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Space Fundamentals for the War Fighter

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SPACE FUNDAMENTALS FOR THE WAR FIGHTER

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations.

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Space Fundamentals for the War Fighter

This excellent paper was first produced by Dr. Clapp in partial satisfaction of the requirements of the Operations Department at the Naval War College. Because of the timeliness of the topic and the belief that it deserved wider circulation, the paper has been updated for publication as a Strategic Research Department Occasional Paper.

There is almost universal consensus that we are involved in a revolution in military affairs identified as the 'age of information.' Space plays an increasingly important role in this new age. Indeed, it may well prove to be the 'high ground' in future battles. Whereas the United States, as an island nation, in the past sought to maintain maritime superiority, according to today's National Security Strategy it seeks maritime and *aerospace* superiority.

This easily read and understood primer will help the war fighter understand the environment in which the battle for aerospace superiority must be fought and won.

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INTRODUCTION

Commercial and military space assets are all around us and we use them without thought or concern, unless they fail to meet our expectations. Technology leads us to believe that anything is possible and that we are all privileged users. This is only true if unlimited resources are available to design, build, and purchase these products. Technology is very expensive and not all of us are able to be privileged users.

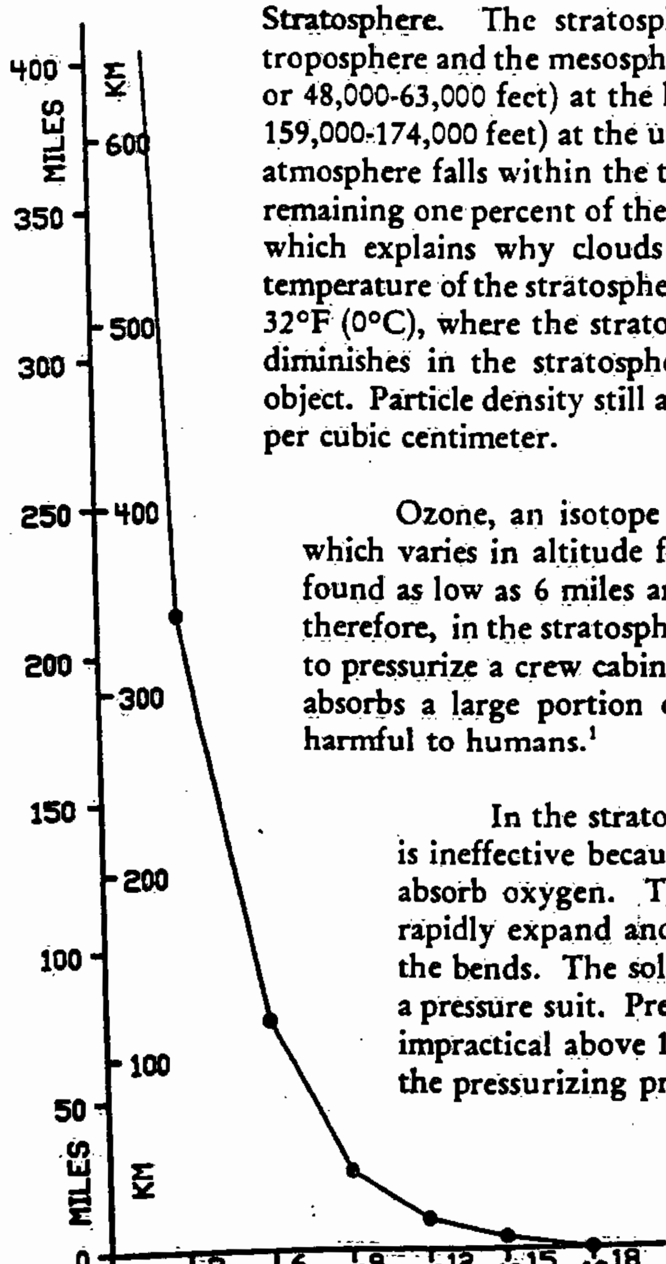
An understanding of some of the limitations of our space assets should moderate our expectations. The purpose of this paper is to provide a short and concise overview of the space environment and a fundamental understanding of space assets in order to understand their capabilities. Many space assets are often used without the user's knowledge. Space assets are vital elements that influence both peacetime and wartime missions at all three levels of military activity: (1) strategic, (2) operational, and (3) tactical.

The paper has been limited to the basic concepts of the atmosphere, rocket propulsion, launch vehicles, communications spectrum, and satellite assets. Thirty minutes of your time, reading this paper, hopefully will provide you insights concerning a few of the limitations and capabilities of U.S. space assets.

swings between night and day become greater than at sea level.

Gasoline propulsion systems perform well near sea level but experience air starvation at altitudes above 25,000 feet. Gasoline engines require great quantities of air for proper air/fuel mixture ratios. Turbojet engines perform well within the troposphere because the turbines within the turbojet compresses the air for proper combustion.

Moving objects within the atmosphere experience friction when in motion. At the Earth's surface, the concentration of particles exceeds 1,000,000,000,000,000,000 (10^{18}) particles per cubic centimeter (Figure 2). As mentioned earlier, these particles allow aircraft to fly, but cause considerable drag that makes orbiting objects at these altitudes impossible.



PARTICLE DENSITY PER CC^2 (CAUSES DRAG)
FIG. 2

Stratosphere. The stratosphere, which is sandwiched between the troposphere and the mesosphere, extends from 9-12 miles (i.e., 15-20 km or 48,000-63,000 feet) at the lower end to 30-33 miles (i.e., 48-53 km or 159,000-174,000 feet) at the upper end. About 99 percent of the Earth's atmosphere falls within the troposphere and stratosphere. Most of the remaining one percent of the Earth's water vapor resides in this region, which explains why clouds are practically non-existent in it. The temperature of the stratosphere continually climbs until it reaches about 32°F (0°C), where the stratosphere officially ends. Atmospheric drag diminishes in the stratosphere, but still cannot sustain an orbiting object. Particle density still averages 100,000,000,000,000 (10^{14}) particles per cubic centimeter.

Ozone, an isotope of oxygen, is present in the ozone layer which varies in altitude from 12 to 21 miles. Traces of ozone are found as low as 6 miles and as high 35 miles. Ozone is poisonous, therefore, in the stratosphere the outside atmosphere cannot be used to pressurize a crew cabin. The ozone layer is important because it absorbs a large portion of the sun's ultraviolet radiation that is harmful to humans.[1]

In the stratosphere, breathing oxygen through a mask is ineffective because the lungs no longer have the ability to absorb oxygen. The blood begins to boil as small bubbles rapidly expand and the resulting painful condition is called the bends. The solution is to pressurize the cabin or to wear a pressure suit. Pressurizing a cabin with outside air becomes impractical above 15 miles (i.e., 24 km or 79,000 feet) because the pressurizing process generates too much heat.

At 15 miles, air density is 1/27

Exosphere. The exosphere is the highest and last major region of the Earth's atmosphere. The exosphere extends from the thermosphere, 200-375 miles, to outer space. Particle density drops off from a maximum of about 1,000 particles per cubic centimeter at 200 miles to less than one particle per centimeter in deep space. This density varies with local conditions. The sun's solar flare activity is constantly changing the drag of Earth's orbiting satellites. Satellites above 350 miles experience a negligible amount of drag.

The temperature at the lower end of the exosphere is about 2,960°F during the day and 440°F during the night. Space really has no temperature of its own because it takes atmosphere to actually take on a temperature. The temperature of space is measured by the temperature of an object in space. An object takes in heat on the sun side and gives off heat on the dark side.

Satellites must be carefully designed to maintain a feasible temperature. Materials used in satellite designs must have the right combination of heat absorption and dissipation factors. For example, solar panels have a tendency to overheat on the sun side in space unless considerable care is taken to dissipate the heat out the back of the panel using special materials. Satellite electrical systems must be kept cool enough to ensure long life, but not so cool as to prevent electro-mechanical systems from functioning.

Ionosphere. The ionosphere is another region within the Earth's atmosphere (30-240 miles), but is not determined by temperature. The ionosphere is an area of the atmosphere that becomes electrically charged, or ionized, by solar x-rays and ultraviolet radiation. The amount of ionization is dependent on the time of day and the level of solar activity. Sunspots and solar flares on the surface of the sun produce fluctuations in the ionosphere (**Figure 4**).

The ionosphere absorbs, delays, or reflects radio signals of certain frequencies that can both help or hinder radio communications at different times of the day. Radio frequencies up to high frequency (HF) are greatly affected by the ionosphere, whereas, higher frequencies are generally unaffected.

