ASTRONAUT-ACQUIRED PHOTOGRAPHY OF EARTH: ITS HISTORY AND CONTINUED APPLICABILITY IN QUANTITATIVE ANALYSES

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ABSTRACT

Aerial and satellite photography has been used extensively in many different research efforts, for example, atmospheric studies, vegetation analysis, and change detection. Archives of historical aerial and satellite photography are a valuable resource to the science community. There is currently an archive of over 450,000 photographs of Earth taken by United States astronauts dating back to the early 1960's. This archive covers the majority of the Earth's surface and offers imagery taken by a variety of camera configurations including film and digital, various lenses, different look angles, and changing solar illuminance. There is extensive repeat coverage over many regions of the world's landscape. These photographs have been increasingly analyzed in order to assess their potential as a remote sensing resource. The objectives of this paper are to give the reader an evolutionary history of astronaut-acquired imagery of Earth, and to discuss the many scientific analyses that have been successfully completed using this underutilized resource.

THE EVOLUTION OF ASTRONAUT-ACQUIRED IMAGERY OF EARTH

Remote sensing has evolved significantly in the past two centuries. It is impossible to appreciate the present technology and scientific applications without first reviewing the progression of remote sensing instruments through time and innovation. Astronaut photography continues in the present day world of complex satellites because it is rooted early remote sensing photography, it is the longest continuous archive of orbital observations of the Earth, and because it connects people on the ground with human observations of Earth from orbit.

Evolution of Aerial Photography

As reviewed by Jensen (2000), the union of land cover mapping and photography took place during the late 1800's. The first aerial photograph of Paris was acquired by Gasper Felix Tournachon from a hot air balloon in 1858 The camera technology was eventually developed further in the 1860's when balloons were altered to hold camera systems that mapped forests in the American Civil War. After the American War, in 1887, the Germans began conducting research with photography for the purpose of forest delineation. With the completion of this research, they developed photogrammetric techniques for measuring features and areas.

While aerial photography from balloons had become commonplace during the late 1800's, Albert Maul obtained the first aerial photograph from a rocket in 1906 Only three years later, Wilbur Wright captured the first aerial photograph from an airplane flying over Centocelli, Italy After this early experimentation, there was an increased interest in utilizing aerial photographs for creating military maps during World War I. During World War II, more sophisticated techniques in Aerial Photographic Interpretation (API) were developed (Jensen, 2000). These techniques included detection methods for identifying invasion barges, bomb-damage assessment, and troop movements. Later, during the Cold War, the perceived potential threat of the Soviet Union to the United States (and vice versa) caused both sides to declare "..any aerial reconnaissance overflight of another state without authorization was considered to be an illegal and hostile act unless national leaders agreed to it beforehand" (Jensen, 2000). To sidestep this President Eisenhower began the Genetrix Reconnaissance Balloon Project which floated 448 weather balloons across the Soviet Union. These balloons obtained 13,813 aerial photographs of Soviet and Chinese territory. This program ended in 1956 when the Soviets held a press conference and presented approximately 50 of these balloons and demanded a response. The official U.S. response was that the said balloons were for gathering weather data (Jensen, 2000). From 1954-1957 there was a steady advance in worldwide observational technology. The U-2 payload consisted of two high spatial resolution camera systems. The first had a very long focal length to be able to detect objects two-three feet in length from an altitude of 70,000 feet. The second camera system was a tracking camera that produced a continuous film strip for the entire length of the flight (Rich and Janos, 1994). To replace the slow U-2 plane, a newer and faster reconnaissance plane was developed: the SR-71, setting the world speed record for an aircraft at 2,193 m.p.h. The SR-71 used remote sensing and signal intelligence equipment (Jensen, 2000).

Earth Observations from Photography to SatellitesCorona and Early Defense Photography

The launch of Sputnik on October 4, 1957, the world's first artificial satellite and engineered by the Soviet Union, began the "Space Age" (Day et al, 1998). There was public interest as well as government interest for classified projects in imaging the Earth from space. In February 1958, President Eisenhower approved the Corona Project to take pictures from Earth's orbit of the Soviet Bloc countries and then de-orbit the photographic film for processing and as an aid to military operations. While in orbit, Corona acquired photographs with a constantly rotating stereo panoramic camera system and then loaded the exposed photographic film into recovery vehicles. The Corona recovery sequence is shown in Figure 1 (**National Reconnaissance Office (NRO)**, 2000).

