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Aerial Photography: World Class Disaster Fighter

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Abstract The value of utilizing aerial photographic collection systems along with varied photo interpretation and photogrammetric techniques in connection with disaster management is better understood with each passing year. Not only is it possible to compare new sensor coverage with historical graphic records, but analytical methods allow a sophistication of data manipulation considered impossible in the recent past. Damage assessment, together with a remarkable capability for predictive reporting, has brought a new dimension to emergency management.

Man has constantly sought new windows on his world and has, with each increase in altitude attained by aircraft, and now spacecraft, gained an ever widening view of the earth. This insatiable quest for knowledge of every aspect of his environment has led man to photograph the planet from a wide range of platforms—from balloons and helicopters hovering a few feet above the earth to meteorological satellites photographing the hemispheres and oceans from an incredible 23,400 miles in space. Man has also broadened his view and increased his perception by using a wide variety of sensing devices.

Aerial photography has three important roles to play in natural and technological disasters. First, it is a valuable historical record. Second, it is unparalleled for conducting damage assessment surveys. Third, it could become a most important vehicle for predicting disasters. Affording precise knowledge of how, when, and where a disaster might occur, aerial photography could play an invaluable role in planning how to avoid or mitigate disasters. Using a variety of modern interpretation and photogrammetric techniques, data from aerial photography and multisensor imagery can be derived in a relatively short period of time on such subjects as ground areas, volumes, heights, shapes, occupancies, relative age, and state of repair.

High-altitude photography is extremely useful in these endeavors because so few photos are needed to cover a given area, compared to conventional lower-altitude photography which has to be pieced together in order to get the overall view. Surveying the earth from orbiting platforms fitted with remote sensing devices could be the most significant technological development of our time. There are many who are convinced that the impact of overhead photography and remote sensing on modern life will be more significant than the impact of gunpowder in an earlier time. Looking down on our planet with increasing frequency from vantage points in space has shown us the complex and continuously changing interrelationships of land, sea, and air and has added immeasurably to our knowledge of the fragile relationship between man and his environment. The combination of synoptic observations, broad area coverage, and large-scale photography has permitted many unique interpretations and possibilities for application to both natural and technological disasters. The continuing search for improved methods of securing the data required to assess, mitigate, or prevent disasters should be an endeavor of the highest priority for our government.

Historical Record

As a historical record, aerial photography has few equals. Each photographic exposure is an irreplaceable record of a moment in time, as to what was happening at that very moment, and each photo establishes a baseline that is of critical importance in recognizing the inevitable changes that will occur in the future. Sequential aerial photography, taken over a period of years, has yielded valuable information on the impact of man and natural forces on the environment. This repetitive coverage allows the observation and notation of change over a given period of time and is especially valuable when one looks back to document weather, volcanic, fire, earthquake, flood, technological, and other phenomena pertinent to disasters.

Aerial photography was for many years primarily a military reconnaissance tool but shortly after World War I the potential for peaceful applications of this art was recognized. The need for more accurate surveying and mapping to support rapid industrial development in the United States became a priority project of the U.S. Coast and Geodetic Survey.[1] The rapid advances in aviation also dictated a need for compiling charts specifically designed for aerial navigation. Until that time, most pilots used rudimentary road maps. On February 26, 1919, President Wilson recommended legislation placing the licensing and regulation of all aerial navigation under the U.S. Department of Commerce.[2] In the late 1920s and early 1930s, hundreds of aerial surveys and thousands of aerial photos were utilized in the routing and construction of new transcontinental highways. Aerial photography was instrumental in determining how to straighten roads and for estimating the volume of earth moving needed to reduce hills to valleys and to make the roads as straight and level as possible in the most economical manner. In the 1930s, the Agricultural Adjustment Administration systematically photographed the nation's crop and grazing lands; the Forest Service photographed the nation's timber reserves; the Soil Survey mapped the soils of the United States; the Tennessee Valley Authority mapped areas in efforts to resolve chronic flooding and erosion problems; and aerial photography was also used in site selection for the many dams and hydroelectric projects undertaken during this period.

