

# **PRACTICAL APPLICATIONS OF REMOTE SENSING**

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August 5, 1998

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## ABSTRACT

The NASA Langley Research Center summer project objective was to research the various uses of remote sensing. Through use of the internet and various books, information was analyzed on seven research topics. The research done on these seven topics resulted in a compilation of data that suggests numerous ways in which remote sensing can benefit both people and industries. The imagery collected was retrieved from satellites such as the Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar, LANDSAT, and the TOPEX/Poseidon.

## INTRODUCTION TO REMOTE SENSING

Remote sensing is rapidly becoming a widely used tool for people in all areas of work. It is used to record information from space and send it to computers where this analog information is then translated into digital numbers. From this, satellite imagery is produced that can report many different findings from all types of places. Remote sensing is commonly used today as an aid for map making and for observing phenomena that cannot be seen through ordinary aerial photography. Sensors using thermal infrared, radar, and false color infrared are used to give feedback on different phenomena taking place above and below the earth's surface. Thermal infrared is used to look at fires, weather patterns, water pollution, and energy conservation issues. Radar can be used to map out the geography of an area that is usually blocked from vision by clouds. False color infrared is used in crop analysis and investigating different vegetation growths. There are two types of sensors that can be used to take these photographs: passive and active. Passive sensors are used to sense radiation from areas illuminated by the sun or other thermal sources. Active sensors, more commonly known as radar, can generate their own illumination. These pulses of energy are directed to the target area and are then sensed as fractions of the total energy returned. A radar system uses round trip travel times of a directed beam of energy pulses spread out over specific distances to measure actual distances far away. This means that radar can be used to determine the location and separation distances from the instrument to a target. The intensity of this received signal indicates different surface characteristics [14]. Today, remote sensing is still most popular among non-commercial areas such as education and research. While this is true, it is also becoming increasingly useful in commercial areas such as companies that specialize in mapping, energy studies, environmental research, weather research, and natural resources. This study of remote sensing investigates the many ways that satellite imagery can be used to investigate all geographical areas. Seven different areas with varying global conditions will be analyzed by satellite imagery in search of data for differing reasons. The seven regions where different focuses were made are the Pacific Islands, the United States of America, the Pacific Ocean, Asia, Europe, Africa, and the Middle East. In the Pacific Islands, satellite imagery was used as an aid in the search for Amelia Earhart's lost Lockheed 10-E Electra. Satellite imagery of an airplane graveyard in Arizona, USA was examined to see how aircraft appear on a satellite image. In the Pacific Ocean, this technology was used to study the weather patterns of El Nino. In Asia, a study was done to determine some of China's available mineral resources and to visualize the effect of urbanization in rural areas. Satellite imagery was also used to analyze the effects of the Chernobyl nuclear power plant accident in the Ukraine. In this study there are before and after images to pictorially represent the detrimental effect that the radiation had upon the surrounding area. Satellite images of the Sahara Desert in Africa were used to visually picture the remains of a lost civilization located underneath the desert. The final topic of interest resulted in an analysis of images of the Rub al-Khali desert in the Middle East to locate ancient frankincense trading outposts.

## PACIFIC ISLANDS:

The islands of interest in the Pacific are Truk (Chuuk) Island and Gardner (Nikumaroro) Island.

Truk Coordinates:  
Latitude: 7.42 N  
Longitude: 151.67 E

Gardner Coordinates:  
Latitude: 4.67 S  
Longitude: 174.5 W

## MISSION OBJECTIVE:

Truk and Gardner were chosen as areas of interest because of their historical background. Truk Island was a key position in the Pacific during World War II. Hundreds of ships, planes, and submarines lie along the shoreline as a result of the many battles between the Japanese and the Allied forces. Gardner Island is believed to be the final resting place of famed aviator Amelia Earhart. After her disappearance on July 2, 1937, investigations implicated Gardner Island to be the most likely location for the Lockheed 10-E Electra to have gone down when it ran out of fuel. The goal of studying Truk Island is to find satellite images of sunken aircraft. The study will help researchers to identify what an aircraft under water appears as on a satellite image. Using the research gathered from Truk Island aids the study of Gardner Island. The hope in finding satellite images of Gardner Island is that Amelia Earhart's aircraft will appear on the images, putting an end to the mystery of what happened to her after she lost radio contact.

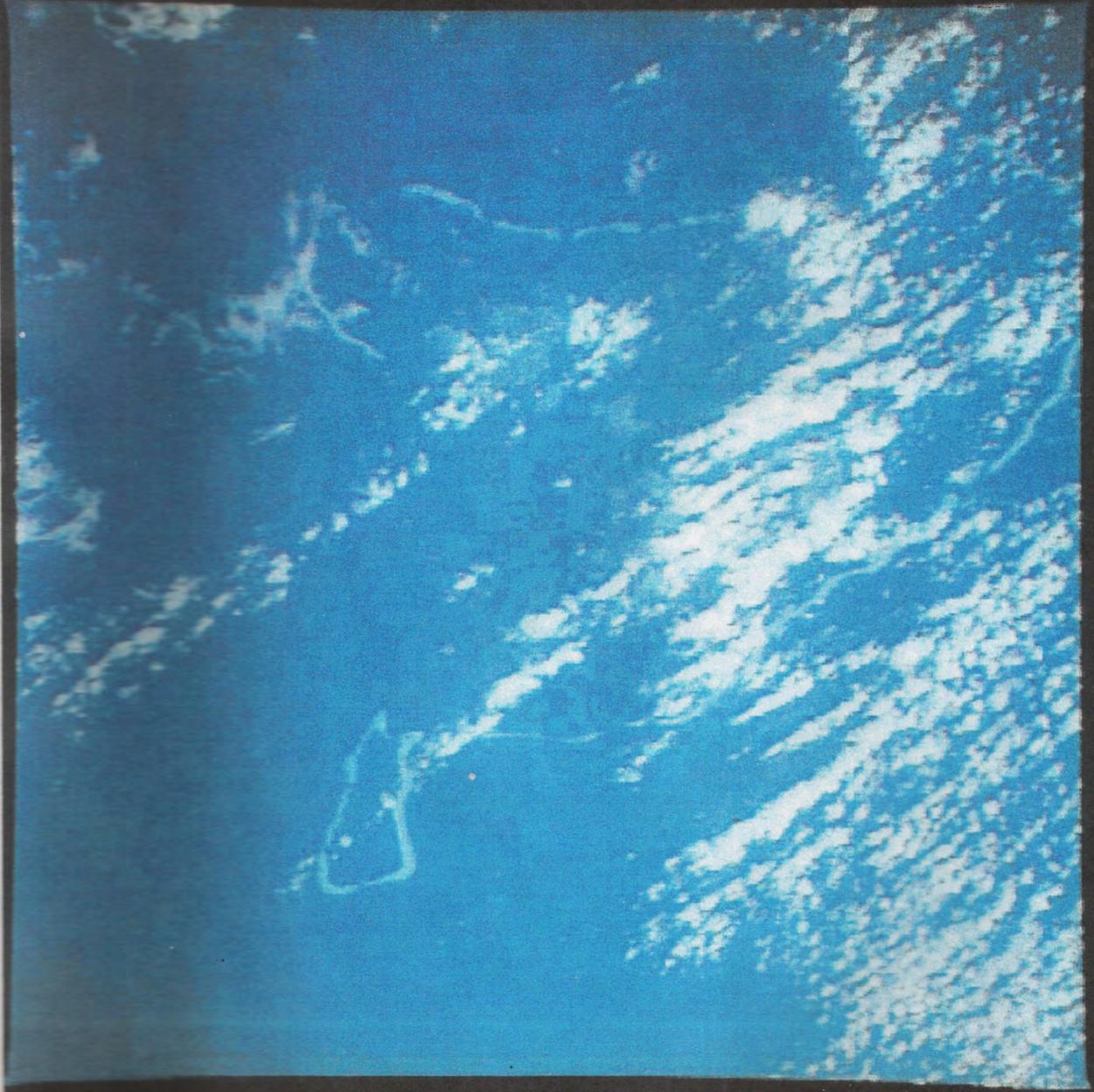
## MISSION RESULTS:

Numerous photos of the two islands were found after weeks of searching on the internet, but only two photos were chosen because they had the best quality. However, these two photos were still not the desired type. Active radar satellite images were needed to see objects under water. The only way to get active radar satellite images of Truk and Gardner would be to pay thousands of dollars to send commercial satellites to cover the area.

The image in Appendix A-1 is a photo of Truk with some cloud cover. Truk is actually a group of small islands. Some of the islands that make up the group can be seen on the right and left center of the image. If the image had been taken with active radar, all the islands in the group would be seen plus anything that was about 20 feet under the water. The image in Appendix A-2 is a photo of Gardner Island also with varying amounts of cloud cover. On this image, however, there is a break in the clouds and Gardner can be seen clearly. By finding an active radar image researchers would have been able to see if anything could be identified along the shoreline or in a lagoon at the southeast end of the island. Finding Amelia Earhart's Lockheed 10-E Electra, or at least parts of it, would have put to rest a 60 year mystery.

Another photo of an island that is relevant to the Earhart mystery was also found on the internet. The image in Appendix A-3 is a photo of Canton Island, which is part of the Phoenix group of islands in the Pacific. Gardner Island is also part of the Phoenix group. The story of the island takes place in late 1970/early 1971. A helicopter mechanic was stationed at Canton Island during the time and frequently went on surveying missions with the helicopter crews. He recalls that on one flight he spotted a radial aircraft engine on a reef of one of the islands in the group, possibly Gardner. He had the helicopter pilot airlift the engine to Canton where he toyed with it while on the island. The helicopter operation in the Phoenix Islands later closed down and the engine was put in a dump. The dump was located on the east end of a runway that is on the northwest end of the island. If the engine was part of Amelia Earhart's plane it would shed some light on what happened to her in 1937 [22].

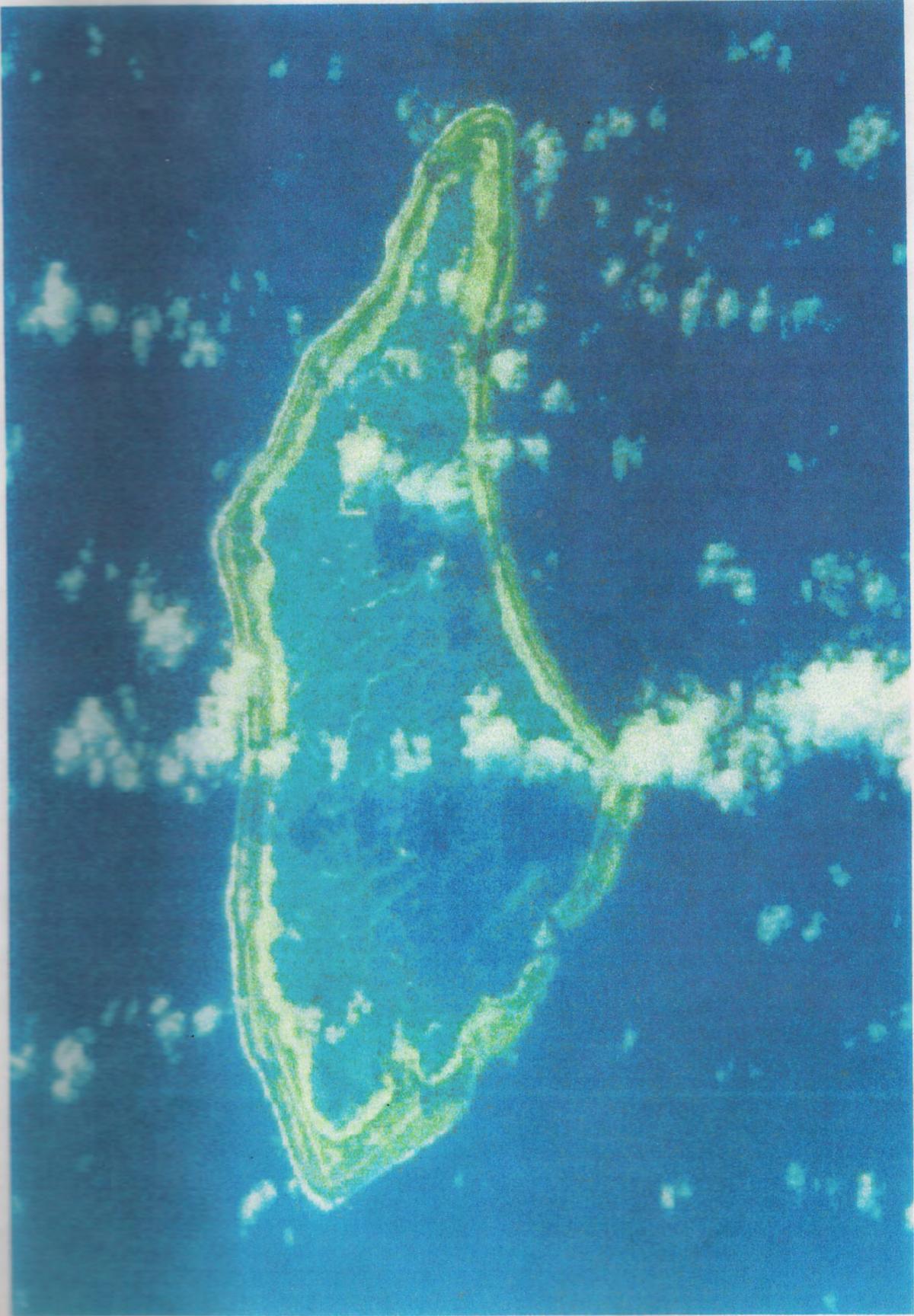
Though the desired satellite images were not found on the internet, it is no indication that they do not exist. Some images exist and people just may not realize what could be revealed on the images. Other images cost so much that people may not wish to purchase an image of the area. Hopefully, one day researchers will get a hold of active radar satellite images that will end one of the biggest mysteries of the century.