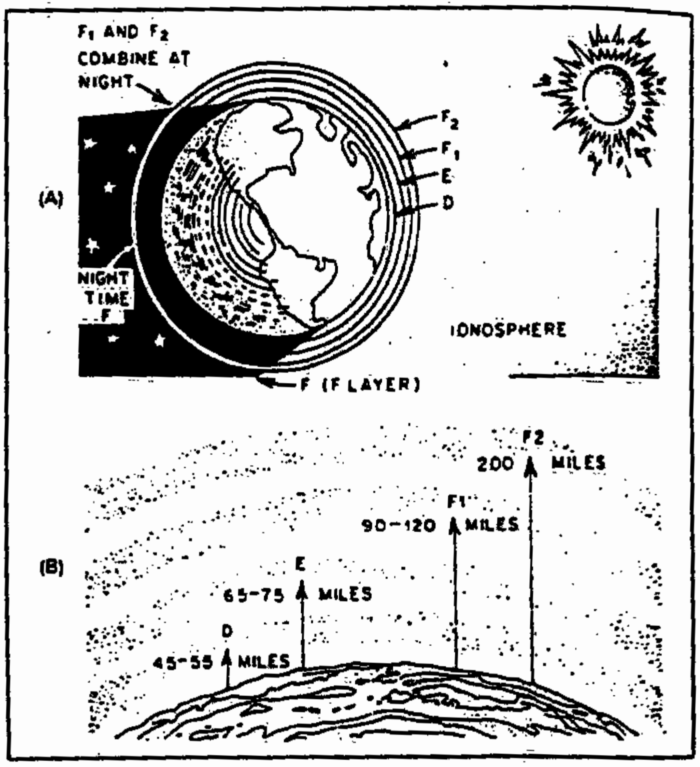


FIGURE 4
IONOSPHERIC LAYERS[2]

SATELLITE ORBITS

A number of conditions must be met to put a satellite into orbit. The two most critical elements are velocity and altitude. A satellite must be accelerated to a velocity parallel to the Earth's surface that matches the downward pull. On the Earth's surface, an object will drop about 16 feet the first second due to gravity. The Earth's curvature drops off at about 16 feet per every 5 miles. It can be concluded that an object must travel five miles in one second to match the drop equal to the curvature of the Earth. 5 miles per second x 60 seconds per minute x 60 minutes per hour = a speed of 18,000 mph. (Figure 7).

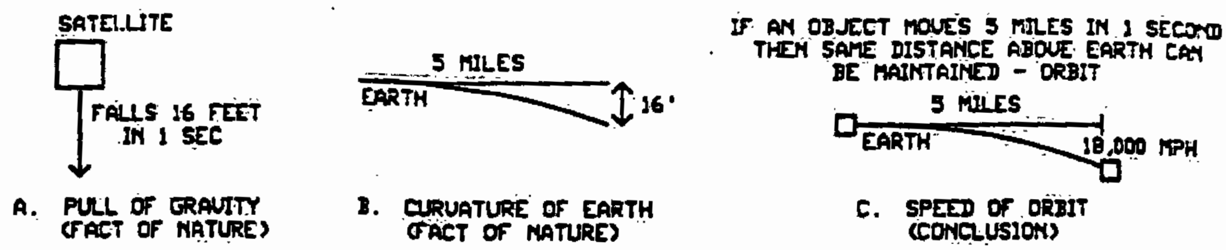


FIGURE 7
THE SPEED REQUIRED TO ORBIT AN OBJECT NEAR EARTH'S SURFACE

At the Earth's surface, an object traveling at 18,000 mph would experience considerable heat from drag and would quickly burn up before traveling very far. Near surface orbit around the Earth is therefore impossible, but is possible on planets that do not have an atmosphere. As altitudes increase, the speed required to maintain orbit decreases. For example, the gravitational pull of an object at an altitude of 100 miles is 95% of that experienced at the surface; therefore, a satellite must travel slower at 100 miles because the Earth's gravitational pull is less. At an altitude of 100 miles, an object will drop about 15 feet the first second. The Earth's curvature drops off slightly more than 16 feet per every 5 miles. We can conclude that an object must travel about 4.7 miles in one second to match the drop equal to the curvature of the Earth. 4.7 miles per second x 60 seconds per minute x 60 minutes per hour = a speed of about 17,000 mph. (Figure 8).

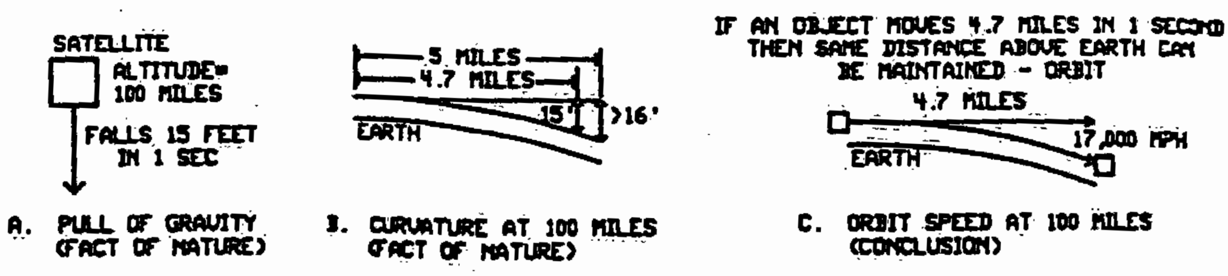


FIGURE 8
THE SPEED REQUIRED TO ORBIT AN OBJECT AT 100 MILES ALTITUDE

satellites across the sky in less than ten minutes.

The inclination of the launch determines the north and south latitude ground track that a satellite will follow. The ground path of a satellite will follow the inclination angle as it completes its orbit. The location and angle a rocket is launched, determines the final orbit inclination angle. A rocket fired at a 45 degree angle from the equator will end up in a 45 degree inclination orbit. Launches from Kennedy Space Center require special consideration to obtain a particular orbit inclination. For example, a due east launch from Kennedy will put a satellite into a 28.5 degree orbit inclination because the latitude at Kennedy is 28.5 degrees. To put a satellite into a 57 degree orbit inclination, the rocket must be fired at 35 degrees (Figure 11).

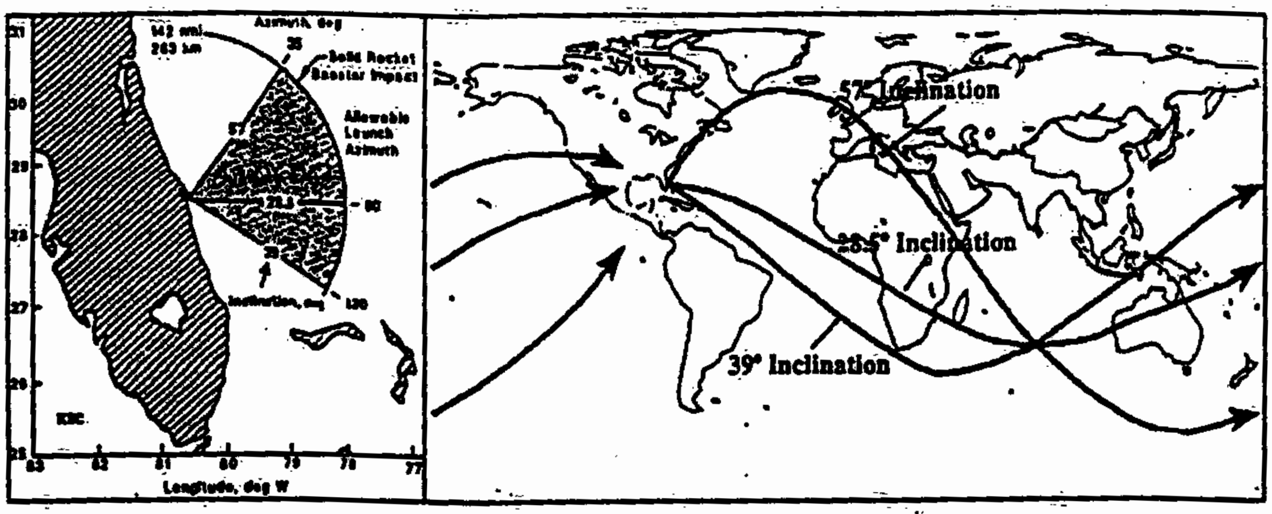


FIGURE 11. ORBITAL INCLINATIONS FROM KENNEDY SPACE CENTER

The Earth rotates on its axis once every 24 hours, which means that it rotates 15 degrees per hour (360 degrees/24 hours = 15 degrees). Therefore, the Earth will rotate 30 degrees while a satellite with a 2 hour period completes one revolution. The ground path will cover a new area 30 degrees to the west with each successive orbit. (Figure 12).

