# ISLAMSAT: A TECHNOLOGICALLY ADVANCED SYSTEM FOR EFFICIENT CHARTING OF NATURAL RESOURCES

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## Abstract

*The landmasses encompassing the Muslim World have vast resources contained in every conceivable type of terrain, from forested mountains to plains and deserts. These landmasses enclose such valuable resources as fertile soil and minerals and oil. Islamic countries also encompass numerous water bodies of lakes and rivers. However, except in a few cases, most of these resources have not been efficiently utilized.*

*The scarcity or lack of basic data have hampered the effective utilization of these resources. First and foremost, accurate topographic maps and detailed photographs are required to survey, assess and develop these resources. Conventional methods of photo acquisition and map making are no longer viable because of the time and expense they require to do the job. In the meantime, space-age techniques offer new ways to reduce the time, cost and expertise that are required for the efficient charting of natural resources.*

*It is here proposed that Islamic countries join together to initiate a plan to launch a resource survey satellite within five years. The satellite here named Islamsat is to obtain high resolution, stereo, mapping quality photographs from space. The most suitable photographic systems for such a satellite are: (1) a high resolution panoramic camera; (2) a topographic quality mapping camera; and (3) a six-lens multispectral camera. Such a complement of photographic systems can either be mounted on the Space Shuttle cargo bay or launched by the Shuttle as a free-flying satellite, with film return capability. The use of such technologically advanced methods and techniques assures the acquisition of the necessary data for development of the resources of Islamic countries in a timely and cost-effective manner.*

## Introduction

Throughout human history, civilization was borne only among those who learned how to fully utilize their natural resources. Case after case, and in various parts of the world, civilizations were established by human populations that were able to produce an excess of food and otherwise fully utilize the resources of their land.

Today, the Islamic World has lost its rightful place among the community of nations. To improve its lot and to regain its power, the nation of Islam must relearn how to utilize its vast resources. This must be done by both improving and speeding up the methods and techniques of resource survey and evaluation.

In most Islamic countries it is customary to rely upon experts from the West to do the job. Furthermore, Western aid-givers and investors rely basically on data that exist outside a given nation to plan for its development. Thus, the choice of the type of resource and method of its development is usually that of an outsider. As long as this situation persists, no real development would occur and no indigeneous civilization would take roots.

Thus, it is imperative that the Islamic World is awakened to the dire necessity of the development of its resources at its own pace and based on its own means and requirements. To do this one must be armed with the complete and accurate indigeneous information. Such information may be obtained through conventional means if one has the luxury of time and the great numbers of experts and specialists to perform the necessary tasks. However, because of the necessity for rapid development in the presence of small numbers of trained specialists one must resort to advanced space-age techniques.

Accurate, large scale maps and detailed photographs provide the basic data for development of the terrain from the geographical, geological, agricultural, hydrological, and landuse points-of-view. Thus, such data must be obtained by advanced systems as the one proposed in this paper.

## Photographic Requirements

As early as in the summer of 1967, the United States National Aeronautics and Space Administration (NASA) asked the National Academy of Sciences to perform a study on useful applications of earth-oriented satellites. Thirteen panel reports were presented on a variety of interests. Although differing in details, the Forestry, Agriculture, Geography, Geology and Hydrology Panels essentially confirmed their requirements for a system providing repetitive cover at relatively coarse resolution.

The Geodesy-Cartography Panel considered the problem of providing data for geodetic control and topographic mapping on a world-wide basis. The Geodetic Satellite Program is currently producing a world-wide network of some forty stations in a unified geocentric coordinate system. Continental intensification networks, if carried to completion as recommended by the Panel, will locate points with better than three meter accuracy at about 800 kilometer spacing. These points, together with existing geodetic control, can form the foundation for map compilation at scales as large as 1:25,000 (Doyle, 1972, p. 38).

The Panel recommended two camera systems: metric camera system for complete small-scale mapping and establishing control for large-scale mapping; a long focal length convergent camera system for providing the detail necessary for large-scale map compilation. The recommended metric camera system would comprise the following components: (1) a 305-mm focal length, 230 by 365-mm format, vertical frame camera with 70 percent forward overlap between frames; (2) a 150-mm focal length, 70-mm format, stellar-attitude camera synchronized with the terrain camera; (3) a laser altimeter measuring the distance from camera to terrain in synchronism with each camera exposure; and (4) a timing device to record the midpoint of each exposure. Although the Panel did not define the large-scale camera in detail, the panoramic camera from the Apollo lunar program would be an obvious candidate for this application (Doyle, 1972, p. 38).