941006 040526 STS-60 217 084



A-2



A-3

## UNITED STATES OF AMERICA: ARIZONA

Area of interest is Davis-Monthan Air Force Base located near Tucson, Arizona.

Coordinates:

Latitude: 32.18 N

Longitude: 110.89 W

### MISSION OBJECTIVE:

Davis-Monthan Air Force Base was chosen as a research topic for the remote sensing project because it is the home of the Aerospace Maintenance and Regeneration Center (AMARC). The AMARC can best be described as a graveyard for military aircraft. When military aircraft are finally retired they find themselves at the AMARC where they can be preserved and stored away until they are called to active service again as remotely controlled drones or until they are sold to friendly foreign governments. One of the most prestigious residents of the AMARC is the B-52 Stratofortress, the dominant bomber of its time. Since the area is known to have a large amount of aircraft, studying satellite images of Davis-Monthan Air Force Base will help in determining how aircraft appear on an active radar image. The results of the study will aid in the search for lost aircraft. With active radar, aircraft can be located under water, in the shrubbery of the jungles, and in woodland areas. Knowing what an aircraft looks like on a radar image may help in further missions such as search and rescues.

### MISSION RESULTS:

As a result of the extensive research that has been conducted, aerial photographs of Davis-Monthan Air Force Base have been found, as well as an active radar image of the area in which the base is located. By studying the photographs and the radar image it can be determined what is needed for an aircraft to be spotted on an active radar image.

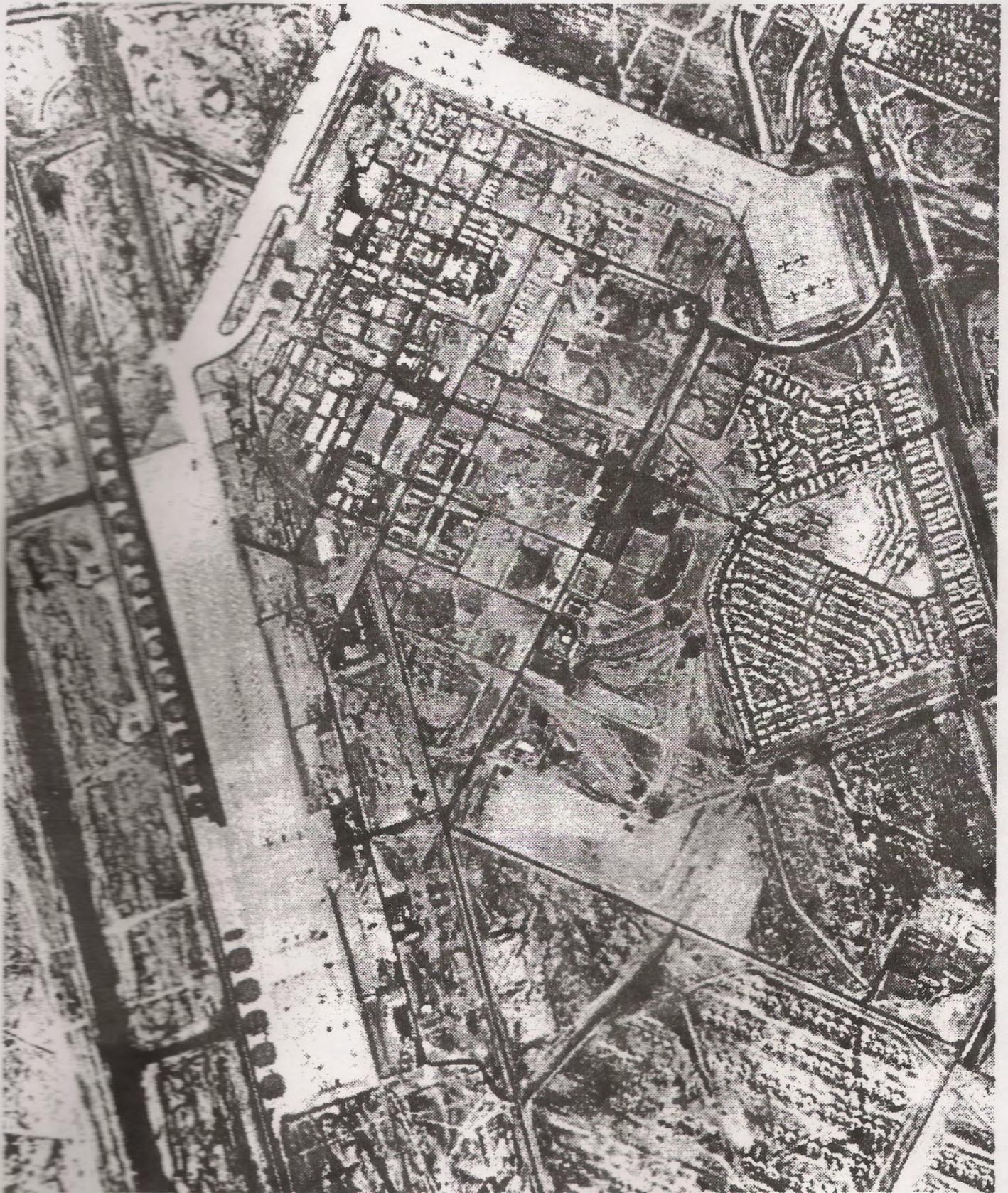
Aerial photographs of the Air Force Base were found on webpages that gave the military history of the base. Aerial photographs were also found on Terraserver, a huge database of photographs from around the world [21]. The photographs on the web server were taken by the United States Geological Survey (USGS). The image in Appendix B-1 shows the detail of the base and the aircraft on the field. Part of the AMARC can be seen in the lower right of the image. Images in Appendix B-2, B-3, and B-4 are images of the base at 16 meters, 8 meters, and 1 meter resolution. Resolution refers to the square meters of an area that one pixel on the image represents. At a 16 meter resolution the Air Force Base can be identified, but aircraft are not distinguishable. At an 8 meter resolution more detail of the base can be seen, but it is still hard to see a clear outline of an aircraft. At a 1 meter resolution the rows of aircraft at the AMARC can easily be distinguished. The 1 meter resolution image was the best for clearly identifying aircraft using the aerial photographs.

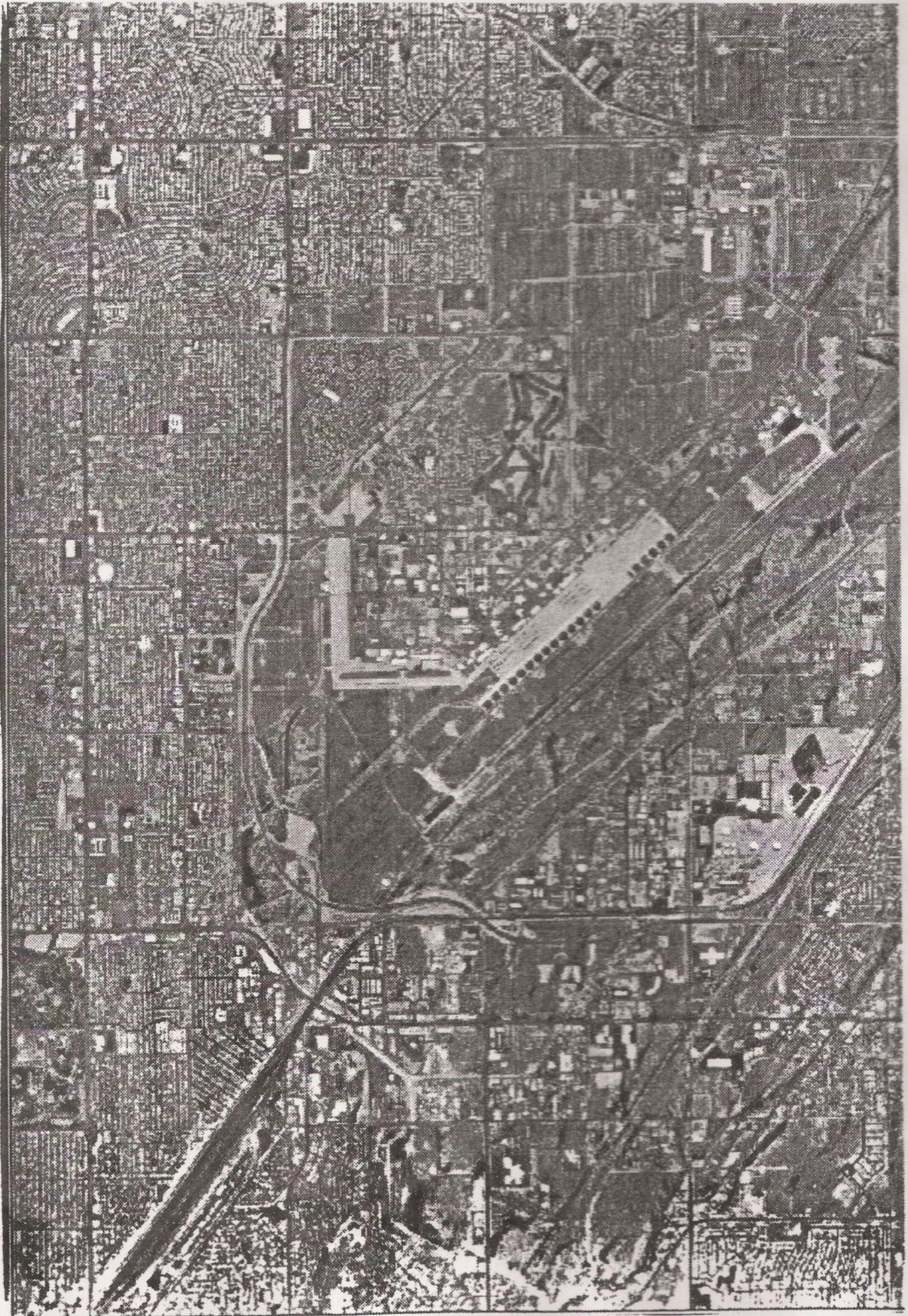
An active radar image of the area where Davis-Monthan Air Force Base is located was found in the data taken by SIR-C (Spaceborne Imaging Radar-C). The third of its kind, SIR-C is an imaging radar system that was launched aboard the Space Shuttle twice in 1994 [10]. The image in Appendix B-5 is the only active radar image of the area that was found during the search. The subject in discussion is located in the upper left corner of the image. Although SIR-C data has a lot of uses, its use in trying to identify aircraft is undesirable. SIR-C data uses a resolution of about 50 meters. That resolution is not suitable for trying to identify an object the size of an aircraft.

