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Remote Sensing of Narcotics:

With Special Reference to Techniques for Detection and Monitoring of Poppy Production in Afghanistan

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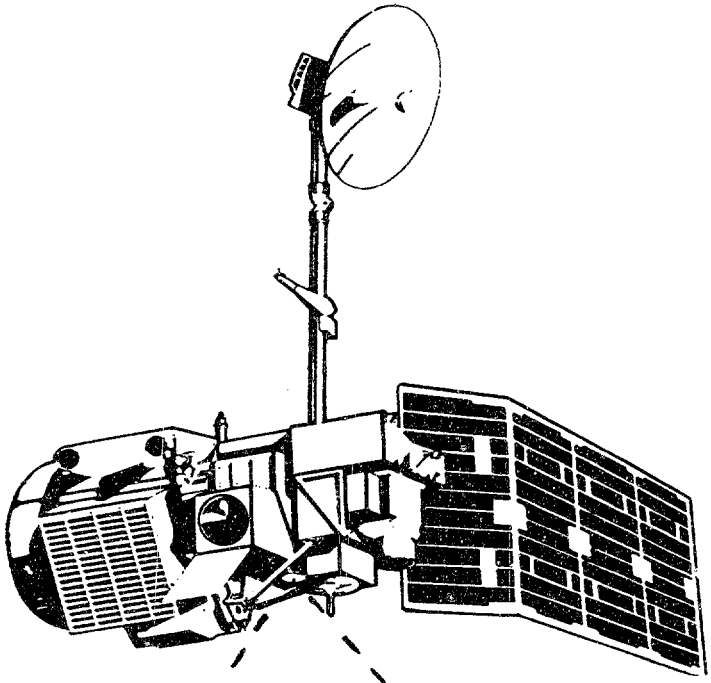

Remote Sensing of Narcotic Crops

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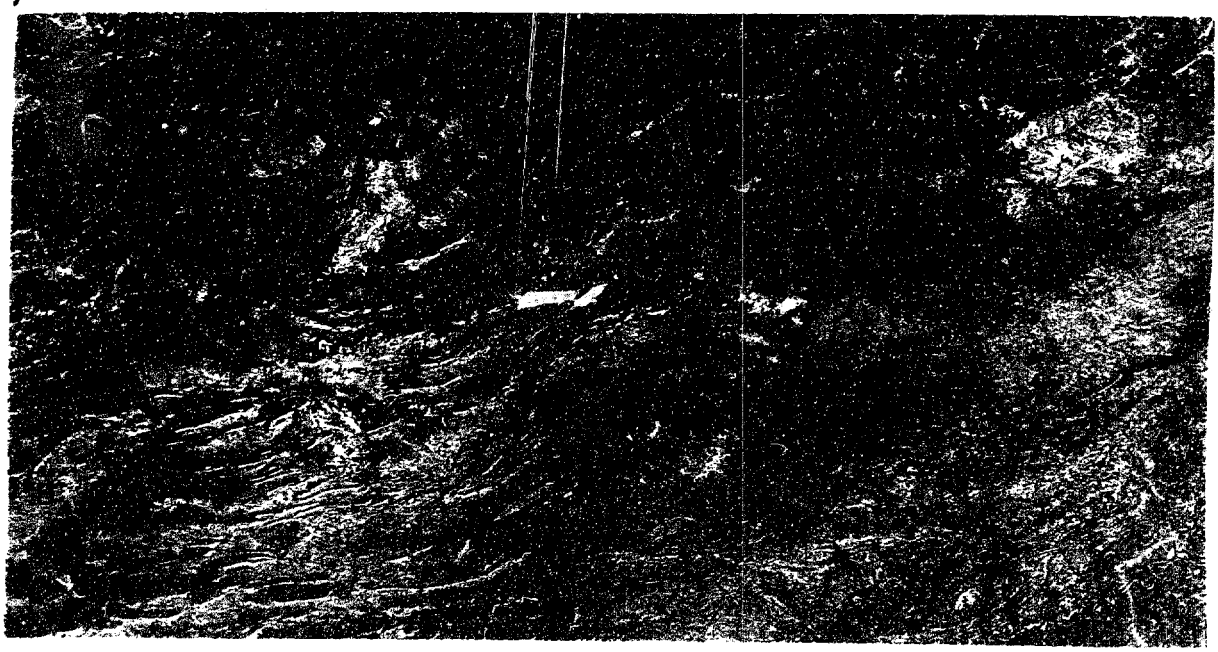

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EXECUTIVE SUMMARY

The reduction of narcotics production in Afghanistan, by economic incentives and a drug awareness program, is the primary goal of the Narcotics and Awareness Control Project (NACP). To achieve this goal, the project must be able to monitor changes in poppy production. The objective of this report is to evaluate the capabilities of commercially available remotely sensed data[1] to detect poppy cultivation and monitor changes in poppy production.

Monitoring of poppy production has been attempted in India and Thailand. Neither of these projects confirmed the ability to locate poppy by identifying its spectral signature. The procedures used in these projects, however, may not represent an exhaustive effort to use satellite imagery to identify poppy. Surveillance of poppy from aircraft, as conducted in Turkey and Mexico, shows promise, but at present this procedure is too dangerous in Afghanistan and not a viable option for an operational monitoring program.

The collective experience of a United Nation's group of experts on remote sensing of illicit narcotic crops, as well as independent research by this author, suggests that satellite monitoring of poppy production in Afghanistan could be successful under optimal conditions. Examples of optimal conditions include readily available and good-quality satellite data, knowledge of the crop calendar, ability to do ground truthing, sufficiently large field size, and minimal intercropping. It should be emphasized that there is no evidence that satellite imagery can be used successfully to monitor poppy production under less than optimal conditions.

Acceptable satellite imagery appears to be available for all of Afghanistan, and evidence suggests that fields of an acceptable size and crop pattern exist in some areas of Afghanistan. In addition, the necessary expertise and equipment (computer hardware and software) exist in the private sector to perform the work.

This report recommends, therefore, that a pilot project be conducted in the southwest (Helmand Province), where conditions are most favorable to judge the potential of satellite technology to meet the needs of the NACP. If results seem promising, this technique could be applied to other regions of Afghanistan, as well as in projects elsewhere.

The pilot project should begin with the development of a crop calendar and acquisition of imagery during the poppy flowering season (probably mid-March to early April). Both visual and digital image analysis procedures should be tested to compare mapping results. Ground truthing support will be necessary in the early stages to locate known poppy fields, to train human interpreters and computers to identify the poppy spectral signature. Moreover, ground support will be needed to confirm the existence of poppy fields identified by satellite imagery to establish the reliability of the satellite products.

If safety factors, logistics, or other reasons prevent a pilot project from being conducted in Afghanistan, a Pakistan test area could be chosen in a region with a similar climate and poppy cultivation practices. A time lag of three to four months can be anticipated from the initiation of satellite data procurement to the completion of finished output maps.

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[1] "Remotely sensed data" refers to satellite imagery, aerial photographs, or airborne sensors.

Evidence indicates that poppy field sizes in Afghanistan range from .2 to 1 hectare. Commercially available satellite imagery, in theory, has the required resolution to detect larger fields. Identification accuracy, however, will be lower for small fields that are less than .4 hectares (approximately the size of a North American football field). Because there is no quantitative information about detection accuracy available from preliminary studies in other regions, a definitive estimate cannot be made for Afghanistan.

The purpose of the pilot project would be to determine the accuracy limits and establish a baseline for evaluating satellite poppy monitoring performance. Changes in production area can be determined by two observation dates of imagery — one in the early stages of the project and one a year or two later. If poppy identification accuracy is 80 percent correct from the first date of imagery, the same accuracy level can be expected from the second date, assuming image quality and analytic procedures are similar. This level of similarity in accuracy of poppy classification will indicate that any change in production area estimates between the two dates should be a close estimate of actual change.

Development of a geographic information system (GIS) for the NACP priority areas could facilitate poppy monitoring by improving the analytical capability to predict and map poppy locations and, thus, contribute to planning for crop reduction. However, development of a GIS capacity will add significantly to the cost of the project. Some cost savings could be realized if the existing GIS capacity of the Agricultural Sector Support Project (ASSP) could be integrated with NACP GIS needs. Separate GIS operations for the two Afghanistan projects would be less efficient and more costly.

SECTION ONE

OVERVIEW

The goals of the Narcotics Awareness and Control Project (NACP) are to (1) reduce narcotic crop production in Afghanistan and (2) lay the groundwork for an anti-narcotics program by increasing awareness of the destructive nature of narcotics. The information and research unit (IRU) of the NACP will be responsible for monitoring and evaluating the impact of project activities. One of the priorities of the IRU is to monitor poppy production and production changes resulting from project activities. Specifically, the success of the NACP will be judged primarily on how well project activities have contributed to the reduction in area planted to poppy fields. The combined use of remote sensing and geographic information system (GIS) technology has been proposed as a feasible approach to accomplish this important monitoring task.

