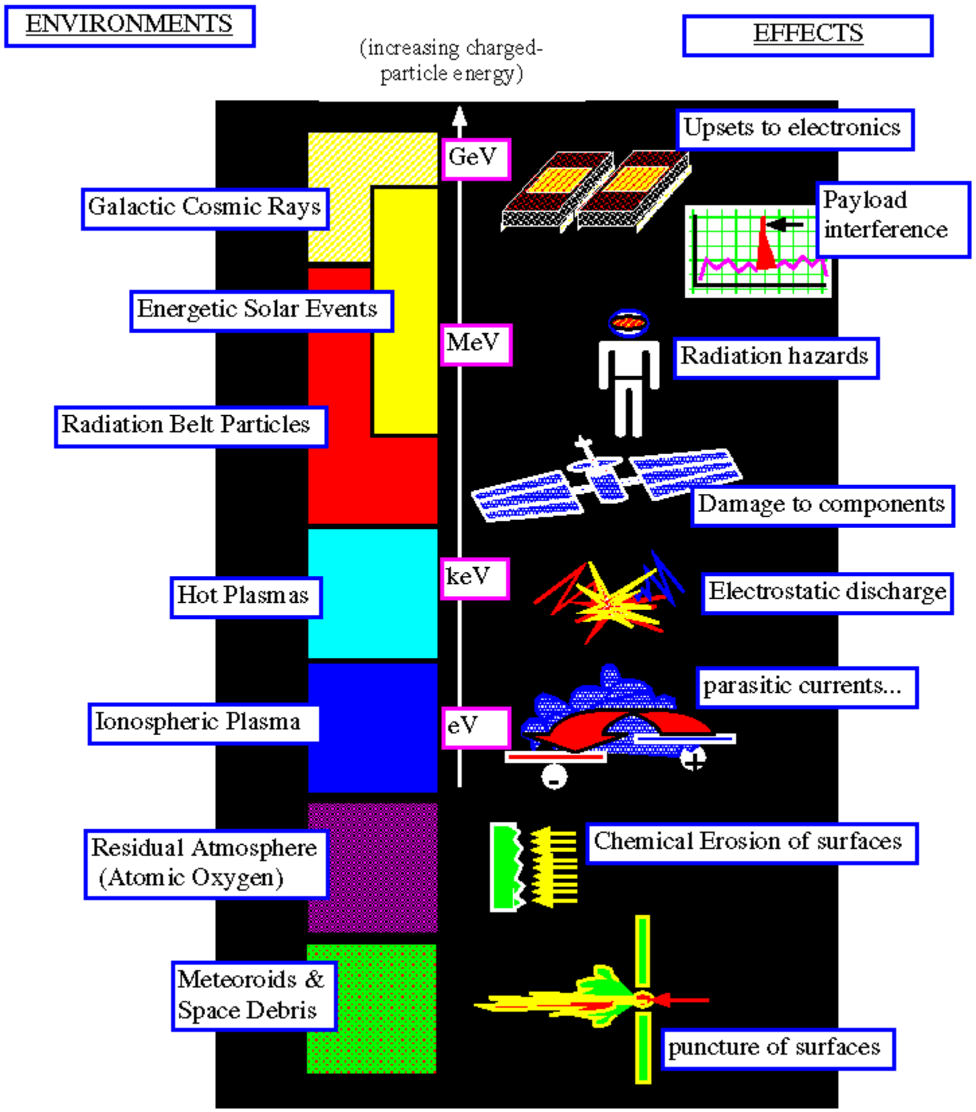
Solar Wind

- The solar wind is a stream of energized, charged particles, primarily electrons and protons, flowing outward from the Sun
- Composition similar to the Sun's corona
  - Protons (~ 70%), electrons, ionized helium, less than 0.5% minor ions
  - Genesis mission
- Approximately 10^9 kg/s of material is lost by the sun as ejected solar wind
- Speed: 200 – 900 km/s
- Solar sail
- Solar wind is also a plasma environment
  - Not just gas
  - Electrically conductive