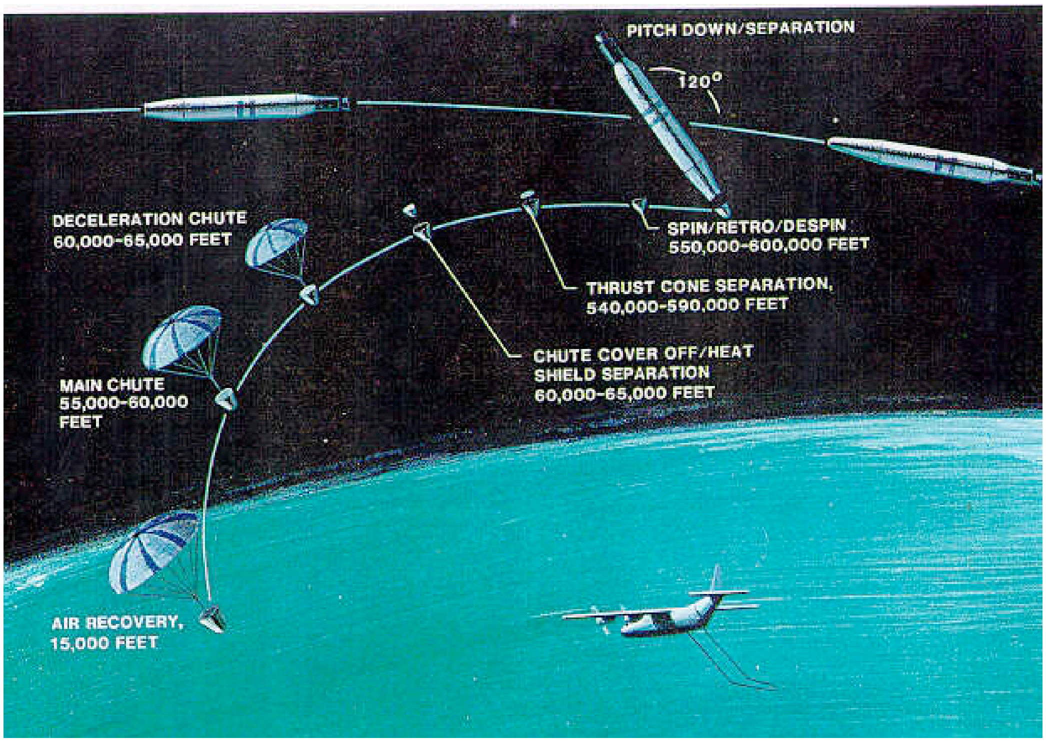

Figure 1. The Corona recovery sequence of the photographic film it collected while in orbit (NRO, 2000).

Based on both public interest and military interest, aerospace research was separated into two divisions. The first division was the National Aeronautics and Space Administration (NASA); it was created in 1958 to achieve the peaceful exploration of space and to carry out fundamental aeronautics research. The second division was the Department of Defense (DOD). This group became accountable for research and development in the subject of aerospace military activities (Burrows, 1998).

When these divisions were created, it was hoped that maps of the Earth, based on these photographs, would be completed and become available to the public (Burrows, 1998). However, the majority of the funding for these Earth observation programs came from the intelligence world for their surveillance projects. Therefore, once satellites were deployed which were camera-equipped, the cameras, their film, and all ensuing photographs were classified (Burrows, 1998). All remained classified until recently, when an Executive Order was published to commence the ultimate declassification of the photography from the CORONA, LANYARD, and ARGON camera systems (Burrows, 1998).

In contrast with defense-related observations of the Earth, images of Earth associated with human space flights have generally been made available to researchers and the public, although technologies and distribution has varied with different programs. There have been eight major phases of human space flight throughout U.S. history, they are the following NASA programs: the Mercury Program (1961-1963), the Gemini Program (1965-1966), the Apollo Program (1968-1973), the Skylab Program (1973-1974), the Apollo-Soyuz Test Project (1975), the Space Transportation System (Space Shuttle, 1981-present), the Shuttle-*Mir* Program (1996-1998), and the International Space Station (2000-present).