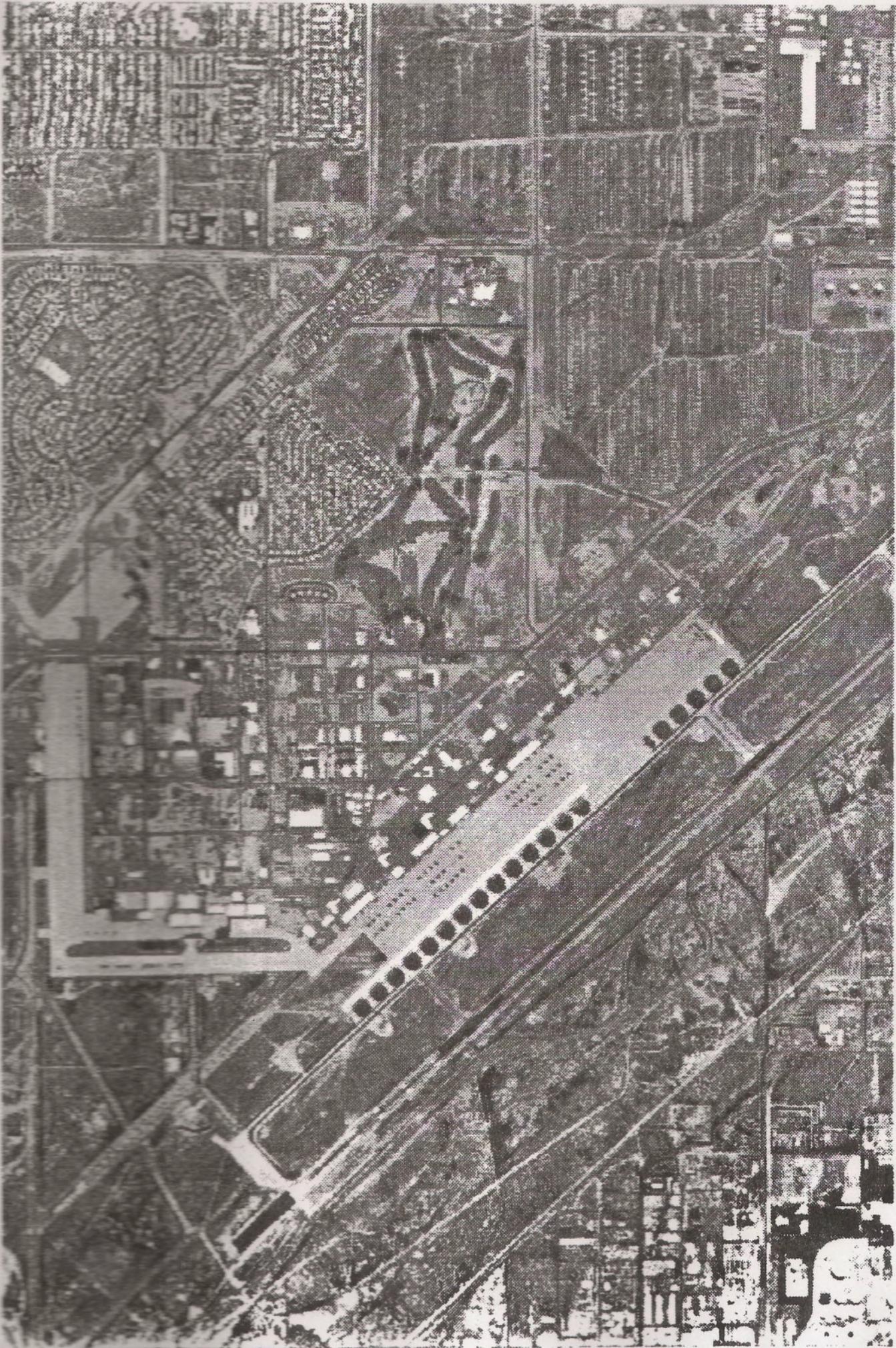
As a result of analyzing the aerial photographs and the active radar image of Davis-Monthan Air Force Base an important factor was realized. In order to utilize the capabilities of an active radar image to aid in identifying aircraft, the image must have at least a 1 meter resolution. Only with a 1 meter resolution can an aircraft be identified clearly.

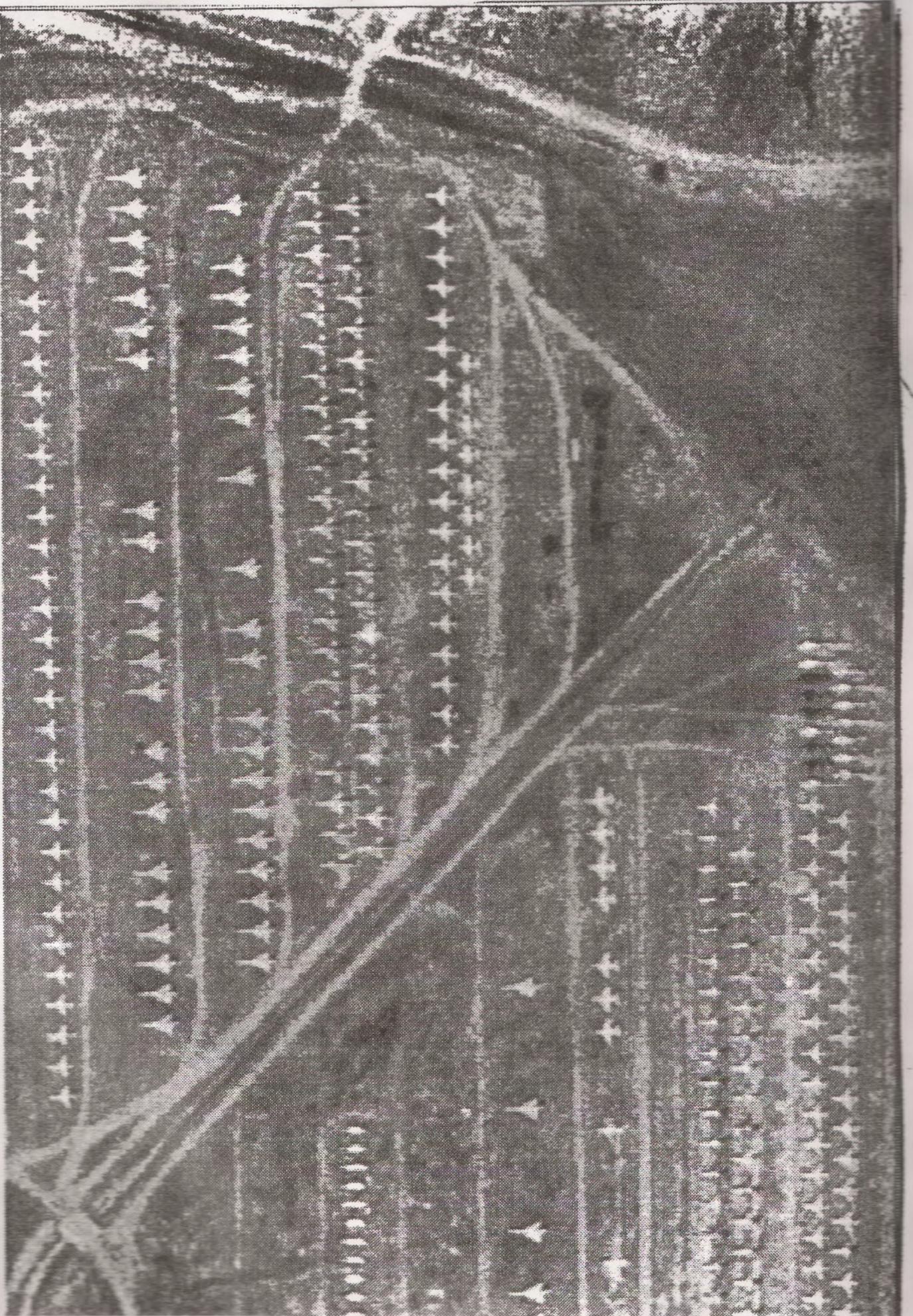
# Davis-Monthan AFB

KH-4 CORONA Product









B-4

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0-0

## PACIFIC OCEAN:

The topic of interest is El Nino.

## MISSION OBJECTIVE:

El Nino was chosen as a topic of interest to research because of its impact on global weather patterns. Since 1976 El Nino has become more frequent and intense, creating a greater need for an understanding of its possible effects.

## MISSION RESULTS:

El Nino is the abnormal flux of hot water [20], warming equatorial Pacific Ocean surface waters [19]. The cause of this warming is from normal fluctuations in water and wind patterns every 3 - 7 years. However in the last two decades El Nino events have been more frequent and severe according to the National Oceanographic and Atmospheric Administration (NOAA) [20]. Severe effects of El Nino include floods, droughts, and other foul weather [19].

Appendix C-1 shows the developmental stages of the 1997 El Nino in six stages. Color indicates water vapor and its gradual move from the west pacific to the east pacific. Deep blue coloring represents areas of dryness, or little water vapor, while on the other end of the spectrum red indicates areas of high moisture, or El Nino. This gradual move of warm moisture, increase in water temperature, and the evaporation rate of water causes a rise in temperature and humidity in the eastern Pacific. The increase of warm water evaporation caused moisture to form huge cloud towers which produced enormous amounts of rain for regions in the eastern Pacific [1].

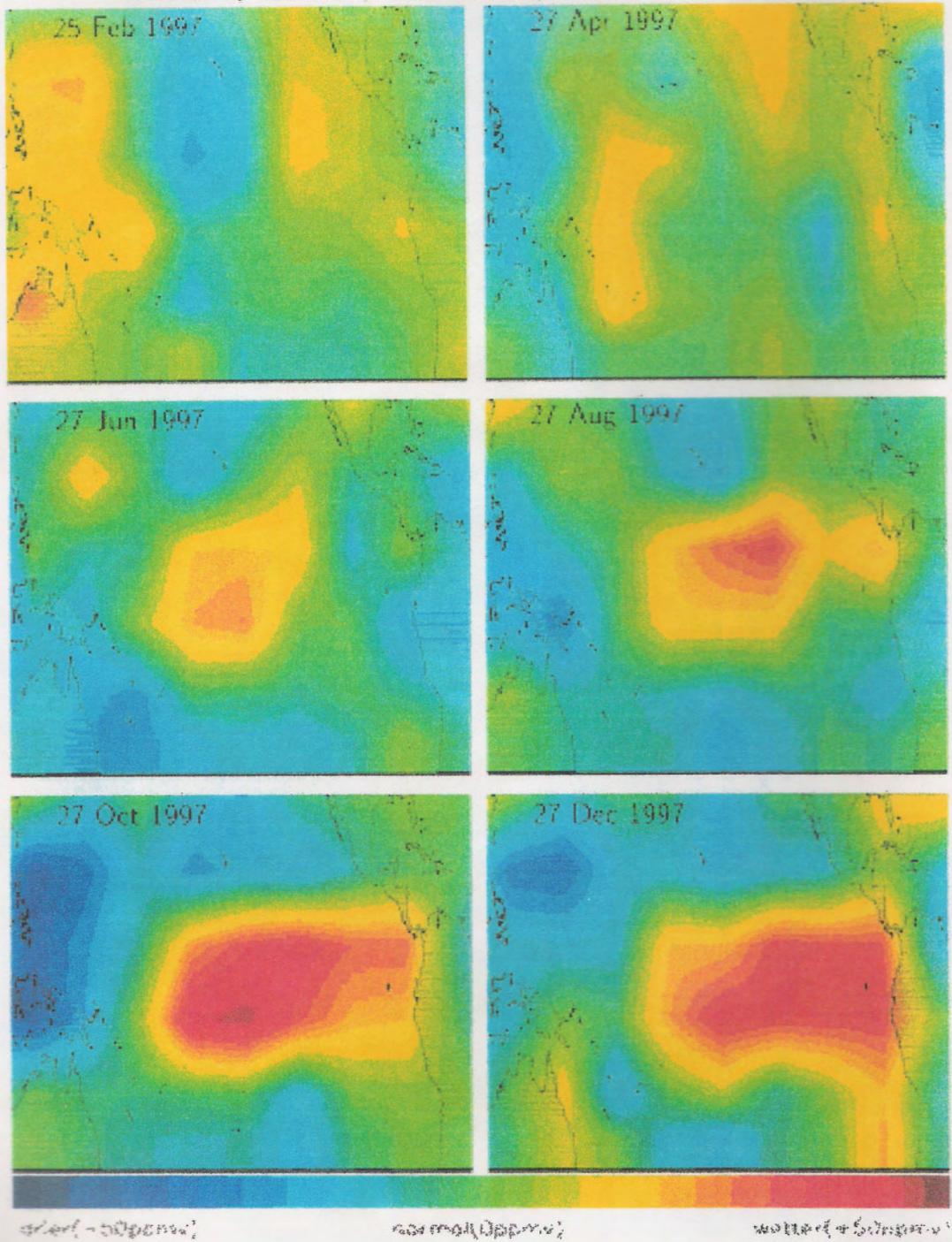
The 1997 El Nino had a drastic effect on global weather because of the excess moisture in the air, but began to wear off in 1998 [1]. Pictures in Appendix C-2 and Appendix C-3 reveal how the levels of water vapor around the equator gradually decreased from dark reds and blues to more greenish tints. Green coloring represents areas of normal moisture levels. These pictures not only measured water vapor, but sea surface height, which serves as a heat content. To distinguish sea surface height, red areas are 10 cm, or 4 inches above normal, white areas are between 14-32 cm or 6-13 inches above normal, and green represents areas of normal sea levels [5]. Effects of high moisture in the east, or red areas, resulted in heavy rains. Areas of blue suffered from extreme dryness or drought. The gradual decrease in temperature and water vapor in the air allowed for the gradual decrease in drastic rains and droughts in the world.