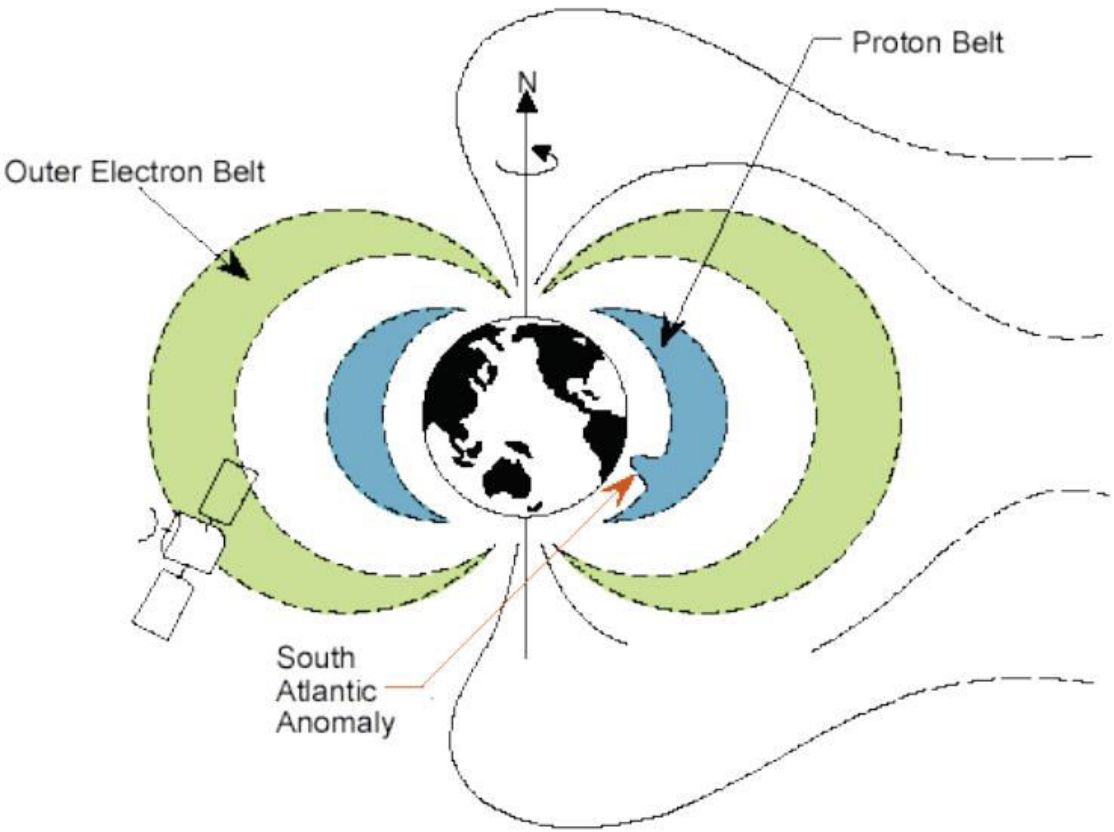
Ionizing Radiation

- Radiation has a major impact on on-board digital circuitry
  - Long-term degradation and failure (ranges from months to years)
  - Short-term, single event effects (SEE)
    - Minor (bit flips)
    - Major (catastrophic burnout)