Most of these photographs are now stored in the National Archives and constitute a most important historical trust. They continue to be used for a variety of comparison purposes: to review beach erosion, to observe sedimentation in rivers and

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lakes, to chart expansion of cities and towns, to decide on the cutting of timber, and determine the effects of locating missile, nuclear, and chemical proving grounds in desert areas. The full potential of this mass of photographs has been recognized by the Environmental Protection Agency which uses it regularly to solve operational problems. Entrusted with the responsibility for locating and inventorying hazardous waste sites, the Environmental Protection Agency has found these photographs to be the most valuable record of the existence and location of waste sites used decades ago, then abandoned and forgotten, but still considered dangerous.[3] These old sites are of particular concern because they often have been covered over, overgrown with vegetation, reconfigured, or built upon. There are few precise written records of the what, how, when of the ways and methods that were used to store the hazardous wastes.

Photographs taken over a period of years frequently show the precise location and size of the facility, and the methods used to store hazardous wastes: i.e., drum, tank, pit, lagoon, etc. The effects of any released pollutants and the routes of migration of the waste materials away from the source either through ditches, drainage canals, swales, or to low-lying areas can still be charted through aerial photography. Knowing the potential areas of contamination, monitoring teams can quickly sample soil, water, food, and air to assess the degree and extent of pollution.[4] On a number of occasions, these photos have been used in litigation against individuals and corporations charged with breaking anti-pollution laws.

Rain is a continuing, natural phenomenon which results in a pattern of water flowing down through the earth's surface to find its way to underground channels and saturation areas from where it subsequently moves to the sea. But on its way, it moves in random and little known routes and may thus come into contact with anything that we bury. Anything that is buried in the earth is therefore subject to solution and transportation away from the site where it was originally placed. This fact could mean potential danger for everyone. We are already hearing about the contamination of well water in some areas of our country and the possibility of contamination of aquifers in others. One of the greatest challenges in the future will be to sense the flow of these waters and the effects on them as they pass through areas where we have buried our hazardous wastes. Historical aerial photography could play an important role in this endeavor.

Assessment of Disaster Damage

Earthquakes

Whenever a major earthquake strikes a large area, there are massive breakdowns in communication, transportation, public safety, and health facilities. The first requisite for any responsive plan of action is to acquire timely and quality information on the scope and magnitude of the destruction. The second requirement is to establish the ability to quickly transmit that information to the highest echelons of government where the necessary decisions can be made and concerted actions taken. Such was the case when a massive earthquake measuring 7.5 on the Richter Scale struck Guatemala at 3:02 A.M. on February 4, 1976. The quake caused widespread destruction over a large portion of the country but was especially severe in the populated central highlands which sit astride the fault that runs from east to west. The quake caused many bridges to collapse and triggered numerous landslides in the mountains which buried roads and rail lines and isolated the devastated mountain villages. Although medical and relief aid was rushed to Guatemala by neighboring nations, little was known in Guatemala City as to the extent of damage done to over 300 cities, towns, and villages.

The Guatemalan government appealed to the U.S. State Department for aid, not only in determining the extent and magnitude of the destruction but also to establish the level of medical and relief aid necessary. A U-2 overflight of Guatemala was quickly authorized and the exposed film was rushed to the CIA's National Photographic Interpretation Center for processing and interpretation. Working through the night, the interpreters quickly pieced together the patterns of destruction. A list of the most hard-hit cities and towns was created and transmitted to Guatemala City, along with a damage assessment report. The towns of Joyabaj, San Pedro, Tecpán, Patzicia, Chimaltenango, Comalapa, El Progreso, Zaragoza, and San Miguel Jilotepeque were flattened. Enlarged photos dramatically showed the damaged adobe homes, the rubble-filled streets, the downed bridges, and the landslides blocking road and rail lines. Of particular interest to geologists were the photos which showed the dramatic earth slippage where the fault movement had bent rail lines and scissored roads in excess of three feet. The interpreters could also follow the visible serpentine fissures for distances of over 150 miles.