It is wind that causes this flux in heat and moisture. The picture from NSCAT revealed how winds in the circulation pattern from the equator branched off and carried heat and moisture from the tropics to the east Pacific. In other words, instead of having normal tradewinds blow east to west maintaining balance, tradewinds blow west to east, so that all the moisture and heating moves to the east [1].

The 1997 Development pictures of El Nino (Appendix C-1) are taken by the Upper Atmosphere Research Satellite (UARS), which measures temperature, pressure, wind velocity, and gas species [23]. Pictures from March 8, 1998 (Appendix C-2) and May 3, 1998 (Appendix C-3) are taken by the TOPEX/Poseidon satellite. This satellite is designed to monitor global ocean circulation, discover the ocean and atmospheric relationship, and improve global climate predictions [12]. The final picture (Appendix C-4) taken from NASA Scattometer (NSCAT) during the last 10 days of May 1997, reveals the relationship between the ocean and the atmosphere [1]. Satellite photos are vital because they reveal how heat and moisture fluctuate, changing normal global weather patterns over time. Heat and moisture moving toward the east formed El Nino, causing heavy rains and high temperatures in eastern Pacific regions and droughts in western Pacific regions. The westward movement of heat and moisture caused the weakening of El Nino and the

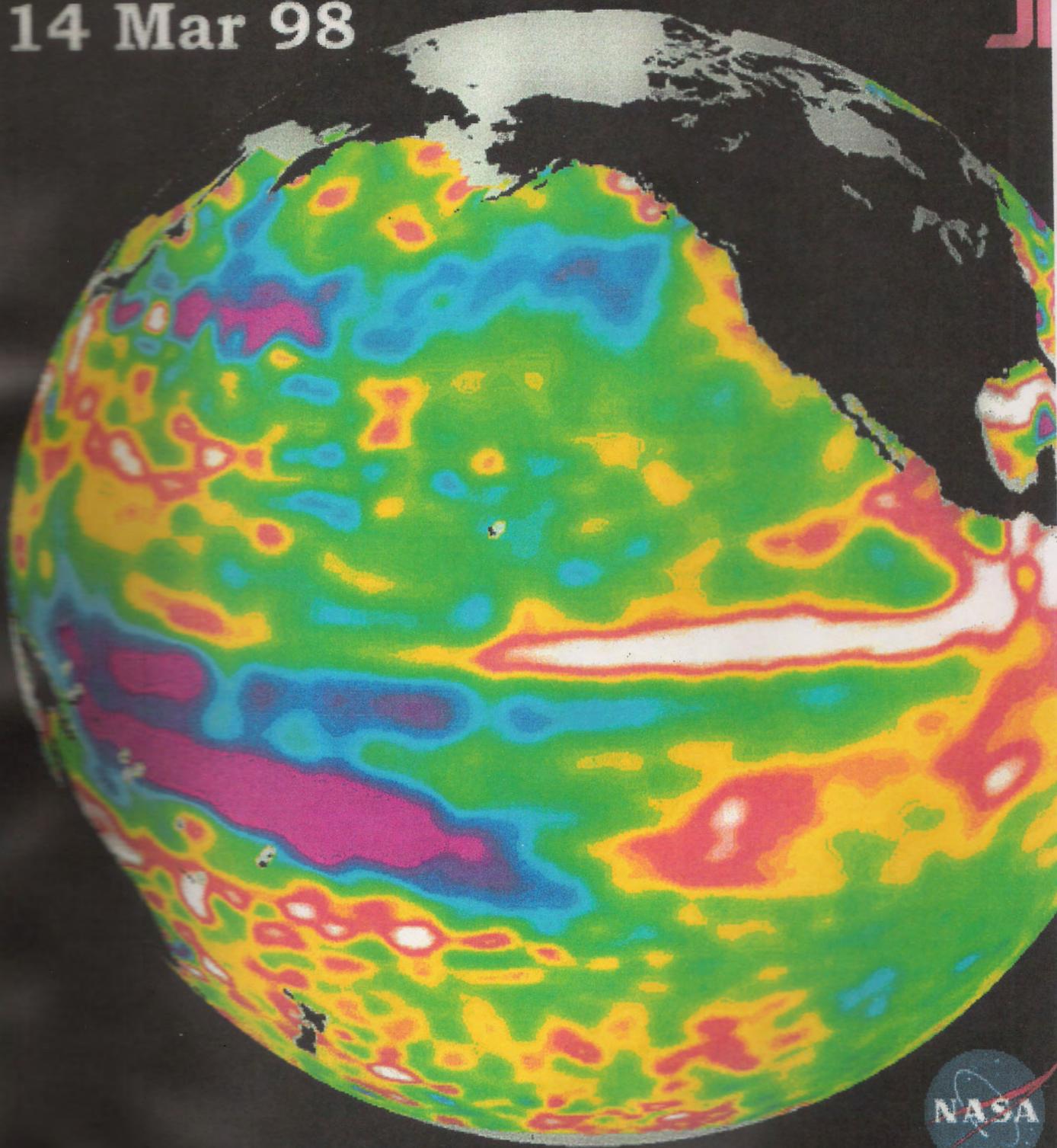
stabilizing of global weather patterns. This data is used by the NOAA to issue weather condition advisories [5].

**1997 El Nino Development**  
**Humidity Anomaly Measured by UARS-MLS at 10-12 Km**

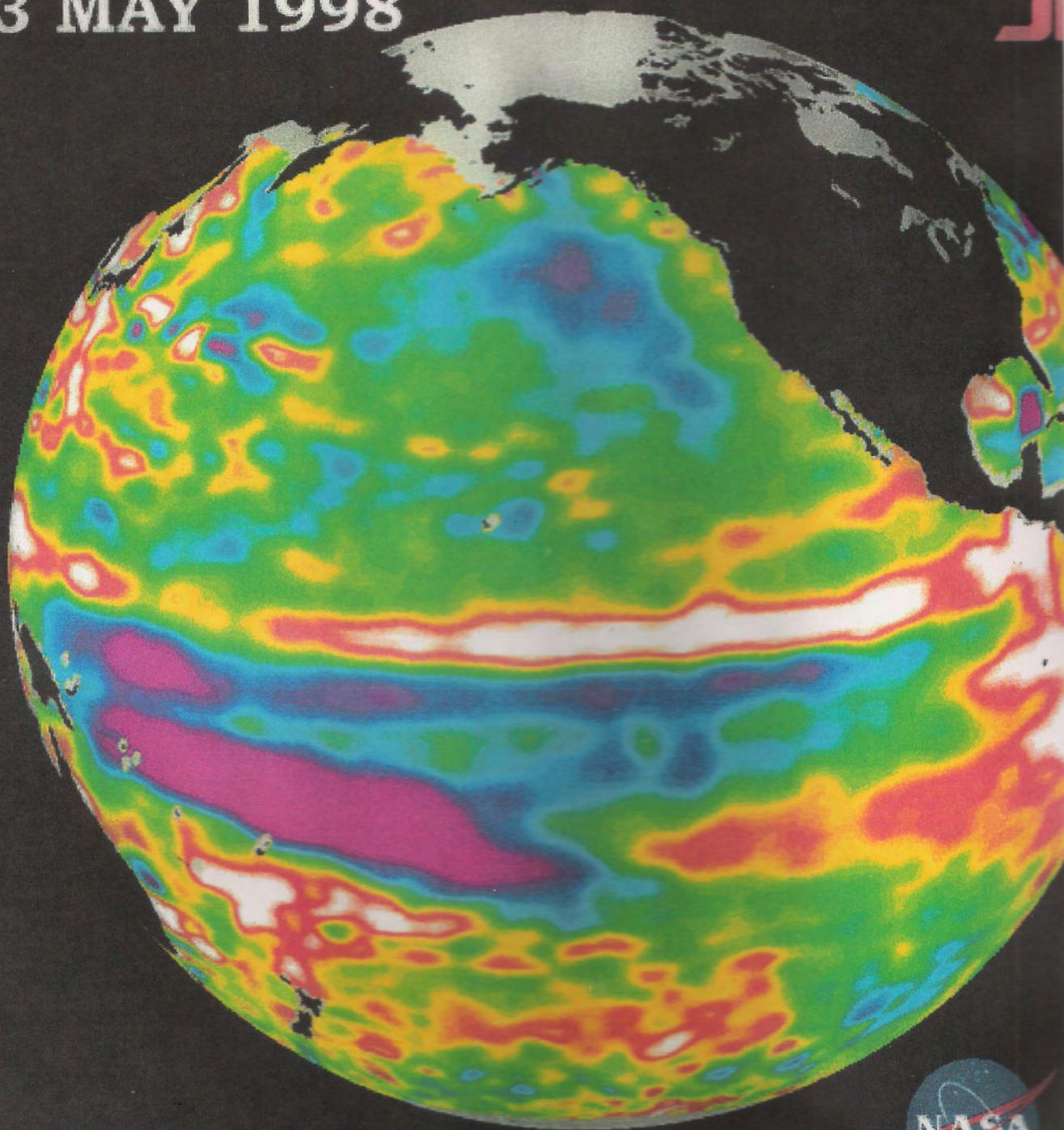


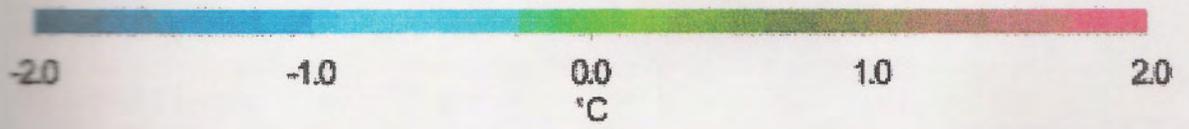
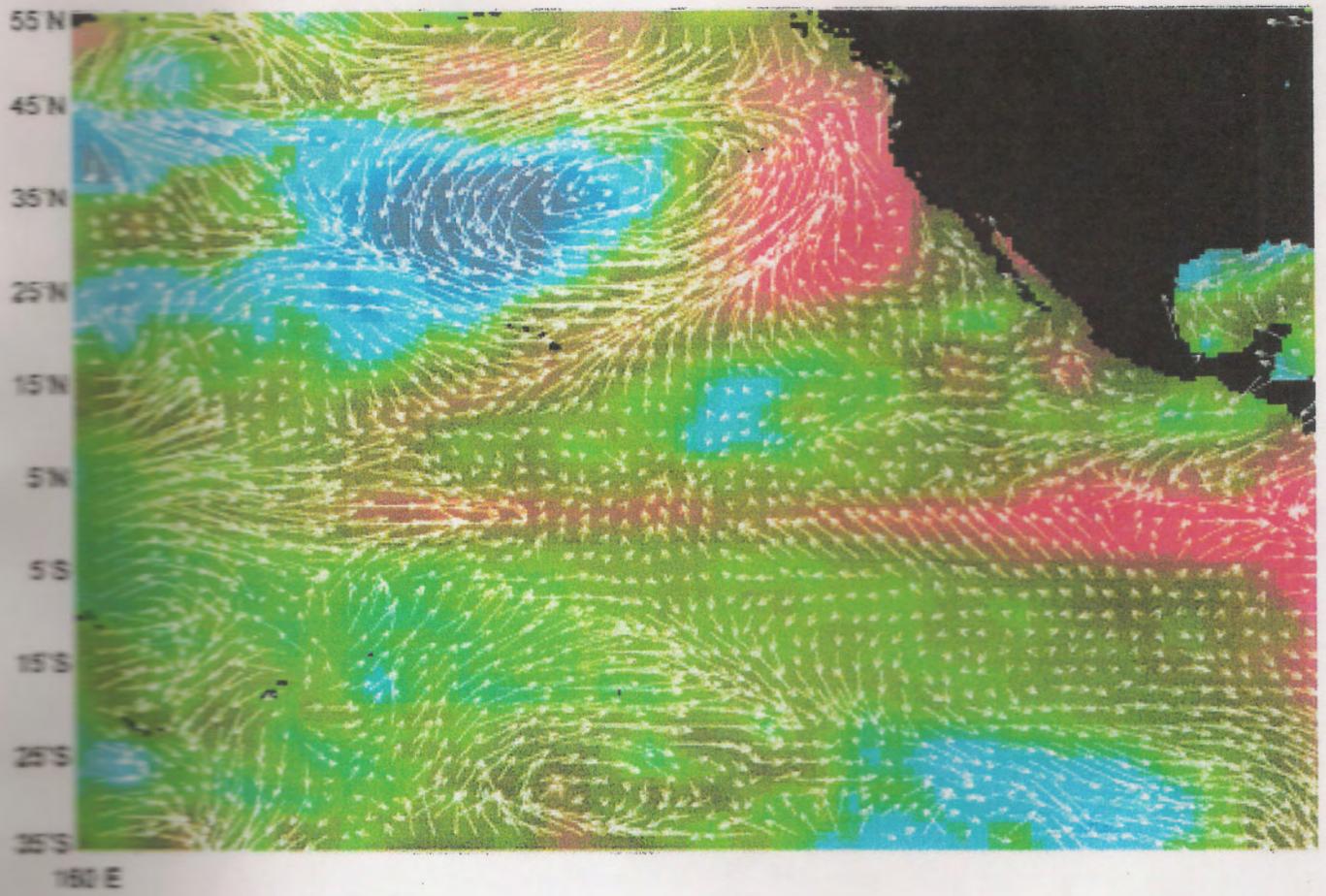
14 Mar 98

JPL



03 MAY 1998





## ASIA: CHINA

Areas of interest include the surrounding areas of Beijing, Hong Kong, and Zhao Qing.