The objective of this report is to review and evaluate the capability of commercial satellite remote sensing technology to detect and monitor poppy production and change in production. Section One contains the introduction, a literature review, and information concerning the capabilities of remote sensing and GIS applications for poppy monitoring. A subsection presents opinions expressed by participants at an October 1989 meeting of remote sensing experts sponsored by the United Nations Division of Narcotic Drugs and the U.S. State Department. Section Two discusses specific subtopics such as identification of characteristic signatures for poppy, availability of commercial sources of imagery, and costs of data procurement.

Published information about narcotic crop detection, monitoring, and eradication efforts aided by remote sensing technology is sparse. Most of the information exists in the "gray" literature — primarily internal documents printed by the United Nations Division of Narcotic Drugs, the U.S. State Department, and agencies within some of the countries in which illicit or licit narcotic crops are grown. Practically nothing is published that provides solid, quantifiable evidence concerning the accuracy of remote sensing detection of any narcotic crop. However, a few pilot projects have been conducted that provide some insight into the possibilities of using remote sensors and GIS technology to monitor narcotic crop production.

LITERATURE REVIEW

Some of the earlier references to narcotic crop monitoring discussed aircraft technology, using either cameras (aerial photography) or multispectral scanners. In 1980, the author of this report, as an employee of a consulting firm in California, wrote an unsolicited proposal to USAID-Peru that described a technique to detect and monitor coca production in the Huallaga Valley, Peru. The proposal suggested the use of an existing ecological map to narrow the search area and the use of aerial photos and a statistical sampling technique to verify the accuracy of the results. Growing conditions for coca have environmental limitations (temperature, precipitation, soils, and so forth), and the ecological map highlighted the optimal coca production zones. Photo interpreters (Peruvians) would be trained to identify the coca crops and distinguish them from other crops and land cover types. In the operational phase of the project, a random sample of the coca fields, mapped by photo interpreters, would be checked by

aircraft overflights (with 35 mm photos taken with a telephoto lens) to verify the accuracy of photo interpretation and to provide a basis for area estimates of coca production in the valley. The use of an ecological map as a source of corollary data was a harbinger of a GIS approach to detection, prediction, and monitoring of a narcotic crop.

Yost (1984) wrote a concept paper for the Food and Agriculture Organization (FAO) that describes the characteristics and costs of available satellite sensors to conduct a detection and monitoring program for coca-growing areas in selected regions of Bolivia and Peru. Yost's review discusses the characteristics of Landsat MSS data, which was the only operational sensor available at that time (1984). The spectral and spatial resolution of Landsat MSS is too coarse for the intended applications in detection and monitoring of illicit narcotic crops. Therefore, Yost's report does not offer much insight into the utility of the most advanced technology now available. Yost's review, like several other documents listed in the reference section of this report, does not contain results of any project actually conducted to detect the target crop.

Experience gained through remote sensing studies in other regions and with different crops might provide some useful insight about techniques and results that might be anticipated for narcotic crop detection. Williams et al. (1987) used Landsat-Thematic Mapper (TM) data to identify vegetable crops in fields as small as two hectares in the state of New York. The authors conclude that digital analysis techniques were faster but visual interpretation was more accurate because human interpreters could identify characteristic colors and patterns, especially in narrow fields (two *pixels* wide) and in areas in which growth stages of crops varied. Detection of target crops was better where (1) the target crops were mature (less soil showing), (2) the terrain was flat, and (3) when additional images were available midway through the growing season (especially in the case of intercropping). The authors claim that a regional crop calendar was the key to success and because TM data were available for the best season. TM bands 5 and 7 (MID-IR) were considered to be important for detection. Reflectance in the middle infrared wavebands is influenced by water content in vegetation and soils. These wavebands in combination with others may help in distinguishing poppy plants from other crops that have slightly different reflectance characteristics in the middle infrared wavelength region (approximately 1.5 mm to 2.3 mm).

GIS CONCEPTS

Perhaps the closest that anyone has come to developing a GIS or "expert system" approach to monitor narcotic crops is described in articles by Waltz and Moore (1986), Waltz and Holm (1986), and Robertson (1986). The target crop was marijuana and the studies were conducted on national forest lands in the United States. The Area Reduction Method (ARM) incorporates predictive spatial modeling techniques to calculate the geographic distribution of the target crop. The models are based upon suitable growing condition factors, psychological inferences regarding growers' behavior in cultivation practice, and environmental restrictions that lower the probability of cultivation in certain areas. Terrain features (elevation, aspect, slope, and topographic position), distance from water or roads, and other spatial features associated with known garden sites were digitized and analyzed in the development of the predictive model. The crop prediction model can be updated as growers adapt their cultivation practices to avoid detection and as the new growing site characteristics are put into the database for model revision. Partial successes were reported in applying the ARM to detect the location of previously unknown fields. Low-altitude aerial photographs, visual identification, and ground visitation were used to make positive identification of the crop type necessary because of small garden plot size (.5 acres) and stealthy practices of growers in disguising the location of the fields.

The ARM approach may have some merit for the NACP. The remotely sensed data enable the identification of target crop locations. The GIS components (such as distance from roads, distance from water or irrigation zone, topographic position or slope gradient, or village location) can help in defining the most characteristic conditions for the target crop. This information can be used in predictive modeling to flag high-probability crop sites that can be monitored closely by satellite surveillance and ground truthing.

Williams (1990) discusses the potential application of GIS to help fight the war on drugs. Although the article is only a concept paper and contains no results of projects conducted, it reinforces the thinking in the research community that remote sensing integrated with GIS and expert systems can be useful in monitoring narcotic crop production and drug trafficking activities. Williams' article takes the perspective of a military or police intelligence approach to fighting the drug war with GIS.

Periodic verification of crop locations is important for validating satellite detection accuracy and improving the data that goes into the GIS for predictive modeling of future crop locations. The Information and Research Unit (NACP) will have an important role to play in strengthening GIS analytic capabilities by providing ground information for verifying crop location and monitoring poppy elimination plans. These issues are discussed below.

CROP ERADICATION MONITORING

It is known from press releases and personal communication with State Department officials and contractors that the U.S. State Department has financed some crop eradication efforts in various countries, especially in Mexico, and Central and South America. A private contractor in the United States is currently engaged in a feasibility project, funded by the State Department, to use a video camera system to monitor the effectiveness of herbicide spraying on marijuana fields in Central America. The objective is to test the feasibility of the video technology to observe the results of the spraying activities in "near real-time" (2-3 days). This approach obviously requires a low-flying aircraft as a platform for the video camera to obtain adequate resolution for the imagery. The advantage of the video technology (for application in regions without aircraft security risks) is the real-time capability of viewing the results using standard low cost VCR tapes and monitors. This system allows immediate decision making and follow-up activities to be conducted, if desired. Real-time capability is not possible with commercial satellite technology and other aircraft systems because photographic or digital processing is required, which can take weeks before the imagery can be viewed or analyzed.

Crop eradication efforts are not an objective of the NACP; however, monitoring poppy elimination plans will require some observational verification of whether alternative crops are being planted to replace poppy. This is a fundamental problem because ground observation teams cannot visit most of the project territory on the ground. Real-time monitoring of crop location on the ground or from low-flying aircraft may not be feasible for NACP; however, delayed information from field observation will still be useful and important for validating the remote sensing and GIS techniques being applied.

GENERAL CHARACTERISTICS OF POPPY CULTIVATION

Illicit poppy crops are grown in two major zones: South-East Asia and the Middle East. Poppy grown in the Middle East (the golden crescent) covers the tribal areas of Pakistan, Afghanistan, and Iran (Harrison, 1986). The climate is dry. In Afghanistan, opium poppy (*Papaver somniferum*) is planted in fall (Helmand and Nangarhar Provinces), with flowers appearing in late March or early April. After flowering (which lasts two to three weeks), the capsule remaining is cut after the fall of the leaves and the latex flowing from it is collected every day after oxidation. The harvest extends from approximately mid-April to early May in the southern provinces. The poppy harvest usually ends two or three weeks before the wheat harvest begins (Owens and Clifton, 1972). The harvesting method is highly labor intensive, requiring 15-20 persons per hectare. The northern and mountain crops mature slightly later than the lowland crops. Cultivation calls for a relatively warm climate (temperature of 20-25°C during the growing season), thus limiting the altitude at which the plant is found.

Poppy can be grown with as little as 50 centimeters of rainfall occurring in winter and spring months, but is almost always grown as an irrigated crop in Afghanistan (DAI/DA, 1990). The crop calendar varies strongly with altitude, which is a factor having substantial effect on timetable and yield. The competing crops are primarily wheat and also corn, cotton, and vegetables. In Afghanistan, the growers follow a double cropping pattern. Poppies are fall planted and spring harvested. Corn, cotton, or vegetables are spring or early summer planted and fall harvested. The next rotation would be wheat, fall or winter planted and harvested in early summer. Corn or poppies would follow and the cycle would be repeated (Owens and Clifton, 1972).