The Mercury Program

Project Mercury was the United States' first attempt at launching a human being into space. The Mercury Project made six manned flights from 1961 to 1963 that included a number of firsts in space flight: the first United States citizen in space, and the first photography taken by a human in space. Alan B. Shepard, Jr. was the first American in space in a 15.5-minute suborbital flight on May 5, 1961.

Astronaut John Glenn took a camera purchased in a drugstore with him on the first U.S. orbital flight on February 20, 1962 and acquired photographs of terrestrial features and meteorological phenomena (Cloud, 1995). Those amateur photographs became the first Earth observation photographs taken by an astronaut in history. Subsequent Mercury flights recorded properties of the Earth limb, examined the possibility of seeing lights at night, and used filters to acquire weather photographs to help in designing satellite sensors (NASA 1963).

The Gemini Program

The Gemini Program took place directly after the conclusion of the Mercury Program from 1965-1966. Gemini consisted of 12 manned missions, as well as 2 unmanned flight tests of the equipment.

Most of the photography was organized through two science experiments, Synoptic Terrain Photography and Synoptic Weather Photography. The objective of the first experiment was to obtain high-quality pictures of significant land areas that had been previously well mapped by aerial photography and to serve as a standard for interpretation of photographs of unknown areas of Earth, the Moon, and other planets. In addition to this, the overall goal was to collect high-quality photographs of comparatively poorly mapped areas of Earth to answer questions pertaining to continental drift, structure of the Earth's mantle, and overall configuration of the continents. This was achieved with a 70 mm modified Hasselblad camera. This flight yielded 100 high-quality terrain photographs (Garber, 2001).

The second major experiment was the Synoptic Weather Photographic Test. The objective of this photography was to supplement information taken from meteorological satellites. At that time, satellites usually took photographs from an altitude of 643.7 km (400 n.m.) or more; Gemini photos were taken from altitudes of approximately 161 km (100 n.m.) (Garber, 2001). The same camera was used in this experiment as for the Synoptic Terrain Photography experiment. Overall, approximately 200 pictures proved to be useful in achieving the goals of this project. In terms of the photography gathered from this flight, this was a triumph and major achievement for the astronauts. The foci of the astronaut-acquired photography were divided into several categories: Geology, Oceanography, Weather and Water Resources.

The Apollo Program

The Apollo Program began in 1968 and extended to 1973. The motivation of this program was simple: to reach the moon and claim it with an American Flag before the Russians did so. The focus of the Apollo program intended to place humans on the Moon and carry the astronauts safely back to Earth. Apollo Missions 11, 12, 14, 15, 16, and 17 achieved this goal. The Apollo 6 mission carried a fixed 70-mm camera over the southwestern US and Africa that produced exceptional color stereo pairs (Lowman, 1999). Apollo missions 7 and

9 were Earth orbiting missions. During the Apollo 7 mission, the crew gathered approximately 200 photographs useful for geology utilizing a variety of filters and film-types. The Apollo 9 mission, in 1969, had a set of four coaxially mounted 70-mm cameras onboard. Using these cameras, the crew effectively completed a returned-film simulation that provided a proof-of-concept for the Earth Resources Technology Satellite (ERTS). The ERTS satellite was the precursor to Landsat (Lowman, 1999). Apollo Missions 8 and 10 tested a variety of apparatus while in the Moon's orbit. Missions 8 and 10 also took photography of the lunar surface (Sawyer, 2002).

The Apollo missions also produced what is known as the "blue marble" pictures of earth. The first blue marble photograph had an extremely important impact on society. It inspired public interest in space exploration, and generated public support for the NASA space program. Seeing the earth from space for the first time has taught us to view the earth, the universe and how we fit into the vastness of the cosmos in a new way (Launius, 2002).