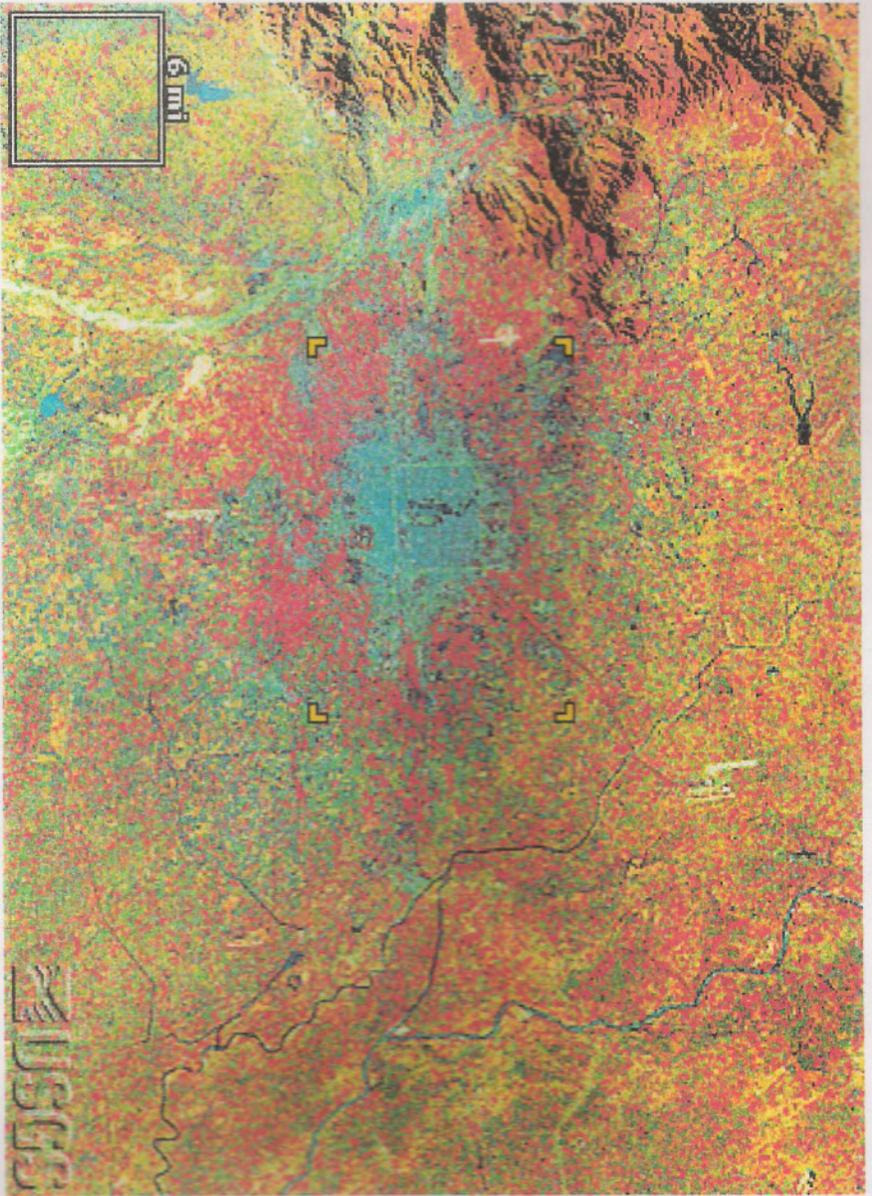
### MISSION OBJECTIVE:

The purpose to this study of the satellite imagery of China involved two objectives. First, to observe how the growth of China has affected its natural and agricultural vegetation. Secondly, to use satellite imagery to find areas suitable for possible mineral exploration. China was chosen to be studied because it is a region of the world that is undergoing rapid growth. The increasing population and urbanization of China makes this country a prime target in which to study the effects of urbanization on rural areas. In addition to its rapid development, China is a country with multiple geographic regions. It encompasses different temperate zones and biomes. 43 percent of China's land surface is covered by mountains, 26 percent by plateaus, 19 percent by basins, and 12 percent by plains. Because of China's diverse topography, it contains a variety of natural resources. Searching for those resources has driven many geologists and scientists to study China's lands. China's abundant resources motivated this satellite imagery study. The vast resources of the internet were used to compile data and pictures of satellite imagery that reflected the results of the objectives.

### MISSION RESULTS:

Multiple images containing information about agriculture were first located and obtained from the internet. The first set of images (Appendix D-1, D-2, D-3) were taken from the LANDSAT satellite showing the growth of Beijing from 1976-1991. On these images, the red areas represent agricultural growth while the green areas depict more developed areas with little or no agricultural growth. The image of Beijing from 1976 shows the least amount of development. During this more socialist era, it was common for people to reside in the same building that they worked. Because people often both lived and worked in the same place, there were very few large housing developments present in Beijing. This changed, however, in the reform era when more and more employers bought apartment buildings or housing blocks in which their employees could live. This meant that fewer people were living and working in the same place, creating a need for massive housing developments. During the 1980's the growing development of Beijing encouraged people to move their industrial plants from the central city to more outlying areas. The development of Beijing is evident in the expanding areas of green portrayed on the images over the time span of fifteen years. This rapid growth is especially apparent in the city of Fangzhuang. This city is located on the top left hand side of the images. On the 1984 image, the population of Fangzhuang was only 1,000 people. At this point in time, the city was portrayed as a reddish image because there was not much urbanization in the area. In the 1991 image, however, this same city appears dark green showing the massive development that occurred in just seven years [3]. Another image that exemplifies how satellite imagery can be used to differentiate rural areas from urban areas is shown in Appendix D-4. This is a radar image of Hong Kong, China taken by the Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) on the Space Shuttle Endeavor on October 10, 1994. In this picture, the more densely populated areas are distinguished by bright yellow colors. The dark blue and red colors depict the South China Sea and the yellow specs in this area represent ships. By analyzing this image one can locate the most heavily populated and most developed areas in Hong Kong. Again, this is the type of image that might be used to record the effect of urban development on tropical environments [7].

The fifth picture of China (Appendix D-5) shows the area around the city of Zhao Qing. This southern portion of China is being used to identify new areas with a potential for mineral exploration. The image was taken on April 17, 1994 by the Shuttle Endeavor with SIR-C/X-SAR radar. The SIR-C/X-SAR type of radar uses L-Band, C-Band, and X-Band microwave wavelengths to take images of many different areas. In the lower left hand corner, the light blue area along the river Xi Jiang is the actual city of Zhao Qing. The largest gold mine in southern China can also be seen in the top left of the image along a mountain ridge. This area of the mountain ridge and the area to the east are currently being studied to identify possible mining areas (North is located in the upper left on this particular image). The image is an excellent example of how satellite imagery is being used by geologists to aid in the development of China. Satellite images such as those shown in Appendix D are extremely helpful to both geologists and land-use planners [9].