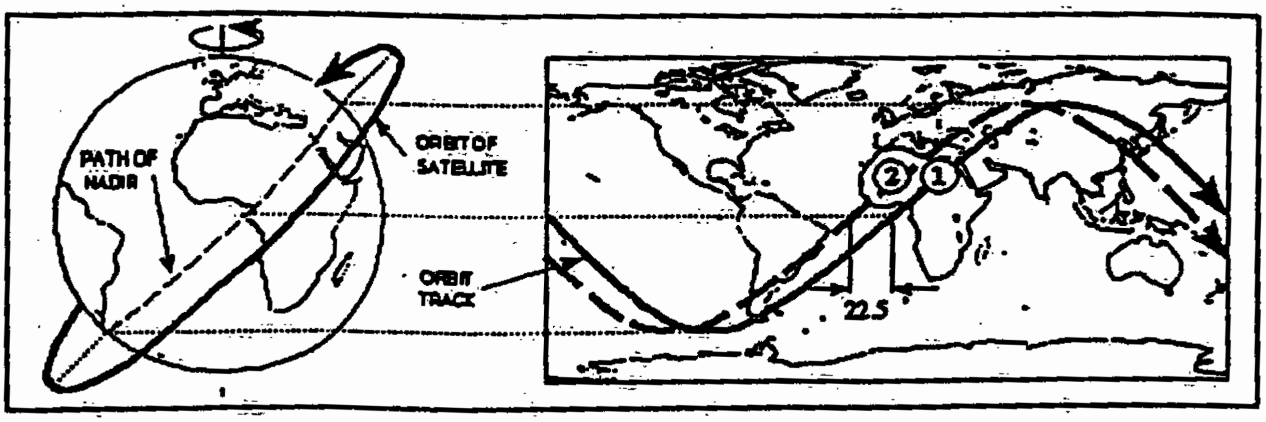


FIGURE 12. SATELLITE GROUND TRACK FOR TWO ORBITS

Elliptical Orbit. All orbits start out as elliptical orbits until their final orbit is reached. Most elliptical orbits are used as transfer orbits to put a satellite in its final circular orbit. To circularize an elliptical orbit, rocket motors are fired at the highest point of the orbit, called the apogee. A Molniya orbit is a specific elliptical orbit that spends considerably more time, at apogee, over a specific target area than it does at its close-to-the-Earth perigee (Figure 14). The Molniya orbit works well for communications satellites intended to provide coverage near the poles where geostationary satellites are out of range.

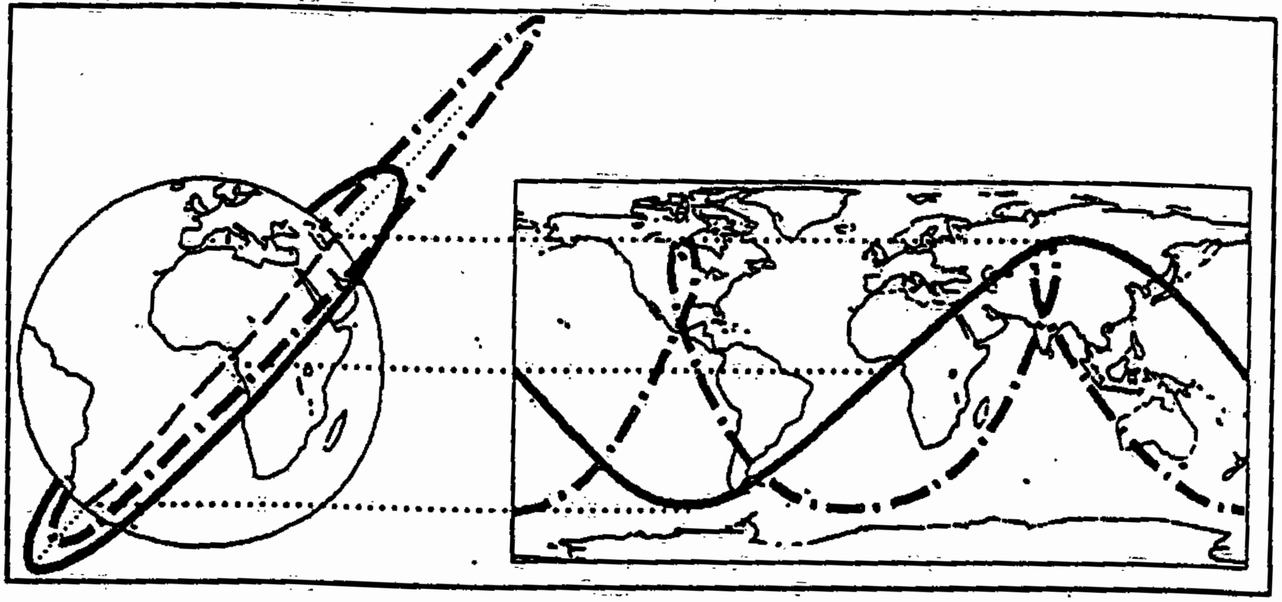


FIGURE 14. ELLIPTICAL ORBIT GROUND TRACKS

Satellites in elliptical orbits slow down as they travel away from the Earth and reach their slowest speed at apogee because of the Earth's gravitational pull. On the other hand they speed up as they return to Earth, also because of the Earth's gravitational pull. This slowing down and speeding up cycle would continue indefinitely if it were not for the particle density near the Earth's surface. Elliptical orbits, at the minimum altitude (perigee) can come as low as 90 miles (145 km) and still make it back out to space. This cycle will not last long, however, because the increased drag experienced at this extremely low altitude slows the satellite to the point it never fully recovers. Early spy satellites took advantage of this low altitude to obtain great photographs, but this method was very costly because of the short life of the satellite.

Geostationary Orbit. A geostationary orbit occurs when a satellite orbits the Earth once per day following a path around the equator. A geostationary satellite gives the illusion that is not moving, but in fact, it is moving very fast to keep up with the Earth's rotation. A geostationary orbit is a high orbit that averages 19,300 miles (31,000 km) above sea level and travels about 6,900 miles (11,000 km) per hour to keep up with the Earth's rotation. The Earth's gravitational pull at this altitude is considerably less than at lower altitudes, which means that satellites must travel much slower to maintain a constant altitude. The difference between a geosynchronous and a geostationary orbit is hundred objects are now clustered within the narrow band at geostationary orbit. These objects will never find their way into the atmosphere and must be monitored. On the other hand, constant cleansing occurs at low Earth orbit. Fifty-five hundred of the seven thousand objects are below 1,000 miles and will find their way into the atmosphere. Small objects cannot yet be tracked and these objects can cause considerable damage to life and property if collision occurs. Many satellites have mysteriously stopped functioning, but evidence is lacking as to whether a collision occurred. There has been evidence that a few launch vehicles have collided with their payloads during ejection. Still collisions in space are rare. A recent Navy experiment simulated the explosion of 10 low Earth orbit satellites into 400 fragments traveling up to 100 meters per second. A six-hour simulation revealed that even though 300 satellites would come within 5 km of a fragment there were no collisions with any of the 500 active satellites. The closest a fragment came was 500 meters (Figure 16).[4]

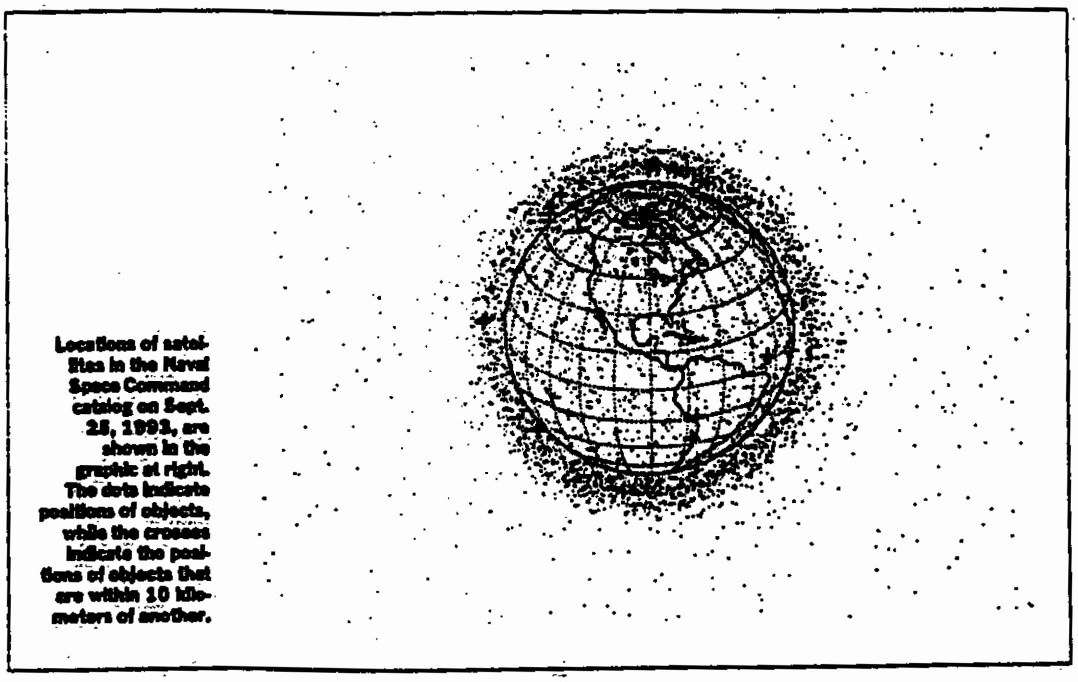


FIGURE 16. COMPUTER REPRESENTATION OF OBJECTS IN ORBIT

Moon. The Moon gracefully circles the Earth every 27 days and gives the illusion that it rapidly travels overhead, but it is really lumbering along to equal the Earth's gravitational pull. The mass of the Moon equals 1/83 that of Earth and its effects can be felt on Earth as it circles overhead. When the Moon is overhead, the Earth's tides are at their highest. The gravitational pull of the Moon gathers the water from the sides of the Earth and this high water follows the Moons path over the surface of the Earth. The large amount of water that is displaced to one side would create a tremendous imbalance of weight if centrifugal forces did not compensate by creating equally high tides on the opposite side.

of the remaining rocket stages. Specific impulse, or engine efficiency, still falls short of being able to take a single-stage space plane to orbit.