Radiation Effects

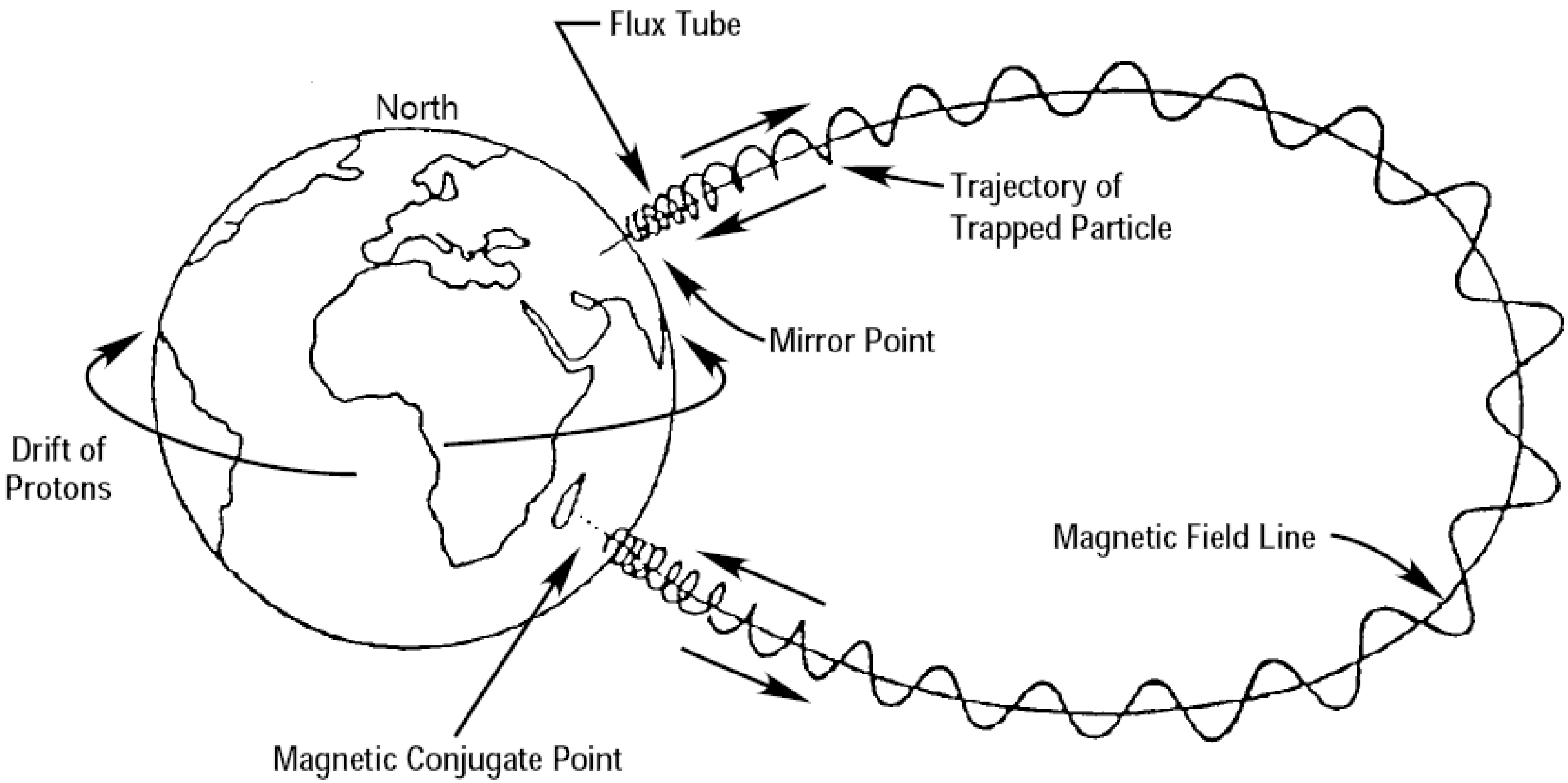


Radiation Belts

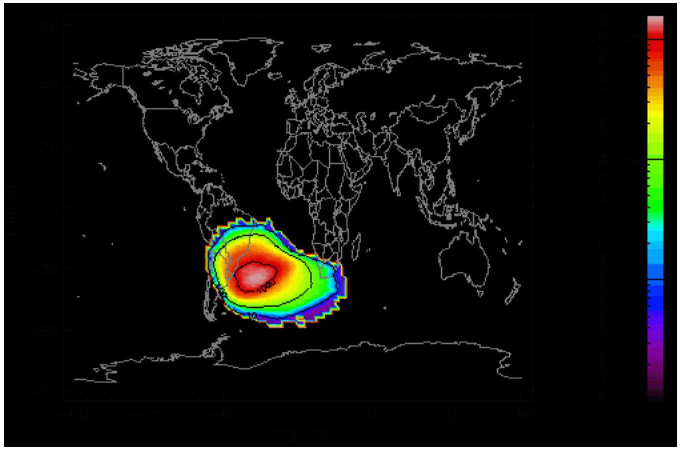


- Two belts (donut shaped)
- Magnetic field traps the particles
- Discovered by Explorer III in 1958
- Composed of
  - Electrons
  - Protons
  - Some heavy ions
- Effects
  - Electrons: total dose
  - Protons: total dose and SEE
  - Ions: SEE