REMOTE SENSING OF OPIUM POPPY CULTIVATION

Detailed mapping of the geographic extent of illicit cultivation has never been attempted in any country. No national or international agency has been willing to take responsibility for a project that could be fairly expensive, politically sensitive, and require advanced technology and applications that are not well understood by most administrators and nonexperts. This author is not aware of any satellite detection studies of narcotic crops conducted through the U.S. private sector other than as a by-product of ongoing USAID agricultural or rural development projects in some countries. I have observed satellite imagery of suspected illicit narcotic crops in Peru, Bolivia, Brazil, Thailand, India, Pakistan, Mexico, Columbia, Jamaica, and Afghanistan, but most of the images were not collected as part of a specific project to test the feasibility of detecting these crops from satellites.

According to a report by Harrison (1986), FAO had not attempted any studies of opium poppy detection using satellite data in the Middle East. The United Nations meeting of experts on remote sensing of illicit narcotic crops held in Vienna, Austria, in October 1989 (attended by this author) did not reveal any current satellite detection projects being conducted by FAO. However, it is likely that a U.N.-funded project will be initiated in 1991-1992.

Two pilot projects using satellite imagery for monitoring poppy production have been conducted: one in Thailand and one in India. Other poppy detection and monitoring projects have been conducted in Mexico and Turkey; however, both of these projects have used aircraft multispectral scanners. Although aircraft systems would provide better ground resolution or detail on small fields, these systems are not available to the Afghanistan project. The Turkey poppy monitoring project was reported to be

successful using the multispectral opium poppy sensor (MOPS), but the maintenance and operation of the aircraft and sensor has been very expensive (Harrison, 1986).

The Mexico project began as a cooperative effort between NASA-Stennis Space Center and the Government of Mexico. A complete aircraft (lear jet) and multispectral scanner system (Thematic Mapper Simulator) were supplied to the Mexican government through the project in the early 1980s. Appendix A contains tables indicating the best wavebands suggested for poppy detection and some technical specifications of the Mexican aircraft system.

If the NACP sponsors decide to proceed with remote sensing and GIS elements of the project, the endeavor will be a pioneering effort for its intended application in narcotic crop monitoring. Previous research presented here suggests that the proposed project would have a good probability of success because of the recent advances in satellite sensor technology and the experience of knowledgeable users of these technologies. Several private companies and some universities have the necessary equipment, software, and expertise to perform this work.

Table 1 is a summary of information that has been derived from a variety of sources addressing remote sensing detection of poppy cultivation. Documentation for some of these projects and other related literature are listed in the reference section of this report. With the exception of the Thailand Study (Appendix B), there have been no GIS approaches attempted for poppy detection at this point in time, although the U.N. expert group meeting in October 1989 proposed to test these concepts in pilot projects initiated in selected regions.

SUMMARY OF THE U.N. EXPERT GROUP MEETING ON REMOTE SENSING OF NARCOTIC CROPS

At its regular 1988 session, the Economic and Social Council requested the Division of Narcotic Drugs to organize and hold a meeting of experts responsible for:

- Analyzing the possibility of identifying illicit plantations of coca, poppy, and cannabis on satellite images, and defining the processing procedures to be used;
- Determining whether it is possible to evaluate, by satellite monitoring methods, the damage caused to the environment by these illicit crops; and
- Identifying the costs of analysis and interpretation of the data thus obtained.

The purpose of using satellite imagery or aerial photography in connection with narcotic drug cultivation is to evaluate and locate the areas illegally planted and to monitor the implementation of policies for the introduction of replacement crops. Suppression of trafficking was not within the terms of reference for the meeting.

The meeting was held in Vienna in October 1989 (see press release - Appendix C). With specific reference to opium poppy, some of the opinions and statements of the U.N. expert group are summarized below by subject area.

Table 1. Summary of Remote Sensing Projects that Have Addressed Opium Poppy Detection.

Study Site	Sensor/Wavebands		Date	Analysis Method	Ancillary Data	Other Crops	Results/Conclusions
India (Plains) Mandsaur	IRS LISS-1	False Color Composite	Dec.'88 Feb.'89 Mar.'89	Visual/ temporal	Crop calender, limited ground truth	Winter wheat, some inter-cropped	Poppy detectable in Dec., but not in Feb.-March because of confusion with wheat.
India (Hills) Chakrata	Landsat TM	NEAR-IR (Ch 4) & MID-IR (Ch 5)	Mar.'86 & '89	Digital/ supervised Max. likihood & bivariate Ch. 4 & 5	Same as above	Same as above	Good separation between poppy & wheat, with band 4 & 5
Thailand	SPOT	Panchromatic & Multispectral	Various dates	Visual, Digital/ supervised	Road, river, village crops, ground truth	rice rice	Confusion of poppy with other crops, and old fields
Turkey	MOPS (aircraft)	Multispectral	?	Digital ?	?	?	Successes reported but expensive investment
Mexico	TMS (aircraft)	Multispectral NEAR-IR (Ch. 4) & MID-IR (Ch. 5)	?	Digital ?	?	?	No conclusion available

Poppy Identification Possibilities

- For the three major illicit crops (marijuana, coca, and poppy), the best chance of detection by satellites probably rests with poppy, especially in the drier climates and when more than one image can be obtained during periods of key growth.

- The best situation for crop detection are when the following conditions can be met.

  1) Arid climate

  2) Flat land

  3) Larger field sizes

  4) Nonintercropped fields

  5) Availability of good quality, multitemporal imagery at optimal periods in the crop calendar and when other crops are not in similar growth stages.

  6) High resolution satellite data available (such as SPOT, TM, and KOSMOS).

  7) Good corollary data available concerning historical growing areas, ground truth, air photos, other maps, and so forth.

- Poppy can be identified best during the flowering season; however, flowering lasts only about two weeks. In some regions it was suggested that poppy could also be detected during the harvest season or up to two months after flowering.

- Poppy spectral signature varies by multiple factors and generally is a scene-dependent phenomena, although characteristic patterns can be detected if conditions are optimal.

Growers' Habits

- Many growers in the Middle East have been known to plant poppy in the same fields without rotation or fallow for several years in a row.

- Whenever effective eradication was carried out by law enforcement agencies, poppy cultivators tend to relocate their crops on smaller plots in more isolated and remote locations in mountains or forest.

- In Thailand, there was some tendency for the illicit poppy growers to congregate, making detection by remote sensors possible despite the small size of individual fields.

- Finer resolution sensors may be required in areas where field sizes are small.

- In some cases, detection of a target crop may be possible by association with features or activities related to cultivation rather than by spectral signature alone.

Crop Calendar/Phenological Stages

- Crop calendars should be developed for each study area so that the optimal dates of satellite imagery acquisition are known.

- Variation in the crop calendar will be controlled by environmental conditions (especially elevation). Therefore, more than one calendar may be needed in regions with highly variable terrain and climate (such as northeastern versus southwestern Afghanistan).

Visual versus Digital Methods[1]

- From pilot studies, visual interpretation of satellite imagery at the appropriate time in the crop calendar and digital analysis using the appropriate classifier can allow reliable discrimination of illicit poppy fields in remote locations (assuming other factors and conditions are favorable.)

- Visual interpretation of enhanced imagery may be at least as good as, if not more successful than, digital classification, especially in cases in which there is no unique spectral signature for the target crop (for example, nonflowering or early growth stage). However, the advantage of the digital approach over visual interpretation is apparent when indirect clues and GIS attributes can aid in detection and monitoring. A hybrid approach (such as visual detection or digitization plus GIS database queries) may be feasible in some regions for which good maps and information exist.

Contributions of GIS

- GIS techniques have been proposed for feasibility studies in crop detection and monitoring. The GIS components will depend on the availability of maps (reasonable quality) and other sources of data. GIS components might include climate (temperature, precipitation, and ecological zone); topography (elevation, slope, aspect); surface hydrology; historical crop locations; settlements; and transportation network (see Appendix B).

- In addition to the GIS, the preparation of crop calendars by region (for example, plains/desert and hill/mountain) and characteristic spectral signatures for different field conditions and different dates of imagery would be useful.

- The primary objective of the narcotic crop monitoring GIS would be to narrow the search area and increase the reliability of detection. It is unlikely that all poppy fields will be detected "automatically" through a unique spectral signature. The model for the GIS query sequence or "expert system" might be first developed by visual analysis performed by trained image interpreters who can logically integrate visual clues to arrive at the correct

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[1] Visual interpretation refers to analysis of the image by a human interpreter. Digital interpretation refers to analysis by a "trained" computer, using various kinds of enhancement procedures to improve appearance of imagery, and statistical pattern recognition techniques to identify the signatures of different classes of land use.

identification. The model can be updated as new fields are discovered and their relational attributes are input into the database.

UNDND Plans

- If appropriate funding can be secured, the United Nations plans to implement a project (designed by the expert group) to test the feasibility of satellite detection of illicit coca and poppy.

- The specific countries and organizations involved in this project have not been determined, but FAO will likely be the lead organization responsible for technical implementation of the pilot projects. An advisory group of experts will be appointed to assist FAO with technical direction of the projects.

- Quantifiable results will be obtained through the project, based upon statistical sampling techniques in regions for which aerial photography or limited visual observations can be obtained to verify actual locations.