More recently, also in the United States, the Federal Mapping Task Force has recognized the need for a photographic data base for use in cartographic mapping. The Task Force indicated that United States federal agencies spend over three hundred million dollars per year on cartographic products and that "despite substantial expenditures and the existence of ambitious, orderly topographic and geodetic programs, federal agency needs for maps and control data are not being met. A key factor underlying this deficiency has been the lack of an information data base built on imagery" (FMTF, 1973).

The Task Force also defined the requirements for the national photo data base for the United States as follows:

- Current: less than three years of age over areas of medium to high cultural development.
- Of high resolution: sufficient to resolve detail for a wide spectrum of civilian applications.
- Synoptic in coverage (covering a large area on one photo): to afford substantial economies in map production.
- Of sufficient geometric fidelity: to support topographic map compilation at scales at least as large as 1:24,000 with appropriate contour intervals.

**Data Currency:** The Space Shuttle provides an excellent camera platform from which to acquire the recommended imagery data base. The frequency of Shuttle operations, range of inclinations and illumination conditions, and inherent film return capability permit economic use of high data rate photographic sensors consistent with the objective of currency.

**High Resolution:** Requirements as fine as three meters of ground resolved distance (GRD) have been documented for a variety of applications (Figure 1), including map content completion, resource survey, environmental monitoring, landuse survey and population census. This level of quality, is best provided by the high resolution panoramic camera, such as the 610-mm focal length optical bar camera (OBC) used on the Apollo program to photograph the lunar surface.

**Synoptic Coverage:** A wide field-of-view is required for exploitation efficiency and short target access cycles from Shuttle altitudes as low as 200 kilometers. Panoramic and mapping cameras have inherently wide fields (40 degrees or larger). However, the Skylab multispectral camera with a 20 degree cross-track field-of-view provided useful thematic information from an altitude of about 500 kilometers. A wider lens field, providing a swath width equivalent to that of the higher resolution mapping camera is suggested for the lower shuttle altitudes to provide a larger footprint.

**Geometric Fidelity:** An accurate mapping camera will be characterized by the following features:

— Long in-track format or large convergence angle, to allow the widest possible separation between overlapping exposures of a common ground point for stereo reconstruction.

— Large scale, to minimize the sensitivity of object location to errors in image point mensuration.

— Stability, to allow precise correction for geometric distortion inherent in lens and film.

— High resolution, to permit precise object location.

— Precise timing of shutter exposures and fiducial reference marks, to permit accurate orientation and location of the camera at exposure time with respect to orbital ephemerids and established ground control.

## Advanced Cameras

Thoughtful consideration of the above factors results in the selection of the following three high-performance cameras, which are all manufactured by Itek Optical Systems, to address the photographic requirements:

— **Panoramic Camera:** A 610-mm focal length, high resolution camera, derived from the Apollo Optical Bar Panoramic Camera.

— **Mapping Camera:** A 305-mm focal length, 46 X 23 cm format topographic camera, derived from the Space Shuttle Large Format Camera (LFC).

— **Multispectral Camera:** A 152 mm focal length camera with 11.5 X 11.5 cm formats, similar to those of the Skylab S-190A camera.

### The Panoramic Camera:

To obtain high resolution stereoscopic coverage of the terrain it is necessary to utilize a long focal length camera. A 610-mm lens is adequate for most applications of earth orbital photography. The field-of-view of such a lens is limited; therefore, a panoramic operation is required to cover a large stretch of the terrain. Such a panoramic camera was most satisfactorily used on Apollo missions 15, 16 and 17 to obtain high resolution stereoscopic photographs of the lunar surface (El-Baz, 1975).

The panoramic camera used on the three Apollo missions to the moon was a modified version of the U.S. Air Force's KA-80A optical bar camera, and was placed in the Scientific Instrument Bay of the Apollo Command and Service Module, which orbited the moon at an altitude of about 110 kilometers. Its advanced lens design allowed the acquisition of excellent photographs from which large scale maps were made. The panoramic camera mechanism allowed an exceptionally wide area to be covered with a narrow-angle lens. This was accomplished by rotating the lens during the exposure. The f/3.5 lens had eight elements and two folding mirrors. The optical bar, which consisted of this optical system, an exposure slit, and a roller cage that supported the film, rotated continuously during camera operation (Figure 2). Film exposure started at 54 degrees on one side of the flight line and extended to 54 degrees on the other side for a total scan of 108 degrees perpendicular to the flight path. In the direction of flight, the field-of-view was 10.6 degrees. The photographic exposure of the film was determined by the rate of rotation of the optical bar and the width of the slit. To prevent image smear due to the rotation of the lens, the film was pulled across the slit in the opposite direction (Masursky, et al., 1975).