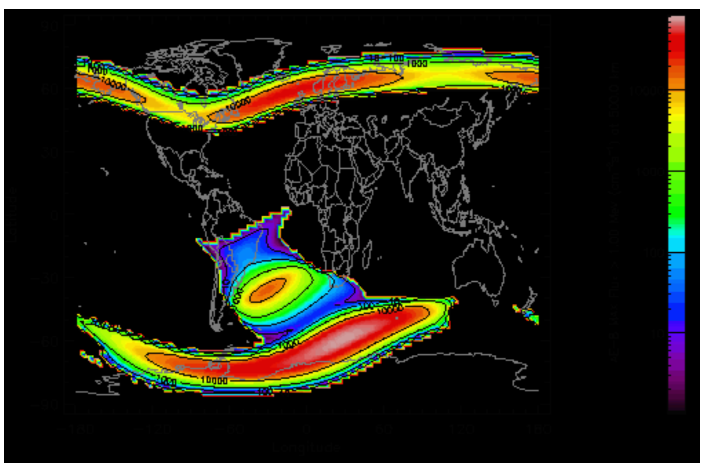
Movement of Particles

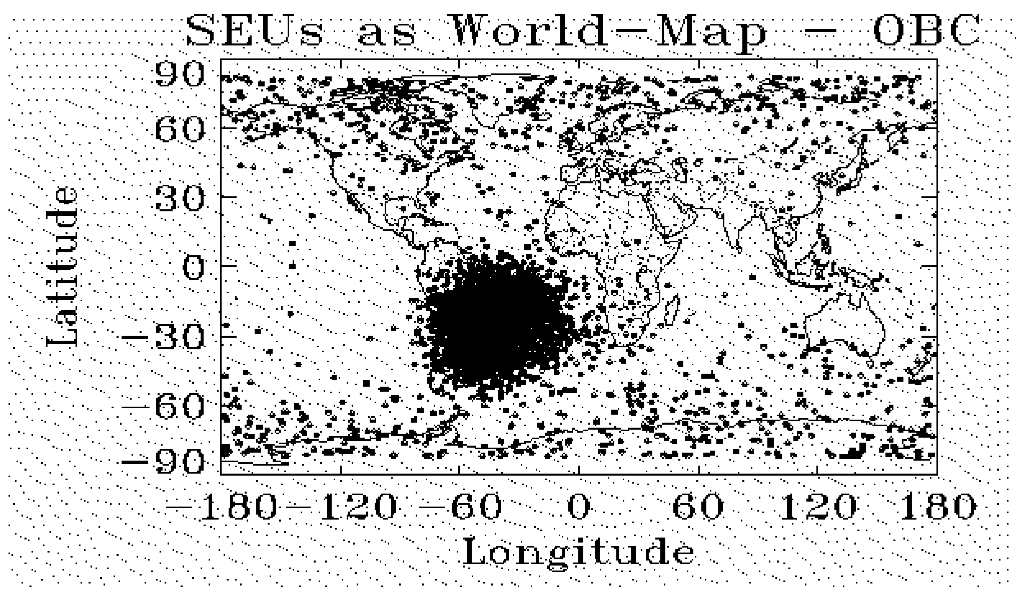


South Atlantic Anomaly



- Magnetic field weaker in South Atlantic
- Result is particle penetration
- Note polar effect as well
- SEU effect on UoSat-2