SECTION TWO

FEASIBILITY OF REMOTE SENSING TECHNIQUES TO ADDRESS NACP MONITORING NEEDS

CONSIDERATIONS ON THE IDENTIFICATION OF CHARACTERISTIC SIGNATURES FOR POPPY IN THE TARGET AREAS

Previous research suggests that development of spectral signatures can be useful as a method for automatic crop detection in many regions. However, there are many factors that will influence the amount of reflectance (at wavelength) received by sensors on orbital platforms and spectral signatures of the target crop may be difficult to separate from other ground features.

Poppy crops in various growth stages will have different signatures because the ratio of plant canopy to shadow and soil area will influence the overall reflectance in the sensor field-of-view (Table 2). Poppies intercropped with wheat and other crops will have a different signature compared to pure poppy fields. If the poppy fields are very small with narrow boundaries, the crop signature may be influenced by surrounding surfaces (hence the mixed *pixel* effect), especially when the fields are at or near the size of the ground resolving area (*pixel*) of the sensor (Figure 1).

TABLE 2

VEGETATION/LAND COVER VARIABLES THAT INFLUENCE ENERGY REFLECTED OR EMITTED FROM THE LAND SURFACE

(1) Plant species
(2) Vigor/age of vegetation
(3) Density of vegetation
(4) Ground cover or understory vegetation
(5) Soil moisture, if exposed soil
(6) Surface condition, if exposed soil
(7) Soil Characteristics, if exposed soil
(8) Slope, if pronounced
(9) Aspect, if pronounced
(10) Characteristics of inert materials

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The best chance for a unique signature is probably during the flowering stage, and at maturity just before harvest time. Only the best-quality data (low clouds, low haze) should be acquired. Atmospheric and radiometric corrections should be applied to each sensor data set. Image enhancement techniques (such as band ratioing) may highlight the appearance of poppy compared to other crops. These techniques should be evaluated early in the project.

Multispectral signatures for poppy should be developed specifically for the different growth stages and conditions in Afghanistan. The spectral reflectance of poppy or any other crop is not universal and varies in accord with the factors discussed earlier. Therefore, the signature development and analysis procedure must be repeated for every new satellite scene analyzed. This is a routine process and is not a problematic or arduous task. It is simply part of the sequence of processing and analyzing the satellite data for detection and mapping of crop locations.

A Suggested Procedure for Crop Detection and Evaluation

1. Develop crop calendar for different regions in Afghanistan (northeast and southwest). See Pakistan example for the Dir district (Figure 2).

2. Acquire best-quality imagery at optimal time in crop calendar.

3. Perform preprocessing (atmospheric, radiometric and geometric corrections).

4. Perform image enhancements for visual interpretation of imagery.

5. Locate known fields on imagery for supervised training, if possible.

6. If more than one growth stage is present in the imagery, locate several examples (and repetitions) for supervised training.

7. Draw polygons interactive on image display around poppy training sites and code suspected growth stage.

8. Pick training sites for other crops/cover types in local areas.

9. Derive and plot spectral signatures and evaluate divergence or statistical separability. If multidate imagery available, do the same for each date.

10. Use unsupervised classification to stratify all nonagricultural sites. Combine statistics prior to classification or merge strata after classification.

11. Perform independent visual interpretation on enhanced imagery (use trained interpreters).

12. Evaluate crop classification results; determine most appropriate techniques and apply to full scenes or subsets of probable cultivation zones.

Figure 1. Wheat and poppy intercropped. (Source: National Geographic)

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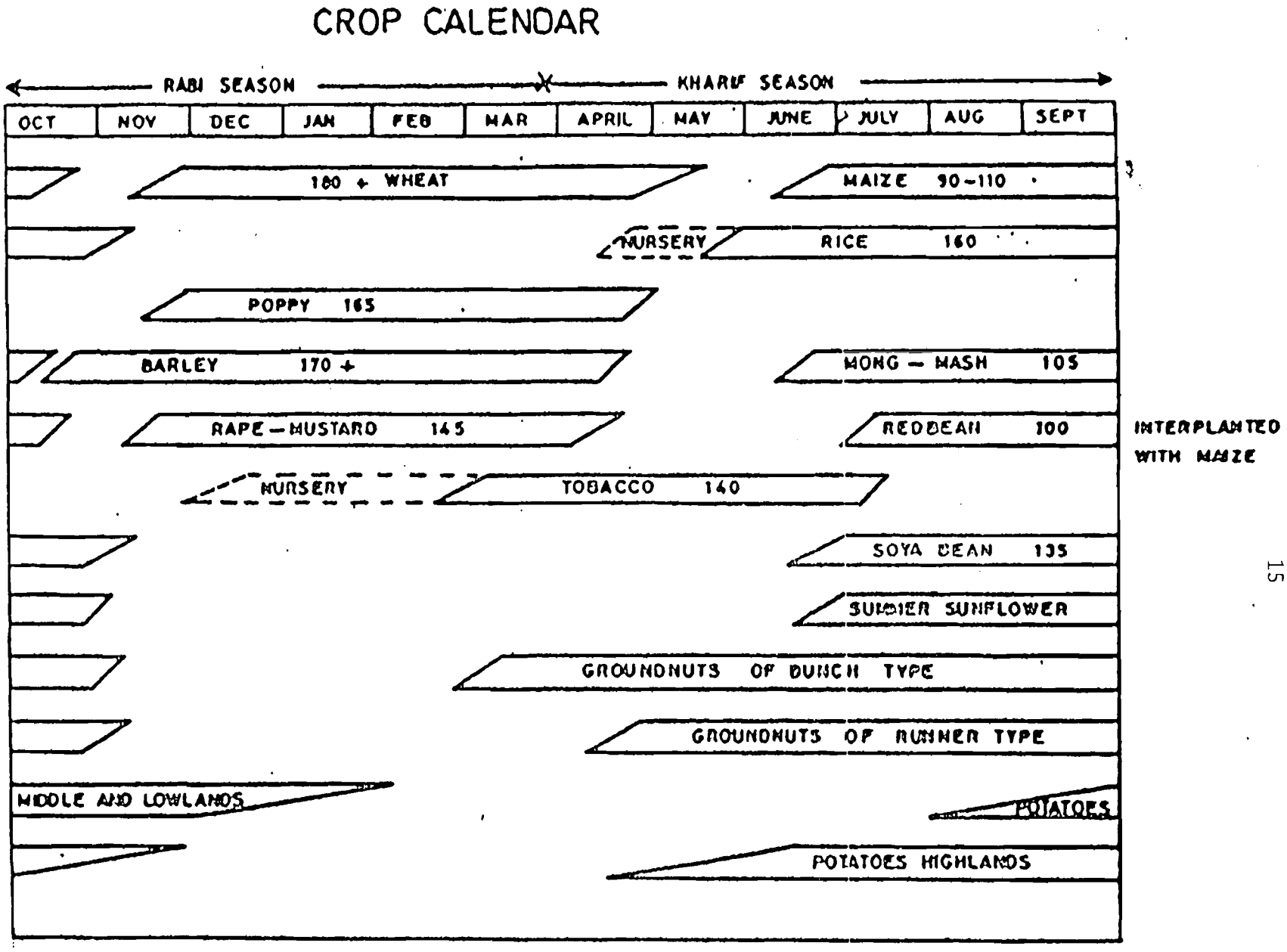

Source: Dir District Development Project. Supporting Report II. Natural Resources. 1984.

THE FIGURES IN THE CROP BARS REFER TO THE APPROXIMATE CROP DURATION

Figure 2. Crop calendar for DIR district - Pakistan.

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Visual Interpretation

The details of digital image analysis or image pattern recognition may be difficult for a lay person to understand because the fundamental ideas, concepts, and technical jargon are grounded in such fields as physics, earth sciences, mathematics, and computer and mapping sciences. However, some elucidation on visual interpretation techniques may help the reader to understand the subtitles of identifying characteristic "spectral signatures" of poppy fields in the NACP target areas.

Human interpreters employed on the NACP must know the study area or have experience in photo interpretation techniques to know what to look for at different stages in the crop calendar. If imagery is collected during the flowering season, then the "spectral signature" as manifested by the visual appearance of poppy fields can be expected to be similar throughout the scene area. If imagery is collected at other growth stages, the poppy signature will look slightly different than it did during the flowering stage, because the reflectance contribution of flowers is different from leaf material and pods. The advantage that human interpreters have over computers is their ability to use reasoning processes and subjective associations. Interpreters will key on color, texture, shape, size, pattern, and association for object identification, and these characteristic features for poppy and other crops will be variable throughout the crop calendar. The poppy appearance on the image will be dependent on the date (growth stage) and quality of imagery being interpreted or digitally processed for computer pattern recognition.

As suggested earlier, the flowering stage (late March to early April) is the optimal data acquisition period; it will offer the best opportunity for a unique poppy signature and best chance of success in identification.

Ground Truthing

The ground truth operation is important for verification of poppy mapping accuracy, but the ability to access crop locations may be limited. The field teams should attempt to document the location of any known poppy field during routine field work. The location of the fields should be plotted on a map (as best as possible) or the field location should be recorded using a Global Positioning System (GPS) device (if available). Ground truthing needs to be done in two phases. Ground observations are needed in the test phase to locate a suitable number of poppy fields to train human interpreters and computers in identifying the characteristic "signature" or appearance of the crop. Also, other crop fields such as wheat should be identified during this stage for training purposes.