Liquid Propellants. Liquid propellant rocket engines burn two liquids that are stored in separate tanks until needed. Common liquids used are hydrogen and oxygen. Both of these liquids are gasses at room temperature and must be cooled below -300°F to convert them into a liquid form. Hydrogen and oxygen, as gases, cannot be compressed enough into the onboard storage tanks to provide the necessary specific impulse. The conversion into a liquid is required to bring the density up to the required efficiency.

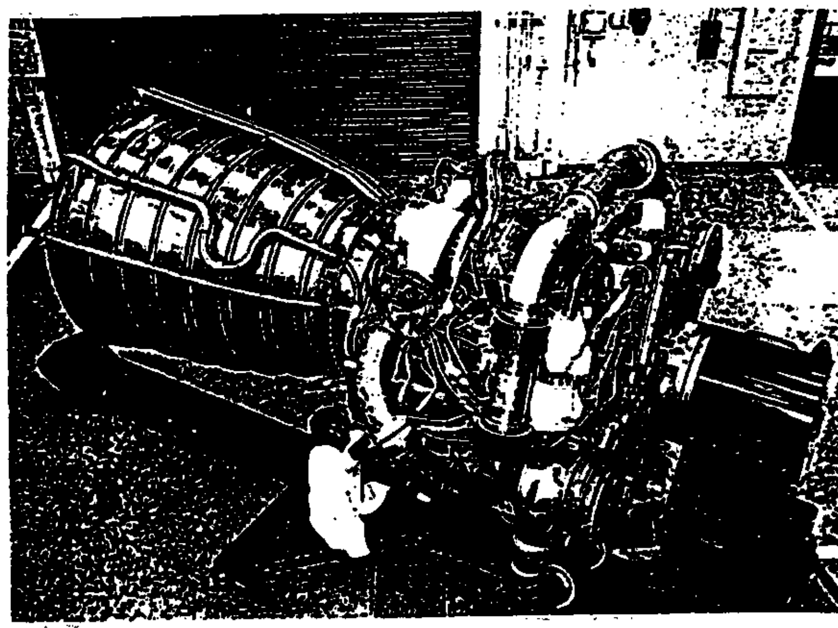


FIGURE 18. SPACE SHUTTLE MAIN ENGINE[5]

Liquid propellant rocket engines are very efficient and specific impulse ratings are generally high. A significant advantage is that the thrust can be adjusted during launch and can even be cycled on and off. If the fuel used is oxygen and hydrogen, the cost is low and quantities are plentiful.

There are a few significant disadvantages that must be considered when considering using liquid propellant rocket engines.

One significant disadvantage of liquid propellant rocket engines is that they require complex fuel metering and control plumbing to sustain the proper combustion (Figure 18 and Figure 19). Rapid launch systems are not feasible for cooled liquid hydrogen and oxygen because they cannot be maintained in the launch vehicle for more than a few hours before launch. Hydrogen and oxygen

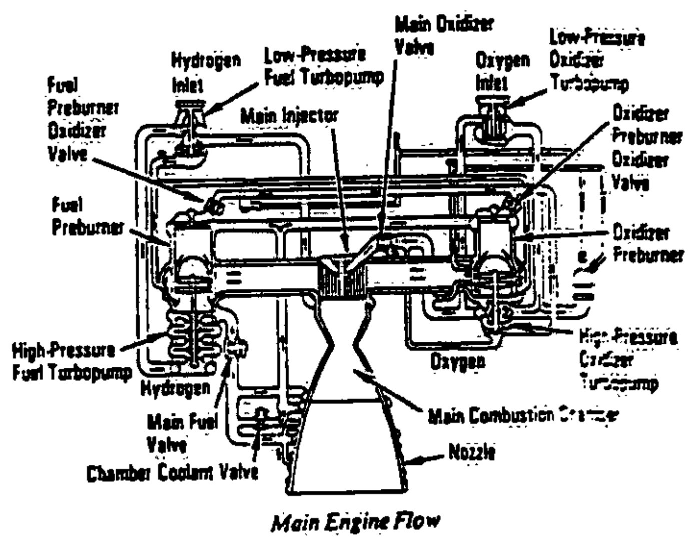


FIGURE 19. MAIN SHUTTLE ENGINE FLOW[6]

LAUNCH VEHICLES

The military Services and NASA use a mixed fleet concept for placing payloads into orbit. The Atlas, Delta, Pegasus, Scout, Shuttle, and Titan are current U.S. space launch vehicles. Contracts have been awarded to develop two new launch vehicles called the Taurus and the LLV. The Shuttle was intended to be the ultimate answer and replace the Expendable Launch Vehicles (ELV's) by the end of the 1980s. The Challenger disaster in 1986, however, grounded the Shuttle for two years and contractors scrambled to find alternate launch vehicles to put their satellites into orbit. The Challenger disaster radically changed the direction of the U.S. space program, which now uses a mixed fleet concept. Missions are now matched with available launch systems.

Atlas. The Atlas is a medium lift launch vehicle that was originally developed in the late 1950s. Later versions were used to put the first U.S. manned orbital flights. The Atlas has been updated many times and the current vehicle is the extended Atlas 2. The Atlas launch vehicle can put 5900 lb. (2700 kg) satellite into a geo transfer orbit (GTO). The Atlas has been used to launch GPS, Military Fleet Satellite Communications (FLTSATCOM), Defense Satellite Communications Systems (DSCS) and Defense Meteorological (DMSP) satellites (Figure 21). General Dynamics, Space Systems Division, currently produces the Atlas which had an 85.5% success rate before 1991 and an 85% rate on the last 20 vehicles.[8] Of the two failures in the last 10 years, one was due to lightning.

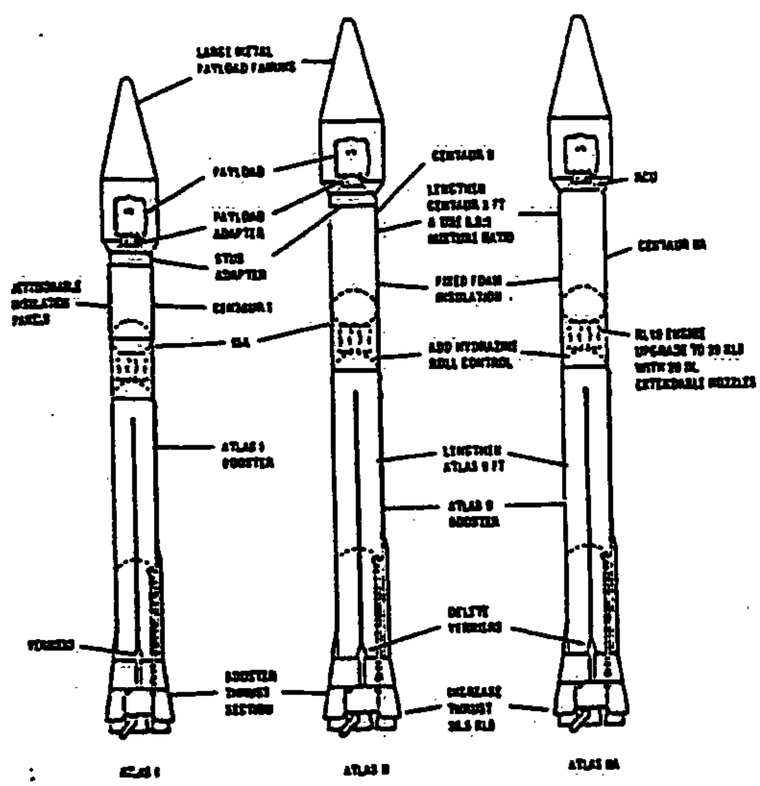


FIGURE 21. PARTIAL ATLAS FAMILY OF LAUNCH VEHICLES

Pegasus launch vehicles. A new, larger capacity, Scout is under development, but has not been awarded any U.S. contracts.