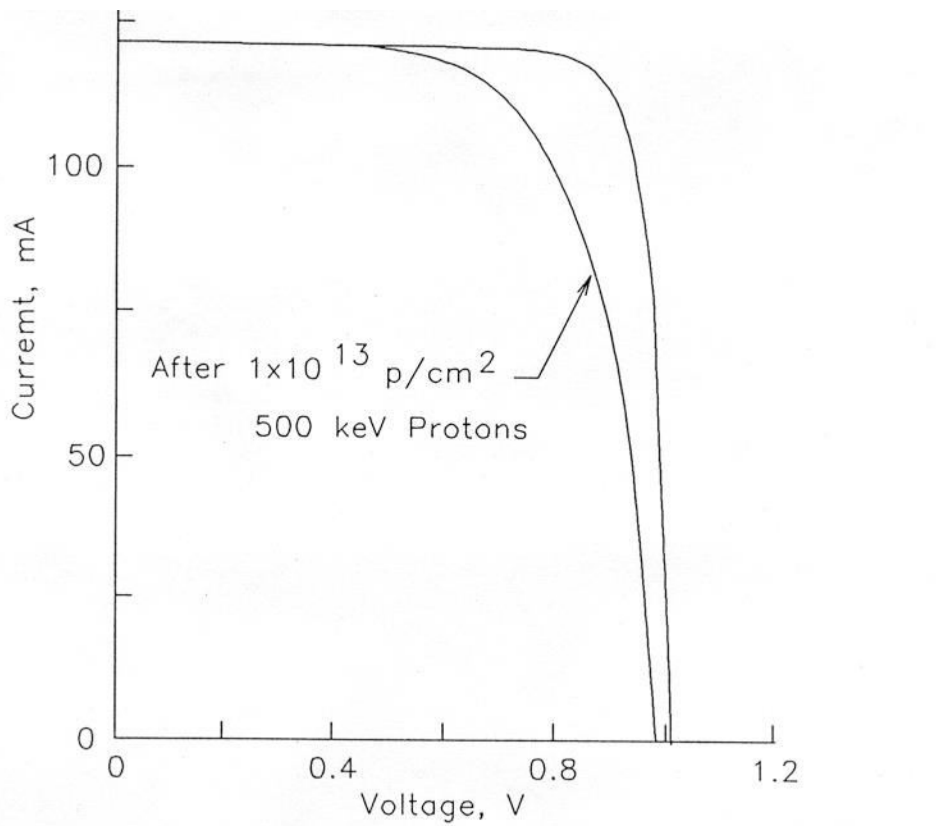




Galactic Cosmic Rays

- High energy particles from interstellar space
- Flux inversely related to solar max periods
- Primary effect
  - Single event upsets

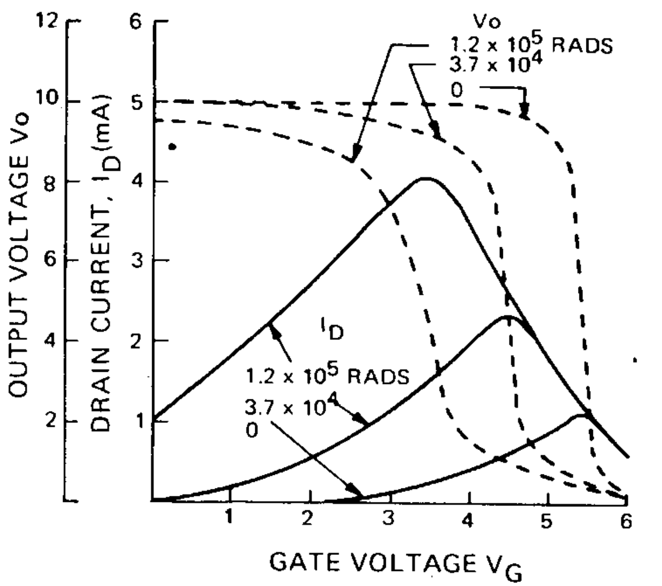
Radiation Effects on Spacecraft: Solar Cells



GaAs/Ge Solar Cell Performance after Irradiation with 500 keV Protons to a Fluence of 1 x 10^{13} p/cm^2

- High energy protons & electrons collide with the crystal lattice structure
- Collisions displace atoms from their lattice sites
- Eventually, the displaced atoms form stable defects
- Defects change the propagation of photoelectrons in the lattice structure

Radiation Effects on Spacecraft: Solid State Devices



Change in CMOS Inverter Transfer Characteristic for Condition I (V_I, the Gate Bias During Irradiation, is 0 Volts for the p-Channel and +10 Volts for the n-Channel; V_{DD} is 10 Volts.