U.S. Army and U.S. Air Force personnel, along with supporting aircraft and helicopters, were flown in from bases in the continental United States and from U.S. bases in Panama. The heavier aircraft of the U.S. Air Force and the Guatemalan Air Force were of little use in the relief efforts in the mountainous terrain. Rescue teams, medical personnel, and relief experts were either helicoptered into the stricken areas or were flown in by light aircraft—piloted by the Civil Air Patrol and volunteers—which landed on fields near the stricken areas or on nearby roads.

The quake left more than 23,000 dead, injured more than 77,000, and left more than a million homeless. To avert the spread of disease, massive pits were dug and bodies placed in common graves. These graves could be seen on aerial photos, along with thousands of tents fashioned from blankets and sheeting that provided meager shelter in the streets for the thousands of refugees who were afraid to return to weakened or damaged homes.

Although the casualties were astronomical, they could have been much higher had it not been for the information obtained from the aerial photos that vectored medical and relief aid to the stricken; the blocked rail lines and roads were precisely pinpointed so that they could be reopened and relief supplies could proceed to the devastated areas. The photos were subsequently used to plan the reconstruction effort.

Hurricanes

Another kind of disaster occurred when Hurricane Camille roared onto the Gulf Coast on August 7, 1969, with sustained winds of over 150 m.p.h., pounding miles of Mississippi, Louisiana, and Alabama beaches with devastating force. At the peak of its fury, Camille developed 190 m.p.h. winds and 20-ft. storm tides. It was the most violent storm ever to hit the U.S. mainland. The storm slammed ashore in the Gulfport-Biloxi area and hun-

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dreds of beachfront homes were shattered, roofs of houses were torn off, walls caved in, thousands of trees snapped or were uprooted, and power and telephone lines were down throughout a large area. Walls of water swept ashore and boats and fishing trawlers were heaped atop one another or blown completely out of the water to land in residential areas or pine forests. Three large oceangoing freighters, the *Hulda*, the *Alamo Victory*, and the *Silver Hook*, were beached by the winds and water. Low-lying areas experienced severe flooding.

Although the hurricane was closely monitored and ample warnings were given, there was an unrealistic notion that a hurricane could not wreak such damage and people went about their business as usual, ignoring repeated warnings to evacuate their homes voluntarily. As a result of not heeding the warnings, more than 300 people died.

Although President Nixon declared Mississippi a disaster area the next day, conflicting reports were being received in Washington on the extent and nature of the damage sustained. The President asked that a proper assessment of the damage be completed as soon as possible. A U-2 mission was flown over the distressed area and the CIA's photo interpreters again were called upon to conduct a damage assessment. Along with the damage report, dramatic photo enlargements showed the fury of Hurricane Camille, its winds, its rains, and the attendant flooding. Hurricane Camille eventually swung northward, leaving more death and destruction in its wake. Torrential rains and the attendant flooding pummeled mountainous western and central Virginia, washing out a number of towns. The James River crested at 28.6 feet, 19.5 feet above flood stage.

The total losses would reach over a billion dollars before Hurricane Camille turned northeastward and dissipated its wrath in the Atlantic Ocean on August 25, 1969. A number of states would be declared disaster areas as more aerial reconnaissance missions were flown and more damage assessment reports were created and submitted to federal and state officials. The lessons learned from Camille were many—not the least of which was the use of aerial reconnaissance in the spotting, tracking, and assessment of damage.

Technological Disasters

The use of aerial photography to support emergency responses to technological disasters has increased dramatically in recent years. It has been used to provide information on the extent and magnitude of chemical spills, explosions, fires, pollutant leakage into waterways, aerial pollution, oil spills, acid rain, nuclear accidents, and waste and sewage problems. Not only have state and federal agencies become concerned with the public's exposure to toxic chemicals, but a number of federal and state laws have been enacted in the past two decades requiring states, cities, and localities to inventory and monitor activities related to air, water, soil, and food contamination.

Whenever such accidents occur, in addition to concern about the public safety, the possible contamination of water and food supplies also become major concerns. Aerial photography can be a most effective tool for the quick assessment of potential damage to food supplies. For example, when the Three Mile Island nuclear power plant accident occurred, all of the dairies in the area were quickly catalogued for investigation of possible contamination by using aerial photos.