Pegasus. The Pegasus is a winged launch vehicle designed to be launched from under the wing of a high flying aircraft (Figure 23). The Pegasus is a small satellite delivery system which can place 900 lb (410 kg) satellites into equatorial low Earth orbits and 600 lb (270 kg) satellites into polar orbits (Figure 24). The purpose of the Pegasus design was to reduce the launch costs of placing small payloads into low Earth orbits without the usual delays of building the rocket on the launch pad. Pegasus payloads could be launched with short notice to accommodate rapid employment of special payloads for emergency contingencies. The first launch took place off the coast of California, in 1990. Orbital Sciences corporation and Hercules manufacture the Pegasus. The Pegasus can be launched anywhere and is not limited to existing launch facilities.

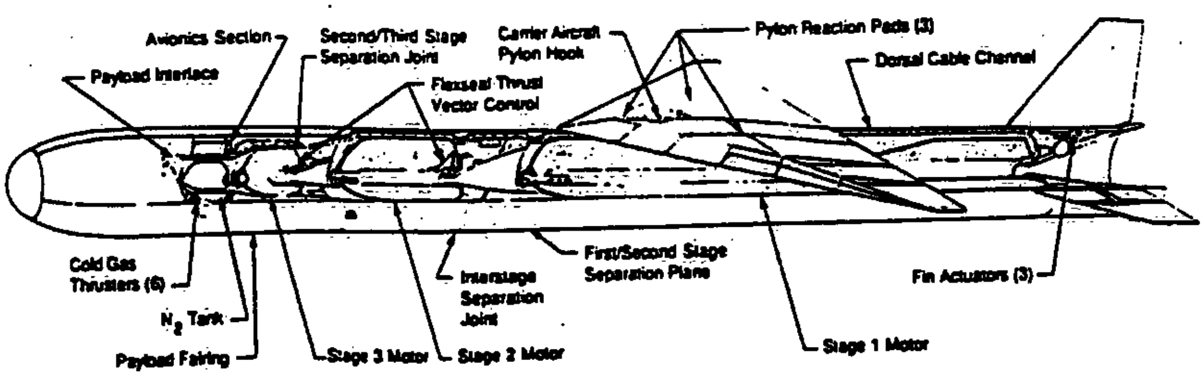


FIGURE 23. PEGASUS AIRCRAFT LAUNCHED SPACE VEHICLE[12]

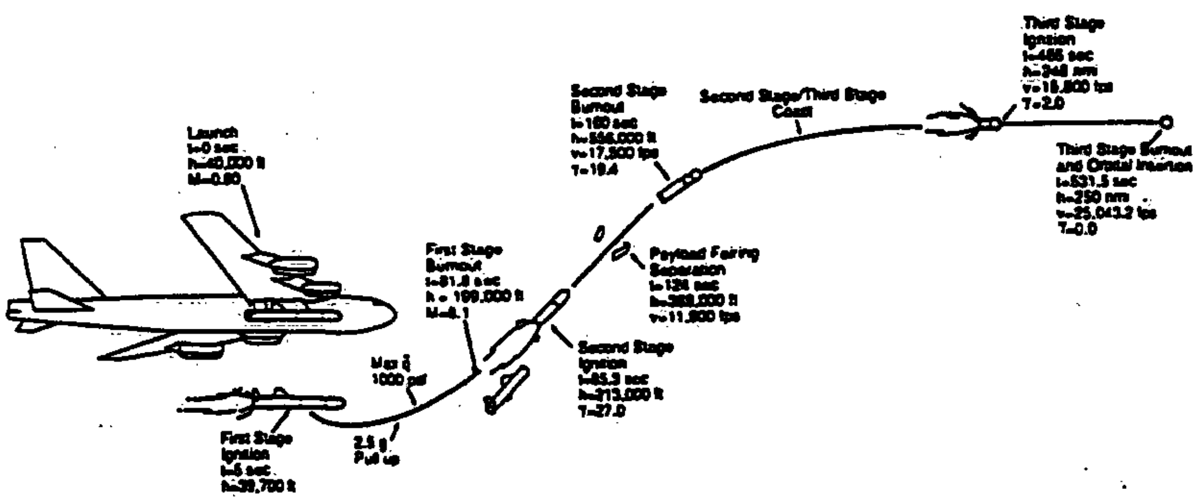


FIGURE 24. PEGASUS LAUNCH SEQUENCE[13]

Martin Marietta Space Launch Systems currently manufactures the Titan III and IV series launch vehicles which can be launched from either Vandenberg AFB in California or from Cape Canaveral Air Force Station in Florida. Because a Shuttle launch facility was never completed at Vandenberg AFB in California, the Titan has been the primary launch vehicle for polar orbit missions.

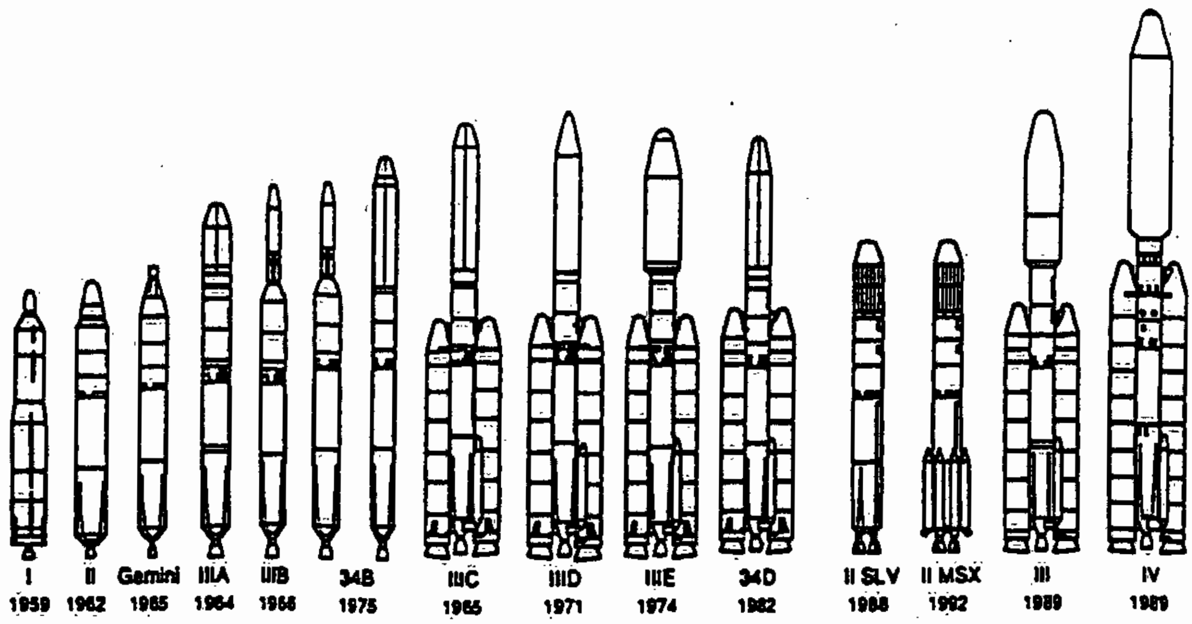


FIGURE 26. TITAN FAMILY CONFIGURATION HISTORY[15]

Taurus. The Taurus is basically a Pegasus with a rocket motor replacing the aircraft launch vehicle. The purpose of the Taurus is to accommodate short notice launches within 72 hours from dispersed locations. Payloads of 3000 lb (1360 kg) to low Earth orbits or 700 lb (330 kg) to geo transfer orbit are possible. The first stage is a Thiokol MX/Peacekeeper motor. The Taurus launch system is made by Orbital Sciences.

LLV. A new, yet untested, entry into the rocket launch vehicle family, the Lockheed Launch Vehicle (LLV) is contracted to fly by the end of this year with DOD or NASA payloads. The LLV is capable of lifting 8900 lbs (4000 kg) into low Earth orbit. The new rocket family also uses a Thiokol MX/Peacekeeper stage 1 motor (Figure 27).

SPACE LAUNCH FACILITIES

The United States owns and operates four orbital launch facilities: (1) Eastern Space and Missile Center, (2) Kennedy Space Center, (3) Western Space and Missile Center, and (4) Wallops Flight Facility. Each one of these facilities has unique characteristics and limitations.