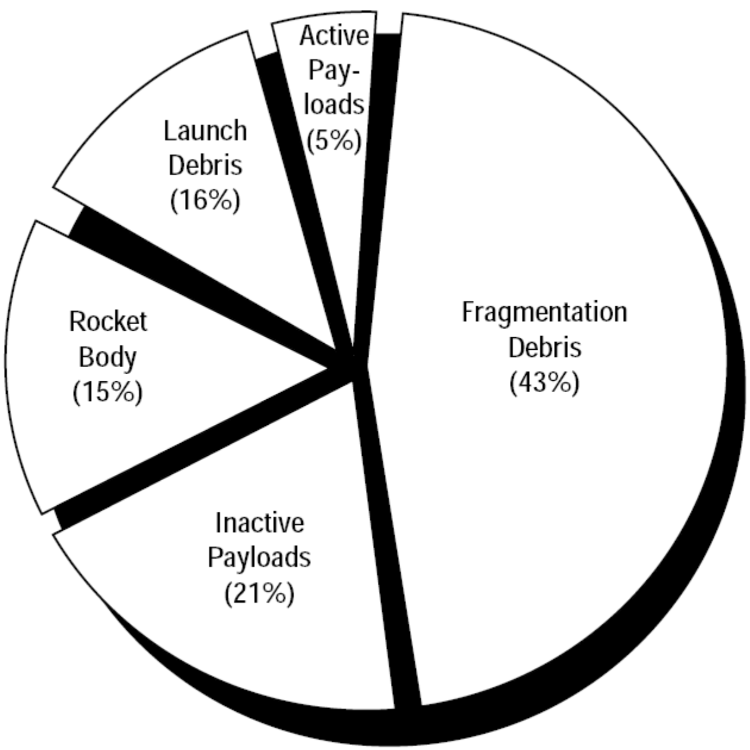
- Nominal MOS or CMOS technology
- Charged Particles:
  - Voltage output of a "GATE" switches abruptly from a "0" to a "1" at a specified voltage
- Radiation:
  - Switching threshold changes
  - Drain current and output voltage also change
- Effects caused by cumulative effect of high energy protons and electrons (Cumulative Dosage measured in rads)