The Skylab Program

By 1969, NASA had successfully flown humans to the moon and brought them back safely. The next phase in space exploration was to examine the possibility of humankind as space settlers. However, one unknown factor was how well humankind could adapt to long-term space exploration. Based on this unknown element, NASA began the Skylab Project. The Skylab program began in 1973 and lasted only one year, through 1974. It was to be much larger than either Gemini or Apollo space capsules. On such a vehicle, astronauts could assume certain aspects of "normal life" that would potentially adapt them to long periods in space. The initial plans for Skylab were that astronauts would work for eight hours, sleep undisturbed for an interval of time, and have free time for relaxation. Three successful crews stayed for record-breaking lengths (Osman, 1983). The Space Shuttle was to be built and serve as a "bus" for transporting crew and materials to Skylab as well as future space flights. Unfortunately, the Shuttle was not built in time and NASA saw Skylab's re-entry into the Earth's atmosphere on July 11, 1979 (Osman, 1983).

There were three crewed flights in Skylab and one unmanned flight. During these flights, the astronauts had access to an onboard data book and a world map exhibiting the locations that were utilized by the astronauts as ancillary information for the features and phenomena that were identified by scientists during preflight training. These men used the binoculars (10x), handheld Hasselblad (70mm) and Nikon (35mm) cameras. The lens and camera combinations provided wide, medium, and narrow fields of view. Color exterior Ektachrome film was employed almost exclusively for astronaut-acquired photography. However, the small number of frames taken with Ektachrome color-infrared film was usually not as satisfactory as those taken with natural color film. The Skylab 4 crew accomplished a "first" in space by acquiring stereo photographs of a sequence of eruptions of the Sakura-Zima Volcano in Japan

(Dumoulin, 2000). In addition to these images, there were also images taken utilizing the grazing incidence telescope. This telescope produced images of the sun using six different filters. Coronal holes were discovered using this instrument. During the last Skylab mission, the Comet Kohoutek was observed.

Russian Earth Observations

As summarized by Glazovskiy and Dessinov (2001), the Russian Space Program, called “Visual Observations” began with the first Soviet flights into earth-orbit. As the program evolved, so did the technology available to cosmonauts. From 1974-1976, earth-observing experiments were carried out utilizing both portable and fixed binoculars with photographic attachments. The KATE-140 camera was used most frequently and had an objective lens with a focal length of 140 mm. The KATE-140 had and 18x18 cm frame format and could acquire photographs with a footprint of 440x440 km. Hand-held cameras, such as the Praktika-E, equipped with 56x56 mm and 24x36 mm frame format were also used repeatedly (Glazovskiy and Dessinov, 2001).

Launched in 1986, the Mir Space Station continued the Visual Observations program, but at a lower intensity, as funding became reduced for such experiments. As summarized by Evans et al (2001), the Soviet Visual Observation Program was of interest to the United State’s Space Exploration program and thus began the Shuttle-Mir earth observations experiment. There were two main goals for this joint program. The first was to use the observations of cosmonauts and astronauts to document both long and short-term environmental changes such as floods; fires, hurricane activity, urban growth and land cover change. The second major focus of this joint program was to develop tools and methodology in preparation for the next evolution in earth observations from the International Space Station (Evans et al, 2001).

The Apollo-Soyuz Test Project (ASTP)

The Apollo-Soyuz Test Project was the first international effort in the United States history of space flight. On May 24, 1972, President Nixon and Premier Aleksei N. Kosygin signed a five-year "Agreement Concerning Cooperation, that would lead to a goal of a 1975 test mission which involved Apollo and Salyut (later Soyuz) in the Exploration and Use of Outer Space for Peaceful Purposes" (Burrows, 1998). The primary focus of this project was to test the compatibility of rendezvous and docking systems for American and Soviet spacecraft. What this project achieved was a strategy for potential international rescues in space as well as future joint manned flights between the United States and the Soviet Union (Burrows, 1998). In terms of photography, there were also a series of experiments called the Earth Observations and Photography Experiment. The objectives of these experiments were to test the abilities of the camera systems as well as astronaut and cosmonaut ability to examine areas of the earth that had changed over time (Cloud, 1995). There were predetermined terrain features photographed and documented during Skylab 4 two years previously. This experiment tested the crew's abilities to identify and document those same features on this mission. Details of this project included the use of special color wheels that were created to permit astronauts to distinguish between colors of terrain features (Cloud, 1995). Another interesting aspect of these tests was the use of high-altitude aircraft, which were flown with cameras to photograph the same target sites as those focused on by the Apollo-Soyuz crew. The purpose of this exercise was to examine and compare the visual perception and photography of the sites from Apollo-Soyuz to that of high-altitude photographs (Cloud, 1995). This project lasted for only one year: 1975.