The optical bar and the motor that spinned it were mounted in a roll frame that was connected to the camera's main frame by a gimbal structure. By rocking the roll frame about this gimbal, the camera provided both stereoscopic overlap and forward motion compensation. The exposures were made with the roll frame rocked alternately 12.5 degrees forward and 12.5 degrees aft (Figure 2). The camera cycle rate was controlled so that the ground covered by a forward-looking photograph was depicted again five frames later by an aft-looking photograph, thus providing a stereo pair. During the time (about 2 seconds) that each of these exposures was made, the same gimbal mechanism "froze" the ground image by matching the rocking motion to the angular rate at which the ground passed beneath the spacecraft. The camera's velocity/height (v/h) sensor, which measured this rate continuously, was the pacemaker for the entire operation.

The Apollo panoramic camera moved considerable lengths of film rapidly. During the two seconds it took for one exposure, 1.2 meters of film were pulled smoothly over the roller cage and across the exposure slit. This action was repeated every six seconds. A load of film sufficient for 1600 exposures measured two kilometers in length and weighed 25 kilograms. Because the forces that were required to start and stop such a mass of film intermittently were prohibitively large, the supply and takeup spools actually rotated continuously during camera operation. An ingenious "shuttle assembly" functioned as a buffer between the continuous and the intermittent film movements. In the interval between exposures, the supply side of the shuttle accumulated enough film for the next frame while the takeup spool emptied the takeup side of the shuttle. For additional descriptions of the camera system see Kosofsky (1973).

**The Mapping Camera:**

In a paper on satellite photography, photogrammetrist F.J. Doyle (1972, p. 32) stated that "As one reviews the accomplishments of the last decade, there can be little doubt that the routine achievement of successful missions in space is the most technologically significant. Photogrammetrists and cartographers naturally look upon orbiting spacecraft as a logical step in the progression from plane-table to aircraft to satellite. They can foresee the same kind of quantum jump in production, geometric accuracy and content of topographic maps which occurred when aerial photogrammetry replaced ground surveys. At the same time, they are frustrated because as of this date there has not been a single space photograph taken in which photogrammetric considerations were paramount in the selection and operation of the camera system."

The Space Shuttle program will soon remedy the situation. This program will allow the application of what has been learned on previous space missions to better photograph the earth from orbit. This will be done by the use of the "Large Format Camera." This camera will allow, starting in 1984, the acquisition of mapping quality, vertical, stereo, color, and high-resolution photographs from earth orbital altitudes. Photographs from this camera can be used for mapping using conventional techniques and instruments without costly electronic and digital enhancement or image correction.

The Large Format Camera (LFC) is designed to satisfy the operational requirements of cartographers, geologists, landuse planners, agricultural experts, environmentalists, and other earth scientists. It features high photographic resolution on black-and-white or color infrared film. It also features stereoscopic observation, orthographic (vertical) perspective, metric fidelity, and large areal coverage of each frame. Geometric/topographic maps may be made from its orbital photographs at scales of 1:100,000 and 1:50,000. These maps can be used for photogeologic interpretations and the compilation of data acquired by other means (El-Baz and Ondrejka, 1978).

This camera derives its name from the size of individual frames, which are 46 cm in length and 23 cm in width, with a post-mission calibrated format option of 23 X 23 cm. It has a 305 mm, f/6 lens with a 40 X 74 degrees field-of-view. The camera back includes supply and take-up spools with a 1200 meter film capacity. The film will be driven by a forward motion compensation unit as it is exposed on a vacuum platen, which will keep the film perfectly flat. Moving rollers will insure the synchronization of film advance into the vacuum platen and in and out of the take-up and supply spools.

The frame overlap will be 80%, although the option to change the rate will be available for 60%, 40%, 20% and 0% (Figure 3). The 80% overlap provides the required base/height ratio for topographic mapping with a 20-meter contour interval. Across each frame, the radial distortion will be ± 10 micrometers.

The camera's framing rate will vary from 5 to 45 seconds to allow its use at various spacecraft altitudes. The exposure time will vary from 1/40 to 1/300 seconds. The v/h range will be 0.011 to 0.041 radians per second. The illumination uniformity within each frame will be 10%, minimizing vignetting.