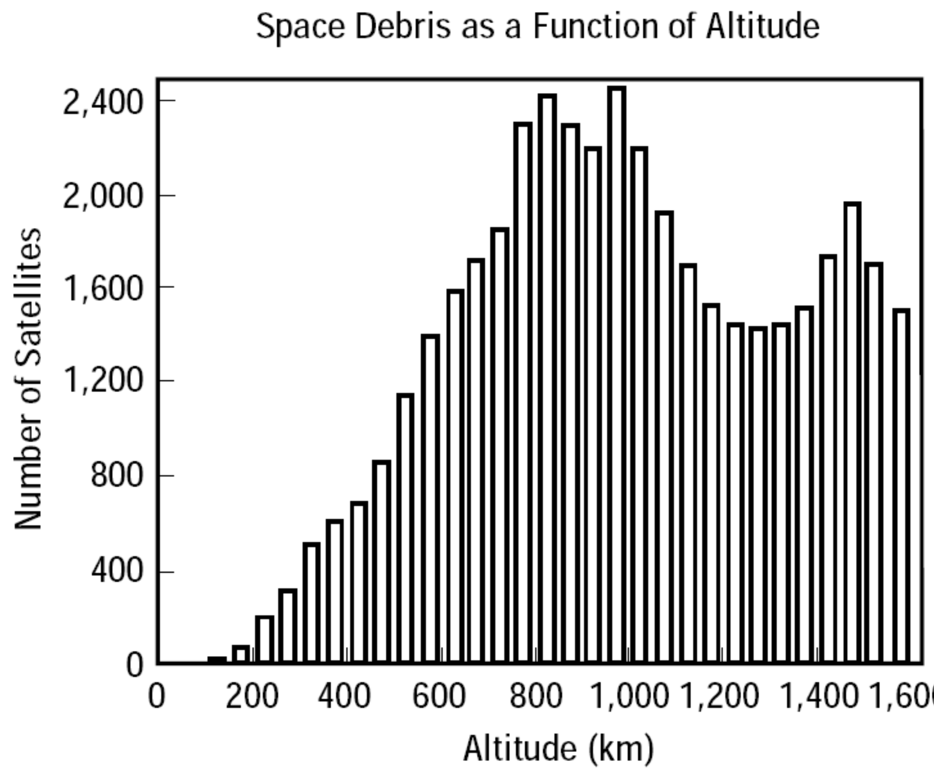
Summary of Radiation Types

Radiation Source	Particle Type	Primary Effects
Trapped radiation belts	Electrons Protons	Ionization damage; Ionization, SEE.
Galactic Cosmic Rays	High-energy, heavy, charged particles	SEE
Solar Flares	Electrons Protons Lower-energy, charged particles	Ionization Ionization, SEE SEE

Meteoroid/Orbital Debris

- Meteoroid population consists the remnants of comets, spent rocket stages, fragments of rockets and satellites, other hardware, as well as operational satellites.





Micrometeoroids/Orbital Debris

- Example collisions
  - Russia/US satellites collision
  - Cerres/Ariane 3rd Stage Debris
- VERY HIGH kinetic energies
- NASA predicted results
  - Fatal spacesuit damage from 0.3 to 0.5 mm particle
  - Catastrophic shuttle damage from 4 mm particle

Micrometeoroids/Orbital Debris: Defense

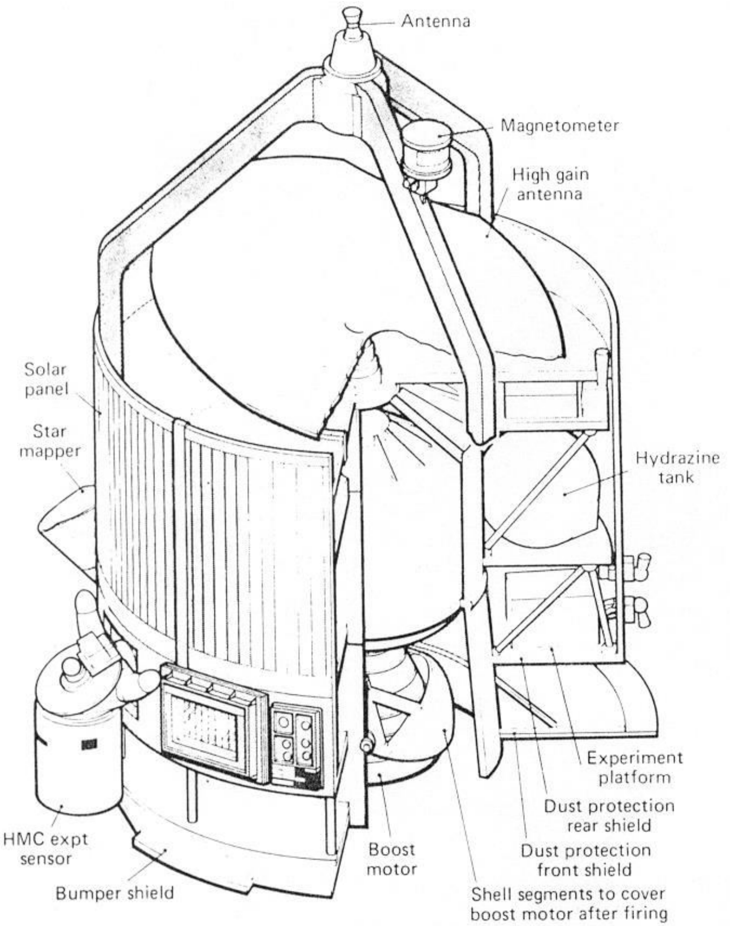


Fig. 3.29 Giotto spacecraft with Whipple meteor bumper.