The Space Transportation System and the Space Shuttle Earth Observations Project

The Space Shuttle flights began in 1981 and continue today with multiple purposes behind each mission. Currently the main function of the Shuttle and the astronauts is construction of the International Space Station (ISS). Up until this point, however, the Shuttle has had an extremely varied history in terms of its astronauts, scientific experiments, instruments, and photography of the Earth.

Several Space Shuttle missions have focused on Earth remote sensing objectives. The two early missions were called Shuttle Imaging Radar A and B, launched in 1981 and 1984, respectively (Jensen, 2000). These radar readings from the Shuttle were combined with photographs from the Linhof cameras. More recently, the important radar exercise called the Shuttle Radar Topography Mission (SRTM) was completed from the Space Shuttle Endeavor in February 2000. The objective of this project was to produce digital topographic data for 80% of the Earth's land surface (all land areas between 60° north and 56° south latitude), with data points located every 1-arc second (approximately 30 meters) on a latitude/longitude grid. The absolute vertical accuracy of the elevation data was 16 meters (at 90% confidence). This data from C-Band is being processed at the National Image and Map Agency (NIMA) and is distributed by EROS Data Center (USGS, 2001).

Earth observations have also been made from the Space Shuttle using a digital camera that was controlled remotely by middle school students. The Earth KAM Program (formerly KidSAT) collected 4733 digital photographs of Earth during five different Shuttle missions (STS-99, February 2000; STS-89, January 1998; STS-86, September-October 1997; STS-81, January 1997; STS-76, March 1996). For more information on EarthKAM see their website at http://www.earthkam.ucsd.edu/.

Cameras that have been employed onboard the Shuttles include the Linhof Aerotechnica 4x5 large format camera, and Hasselblad 70-mm cameras, Nikon 35-mm cameras, and Kodak digital still cameras (Robinson et al. 2002). There have been experimental camera systems taken onboard Shuttle missions such as the European Space Agency's Metric Camera flown in 1984 (Burrows, 1998). There was also an experiment which involved combining a digital camera with a HERCULES orientation system. This arrangement combined camera orientation and space shuttle position at the exact time the photograph was taken to calculate the coordinates of the resulting image (NASA-STS-70, 1995). A recent experiment documented the potential for HDTV television equipment in observing the Earth from orbit (Robinson et al. 2000).

During all Shuttle missions, crewmembers use the onboard cameras to photograph the Earth. All of these archived photographs of the Earth, space and the moon are held at the NASA Johnson Space Center (JSC) in Houston, Texas. Each photograph has metadata associated with it so that the user can query, from the Internet, the vast numbers of photographs to find the exact area and date of interest. The metadata can be accessed several different ways via the Internet: by a clickable map, by searching all the database fields, or by browsing outstanding selections titled *Cities from Space* and *Earth From Space*. To access this search engine go to the following Internet address: http://eol.jsc.nasa.gov/sseop/ . Batch scanning is now routinely conducted so that the photographs can be view on the internet. Custom scanning has also been coordinated for scientific purposes.

CAMERA SYSTEMS USED ONBOARD SHUTTLE

As reviewed by Robinson (2002), there are several camera systems that are currently used by astronauts to photograph the earth. These camera systems include: the Linhof 125 mm, Hasselblad 70 mm, Nikon 35 mm, and the ESC 35 mm camera. Both color and color-infrared film have been used to photograph the earth. Spatial resolution of digitized astronaut-acquired photographs can get as low as 10 m per pixel. These photographs can be a useful ancillary data source to satellite imagery analysis. For an in depth review of camera systems both current and historical, see Robinson, 2002.