The second phase of ground truth observations is necessary to support mapping accuracy verification and monitor the success of poppy elimination plans. Ideally, these poppy fields should represent a random or unbiased representative sample of the total number of suspected poppy fields that have been identified using remotely sensed techniques. The field location would be plotted on images or maps and provided to field teams for location and identification of the actual land cover that appears at the site. This procedure, however, has some difficulties. First, many of the fields randomly selected may not fall in areas that can be visited by ground personnel (for logistical, access, or safety reasons). Second, the crop or land cover identified by the ground crew may not be the same as that present when the image was taken. It is likely that the ground crew will not have the crop location maps during the same season that the crop was imaged by satellite. A considerable lag time for data acquisition, processing, and generation of map products (a few months) can be anticipated. Realizing these problems, the field teams will have to use their own discretion in locating poppy fields and concluding if the suspected site was planted in poppies when the satellite data were collected. Some alternative system may

need to be devised for working out the ground truthing procedures once the constraints and logistical matters are identified during the course of the project.

AVAILABILITY AND UTILITY OF COMMERCIAL SOURCES OF IMAGERY FOR MONITORING POPPY CULTIVATION

Aircraft imagery can be ruled out for Afghanistan because of security risks and other factors that affect operational use of aircraft sensors. Pakistani aircraft, used within Pakistan air space to collect high resolution air photos over poppy fields, would be useful for testing and training computer and human interpreters. Landsat-MSS (multispectral sensor) data does not have the required spatial resolution for poppy detection (see examples in Appendix D) but older MSS data might be considered for merging with recent TM data (after geo-referencing and resampling MSS and TM to 50 meters) to establish change-detection estimates and the location of permanent or new fields.

NASA space shuttle hand-held photography may be available for the Afghanistan-Pakistan border and in the South Helmand Province. The scale is small but the quality of the photography is good so that enlargements can be made at fairly low cost (see information in Appendix E). This photography collected between 1981 and 1989 might be investigated for its potential utility in visual interpretation of historical poppy cultivation activities. Also, KOSMOS (Soviet) imagery has been acquired for Afghanistan and Pakistan but the quality, availability, and dates of this imagery are unknown (to this author) at the time of this writing. The availability of the KOSMOS imagery could be investigated for potential application by the NACP (Appendix F). This author, however, strongly doubts that either KOSMOS or space shuttle imagery would be a suitable primary data source for the remote sensing needs of NACP.

The two most likely commercial sources of imagery are the U.S. Landsat-Thematic Mapper and the French SPOT-multispectral data. A computer search of available imagery from both sources has been conducted. Good-quality, nearly cloud-free imagery from SPOT exists in the archives for all of Afghanistan and Pakistan. The availability of Landsat-TM data is less certain for eastern Afghanistan and Pakistan because it has been necessary to order the data from the Hyderabad India receiving station. The situation with the Hyderabad station will be discussed later.

Table 3 provides a comparison of sensor characteristics and Table 4 lists relative advantages of each sensor for various project considerations. Landsat-TM may be favorable because of lower overall costs, less processing time required and superior spectral resolution. SPOT data has advantages over TM, where field size is very small in some provinces. If visual interpretation of high resolution imagery is the most successful detection technique (based on a test case) then SPOT-X or KOSMOS (if available) may be a viable data choice. It is possible that both TM and SPOT data will need to be processed, depending upon which sensors provide the optimal dates and best quality coverage (low cloud cover) for specific areas.

TABLE 3

SENSOR COMPARISON

	# Bands	Ground Resolution	Area Covered	$ Cost (1990)
Landsat MSS	4	80 x 80 m	185 x 185 km	1000
Landsat-TM	7	30 x 30 m	185 x 185 km	4000 or 2500 (1/4)
SPOT (MS) X	3	20 x 20 m	60 x 60 km	2200
Spot (PAN) P	1	10 x 10 m	60 x 60 km	2200

TABLE 4

SENSOR ADVANTAGES/DISADVANTAGES FOR VARIOUS NACP CONSIDERATIONS

PROJECT CONSIDERATIONS	SENSOR		
	TM	SPOT	KOSMOS
Special resolution	+	0	0
Spatial resolution	0	+	+
Cost 1) data acquisition 2) data processing	 + +	 - 0	 - (if digital) 0
Data availability	+ (Western and Central Afghanistan)*	+	-
(Image processing time for multiple scenes) 1) digital 2) visual	 + 0	 0 +	 0 (if available) +
Change detection	+ (with MSS & TM data)	- (too expensive for large areas)	-

\+ Indicates an advantage over other data source
0 Indicates no clear advantage of one data source over another
\- Indicates a disadvantage compared to other data sources

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* The success of the DAI and subcontractor arrangements for "letter of credit" to acquire data from the Hyderabad, India, or Islamabad, Pakistan, receiving station may negate a "minus" rating for TM data acquisition for Eastern Afghanistan and Pakistan. Moreover, recent conversations between DAI staff and EOSAT representatives indicate that the Pakistan receiving station (SUPARCO) has reached an agreement to supply data to EOSAT.

DETERMINATION OF THE MINIMUM SIZE POPPY FIELD THAT CAN BE DETECTED UNDER VARIOUS CONDITIONS

The minimum-size poppy field that can be detected is dependent upon four major factors:

- Spatial resolution of the sensor (minimum size of area in sensor field of view);
- Spectral resolution of the sensor (sensitivity of sensor to different wavelengths of reflected light);
- Spectral separability (uniqueness) of target crop from other crops; and
- Average size and shape of target fields especially in relation to 1, 2, and 3 above.

The first two factors are fixed for each sensor, with the spatial advantage going to SPOT and the spectral advantage going to Landsat-TM. The third factor depends upon synchronizing the data acquisition with the optimal crop detection period (march to mid-April in southern Afghanistan). The fourth factor may be the most limiting when the average field sizes are very small (for example, one-third of a hectare).

- One TM *pixel* covers an area of 900 square meters or .09 hectares.
- One SPOT *pixel* covers an area of 400 square meters or .04 hectares.
- For SPOT data, the assumption is being made that multispectral data will be required (20-meter resolution) for crop detection.

According to Owens and Clifton (1972), the poppy fields range from about .2-1 hectares in size. On the low end, a field size of .2 hectares is slightly more than one-half of an American football field. One-hectare fields are approximately three times the size of an American football field.

For detection of a single poppy field, a minimum of four *pixels* will need to fall within the boundaries of the field (if square) or at least two *pixels* within the smaller dimension of the field width (if rectangular or curvilinear). The assumption here is that smaller, narrower fields (2 pure *pixels* in width) will be difficult if not impossible to identify positively because the boundary *pixels* might cause mixed reflectance when they do not fall completely within the field. The spectral signature of the target crop must be fairly remarkable (as poppy would be during flowering and perhaps at full leaf maturity) to be separable from other crops or cover types in these small fields. The four-*pixel* requirement suggests that the field size would need to be at least .36 hectares and .16 hectares respectively, to be detectable by Landsat-TM and SPOT. This is an educated guess and not an absolute limit. If we assume that the average field size in Afghanistan is approximately .5 hectares (if the range is .2-1 hectare), then most of the poppy fields should be large enough to be detectable with Landsat-TM or the French SPOT satellite under optimal conditions. As a general rule, the accuracy of detection will decrease as the field size decreases and as the amount of intercropping increases when fields are near the minimum size. Previous work in Thailand and India suggest that visual interpretation may be more successful than digital classification when small fields and variability in growth stages or intercropping are encountered.

PROCUREMENT OF LANDSAT-TM DATA FROM THE HYDERABAD SATELLITE RECEIVING STATION

Representatives of EOSAT Corporation (distributor of Landsat data) claim that any Landsat imagery available from the Hyderabad station in India can be acquired by EOSAT-U.S. The turnaround time from order to receipt of data is uncertain and EOSAT charges a 30-percent surcharge to handle the order. Good quality, nearly cloud-free TM imagery is available for most of western and central Afghanistan. However, at the time of this writing, EOSAT was not able to provide a computer listing of Landsat-TM data for the blackout area (outside the Riyadh, Saudi Arabia station range) in eastern Afghanistan and Pakistan (Figure 3). Apparently, Earthsat Corporation (a DAI subcontractor) has purchased Landsat data directly from Hyderabad with only a six-week turnaround. This would be an acceptable turnaround if it could be repeated in future acquisitions.