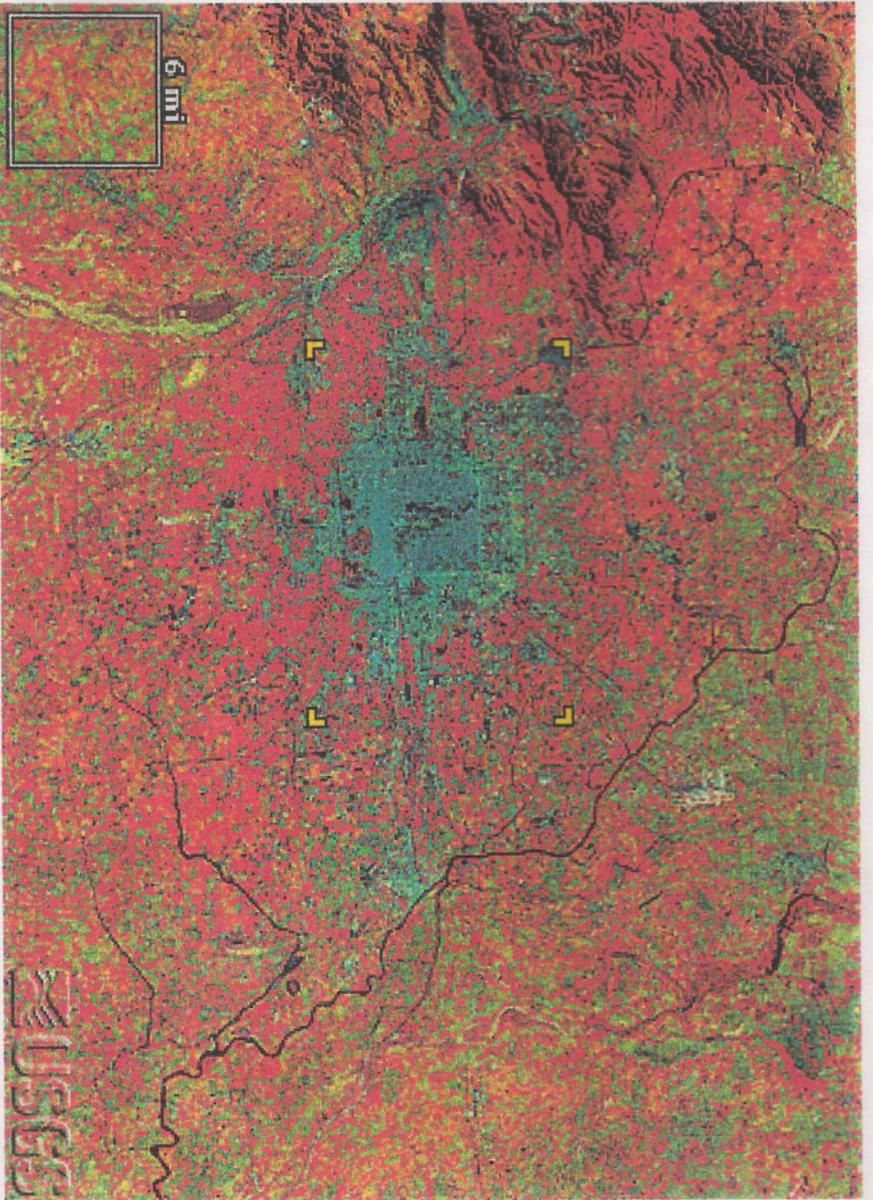


26 October 1976, Landsat 2 MSS bands 4 2 1



1984 -- 1991 -- Map



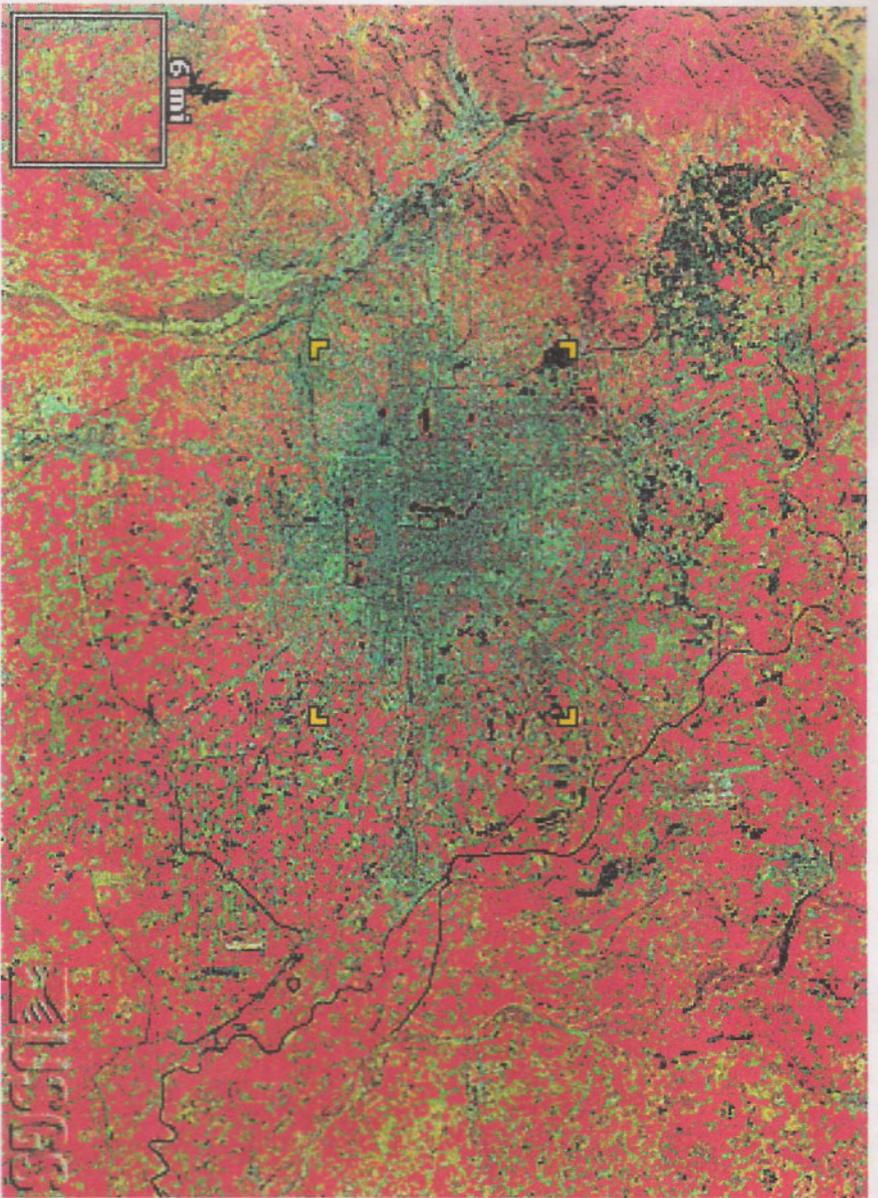


3 October 1984, Landsat 5 MSS bands 4 2 1



1991 -- 1976 -- Map



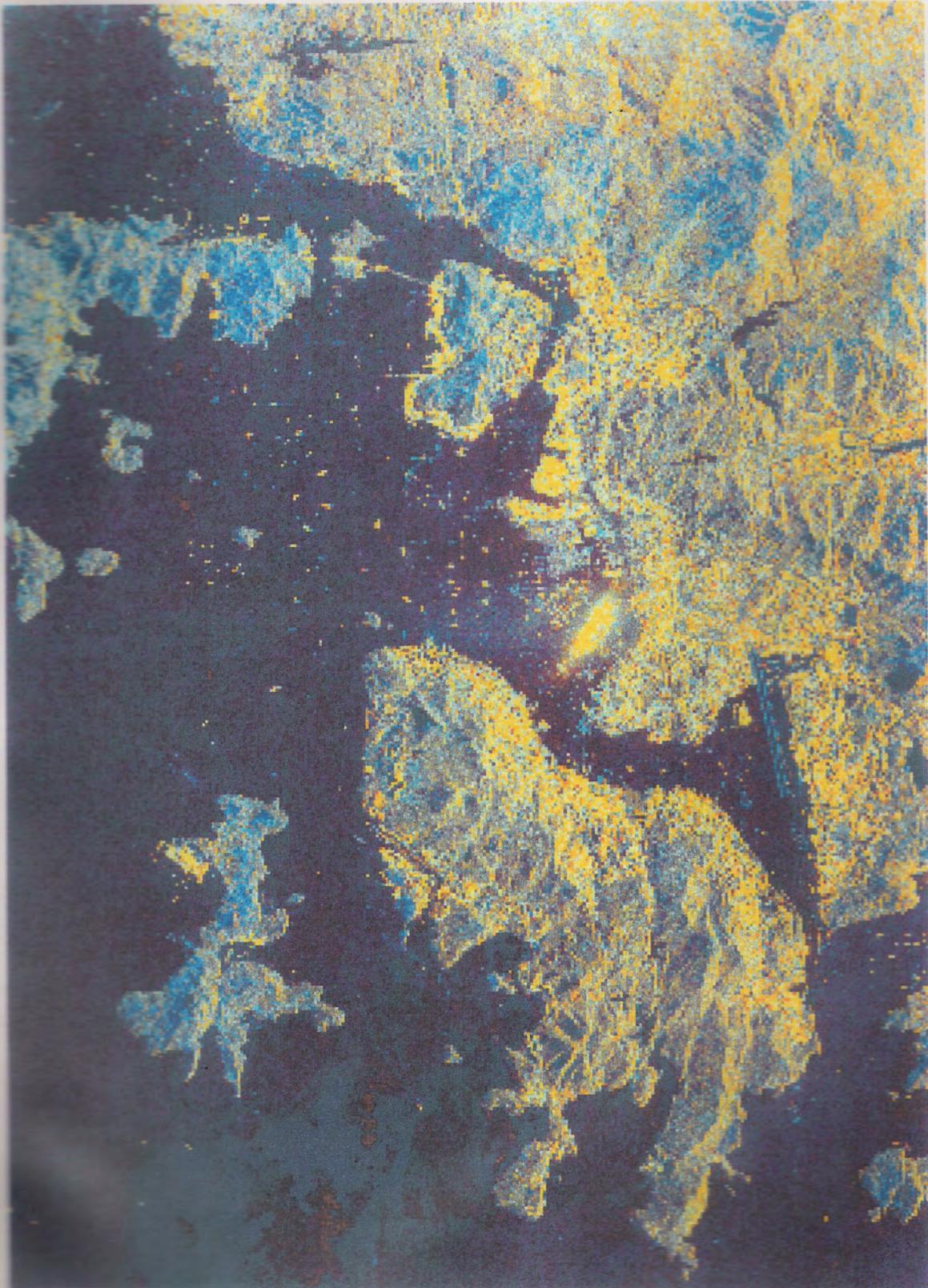


16 May 1991, Landsat 5 TM bands 4 3 2



1976 -- 1984 -- Map







D-5

## EUROPE: UKRAINE

Area of interest is the Chernobyl nuclear power plant.

Coordinates:

Latitude: 51.17 N

Longitude: 30.15 W

### MISSION OBJECTIVE:

The Chernobyl nuclear power plant was chosen as an area of study because it is the site of the most devastating nuclear accident that has occurred since the dawn of the atomic age. When a reactor at the nuclear power plant exploded on April 26, 1986 it prompted the evacuation of more than 120,000 people that lived within a 30 km radius to the plant [18]. The radiation caused by the blast also affected the vegetation and wildlife that was in the vicinity of the nuclear power plant. Pine forests had died and wild animals suffered a decline in number as well as extraordinarily high mutation rates [26]. Even after 12 years, the blast is still discussed because toxic remains have not been completely sealed and another reactor at the plant is still operating. Satellite images of the area near the time of the blast and closer to the present will be researched. By studying satellite images of the area at different times a comparison will show the effects radiation had on the area surrounding the Chernobyl nuclear power plant. A clearer understanding will be reached as to how satellite imagery can be used to study the effects disasters, such as this one, have on the land.

### MISSION RESULTS:

Through a search of the internet satellite images were found that depict the vegetation around the Chernobyl nuclear power plant. The satellite images are from one month after the blast and from six years later in July 1992. The images, as well as some background information, were found on the Earthshots web page [4]. The web page showed images from different events that have occurred throughout the world. The images that were found for Chernobyl were taken by the United States Geological Survey (USGS) which used the LANDSAT instrument. The LANDSAT instrument utilizes false-color infrared to take images. False-color infrared measures the infrared portion of the spectrum. This type of infrared is best used for vegetation because there is a higher reflectance from vegetation in the infrared spectrum. Vegetation appears as red hues on the LANDSAT images.

The image in Appendix E-1 was taken one month after the blast and has the plant centered on the image. The area in the lower left of the image was known to be mostly villages and farmland. When the image in Appendix E-1 is compared to that in Appendix E-2, the effect that the radiation has had on the farmland is extremely evident. The dark red of the villages is lighter in 1992. Also, the bright red of the farmland surrounding the villages is now a tan-green. The change in color is the result of the abandonment of the land, natural vegetation taking over the fields, and the fact that radioactive material has settled into the soil. The image in Appendix E-3 is a 1992 image that is overlaid with zones indicating the amount of Cesium 137 present during a 1990 study of the area [18]. Abandonment and loss of vegetation can be seen more clearly in the zones with the greater intensity, represented by the dark blue outline.

The images of the Chernobyl nuclear power plant are excellent examples of how the technology of satellite imagery can be used to study events from around the world that have had an effect on the land. LANDSAT images can also be used to study agriculture and urban development. Through the use of satellite imagery, such as LANDSAT images, scientists can better study what is going on in the world.



31 May 1986, Landsat 5 TM bands 4 3 2



1992 -- Map





26 July 1992, Landsat 4 TM bands 4 3 2



1986 -- Map

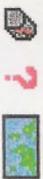




26 July 1992, Landsat 4 TM bands 4 3 2



1986 -- 1992 -- Map





## AFRICA: SAHARA

Areas of interest include the Aorounga Impact Crater, Wadi Kufra, and the Eastern Sahara Desert.

### MISSION OBJECTIVE:

The Sahara Desert was chosen as a topic of study because of the recent talk of possible "lost civilizations" underneath the desert sands. The objective of this search was to find images taken by radar capable of seeing about twenty feet underneath the top layer of sand. This would enable visuals of possible "lost civilizations" located under the Sahara. It is necessary to use active radar in order to see this far under the ground. An example of active radar is Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR). This type of radar is useful when analyzing desert areas because it is able to reach through thin layers of dry sand.