Aerial photos can also be used in cleanup and environmental damage studies. An aircraft flying at 60,000 feet can photograph a swath some 40 to 50 miles wide. The entire state of Pennsylvania, for example, can be photographed in less than eight hours using such a system.

The operational feasibility of using high-altitude aircraft to make quick damage assessment surveys of technological disasters was proven on numerous occasions in the 1960s and 1970s. Leakage from an offshore oil well in Santa Barbara Channel off the California coast became a river of oil on January 31, 1969, spewing out more than 235,000 gallons of oil before the blowout was capped. An 800-square-mile slick developed in the Pacific and began washing onto about 50 miles of California beaches. There are many kelp beds in the affected area and, on black and white photography, some of the apparent oil slicks were, in reality, kelp beds. Secretary of the Interior Walter J. Hickel called upon Dr. Lee A. DuBridge, Science Adviser to President Nixon, for help in assessing the disaster. A U-2 mission was directed over the area. The forward camera contained black and white film while the aft camera was loaded with color film. This enabled a quick and accurate discrimination of the kelp beds from the oil slick. Full information on the damage to the beaches and marinas was rushed to the President, along with enlarged photos of the slick, the oil-damaged marinas, and the contaminated beaches and estuaries. Duplicate copies of these materials were sent to the Secretary of the Interior and to state officials in California. The maps and photos were used by experts to determine the most effective way of trapping the spilled oil, and to aid in the cleanup of the beaches and marinas.

Volcanic Eruptions

Among the more recent dramatic disasters was the eruption of Mount St. Helens on May 18, 1980. The subsequent destruction of approximately 230 square miles of vegetation afforded a unique opportunity for the use of airborne platforms, not only for damage assessments but also to chart the geological and other changes that occurred subsequent to the eruption.[5] Shortly after the eruption, Mount St. Helens was photographed by both U-2 and SR-71 aircraft using conventional and multisensor imagery for a quick assessment of the immediate dangers posed by the eruption. The pre- and post-eruption images provide a dramatic view of the destruction resulting from the eruption. The photographs revealed that almost a cubic mile of the Mount St. Helens crown had been blown away. Trees as far as 28 kilometers away had been toppled like match sticks and timber was scorched for some distance beyond that. Sediment filled Swift Reservoir and Spirit Lake was filled with debris. The massive flow of debris that swept down the North Toutle Valley raised its floor more than 600 feet, damming tributary rivers, and creating new lakes and ponds. The formation of these lakes and ponds posed a serious problem since they might erode swiftly and release a deluge of water and mud down nearby valleys. A layer of pumice and ash covered the area. High-altitude winds carried the ash into neighboring states; evidence of that fallout could be clearly seen on the aerial photos. Meteorological satellites photographed the ash cloud as it moved eastward and warnings were issued to aircraft flying in or near the cloud. Aerial photos were used to seek methods to alleviate problems created by swollen lakes and ponds, and the same photos were used by foresters seeking methods to retrieve the blown-down and damaged timber.

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Aerial photographs are being taken periodically of Mount St. Helens and will continue for years to come. Eventually, this photography will provide the most complete record possible of what happened prior, during, and after the volcanic eruption of Mount St. Helens.

Additional Applications

Forest Fires

Forest managers dread that period during the summer months when the lack of moisture creates a "tinderbox" situation on the forest floor. When this occurs, normal fire prevention precautions include the closing of state and national forests to camping, fishing, hiking, and logging. In addition, travel is restricted to the main highways.

The dread of the forester eventually becomes a reality—ignition either by human accident, lightning, or arson. Of particular concern are the violent "dry" thunderstorms that plague the West in which lightning will ignite a number of fires but without the accompanying rain to extinguish the blazes. Often, there is a capricious wind that builds and creates what the forester fears the most: a wildfire that shifts directions, leaps across roads and firebreaks, creates powerful convection columns, and produces fire whirlwinds that pick up and carry firebrands the size of dinner plates for long distances and start still other fires which, in turn, destroy thousands of acres of timber.