Eastern Space and Missile Center. The Eastern Space and Missile Center (ESMC) is located at Cape Canaveral Air Force Station and is managed by the Air Force Space Command (**Figure 28**). ESMC is located on the eastern coast of Florida, west of Orlando. Over 40 different launch stands have been constructed and all the current launch vehicles can be launched with the exception of the Shuttle. The test range extends from Cape Canaveral, across the Atlantic and Africa, to the Indian Ocean. The most efficient launch inclination is due east, which places satellites in 28.5 degree inclination orbits because Cape Canaveral is located on the north 28.5 degree latitude. Other orbit inclinations can be obtained with fuel being the significant limiting factor. Launches are generally made over water to allow for a margin of safety if something were to go wrong. Cape Canaveral launches are limited to a minimum angle launch of 35 degrees to a maximum angle launch of 120 degrees.

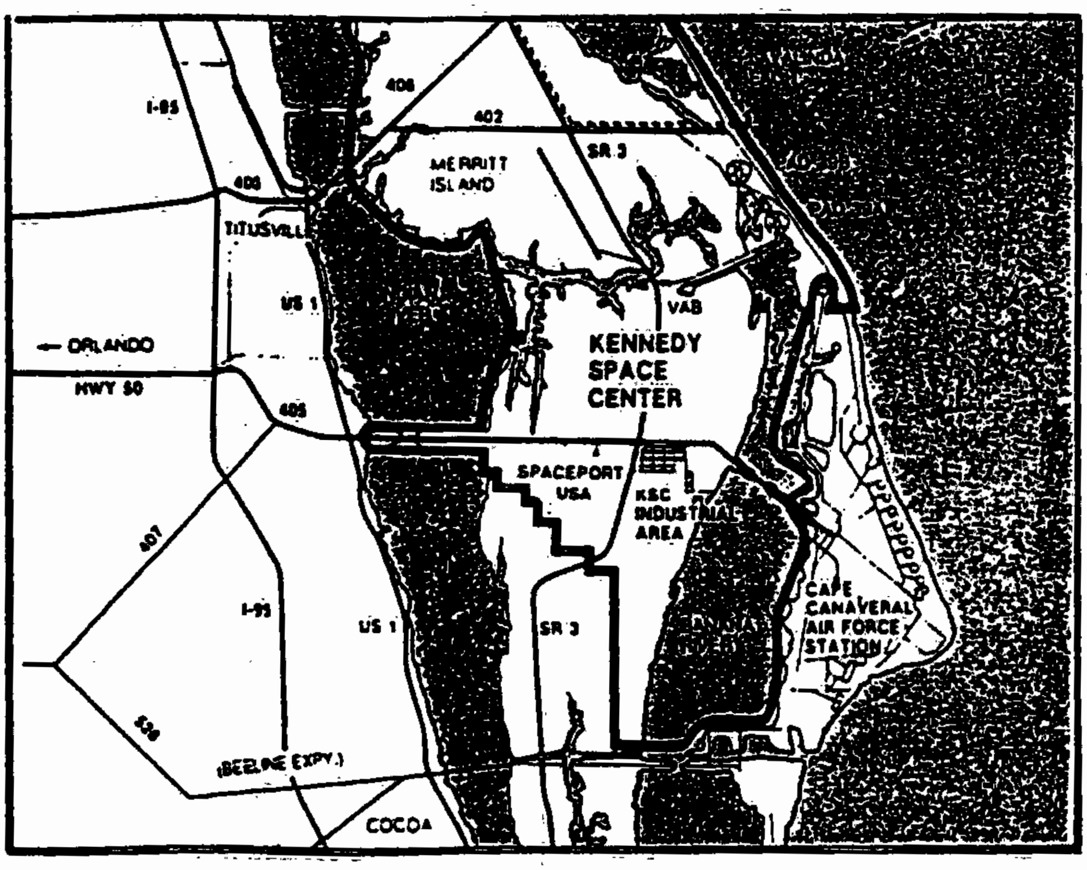


FIGURE 28. CAPE CANAVERAL AND KENNEDY SPACE CENTER

COMMUNICATIONS SPECTRUM

The natural phenomenon of resonant frequency allows us to communicate with each other. Resonant frequency is the ability to maintain a specific frequency oscillation long enough to convey information from one source to another. By changing tones or modulating the resonant frequency with coded information, intelligence can be broadcast, and hopefully a receiver can and will interpret the message. Resonant frequency communications covers a wide spectrum from audio through visible light, which includes very low frequency (VLF), low frequency (LF), medium frequency (MF), high frequency (HF), very high frequency (VHF), ultra high frequency (UHF), super high frequency (SHF), extremely high frequency (EHF), and infrared (IR) frequency spectrum (see Figures 31A, 31B and 31C). A basic understanding of some characteristics and relationships of these frequencies will be helpful in better comprehending satellite communications systems.

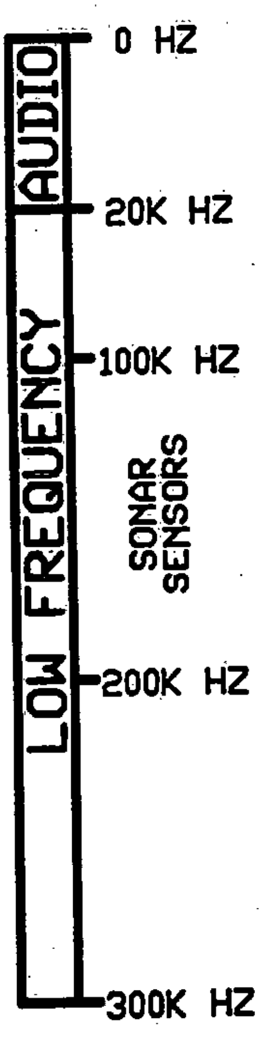


FIGURE 31A

Audio (20 - 20,000 Hz). Human vocal chords can sustain varying intensity and frequency long enough to project intelligible sounds to others. These frequency inflections fall between 100 and 3,000 (3K, where K = 1,000) cycles per second (called Hertz, Hz) with harmonics reaching much higher. Human ears can hear sounds far above (15K Hz) what the typical human voice can generate. Have you ever had difficulty understanding voices coming over radio communications systems? One reason is that audio frequencies in radio receivers are usually limited to 3,000 Hertz, which means that you are not receiving the complete audio signal.

Every mechanical design has its own resonant frequency characteristic. During launch, spacecraft designs generally have resonant frequencies in the audio range. The Shuttle has a resonant frequency of 45 Hertz during launch, which means that onboard satellites must have a different resonant frequency to avoid destructive oscillations. The famous and ill-fated Tacoma Bridge had a very low resonant frequency that allowed the prevailing winds to start it oscillating until it twisted apart.

Low Frequency (LF) (20K - 300K Hz). Resonant frequencies can be created with large electrical coils and capacitors or mechanical crystals. Low frequency, electrically-tuned circuits are very large and corresponding antennas are hundreds of feet in length. Low frequency transmitting devices are not found on satellites because of the immense size of the tuned circuits and antennas. Crystals are commonly used to transmit ultrasonic sounds into water as sonar devices. Low frequency signals are the only radio waves that readily pass in water with little attenuation. Sonar and ultrasound systems take common for narrow band digital transmissions.

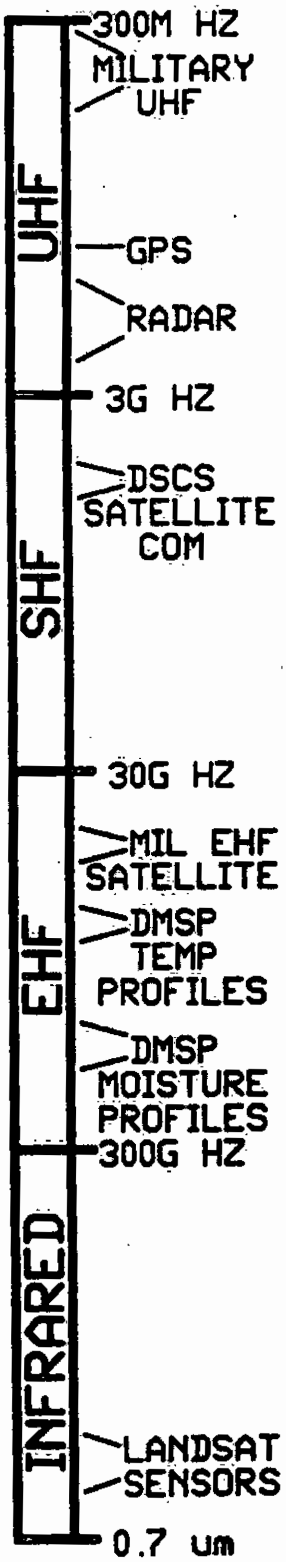


FIGURE 31C

Ultra High Frequency (UHF) (300 - 3000M Hz). UHF radios and antennas are a fraction of the size of VHF systems. Typical users of the UHF band are UHF TV, military aircraft, cellular telephone, microwave, satellite, and radar systems. This is a very popular band of frequencies and an international struggle continues to obtain and keep valuable frequency bands. The higher UHF signals now use reflective dishes to collect and focus the weak signals.