The spectral range of the camera will be 400 to 900 nanometers and the system resolution will be 100 lines/mm (1000:1 contrast) to 88 lines/mm (2:1 contrast). This means a photo-optical resolution of 10 to 20 meters from an altitude of 260 kilometers. The camera will have the ability to utilize a number of films, particularly Kodak's high resolution black-and-white (3414), color (SO-356), and color infrared (SO-131) in magazines with a capacity of 1200 meters of film. An electronic filter changer will permit different films to be used during a single mission (El-Baz and Ondrejka, 1978).

NASA presently plans to fly the Large Format Camera on a Shuttle Mission in mid to late 1984. Photography from the first flight will mainly be used by the U.S. Geological Survey and other federal agencies to update old topographic maps and compile new ones and will also be available for detailed study and resource surveys. Because of the low orbit inclination of the early Shuttle missions (maximum of 57 degrees), the covered areas will be restricted to the equatorial zone of the earth. However, this will allow evaluation of the photography in topographic mapping and resource surveys in all Islamic countries.

**The Multispectral Camera:**

The Multispectral Photographic Camera (MPC), originally developed for earth resource surveys as part of NASA's Skylab program, was a high resolution, multiple format camera that simultaneously took six precisely matched photographs during each exposure. Each photograph recorded information in a specific portion of the visible and photographic infrared light spectra.

The camera comprised six separate low distortion lenses rigidly mounted on the body. Each lens was specifically matched in focal length to the proper spectral band and had its own film magazine, drives, and controls. The lenses were optically aligned with one another. By using different filter and film combinations for each lens, four of the six cameras recorded information on black-and-white film in separate regions of the visible and infrared light spectra. The other two cameras recorded color information. One covered the normal visual spectrum colors and the other extended into the infrared. In a sense, each set of photographs served as a spectral fingerprint of a specific ground condition.

Each of the six high-precision cameras had an f/2.8 lens with aperture variable to f/16 in 1/2 stop increments and a focal length of 152-mm. At a nominal spacecraft altitude of about 500 kilometers, the 21.2 degree square field-of-view provided ground coverage of 160 square kilometers.

Film width was 70-mm, which provided a usable image 5.7 cm square. Shutter speeds were 2.5, 5, and 10 milliseconds, and the six shutter mechanisms were synchronized to within 0.4 millisecond. The camera system compensated for the forward motion of the spacecraft along the flight path, and photographs could be taken singly or in automatic series with intervals of 2 to 20 seconds. To provide for stereoscopic viewing, overlaps of 60 percent were obtained using 10 second intervals (NASA, 1974).

Each of the six cameras was identified by a station number and equipped with combinations of filters and films for the various wavelength bands, as shown in Figure 4.

## System Operation

This advanced photographic system is recommended for use in conjuntion with the U.S. Space Shuttle program. The latter allows the multiple mission use and repeated film return capability.

The Shuttle is launched by two detachable solid fuel booster rockets. When these are expended, they are jettisoned and recovered for subsequent reuse. The Shuttle is then boosted into Earth orbit using its own engine and liquid fuel from a large external tank. When the proper orbit is reached, the tank is jettisoned to burn in the atmosphere upon re-entry. The Orbiter vehicle then performs its assigned missions in space and returns to land as an aircraft. The principal advantage of the Shuttle is that its major component, the Orbiter vehicle, is recovered and reused. It is anticipated that eventually there will be a total of four vehicles and between fifty and thirty missions will be flown each year.

Initial launches of the Shuttle have taken place from the Kennedy Space Center. Range Safety conditions restricted the maximum orbital inclination to 57 degrees. Later, by 1984, launch operations may be available at the Vandenberg Air Force Base, California. From that locality polar orbits can be attained. Circular orbits from 200 to 1200 km altitudes can be achieved depending upon payload weight and orbit inclination. Mission duration will be from three to thirty days (Doyle, 1978).

The Shuttle operates in two different modes. In the sortie mode, experiments are mounted in the Orbiter cargo bay, operated for the mission duration, and then returned to earth. The cargo bay is 18.3 meters long and 4.6 meters in diameter and can carry a maximum of 30,000 kg payload. In the second mode of operation, the Shuttle carries individual spacecraft into space, places them in appropriate orbit, and services them on demand. A Remote Manipulator System (RMS) may extract the payload from the cargo bay and release it into its own orbit. In addition, the Shuttle Orbiter can rendezvous with a free-flying satellite, the RMS can retrieve it to the cargo bay where it can be serviced, or else returned to earth for major refurbishment.