International Space Station

Instrument onboard the ISS are able to observe the Earth, its atmospheres, oceans and landforms from a stable, mid-inclination for a period of approximetely15 years. ISS will orbit over nearly 75% of the inhabited land surface of the Earth, and over 95% of the world's population.   ISS will fly over the same location every three days, and will fly over the same location with the same lighting approximately every three months (ISS, 1994).   With these capabilities, it provides an excellent platform for the many types of earth observations listed above.

The Window Observational Research Facility (WORF) is an optical quality window that provides a nadir view of the earth's surface from the ISS. Cameras, multispectral scanners and other instruments can be attached to the WORF for earth observations. Currently, the Crew Earth Observation program will focus mostly on episodic events and rapidly changing environments around the world such as urban growth in major cities, frequently flooded regions, glaciers, coral reefs, and changing deltas. The currently approved and prospective payloads for the WORF platform include EarthKam and Coral Reef Ecosystem Spectro-Photogrametric Observatory (CRESPO), respectively. EarthKam allows middle school students to obtain photographs of the earth utilizing an electronic still camera. EarthKam is a NASA-sponsored program. CRESPO was proposed by

University of Hawaii, Kaneohe and would utilize multispectral observations to establish how climate change may be influencing coral reefs (NASA, 2001).

RESEARCH BASED ON ASTRONAUT-ACQUIRED PHOTOGRAPHY

Observations of Dynamic Events

One of the foci of the WORF on the ISS is the capture of episodic events on the earth's surface. In the past, astronauts and cosmonauts have obtained photographs of many dynamic events on land and at sea. For example, in June 1991, Mt. Pinatubo, one of the 20 active volcanoes in the Philippine Islands, erupted. This was one of the largest global volcanic events of this century, and has recently been noted as responsible for lowering global temperature. A photograph of Mt. Pinatubo and the surrounding area was taken by a Shuttle crew in 1982 (STS3-10-567), before the eruption. Astronauts took post-eruption photographs of this volcano beginning in December 1991 (STS044-82-33) through 1993 (STS055-151A-184), and continuing to the present (Evans, 2001). These series of photographs clearly document the large areal extent of the area directly affected by the blast, and those areas covered with ash. This time series is being utilized to document the dispersal of debris, ash and mudflows around the mountain after two tropical storms and a second eruption in July 1992.

A second example of an ephemeral event documented and researched employing Shuttle imagery is the study conducted by Evans et al (2000) concerning the 1997-1998 El Nino. The researchers analyzed the photographs obtained during this period representing the 1997-1998 El Nino impacts and thus allowed a visual assessment of the effects of this recurring, intense weather pattern.

A final example of documentation of a common episodic event is research conducted by L.M. Shipilova documenting eddy formation in the Caspian Sea. These eddies are a result of the collective effects of hydrological parameters, various atmospheric conditions, and coastal influences. Eddy formation is an important function to understand because these eddies affect local currents, sediment deposition, nutrient quantity and dispersal, plankton levels, and pollution movement.

Long-time series studies

Referring to long-term studies, Shuttle and Skylab photography have been used to map the areal magnitude of Amazonian smoke palls linked to biomass burning (1973-1988). From these photos, Helfert and Lulla (1990) have been able to assess that the area surfaced by these smoke palls has expanded from approximately 300,000 sq km in 1973, to continental size smoke palls measuring nearly 3,000,000 sq km in 1985 and 1988.

A second example of a long-term study is the research of A.S. Shestakov concerning land-use changes in the northwest Caspian coastal area during 1978-1996. This study was based on Shuttle photography in conjunction with field studies, cartographic materials, aerial photographs and regional statistical data.

From this data, Shestakov (2000) determined that rising seas have been the reason behind the flooding of 150,000 hectares of agricultural lands. A third example of a long-term scientific investigation involves shoreline dynamics and the hydrographic system of the Volga Delta by Alekseevskiy et al. (2000). Alekseevskiy et al. determined changes in this area over the past 200 years based on historical data as well as Space Shuttle photographs and other sources of space-based imagery.