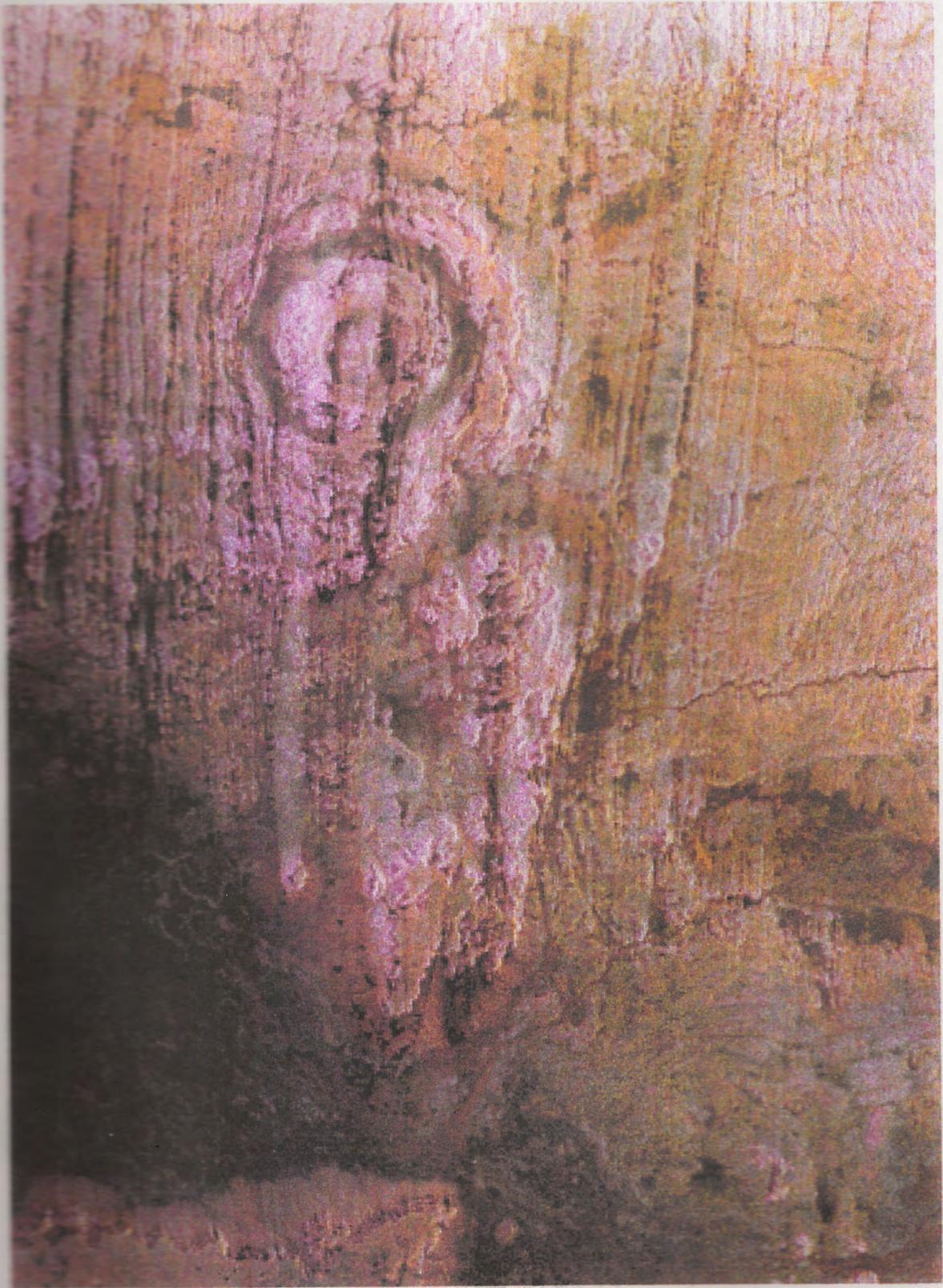
### MISSION RESULTS:

While there were no actual images found of the "lost civilizations," three other examples were found of how satellite imagery helped to make discoveries in the Sahara. Satellite imagery of the Sahara desert was used to analyze crater impacts, the expansion and contraction of the desert, and ancient river beds underneath the desert sands. The SIR-C/X-SAR captured an image (Appendix F-1) of the Aorounga impact crater in a part of the Sahara desert located in northern Chad. This crater, about 17 kilometers in diameter, was the result of an impact caused by either a comet or an asteroid almost several hundred million years ago. In this image, the dark streaks represent deposits of windblown sand built up from years of wind erosion. This is why the crater appears in a ring-like pattern. The dark band located in the upper right hand corner of the image is thought to be part of a possible second crater [2]. In another image of relatively the same area, (Appendix F-2) three craters are visible. To the left of the center, the two-ringed pattern is the Aorounga impact crater. In the center of the image, the second proposed crater is seen as a dark circle (trough) surrounding a lighter area (peak). A third possible crater can be seen to the right of the center as a dark trough. The middle of this structure is thought to be located more to the right of the image, in the center, as a lighter area. These two images show how satellite pictures are enabling geologists to study things that the human eye cannot see alone. Satellite imagery is also being used in this dry area to study the expansion and contraction of the Sahara desert [13]. The images shown in Appendix F-3 depict the changing size of the Sahara desert from 1984 to 1990. The desert areas are shown in brown, while areas of vegetation are represented by a purple color. While these two images show how the desert is contracting in size, earlier data showed that the desert was slowly growing larger from 1980 to 1984. The overall movement of the desert from 1980 to 1990, however, expanded. This type of information is useful to track because it will provide countries with warnings for possible times of famine and drought [6]. The third satellite imagery study being done in the Sahara desert looks at ancient river beds located just beneath the sand. The image in Appendix F-4 shows a Spaceborne Imaging Radar-A (SIR-A) swath superimposed over a LANDSAT image of the same area. Where the LANDSAT image is simply a photograph of the area, the SIR-A image uses active radar to see one to four meters beneath the sand. On this 50 km wide swath, it is possible to see river systems that were created thousands of years ago. This image of the eastern Sahara desert sparked excavation teams to analyze the area for artifacts. Human artifacts dating all the way back to Paleolithic times were found in these river beds. Also, shells of large snails indigenous to moist soil and vegetation, called *Zootecus insularis*, were found [15]. Another image of the ancient river beds underneath the Sahara Desert was taken in Wadi Kufra, Libya by the SIR-C/X-SAR (Appendix F-5). The radar was able to penetrate the dry sand cover of the