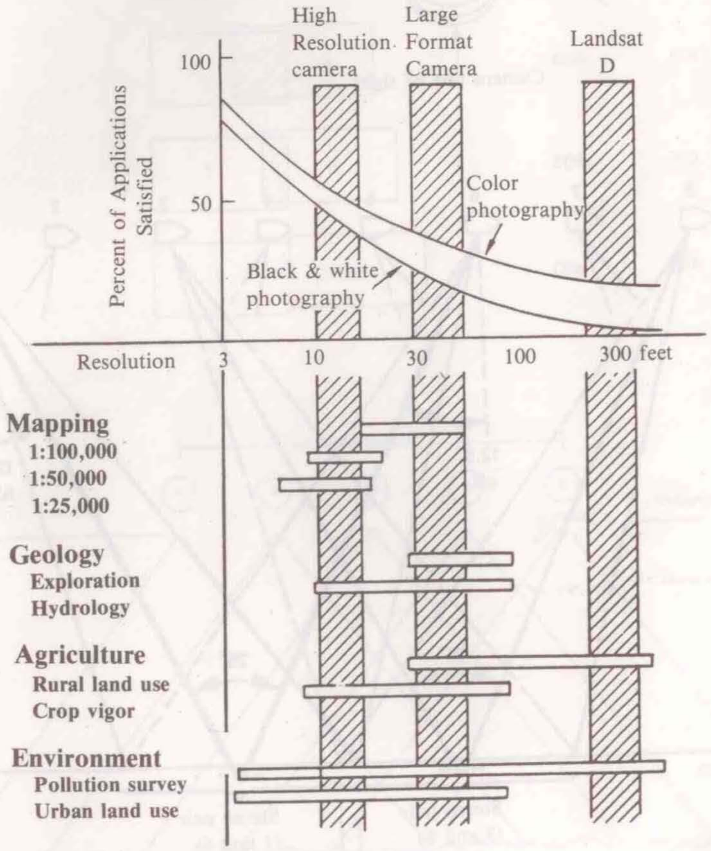


Figure 1. Photographic resolution required for cartographic mapping, geologic interpretation, agricultural surveys, and environmental studies.