Super High Frequencies (SHF) (3 - 30G Hz). Super high frequency transceivers are relatively new because of the advanced technology required to make devices that will resonate at these frequencies (measured in gigahertz where G = 1,000,000,000). A critical shortage of bandwidth spurred development of effective systems commonly used in satellites. Channel assignments are considerably wider, which means millions of bits per second can be transmitted between a ground station and a satellite. Sending high-resolution photographs to ground stations is possible at these frequencies, but still require a few minutes to send each picture.

Extremely High Frequency (EHF) (30 - 300G Hz). Gigahertz frequencies are receiving most of the communications development dollars in order to take advantage of available frequencies and their allocated wide bandwidths. Real time high-resolution image transmission is now possible, but very costly.

Infrared Frequency (IR) (1000 - 0.7 um). Infrared frequencies are usually referred to in terms of wavelength. Wavelength is the distance it takes to complete one cycle and that distance gets smaller as the frequency goes up. Infrared spectrum ranges from 1000 um (0.001m) down to 0.7 um (0.0000007m). Night vision goggles and weather satellites use infrared sensors to collect the energy in this narrow band, amplify it, and present the view to the user. Infrared sensors in satellites can provide data on the temperature of water, land, and clouds. The Defense Meteorological Satellite Program (DMSP) satellites commonly use visible light sensors during the day and infrared sensors during the night. IR night sensors are capable of providing equally high resolution pictures at night as the visible light sensors during the day. The pictures provide a new and totally different perspective because IR night sensors differentiate between heat levels and not variations in visible light. Temperatures and some gas compositions in the atmosphere are now measurable using visible and IR combinations.

SATELLITE SYSTEMS

Satellite systems are very costly to build, launch, and use. Military satellites typically cost a billion dollars by the time all the bills are paid, which includes a sufficient number of user ground stations to accomplish the mission. DOD policy has been to design and operate satellites apart from civilian satellites in order to insure security of links, protection against jamming, and the ability to move satellites to where they are most needed. Military satellite missions have been limited to three major types: (1) **Communications**, (2) **Navigation**, and (3) **Surveillance**.

1. **Communications Satellites.** Communications satellites are divided into three categories based primarily on the frequencies used (UHF, SHF, and EHF). The first category, UHF bands, are used by FLTSATCOM, AFSATCOM, LEASAT, and UHF FOLLOW-ON satellites and are used to communicate with the troops in the field who have small portable radios. The secondary category, SHF bands, are used by the Defense Satellite Communications System (DSCS) and are used for worldwide long haul communications between the National Command Authority and Department of Defense Agencies. The third category, EHF bands, is intended to be used in the coming years by the MILSTAR satellite communications system. Each category has its own strengths and weaknesses that become important factors for the success of future engagements. The differences between cost, capacity, antijam, and mobility are very important characteristics that should be understood by the operational commander (**Figure 33**).

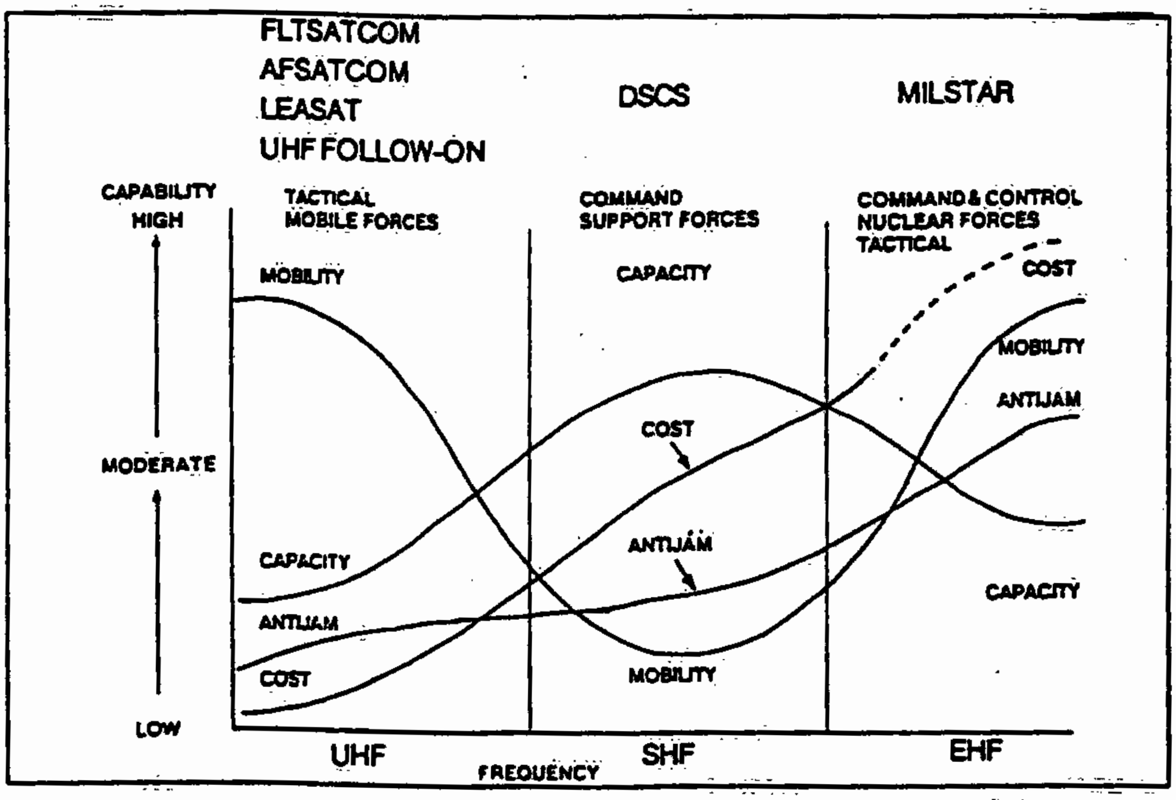


FIGURE 33. COMPARISON OF MILSATCOM SYSTEMS

UHF Follow-On (UFO). Valuable satellite channels are in constant demand, therefore the Navy has contracted to increase the number of UHF satellites in the fleet from 9 (5 FLTSATCOM and 4 LEASAT) to 18. UHF Follow-On satellites have 42 UHF channels and will also be owned and controlled by the Naval Space Command. These satellites will not have any additional USAF equipment.

Lightsats. A number of small low-cost satellites are under development as UHF communications relay stations. These small satellites have been placed into low Earth orbit, which means that the user has to actively chase the satellite across the sky in order to utilize its 10-minute window. Messages are transmitted up to the satellite and stored in its memory until the intended user requests the message to be sent back down. They are called store and forward satellites and the concept has been well proven by the amateur radio community.

UHF Ground Stations. More than 1000 mobile ground stations have been issued to the military services. Small, light, and portable ground stations make the FLTSATCOM system an excellent solution to the difficult problem of reliable troop communication. The AN/PSC-3A UHF SATCOM transceiver is just one of many models available (FIGURE 36).

FIGURE 36. UHF AN/PSC-3A

SHF Satellites. The Defense Satellite Communications Systems (DSCS) was designed to utilize higher wideband communications, Super High Frequency (SHF), to pass large volumes of data worldwide. The most significant SHF user is the Worldwide Military Command and Control System (WWMCCS), which includes early warning operations centers, unified and specified commands, and tactical forces. The highly successful twenty-six Phase I DSCS satellites launched between 1966 and 1968 were followed by Phases II and III. All of the DSCS satellites have been placed into geostationary orbits spread evenly around the globe for worldwide coverage. Their operational design life was five years, but they averaged 6-8 years. Each phase was designed to replace its older predecessor as it neared the end of its expected life.

DSCS II. Six DSCS II satellites were placed into geostationary in the 1980s. The last one, launched in 1989, remains the only one functioning. DSCS II has only two wide band repeaters, but is far more capable and flexible than any previously designed military satellite. The bandwidth for each uplink and downlink channel is an unbelievable

EHF Satellites. The next generation satellites will use an even higher band of frequencies, extremely high frequency (EHF). EHF frequencies fall between 30G Hz (30,000,000,000 Hz) and 300G Hz. EHF are somewhat immune to nuclear blast effects and may be our only source of communications under nuclear attack. On the other hand, EHF frequencies are far from perfect because they can be absorbed by rain in the signal path, if rain drops are the same size as the wavelength of the radiating signal. EHF transponders are part of the UHF Follow-On satellite.

MILSTAR. A constellation of 10 MILSTAR satellites was originally anticipated, but was reduced to two because of the tremendous cost overruns and will be launched in 1994 (**Figure 40**). The 4.5-ton, billion dollar satellites will provide worldwide, jam-resistant, and survivable long-haul communications. The uplink frequency from ground stations will be at EHF of 44G Hz and the downlink will be at SHF frequencies. Anti-jam capability is accomplished by frequency hopping sequencing if jamming is detected. MILSTAR will be under JCS control and channels will be allocated to the CINCs. MILSTAR users will be at any of the three levels (strategic, operational, or tactical), depending on the needs of the CINCs.