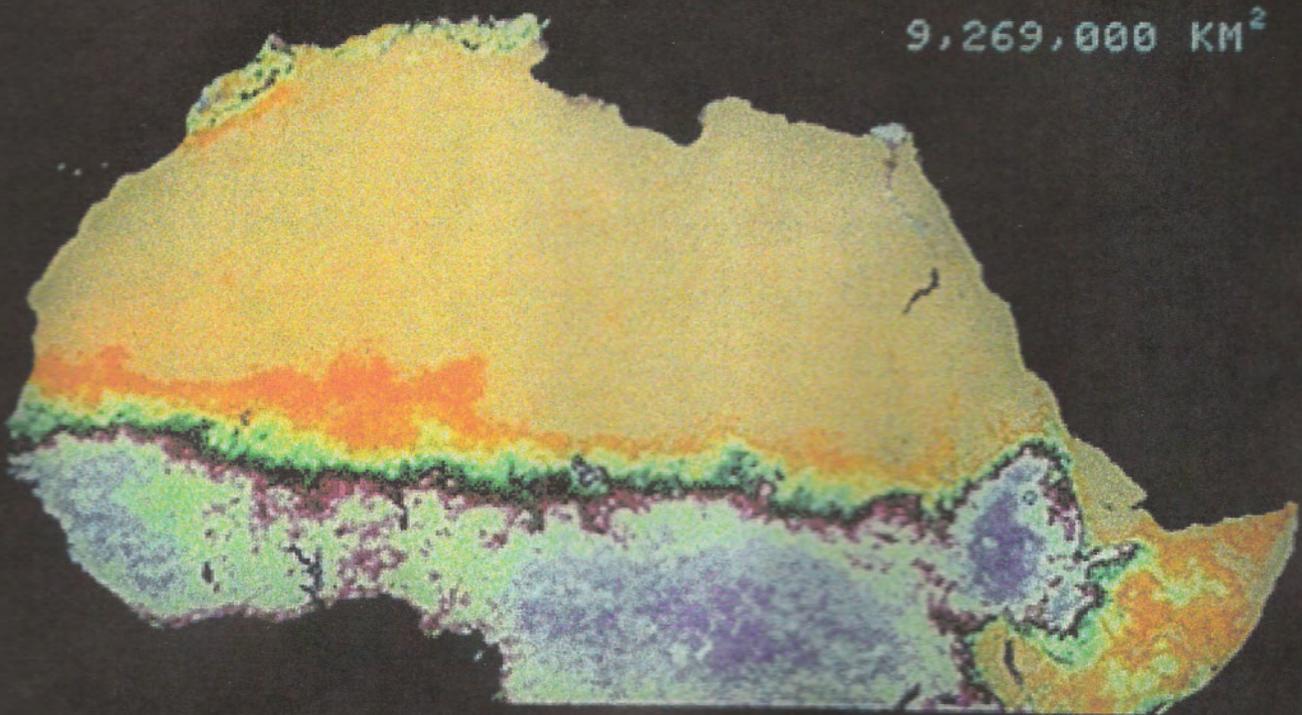
F-1

P-2



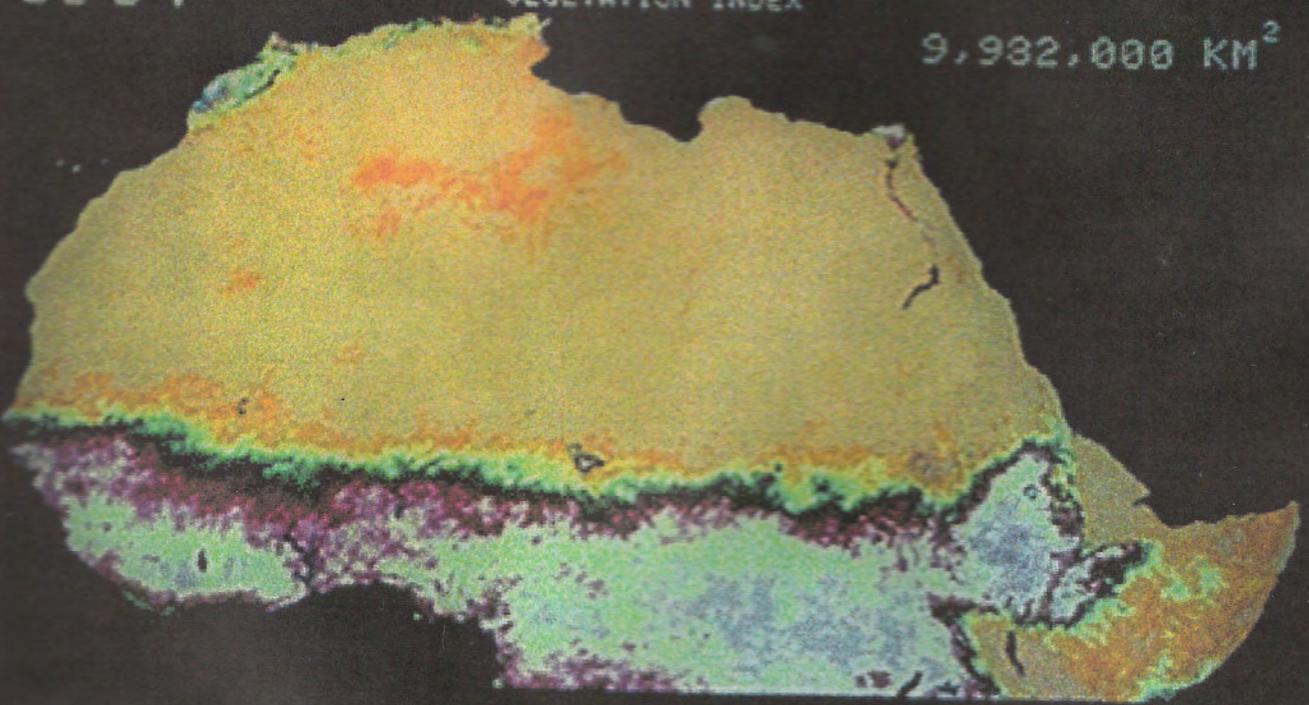
1990

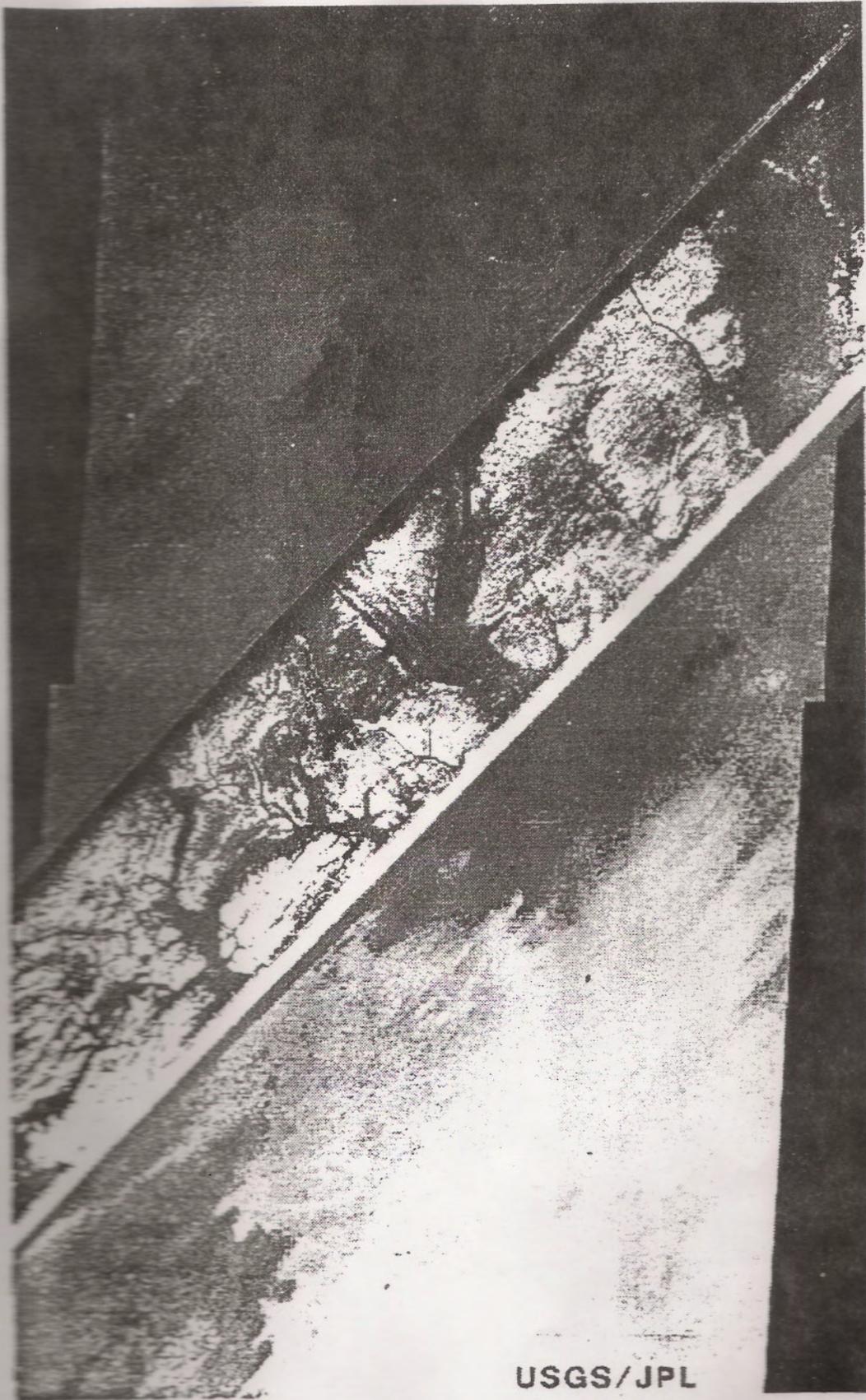
9,269,000 KM<sup>2</sup>



1984

9,932,000 KM<sup>2</sup>





USGS/JPL

## MIDDLE EAST: RUB AL-KHALI

The area of interest is a desert area on the Arabian peninsula. The area is known as the Rub al-Khali or Empty Quarter. The desert is located on the borders of Saudi Arabia and Yemen.

### MISSION OBJECTIVE:

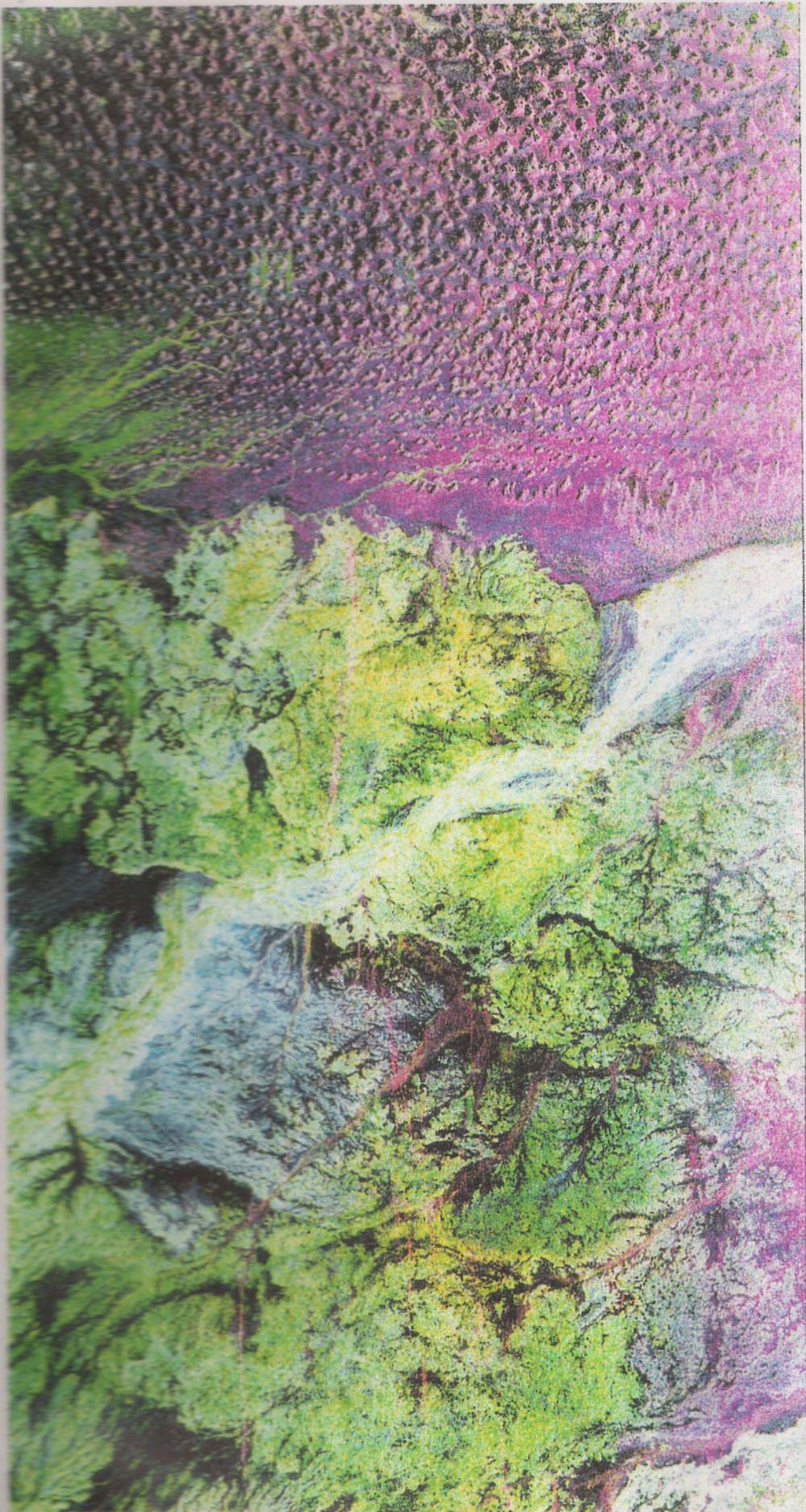
The stretch of desert was chosen because around 3000-1000 b.c. it was home to the frankincense trade routes between India and places north of the Arabian peninsula [16]. Along the trade routes were ancient cities where the inhabitants acted as middlemen in the spice trade. The ancient cities had trade routes that fanned out in every direction, but mostly towards the north. Over time, however, the trading started to become obsolete and the trading routes were barely used anymore. Eventually, the ancient cities began to deteriorate and fall into disrepair because trading caravans were traveling through the cities. The ancient cities did not survive the test of time and are believed to be buried in the sands of the Rub al-Khali. Using satellite imagery of the Arabian peninsula a search was conducted to find one of the ancient cities: Ma'rib. The ancient city of Ma'rib is suspected to be buried near the present day city of Ma'rib and also near a massive dam that was constructed during the time of the frankincense trade routes.

### MISSION RESULTS:

As a result of an extensive search of satellite images in the Rub al-Khali not one image was found that would help identify the ancient city of Ma'rib. However, another ancient city in the Rub al-Khali was found through the use of satellite imagery. With the help of history and the use of satellite images the lost city of Ubar was identified in the Rub al-Khali. Ubar happened to be a larger trading outpost than Ma'rib.

The satellite image that was found was taken by the Spaceborne Imaging Radar C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR). Looking at the image in Appendix G-1, the magenta colored area is a region of large sand dunes. The green areas are rough limestone rocks, which form a rocky desert floor. The white area that runs across the middle of the image is a dry stream bed. The lost city of Ubar is too small to be detected on the image but is known to exist near the dry stream bed. The reason Ubar is known to exist is because the red streaks on the image are tracks that lead towards the center of the image (18.4 degrees North, 53.6 degrees East) near the dry stream bed. Field investigations have showed that many of the tracks were used in ancient times [8].

Finding the lost city of Ubar is an excellent example of how satellite imagery has helped historians discover more about the past. Although the initial objective of finding the lost city of Ma'rib was not accomplished, insight into the uses of satellite imagery was still gathered by studying the image taken of the Rub al-Khali. Satellite imagery has helped historians discover the past, helped scientists determine the future, and has many other uses that have yet to be realized.



## CONCLUSION

Research done on each of the seven topic areas brought about a significance to the development of remote sensing. Remote sensing can be applied in many ways such as conducting search and rescues, studying weather patterns, finding new archaeological sites, studying agricultural depletion, locating natural mineral sites, and for studying the effect of radiation on surrounding areas. Each of these applications were developed years ago, indicating that there are already many new applications of remote sensing and that more will soon be developed. There are more areas in the world that could be hiding a lost civilization or be the site of a cataclysmic event. With the use of instruments such as SIR-C/X-SAR and LANDSAT, plus commercial systems such as SPOT and Earthwatch, researchers can examine other parts of the world. The remote sensing field of technology is rapidly growing because of the many ways that it can benefit all of mankind. Not only can remote sensing do things such as studying weather patterns, but it can also be used for more serious matters such as national security. All of these examples prove remote sensing technologies to be extremely beneficial and reinforce the idea that improvements and commercialization of remote sensing should continue.

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## APPENDIX (IMAGE REFERENCES)

### Pacific Islands

- A-1 <http://images.jsc.nasa.gov/iams/images/earth/STS068/lowres/20168423.jpg>  
A-2 <http://images.jsc.nasa.gov/iams/images/earth/STS41B/lowres/10047804.jpg>  
A-3 <http://www.nawastsoc.org/solar/raw/earth/caton.gif>

### United States: Arizona

- B-1 [http://www.fas.org/irp/imint/4\\_af6.htm](http://www.fas.org/irp/imint/4_af6.htm)  
B-2  
<http://www.terraserver.microsoft.com/GetPageByXY.asp?XID=6428&YID=2967&Sdclid=1&Imgdate=05/16/1992&ImgSize=2&DSize=1>  
B-3  
<http://www.terraserver.microsoft.com/GetPageByXY.asp?XID=6428&YID=2967&Sdclid=1&ImgDate=05/16/1992&ImgSize=1&DSize=1>  
B-4  
<http://www.terraserver.microsoft.com/GetPageByXY.asp?XID=6429&YID=2967&TileX=0&TileY=-1&SrcId=1&ImgDate=05/16/1992&DSize=1>  
B-5 [http://edcdaacftp.cr.usgs.gov/bin/sircbrowse/sirc\\_fl2\\_22/dt072\\_42/2000/1246/10](http://edcdaacftp.cr.usgs.gov/bin/sircbrowse/sirc_fl2_22/dt072_42/2000/1246/10)

### Pacific Ocean

- C-1 <http://www2.jpl.nasa.gov/files/images/browse/p49503.gif>  
C-2 <http://www2.jpl.nasa.gov/files/images/browse/p49667.gif>  
C-3 <http://www2.jpl.nasa.gov/files/images/browse/p49847.gif>  
C-4 <http://www2.jpl.nasa.gov/files/images/browse/p49890.gif>

### Asia: China

- D-1 <http://www.usgs.gov/Earthshots>  
D-2 <http://www.usgs.gov/Earthshots>  
D-3 <http://www.usgs.gov/Earthshots>  
D-4 <http://www.jpl.nasa.gov/radar/sircxsar/hongk2.html>  
D-5 <http://www.jpl.nasa.gov/radar/sircxsar/sc-china.gif>

### Europe: Ukraine

- E-1 <http://www.usgs.gov/Earthshots>  
E-2 <http://www.usgs.gov/Earthshots>  
E-3 <http://www.usgs.gov/Earthshots>

### Africa: Sahara

- F-1 <http://www.jpl.nasa.gov/radar/sircxsar/chad2.html>  
F-2 <http://www.jpl.nasa.gov/radar/sircxsar/chad1.html>  
F-3 [http://eosps0.gsfc.nasa.gov/eos\\_edu.pack/p17.html](http://eosps0.gsfc.nasa.gov/eos_edu.pack/p17.html)  
F-4 [http://ourworld.compuserve.com/homepages/mjff/rad\\_rivs.htm](http://ourworld.compuserve.com/homepages/mjff/rad_rivs.htm)  
F-5 <http://photojournal.jpl.nasa.gov/cgi-bin/PIA/GenCatalogPage.pl?PIA01310>

### Middle East: Rub al-Khali

- G-1 <http://www.jpl.nasa.gov/radar/sircxsar/sc-ubar.gif>