The burned timber is not the only loss, because fires affect more than just the trees. Fire destroys shrubs that provide food and cover for wildlife, and the intense heat destroys root systems and vaporizes important soil nutrients.

Spotting the fires and reporting their locations were, for more than a century, the job of the fire spotter in the lookout tower. There are, of course, many drawbacks to such a system. The spotter's vision is limited and often obscured by dense tree cover, haze, or smoke. The towers also had to be located in areas with access to nearby roads. There are, however, other thousands of acres of timber in inaccessible, unprotected areas.

After World War II, the search for a better, more effective means of protection of our forests was intensified. The ideal system, of course, would be operational 24 hours a day to detect and precisely locate a fire before it could cause serious damage. Aerial surveys over remote areas using surplus World War II aircraft were instituted by the Forest Service in the postwar period. Although the observation point was thus lifted and the horizons widened, aerial surveys were not economical or satisfactory methods for fire protection over large areas.

In the 1950s, the U.S. military began experimenting with airborne thermal infrared sensors to be used in intelligence-gathering operations. These heat-sensing instruments react to even the smallest blaze and maps of the areas of burning can be quickly created. Fire shows up in varying degrees of intensity, usually against a cool background of vegetation or water. Infrared sensing can be employed day or night. It can penetrate dense smoke and certain types of clouds. During the Vietnam conflict, thermal infrared scanners were used to pinpoint the small fires used by the Viet Cong to cook their evening meals.

The Forest Service, profiting from the military experience, began using infrared scanners in their aircraft in the late 1960s. From aircraft flying at 15,000 feet, approximately 250,000 acres of terrain could be encompassed on the infrared scope.[6] Areas of particular concern could then be transferred to a film record. Infrared scanners were also installed in the NASA U-2s giving an even more impressive view of unprotected forests. But whether it was a light aircraft or a U-2 flying over the forests, the cost of maintaining continuous aircraft sweeps over large areas becomes prohibitive and flying over inaccessible areas can also be very dangerous.

With the advent of the NASA "ERTS" and the later Landsat orbital imaging systems, forest fires could be frequently seen blazing out of control in inaccessible areas. In the near-infrared spectrum, the outlines of the fires could be quickly determined. Recent experimentation with thermal infrared sensors aboard NOAA polar orbiting satellites has demonstrated their potential usefulness as an effective, efficient, and economical means of detecting and monitoring not only forest fires but range and tundra fires as well. Using the 3.8 micron channel, the NOAA satellites "paint" a swath of 2,600 kilometers with a latitude coverage of about 15 degrees. For example, most of Alaska can be covered in a single frame and any forest or tundra fire can be detected. The same area would be covered twice daily, once during the daytime and once at night. At the present time, NOAA has two satellites aloft, affording four coverages of the same specific area during each 24-hour period. While the infrared system cannot penetrate certain cloud covers, and cannot differentiate between controlled and uncontrolled fires, it has the potential to become the most economical system for the detection of fire in large, remote geographical areas.[7]

Floods

Floods regularly account for 90 percent or more of the nation's property damage from natural disasters. Since the turn of the century, for a number of sound and logical reasons, floodplain land has become both attractive and desirable for high-density urban development. However, most of this construction has been accomplished through a permissive and speculative policy which has allowed an enormous and continuous encroachment onto floodplains. There has also been a tendency to minimize the adverse consequences of these actions. This encroachment, however, has raised and will continue to raise the potential level of damage that people and structures will face when rivers overflow their natural confines.[8]

In 1983, flooding in the United States claimed 204 lives and caused property damage totaling more than four billion dollars. For 1984, U.S. Weather officials predicted flood damage that would exceed 1983 by some four to six billion dollars. There has been flooding in New England, the Mississippi Basin, and the South, but the Far West has experienced the worst flooding ever. Record snowpacks in the Rockies have caused flooding conditions in eight Western states. The massive flooding from snowmelt plaguing the Far West could have been largely prevented or mitigated by the Federal Government which had the technology, methodology, data, and expertise to do so, but for a variety of bureaucratic reasons, chose not to do so.[9] A task force of reconnaissance, mapping, photogrammetric, and photo interpretation experts—augmented by Western regional experts—could have been constituted at a relatively modest cost to prevent billions of dollars of property damage, not to mention the loss of life that could have been averted. Such a collaborative effort could plan actions to prevent flooding, give advance warnings, pre-position equipment in areas of concern, and evacuate people in danger.