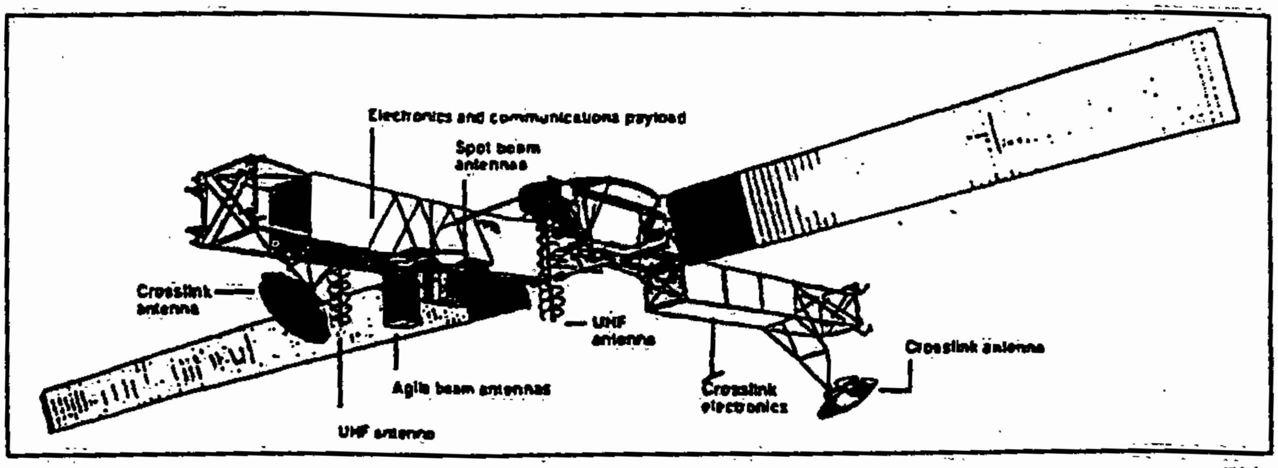


FIGURE 40. MILSTAR EHF SATELLITE

EHF/SHF Ground Stations. The ground stations will include large permanent installations as well as small portable SCAMP terminals. The 15-pound SCAMP terminals will have voice and secure data at 2400 bps (**Figure 41**).

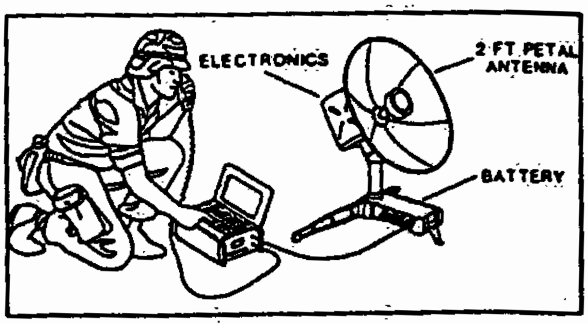


FIGURE 41. MILSTAR EHF SCAMP

3. **Surveillance Satellites.** The surveillance task covers a wide variety of missions, which are essential for the preparation of intelligence to support strategic, operational, and tactical commanders. Satellite tasks have been divided into the following categories: **(A) Early Warning, (2) Geographic Imaging, (3) Meteorology**, and **(4) Nuclear Detection.**

DSP Early Warning Satellites. The Defense Support Program (DSP) uses satellites as the most important element of a large scale system to warn of an attack by incoming ballistic missiles. (**Figure 44**). DSP satellites can see and track a missile launch and immediately transfer the data back to ground Data Reduction Centers for processing. Confirmed warnings are relayed to the appropriate designated commanders. All of the SCUD missiles launched by Iraq in Desert Storm were identified and warnings were relayed to the field, which provided only a few minutes of warning because of the short trajectories.

DSP Generation 3. Nine DSP Generation 3 satellites were ordered with the first launch in 1990. At scheduled 18 month intervals, DSP Generation 3 satellites were to be placed on station in geostationary orbits spaced around the equator. The satellites can be moved to different locations in time of crisis situations. The heart of the system lies with the IR wavelength imaging system used to detect the hot exhaust from missiles. Two different IR wavelength detectors are used to avoid laser jamming. IR sensor systems are very expensive, so a 6000 IR detector row is rotated through the observation window by spinning the satellite. A complete scan takes about 10 seconds and a launch confirmation requires a number of scans, so verification make take a couple of minutes. The next generation DSP will not require a scan time because well over 100,000 IR detectors may be used, but the cost will be considerably higher.

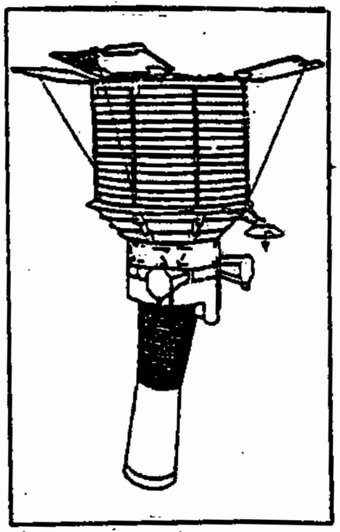


FIGURE 44.
DSP SATELLITE

Geographic Imaging Satellites. Geographic surveillance of the Earth provides a unique view when multispectral imagery (looking at many wavelengths) is used. Geographic imagery can be used to update maps, identify objects and routes, view below the surface of water, and detect contamination. Different wavelength sensors are even able to assess vegetation vigor and soil moisture content. Imaging satellites are usually placed in low-Earth orbits to be as close to the viewing as practical. Earlier U.S. satellites took photographs from very low, short life, 100 mile high orbits. Their resolution was higher because they were much closer, but the cost of replacing them became excessive. The U.S. moved to higher orbit, computer image storing techniques, whereas, the Russians continued to replace low-cost imaging satellites that take photographs at much lower altitudes.

DMSP. The Defense Meteorology Satellite Program (DMSP) was created to gather weather data for military uses. DMSP satellites have been placed into low Earth sun-synchronous orbits. The two active DMSP satellites are placed so one passes overhead at 6 AM and the other passes at 10:30 AM. Data is stored onboard until it can be downlinked to one of two permanent ground stations at Offutt, Nebraska, or Monterey, California. DMSP satellites carry transportable ground stations allow the information to be directly downlinked to tactical users. DMSP information is provided to NOAA for civilian use.

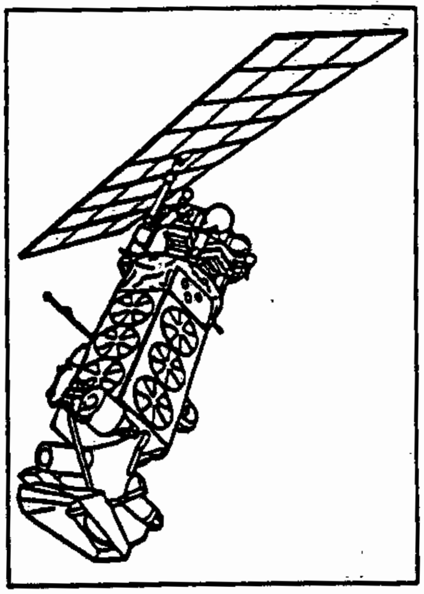


FIGURE 47. DMSP SATELLITE

CONCLUSION

The U.S. has fielded military satellite systems based primarily on a Soviet threat. With the demise of the Soviet threat, much of the justification for these extremely expensive systems also disappeared. Budgets that were going to provide the next generation of bigger and better satellite systems have been reduced significantly. The military must accept the fact that next generation of satellite security systems are now too expensive to field.

The dilemma for CINCs is to sort out the "nice to have" features from the "must have" ones. They must also decide what dedicated military systems must be fielded and which ones can be leased from commercial sources. For the soldier in the field or the sailor upon the sea, the availability of overhead systems will make a significant difference in the transparency of the battlefield. Systems like GPS that were once "nice to have" are now "must have" capabilities. Secure, worldwide communications have also become essential command-and-control tools for National Command Authorities. Yet to assure the availability of these systems, the U.S. must understand that its commitment to space is completely open-ended. A commitment to space also means a commitment to the use of higher frequencies and to pay for the more expensive equipment needed to support them.

A narrow view of space today, by either policymakers or warfighters, can adversely affect tomorrow's battlefield. In searching for ways to maintain the U.S. commitment to space at a reasonable cost, decision-makers will inevitably have to weigh the benefits of international cooperation against the risks of not completely controlling its destiny in space. Even the risks are significant and the costs are high, the benefits of maintaining a vigorous military space program are even greater.

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