According to EOSAT, new negotiations are underway to establish a Landsat sales agreement with the Pakistan receiving station.[1] EOSAT anticipates that the service to the United States and international users will be more reliable (than Hyderabad is now) through the Pakistan station in the near future. It is uncertain how recent political events in Pakistan will affect the progress EOSAT has made concerning the sales agreement.[2] However, Earthsat Corporation may have circumvented the TM data acquisition problem through a "letter-of-credit" and arrangements for a hired agent to facilitate data acquisition with the Hyderabad station.[3] Earthsat is also checking into similar arrangements with the Islamabad receiving station in Pakistan.[4]

Landsat-TM and SPOT Data Cost Estimate for Coverage of Afghanistan and Pakistan

Data Acquisition Cost

Data availability from commercial sources was discussed previously. Costs of data procurement can be made with a few assumptions in mind. For practical reasons it is quite likely that data will be acquired for only a portion of the land area where poppy is known to be cultivated or cultivation is possible as a result of environmental suitability. It is probable that multidate coverage will be desirable for some high-priority poppy growing areas. Data acquisition costs for TM data are approximately $4,000 per scene. SPOT data costs are $2,200 per scene for approximately one-ninth of the area coverage of a TM scene (see Table 3 and Figure 4). The cost of Landsat and the French SPOT-X data will be estimated for one-time complete coverage. Tables 5 and 6 provide the total number of scenes and approximate cost that would be required to provide complete one-time coverage of Afghanistan and Pakistan from Landsat-TM and SPOT-X respectively. The estimated coverage and cost for the three poppy growing regions of Afghanistan are also provided.

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[1] Personal communication, Tony Shupin - NE U.S. sales manager, 8/7/90.

[2] Recent events suggest EOSAT procurement from the Pakistan receiving station will be possible.

[3] Personal communication, Kevin Howald - Earthsat, 8/27/90.

[4] Personal communication, Roger Mitchell, Earthsat Corporation, 9/14/90.

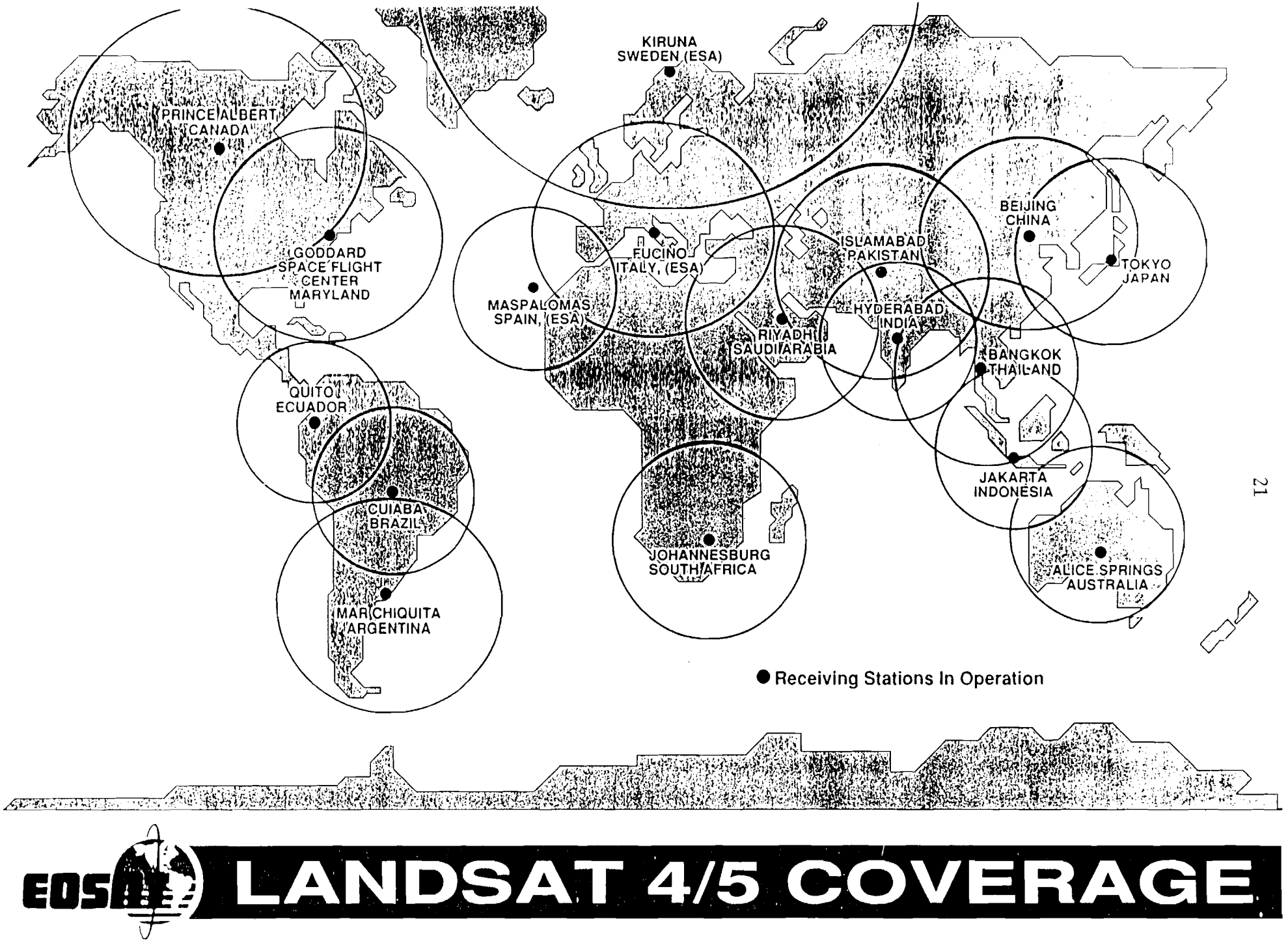

Figure 3. Landsat 4/5 receiving station coverage (source: EOSAT Corp.).

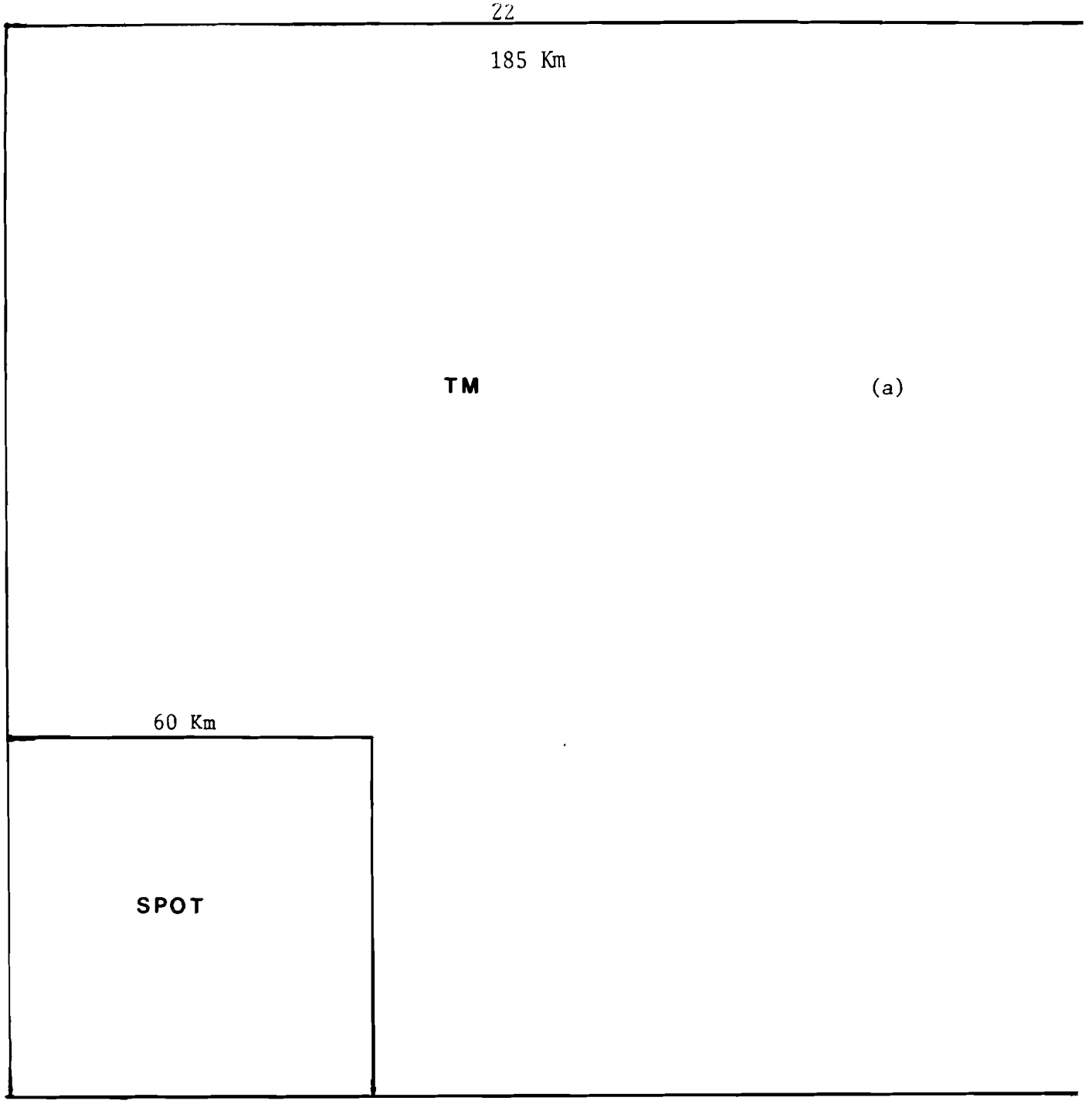

Figure 4.

a. Comparative area coverage of Landsat and SPOT satellite scenes at 1:1,000,000 scale.

b. Comparative Landsat MSS, TM and SPOT-X pixel size plotted at 1:5000 scale.