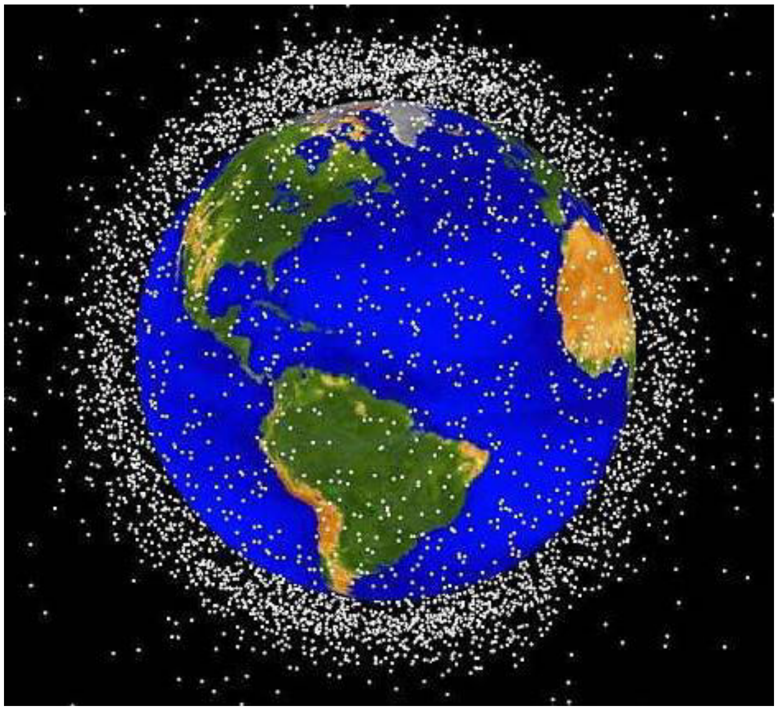
- Double Wall Bumper
  - 1st wall fragments impacting particle into smaller, slower pieces
  - 2nd wall stops those pieces

ESA Scientific Spacecraft

(flew through Halley's Comet dust cloud)

Environments and Effects

Debris: Magnitude of Problem



- NORAD tracks ~7000 objects larger than 10 cm
- Only 5% are operational S/C
- Statistical analysis suggests ~40,000 larger than 1 cm
- Collisions generate more debris
  - ie 1985 hypervelocity ASAT test estimated to have created 10^6 fragments between 1 mm and 1 cm diameter

Gravitational Field

- Free Fall Environment (**not** Zero-G or Microgravity)
  - At Sea Level: $a_g = 9.8\ m/s^2 = 1.0\ g$
  - At 200 km: $a_g = 9.2\ m/s^2 = 0.94\ g$
  - At 1000 km: $a_g = 7.3\ m/s^2 = 0.75\ g$
  - At GEO: $a_g = 0.2\ m/s^2 = 0.023\ g$
- Effects:
  - Structures/Mechanisms: *Minimum size structural components*
  - Propulsion: *Fuel flow (ullage burns, etc)*
  - TCS: *Fluid flow considerations (heat pipes wicking)*
  - etc

Spacecraft Environment Related Anomalies

- Flare/Geomagnetic Storm
  - GOES-7: lost imagery and communications, solar arrays degraded 2-3 years worth
  - DSP: star sensor contamination, memory upsets, lost data, power panel degradation
  - Memory Upsets: DMSP, GPS, INTELSAT, TDRSS
- Spacecraft Charging
  - Milstar: power supply failure
  - Anik: momentum wheel failure
  - GOES: phantom commands
- Galactic Cosmic Ray
  - Pioneer: memory anomalies

Conclusions

- Definition of the flight environment is the first critical step.
- Not all space environments will have a critical impact on a particular mission.
- After definition of the space environment is established including results from trade studies, the next important step is to establish a coordinated set of natural space environment requirements for use in design and development.
- The space environment definition and requirements are documented in a separate program document or are incorporated into design and performance specifications.
- The environments specialist then helps insure that the environment specifications are understood and correctly interpreted throughout the design, development, and operational phases of the program.