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The technology now available includes sophisticated satellite systems, the SR-71 which could cover the 1,450-mile length of the Colorado River in less than 45 minutes, the U-2, and other military reconnaissance and civilian mapping aircraft. The U.S. Geological Survey has detailed maps of the areas of concern for snow-melt measurement and analysis. The Defense Mapping Agency, the CIA, and the Geological Survey have excellent photogrammetric equipment, and the expertise that could be used to compute the snow volume on the mountains. Using this technology, hydrologists could determine the potential runoff. The lay of the snow in the mountains, and the conditions of streams and rivers to which the water would flow, could be readily determined by photo interpreters. The California Water Authority and the Tennessee Valley Authority have experts on drawing down dams to prevent flooding. The Federal Government has the computer capacity to process and analyze the information to accomplish such a task.

The aerial reconnaissance data, along with information garnered from local, state, and regional experts, would permit determination of potential flooding areas. Equipment and experts from the Army Corps of Engineers, the National Guard, other military services, state agencies, and private contractors could then be put in place to prevent or mitigate flooding.

Modern reconnaissance systems, properly used, could contribute materially to the better understanding of, and a capability to better assess, the damage from floods or other natural and technological disasters. Using this advanced technology, the capability to predict the magnitude of natural and technological disasters is within our grasp. With the capability to predict also comes the incumbent responsibility to take preventive measures.[10]

Volcanic Ash

The greatest terror any airline pilot can experience is to see instrumentation warning lights indicating that all engines are experiencing severe mechanical problems which could result in multiple engine shutdowns or failures. Such was the case on June 24 and July 13, 1982, when two Boeing 747s experienced severe engine problems and shutdowns from the ingestion of airborne volcanic ash from eruptions of Mt. Galunggung in Indonesia. Both aircraft were forced to make emergency landings at Djakarta. A DC-9 on May 18, 1980, and a 727 on May 26, 1980, experienced similar problems from the eruption of Mount St. Helens. The loss of an airliner with all passengers aboard would be a calamitous event and these sobering facts prompted a study of volcanic eruptions as they impact airline operations.

Although volcanic eruptions have always been of concern to air operations, the ingestion of volcanic ash into jet engines poses not only that immediate problem of operations but also the damage that could be done to engines, airframes, and sensing devices. The volcanic cloud carries a variety of particles, of varying sizes, composition, and hardness. Some of the particles have a low melting point and deposit on turbine blades; other particles are hard and abrasive, damaging engine blades, windshields, and airframes. Since the particles vary in size, they can be ingested into the many and varied filters, contaminating oil, air conditioning, and sensing systems.

There have been significant increases in volcanic activity since 1979 worldwide, including the eruptions of Soufrière, St. Vincent, in 1979, Ulawun in the South Pacific in 1980, Mount St. Helens in 1980, Alaid in the Kuriles in 1981, Garcloi in the Aleutian Islands in 1981, Pagan in the Pacific in 1981, El Chichon in Mexico in 1982, and Galunggung and Soputan in Indonesia in 1982. Two-thirds of all volcanic sites are in the northern hemisphere. This is especially significant since the majority of all air traffic is also in this hemisphere.

The potential for unanticipated disruption of air operations has prompted the U.S. and the more scientifically advanced nations to look for means to understand the nature of the volcanic clouds in order to issue or cancel volcanic warnings.[11] To do this, knowledge of the plume's height, direction of drift, and the magnitude of the eruption is essential. Once these are determined, which of course must be done quickly, warnings can be issued covering the affected airspace.