The documentation of urban change is another application of Shuttle photography. In spite of the fact that there are a multitude of consecutive, astronaut-acquired photographs of cities as well as other areas around the world, there have been relatively few papers written in scholarly journals documenting urban change using AAP as a resource (Robinson, 2001). However, there is a recent study by Robinson et al (2000), which examines twenty-eight years of urban growth in North America quantified by an analysis of photographs from Apollo, Skylab, and Shuttle-Mir missions. This research introduces a rapid method for estimating urban area employing a time series of photographs taken from low Earth orbit. Once these photographs have been digitally orthorectified, they are useful for discovering phenomena of interest as well as gathering quantitative measurements of various regions of the Earth’s surface (Zheng et al, 1997).

Astronaut Photography as Supplemental RS Data

Finally, validation of land cover maps is a more recent application using astronaut-acquired photography. Research completed by Gebelein (2001) indicates that for five land cover classes in the southwestern United States, photographs were used and statistically compared to Landsat 5 imagery in an accuracy assessment study. At 116 different points on the landscape, astronaut-acquired photographs were not significantly different, in terms of classification accuracy, from the Landsat imagery.

Webb et al. (2000) also conducted research comparing astronaut-acquired photography and Landsat Thematic Mapper imagery of Chanthaburi, Thailand. Ten different classes were found to have an overall agreement of 71.2% between the photography and TM imagery with 45 ground reference sites. From this study they concluded that astronaut acquired photography is a valuable tool for digitally evaluating patterns of land use and land cover.

IMPORTANCE OF THIS RESOURCE IN THE FIELD OF REMOTE SENSING

Critics of astronaut-acquired photography would question the importance of continuing this type of earth observing program now that remote sensing satellites are available. There are several reasons for program continuation. The remote sensing satellites that are currently in orbit all have predestined observation points where they gather earth-observing images. If they pass over an ephemeral event in progress, the event is not captured unless it is within the prescheduled image acquisition program for that sensor. One advantage to having a human behind the instrument from the ISS is the ability to gather data on an unplanned basis. If an ephemeral event occurs and the ISS is directly above the event, data can be gathered that would otherwise be lost. Observing an episodic event as it occurs and documenting it from several different angles or alerting scientists to undocumented human-induced change in regions hard to access on Earth are distinct advantages when assessing a dynamic situation. The *extent* to which Shuttle crew photography can assist in the identification of specific types of land cover change was part of the fact-finding mission of this study. Dr. James Reilly, who was part of the January/February, 1998 crew docking with the *Mir* Space Station related that forested terrain, grasslands, farmlands and deserts are very easy to pick out. He also pointed out that human modification to an area, natural vegetation alteration, for example, are also easy to separate from the surrounding landscape. Dr. Reilly stated that if the air quality is good, with a 400 mm lens it is possible to see detail to the level of a city block, or individual buildings, depending on the altitude (Robinson & Evans, 2001). A second reason for a human behind the camera is purely practical. If a mechanical failure occurs with the instrument mounted on the WORF, for example, it can be repaired on board or sent back to earth in the case of total mechanical failure. If a mechanical failure occurs with a remote sensing satellite and cannot be repaired remotely, there is no easy way to retrieve the satellite and repair the problem.

Another critical observation of astronaut-acquired photography is the question of how photographs can be considered data. As reviewed in the historical section of this paper, aerial photography for military and other applications has proved extremely important in battle and in the advancement of science. Secondly, with the advent of digital photography, the processing involved in digitally analyzing photographs has become easier in terms of incorporation of such imagery into (remote sensing) software analyses packages such as Erdas Imagine.
With increasing quantitative research, it is clear that astronaut-acquired photography can assist in the identification of specific types of land cover change and, potentially, the immediate local causes of such change. This means that experts are bringing to the table their photointerpretation skills, combining this proficiency with the expertise of a satellite analyst and producing scientifically acceptable output from orbital photographic analog and digital data (Helfert, 1989). With the introduction of digital photography, astronaut photography is getting technologically closer to the remote sensing instruments it had fostered.

Therefore, with advances in camera systems, improved software technology for analyzing different data types and the enhanced astronaut training programs for Earth-observing photography, it is clear that in addition to a distinguished history, astronaut-acquired photography has a promising future.

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