Table 5. Landsat TM Data Acquisition Costs

Country	Region	Approximate No. of Scenes	$ Cost/ Scene	Total Cost $
Afghanistan	All	36	4000	144,000
	South Provinces (Kandahar, Helmand Uruzgan)	11	4000	44,000
	Northeast Provinces (Badakshan, Takhar, Kunduz, Baghlan)	9	4000	36,000
	East Provinces (Nangahar, Kunar, Laghman, Logar and Paktia)	8	4000	32,000
Pakistan	All	48	4000	192,000

Table 6. SPOT - X Data Acquisition Costs

Country	Area Sq. Km	Region	Approximate No. of Scenes	Cost/ Scene	Total Cost*
Afghanistan	647,497		180	$2200	$396,000
	137,900 (Approx)	South Provinces	39	2200	85,000*
	69,965	Northeast Provinces	20	2200	44,000*
	46,885	East Provinces	14	2200	30,800*
Pakistan	803,944		224	2200	$492,800

In some cases, the scene coverage of one province overlaps another and the scenes required to cover Afghanistan would overlap part of Pakistan along the border (see Appendix G). If TM data for all three provinces were acquired, the total number of scenes would be reduced by two scenes. Also one-quarter scenes can be ordered if the whole scene is not needed, however, the price is only one-half off the entire scene (or $2,000).

SPOT data acquisition costs are not as simple to estimate (compared to TM) because SPOT Corporation does not provide index maps of orbital tracks with scene centers to allow exact coverage to be easily determined. For an approximate estimate of cost, the total area of the countries or provinces can be divided by the data cost per SPOT scene coverage area.

The estimates in Table 6 are low because they assume that the total number of spot scenes fall perfectly within the boundaries of the country with no overlap (which is not the case). Considering that some scenes will overlap others and that extra scenes would be needed along border areas to ensure complete coverage, the total cost figures listed for SPOT data should include an additional 20 percent. The revised data acquisition costs for the three NACP target areas would be $102,960, $52,800, and $36,960 for the south, northeast, and east provinces, respectively. The data acquisition costs could be reduced substantially if the geographic zones in which poppy is grown were well known, thus limiting data acquisition to a smaller region (Figure 4).

Data Processing Cost

Data processing costs are more difficult to estimate compared to data acquisition costs. It is uncertain how much of the work effort would be divided between junior- and senior-level personnel, and salary rates for personnel involved could be highly variable; therefore, labor hours will be estimated rather than dollar amounts (Table 7). Some factors that might influence the cost of processing the satellite data from beginning to end (output products) are listed below.

1) Total area to be processed in each computer run (for example, multiple scenes merged or each scene processed individually).

2) Type of hardware and software and processing speed and efficiency.

3) Experience level of image analysts.

4) Level of detail or number of processing steps required to produce final output.

5) Type and number of output products required.

6) Amount and nature of outside services required to perform special processing tasks.

7) Inclusion or exclusion of GIS components (map digitizing, and extra processing for GIS data layers).

8) Choice of visual or digital processing methods.

9) Choice of single date or multidate processing.

Table 7. Satellite Date Processing and Analysis Costs

		Person Month/Area	
1.	**Digital Data**		
	(a) pre-processing	.50	
	(b) classification	.20	
	(c) spectral/spatial statistics	.40	
	(d) grouping of classes	.10	
			1.2
1a.	**Analog Data**		
	(a) interpretation	1.00	
	(b) comparison with the ground	.50	
	(c) revision	.20	
	(d) digitization of land cover units	.30	
			2.0
2.	**GIS Functions**		
	(a) digitizing maps	2.00	
	(b) distance from roads, settlements, etc.	.20	
	(c) combination of layers	.50	
	(d) spatial analysis	.50	
			3.2
3.	**Multitemporal Analysis (Digital)**		
	(a) data merging/pre-processing	.30	
	(b) comparison of dates/image differencing	.20	
	(c) change classification/crop monitoring	.30	
			.80
4.	**Accuracy Verification**		
	(a) sample selection	.20	
	(b) photo interpretation	.50	
	(c) comparison of image/ground data	.30	
	(d) calculation of % correct/error matrix	.10	
	(e) analysis of results	.20	
			1.3
5.	**Output**		
	(a) crop/land cover map	.20	
	(b) potential zones of crop occurrence	.20	
	(c) tables and graphic data	.50	
	(d) crop mapping on visual image background	.20	
	(e) change detection	.20	
			1.3

Test/Evaluation Phase	Task 1-5	7.8 Person Month
	Task 1a-5	8.6 Person Month
Operational Phase	Task 1,2,5	5.7 Person Month
	Task 1a,2,5	6.5 Person Month

10) Choice of sensor data to process (such as TM or SPOT).

11) Total number of scenes and size of area to be processed.

Each project area could be completed by two people (one digitizing/GIS and one remote sensing) in 3-4 months (after receipt of satellite data and maps). However, the time schedule estimates (Table 7) are conservative. It is likely that a qualified contractor could streamline the data processing to produce output products in two months or less. A field team (2-3 people) would be needed in the test/evaluation phase. It is recommended that a test/evaluation phase precede an operational phase of crop detection and monitoring.

The estimates of data processing work effort is on a per-scene or per-area basis. Portions of adjacent satellite scenes can be mosaicked and processed as one large data set. This would require that each satellite scene be at or near the same date, and that atmospheric/radiometric corrections are performed prior to digital classification. Problems with geometric correction can be anticipated for regions with very mountainous terrain.

THE COMPARATIVE ADVANTAGES OF GIS AND THE UTILITY OF INTEGRATING A POPPY CROP GIS WITH THE AGRICULTURE SUPPORT SECTOR GIS

The application of satellite remote sensing may be the only feasible approach to monitor poppy production in Afghanistan because other approaches (aircraft or extensive ground surveys) are not viable alternatives for reasons discussed earlier. Remote sensing and geographic information systems are complementary technologies that can become valuable tools to facilitate crop inventories, and support information management and decision making in the agriculture sector.

Previous work in illicit crop monitoring projects suggest that GIS can offer the following advantages:

- Narrows the search area;
- Provides corollary data that may help in crop detection by providing direct clues to crop location; and
- Facilitates long-term crop monitoring, predictive yield modeling, and map updates.

Development and maintenance of a GIS is expensive and might be justified if the implementation of GIS results in improved problem solving and decision making. A common method employed to justify new equipment or technologies is cost-benefit analysis. Cost-benefit analysis applied to GIS implementation is a difficult and perhaps inexact evaluation method because many of the benefits of GIS may be intangible. For example, how does one quantify the benefit of improved decision making? Costs of GIS installation, maintenance, labor, and so forth, can be easily determined. Benefits fall primarily into three categories: improved efficiency, improved defectiveness, and intangible benefits.

Improvements in efficiency might result through the amount of time and labor saved in doing the job. The value of improved decision making through increased analytic capability or access to better

information could be a measure of effectiveness. Intangible benefits are highly qualitative, such as discovering new or unknown information or uses of the information; being able to cope with unexpected events that can be evaluated by GIS; or finding utility in the GIS beyond what was required (Prisley and Mead, 1986).

In the case of the NACP project, the development and implementation of GIS should probably not be considered in isolation from the development of GIS for the Afghanistan Agricultural Sector Support Project. There will likely be some attributes of ASSP's GIS that could be used in developing a GIS for poppy crop monitoring. When satellite imagery is processed and land use (types of agricultural) maps are derived for the ASSP, it should be easy to incorporate the necessary image analysis steps that would result in products useful for poppy monitoring. This dual purpose processing would only be necessary for satellite scenes that encompass the known or potential poppy growing regions, assuming they are a subset of the scenes needed for the ASSP. Even though ASSP activities will not take place in known poppy production areas, a duplication of effort and expense in building a GIS for each project is undesirable.

The development and maintenance of any GIS requires experienced and trained personnel. Institutional capabilities of the users will determine whether the effective utility of the GIS is possible. Many foreign institutions may not be in a favorable situation to develop GIS capability within their own organization. Therefore, the long-term goals and information needs of any project must consider whether the GIS capabilities will eventually reside within the host organization or whether contracting out the GIS services is acceptable over the short or long term. These are institutional decisions that this author cannot address, but they are important criteria for the project planners to decide in the formulative stage.