Presently, there is no adequate system available for the making of such warnings. There is a variety of systems offering some potential but, unfortunately, each has limited advantages and serious disadvantages. Combined in a synergistic manner they might go far in providing the answer:

1. National Weather Service meteorological radar and FAA surveillance radar systems can detect the general area and altitude of ash clouds. But there may be other areas of ash not visible on these systems. Then, too, only the more advanced nations have such systems.
2. U.S. Geostationary Operational Environmental Satellites (GOES), because of their constant surveillance capabilities, can provide images quickly in the visible and infrared spectrums following a volcanic eruption; but there is often difficulty differentiating between an ash cloud and cumulonimbus features. Since this satellite is geostationary, surveillance is only possible between 55° N and 55° S.
3. NOAA polar orbiting meteorological and environmental satellites, because of their multispectral capabilities, offer the greatest possibilities for distinguishing ash clouds from other weather phenomena. These satellites do not have constant surveillance capabilities, imaging any given area usually only twice a day. Processing time for the imagery acquired requires at least an additional six hours.
4. Visible observations made in the daytime usually give the first indication of the magnitude of an eruption, the height of the plume, and the direction of the drift.

In the past, volcanic eruptions were not considered a standard aviation problem and accurate reporting has not been optimal or specifically required by the United States and other nations. Since multi-engine failure can occur within a 2–4 minute period, with the possible loss of an airliner and all passengers, the problem of volcanic ash clouds with respect to aviation operations merits a high international priority for scientific and technical research.

Conclusions

Even with all the foregoing digested and understood, there remain complex, undefined scientific problems ahead that might be resolved with the studied application of future advances in photography and multisensor imagery. Definite cause-and-effect relationships have been established between the magnitude and distribution of volcanic dust in the atmosphere and the weather patterns which follow. If, in the future, we can advance the scientific precision of the detection and precise measurement of

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volcanic dust distribution in the atmosphere, we might provide meteorologists with still another valuable tool for more accurate prediction of the world's weather.[12]

The acquisition, processing, storage, and retrieval of imagery-derived data have progressed in quantum leaps in recent years. Those intimately engaged in the imagery field realize the immense breadth and unlimited capabilities inherent in these endeavors. Although it may not be as clearly defined as, say, the physical science or chemistry disciplines, its applications traverse nearly every field of scientific endeavor from archeology to zoology.[13]

The future portends even greater opportunities because imagery can now be digitized, and the combining of imagery interpretation expertise with computer technology, and their interactions and manipulations, provides us with numerous innovative applications. We are already becoming familiar with terms like "change detection," "computer assisted," and "automatic" as applied to new interpretation, photogrammetric, and analytical techniques. Whereas in the past, photo interpretation studies might only be concerned with local or specific targets, we are beginning to see imagery-derived data utilized in the preparation of technical reports on entire states, regions, or countries. The enormous volume of imagery-derived data now under computer control provides untold opportunities for utilization by analysts in Emergency Operations Centers.

Exploiting aerial photography and multisensor imagery requires unique talent and equipment. In the early 1960s, the National Photographic Interpretation Center, through its staff of specialists, recognized the value of photography and multisensor imagery and its numerous applications in the civilian sector. The creation of a "White Center" where pertinent aerial photography could be used for emergency management purposes was suggested at the time, with the National Photographic Interpretation Center serving as an organizational model.

The capacity to mitigate and prevent disasters exists. The technology, the equipment, the methodology, and the expertise are there. We are simply *not* using them to their full potential. Although today there are some collaboration and cooperation among people on the ground and the aerial collector, in the future sensors on the ground will be read and interpreted by collectors in space. We must create an ongoing mechanism that will enable us to monitor key technological developments and bring proper pressure to bear on the responsible agencies to apply technological advances in the prevention and mitigation of technological and natural disasters.

Congressman Albert Gore, Chairman of the Subcommittee on Investigations and Oversight, Committee on Science and Technology, U.S. House of Representatives, on November 16, 1983 opened the hearings concerning the role of information technology in emergency management with the following statement: "We are all aware of the tremendous technological advances made in the last few years. We have seen and benefited from their applications in the areas of health and medicine, the environment, and other scientific fields. But we must also ensure that this technology is applied to our nation's ability to predict, prevent, and respond quickly and effectively to natural or man-made disasters."

It is doubtful that anyone would disagree with the above statement and, hopefully, this paper may be a stimulus for concerted and collective action which could result in the achievement of this stated objective.

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