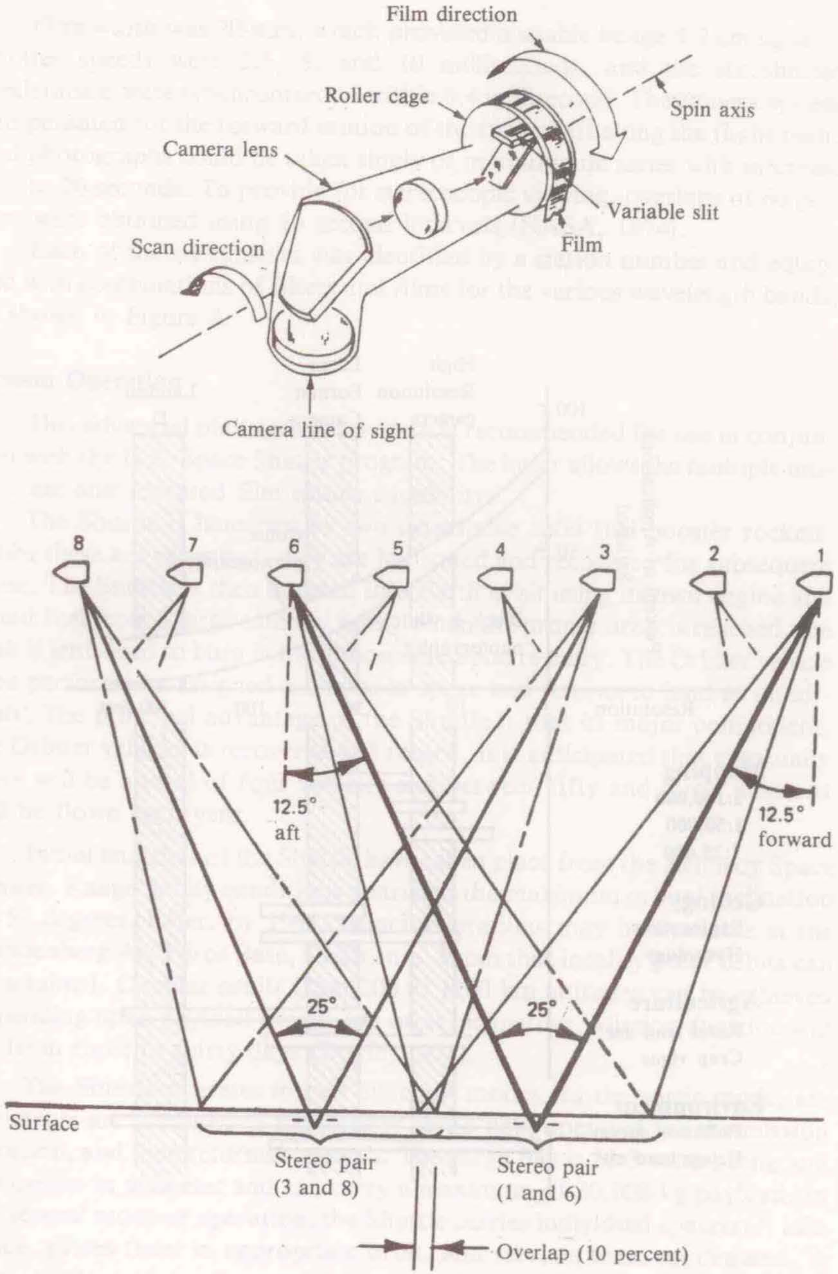


Figure 2. The Apollo panoramic camera and its operation. (Top) The optical bar concept. (Bottom) Alternate exposures for the acquisition of stereo pairs. (After Masurskey et al., 1978, pp 12 and 13.)

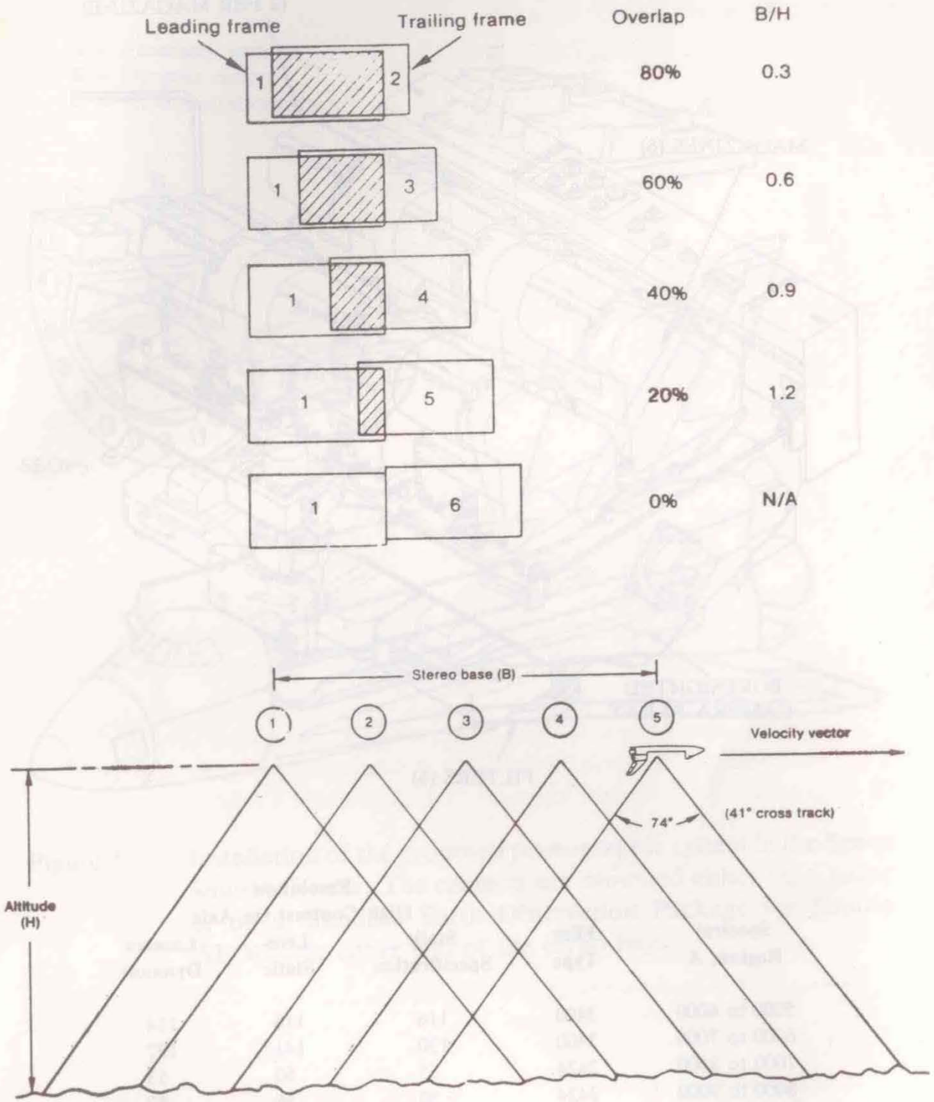
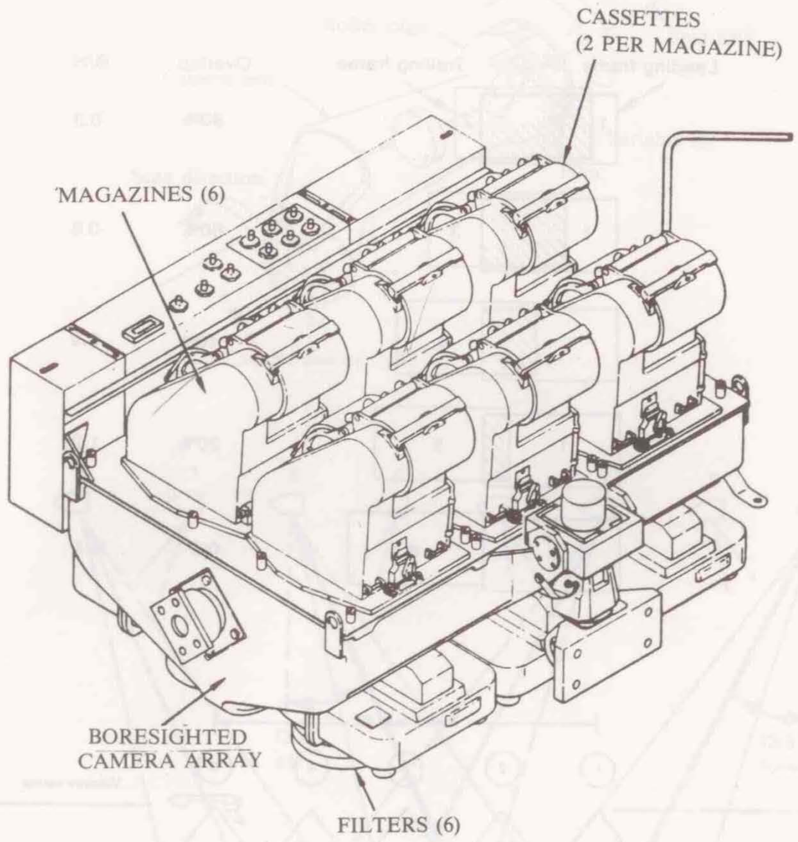


Figure 3. Frame overlap of the Large Format Camera. (Top) Options available for overlap percent. (Bottom) Operation from Space Shuttle for the acquisition of stereo pairs. (After El-Baz and Ondrejka, 1978, p 717.)



| Spectral Region, A | Film Type | Resolution<br>High Contrast On Axis<br>Static Specification | Lens Static | Camera Dynamic |
|---|---|---|---|---|
| 5000 to 6000 | 3400 | 116 | 116 | 114 |
| 6000 to 7000 | 3400 | 130 | 141 | 137 |
| 7000 to 8000 | 2424 | 55 | 60 | 53 |
| 8000 to 9000 | 2424 | 50 | 56 | 50 |
| 5000 to 8800 | 3443 | 45 | 50 | 50 |
| 4000 to 7000 | SO-242 | 130 | 145 | 145 |

Figure 4. The Skylab Multispectral Camera (top) and its photographic performance parameters (bottom).

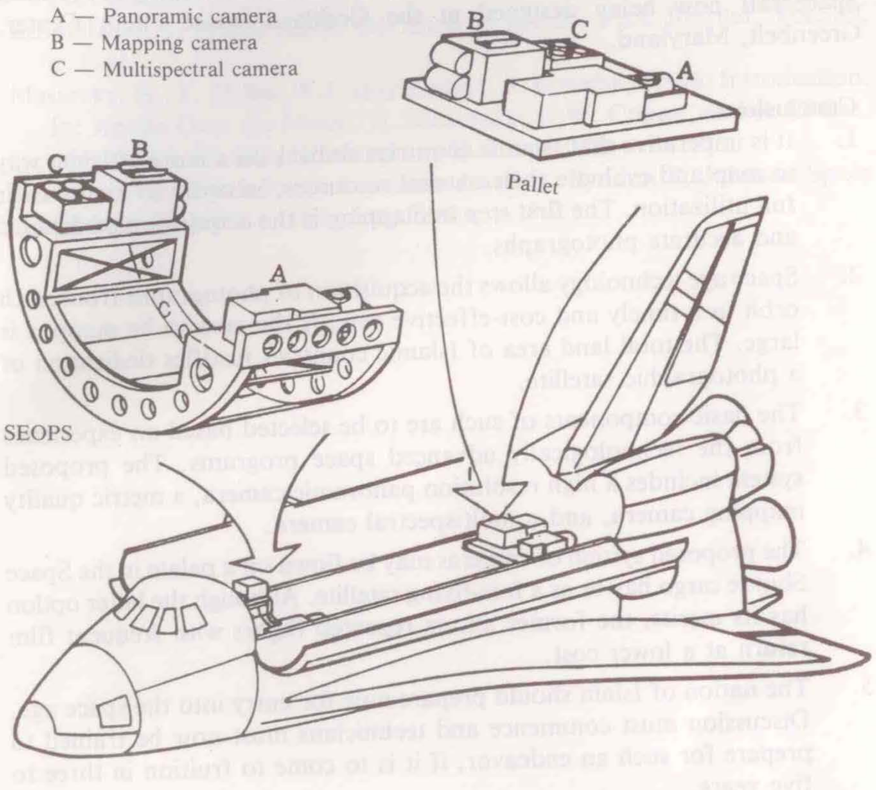


Figure 5. Installation of the proposed photographic system in the Space Shuttle Orbiter. The cameras are mounted either on a pallet or on a Standard Earth Observation Package for Shuttle (SEOPS) at either end of the cargo bay.

The proposed photographic system can be utilized on both operational modes of the Shuttle. The cameras can be mounted on the Operational Flight Test cargo bay pallet (Figure 5). They can also be mounted on a free-flying satellite, to be left in orbit by the Shuttle, such as the Multimission Modular Spacecraft now being designed at the Goddard Space Flight Center, Greenbelt, Maryland.

## Conclusions

1. It is imperative that Islamic countries embark on a more efficient way to map and evaluate their natural resources, in order to assure their full utilization. The first step in mapping is the acquisition of detailed and accurate photographs.
2. Space age technology allows the acquisition of photographs from earth orbit in a timely and cost-effective way, if the area to be mapped is large. The total land area of Islamic countries justifies dedication of a photographic satellite.
3. The basic components of such are to be selected based on experience from the technologically advanced space programs. The proposed system includes a high resolution panoramic camera, a metric quality mapping camera, and a multispectral camera.
4. The proposed system of cameras may be flown on a palate in the Space Shuttle cargo bay or as a free-flying satellite. Although the latter option has its merits, the former allows repeated flights with frequent film return at a lower cost.
5. The nation of Islam should prepare now for entry into the space age. Discussion must commence and technicians must now be trained to prepare for such an endeavor, if it is to come to fruition in three to five years.

## References

Doyle, F.J. (1972) Can Satellite Photography Contribute to Topographic Mapping? World Cartography, Volume XII, Department of Economic and Social Affairs. United Nations, New York, p. 32-42.

Doyle, F.J. (1978) The Next Decade of Satellite Remote Sensing. Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 2, p. 155-164.

El-Baz, F. (1975) Orbital Photographs of the Moon--Why We Need More. In: Lunar Science VI, Supl. Abst. Sixt Lunar Sci. Conf. Goddard Space Flight Center, Publication X-682-75-46, p. 5-6.

El-Baz, F. and R.J. Ondrejka (1978) Earth Orbital Photography by the Large Format Camera. Proceed. of the 12th Internat. Symp. on Remote Sensing of Envir. Vol. 1, Environmental Research Institute of Michigan, Ann Arher, p. 703-718.

FMTF (1973) Report on Mapping, Charting, Geodesy, and Surveying. The Federal Mapping Task Force (FMTF). Office of Management and Budget (OMB). July 1973, U.S. Government Printing Office. Stock Number 2401-02426.

Kosofsky, L.J. (1973) Moon Revisited in Stereo. PSA Journal, Vol. 39, p. 1-11.

Masursky, H., F. El-Baz, F.J. Doyle, and L.J. Kosofsky (1978) Introduction, In: Apollo Over the Moon, H. Masursky, G.W. Colton, and F. El-Baz, eds. NASA SP-362, Washington, D.C., p. 1-29.

NASA (1974) Skylab Earth Resources Catalog. Lyndon B. Johnson Space Center, JSC-09016, Houston, Texas, p. 5-7.