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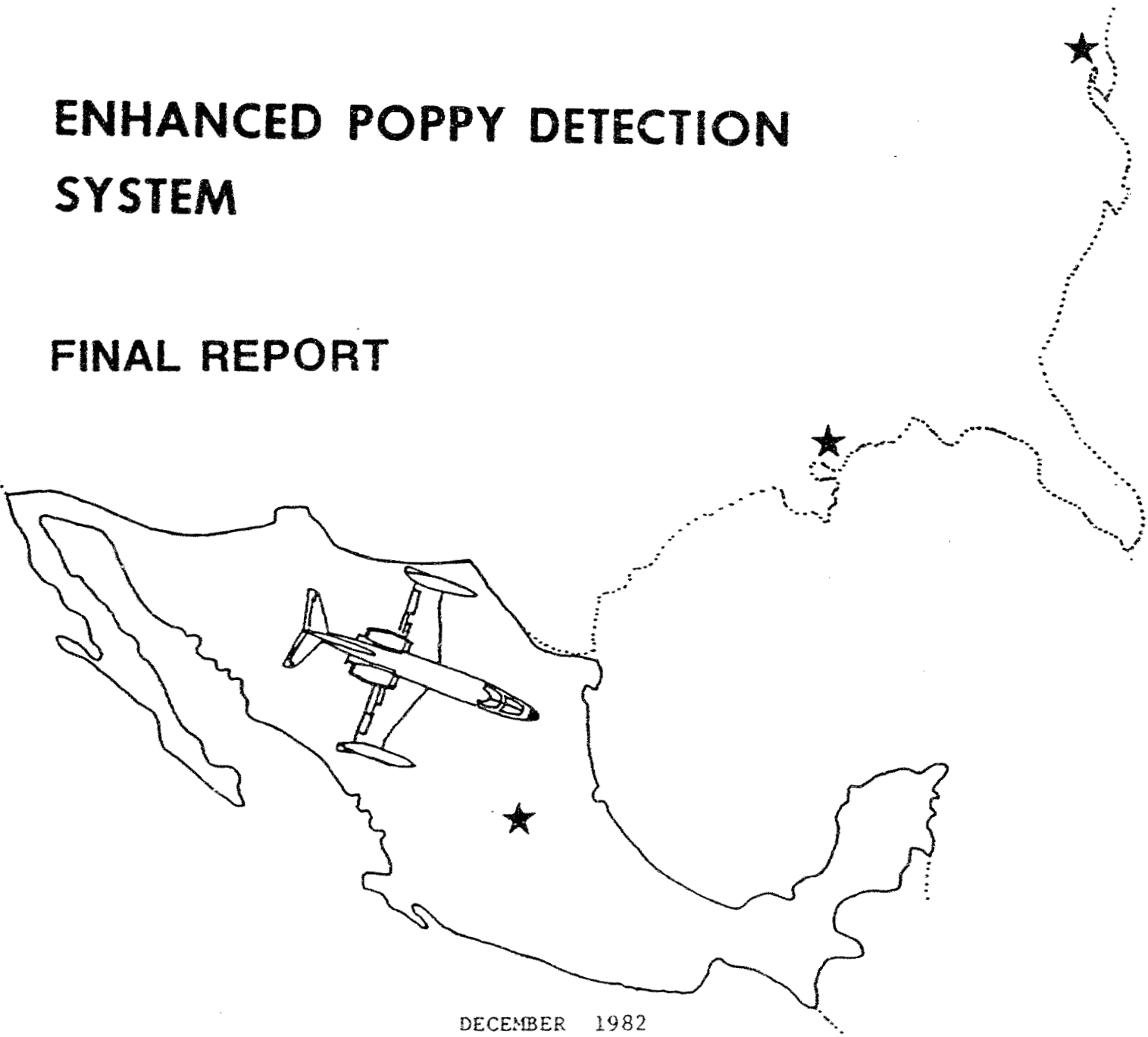
Appendix A. NASA-ERL poppy detection system specifications.

National Aeronautics and Space Administration

EARTH RESOURCES LABORATORY

ENHANCED POPPY DETECTION SYSTEM

FINAL REPORT



DECEMBER 1982

NATIONAL SPACE TECHNOLOGY LABORATORIES

System	Bands	SPECTRAL COVERAGE In Micrometers	PROBABILITY Large/Sparse	Small/Dense
APDS	1-2	0.54-0.59/0.62-0.67	Poor	
APDS	1-3	0.54-0.59/0.74-0.80	Good	
APDS	1-4	0.54-0.59/0.84-0.94	Good	
APDS	2-3	0.62-0.67/0.74-0.80	Good	
APDS	2-4	0.62-0.67/0.84-0.94	Very Good	
APDS	3-4	0.74-0.80/0.84-0.94	Good	
TMS	1-2	0.45-0.52/0.53-0.60	Poor	Poor
TMS	1-3	0.45-0.52/0.63-0.69	Poor	Poor
TMS	1-4	0.45-0.52/0.77-0.90	Good	Poor
TMS	1-5	0.45-0.52/1.53-1.73	Poor	Poor
TMS	1-7	0.45-0.52/10.4-12.3	Poor	Poor
TMS	2-3	0.53-0.60/0.63-0.69	Poor	Poor
TMS	2-4	0.53-0.60/0.77-0.90	Very Good	Good
TMS	2-5	0.53-0.60/1.53-1.73	Good	Good
TMS	2-7	0.53-0.60/10.4-12.3	Poor	Poor
TMS	3-4	0.63-0.69/0.77-0.90	Very Good	Very Good
TMS	3-5	0.63-0.69/1.53-1.73	Good	Good
TMS	3-7	0.63-0.69/10.4-12.3	Poor	Poor
TMS	4-5	0.77-0.90/1.53-1.73	Excellent	Excellent
TMS	4-7	0.77-0.90/10.4-12.3	Good	Good
TMS	5-7	1.53-1.73/10.4-12.3	Good	Good

Table 3.

Relative Probability of Detecting Opium Poppy Fields
With Spectral Band Combinations

1982

TEST PLAN

MEXICAN POPPY DETECTION SYSTEM

FOREWORD: SYSTEM WAS DESIGNED AND OPTIMIZED TO DETECT POPPY FIELDS OF 1/4 ACRE IN SIZE WITH 60% GROUND COVER IN THE ENVIRONS OF SINALOA, MEXICO.

PURPOSE: TO VALIDATE THAT THE SYSTEM MEETS THE DESIGN CRITERIA (SEE ATTACHMENT

TEST AREA: SINALOA, MEXICO

TEST FIELDS: NUMBER - NOT LESS THAN 10 IN VARIOUS TYPES OF TERRAIN (STATISTICAL VALIDITY REQUIRE A GREATER NUMBER OF FIELDS. HOWEVER, THIS IS NOT CONSIDERED POSSIBLE AT THIS TIME).

MATURITY - 60% GROUND COVER AT TIME OF TEST (FIELDS WOULD HAVE TO BE SAVED FROM ERADICATION FOR TO 3 MONTHS).

SIZE - 1/4 ACRE OR LARGER

ACCESSIBILITY - ACCESSIBLE BY HELICOPTER FOR GROUND TRUTH BY U.S. AND MEXICAN TEAMS.

GENERAL - FIELDS MUST BE IN SUNLIGHT AND NOT INTERPLANTED.

TIMING: GREATEST POSSIBILITY FOR MATURE POPPIES IS LATE MARCH OR EARLY APRIL (FIELDS WOULD NEED TO BE IDENTIFIED IN JANUARY AND ALLOWED TO GROW TO NEAR MATURITY)

PARTICIPANTS: MEXICAN SYSTEM TEAM
MEMBERS OF URVE
MEMBERS OF NASA TEAM
DOS REPRESENTATIVES
GOM REPRESENTATIVES

PERFORMANCE: THE TEST SHALL BE SUCCESSFUL IF THE SYSTEM MEETS THE MANDATORY REQUIREMENTS IN THE ATTACHED SYSTEM SPECIFICATIONS

SYSTEM SPECIFICATIONS

PARAMETER	MANDATORY	DESIRED
1. FREQUENCY OF COVERAGE	ON DEMAND	ON DEMAND
2. ACCURACY OF ESTIMATES		
TOTAL ACREAGE/PRODUCTION	±20%	±10%
LOCATION OF FIELDS	1640 FEET	656 FEET
SIZE OF SINGLE FIELD	±15%	±5%
3. MINIMUM DETECTABLE FIELD SIZE	0.247 ACRE	0.124 ACRE
4. PLANTING DENSITY	60%	30%
5. FALSE ALARMS*		
FALSE POSITIVE	10%	5%
FALSE NEGATIVE	10%	5%
6. SCALE OF DATA PRESENTATION	1:250,000	1:100,000
7. MAXIMUM RESPONSE TIME, TOTAL	6 DAYS	2 DAYS
SPECIAL TARGETING REQUEST	48 HOURS	24 HOURS
DATA IN HANDS OF USER	96 HOURS	24 HOURS
8. SYSTEM AREA COVERAGE/SORTIE	463 SQ. MILES	965 SQ. MILES
9. SECURITY CLASSIFICATION OF OUTPUT	UNCLASSIFIED	UNCLASSIFIED

* PERCENTAGE OF FIELDS ACTUALLY PRESENT.

TABLE 1: OPERATIONAL CAPABILITY REQUIREMENTS FOR AN OPIUM POPPY DETECTION SYSTEM, AS DETERMINED BY THE AD-HOC COMMITTEE

Appendix B. Thailand poppy GIS data base flowchart (source: Galtier et al. 1989).

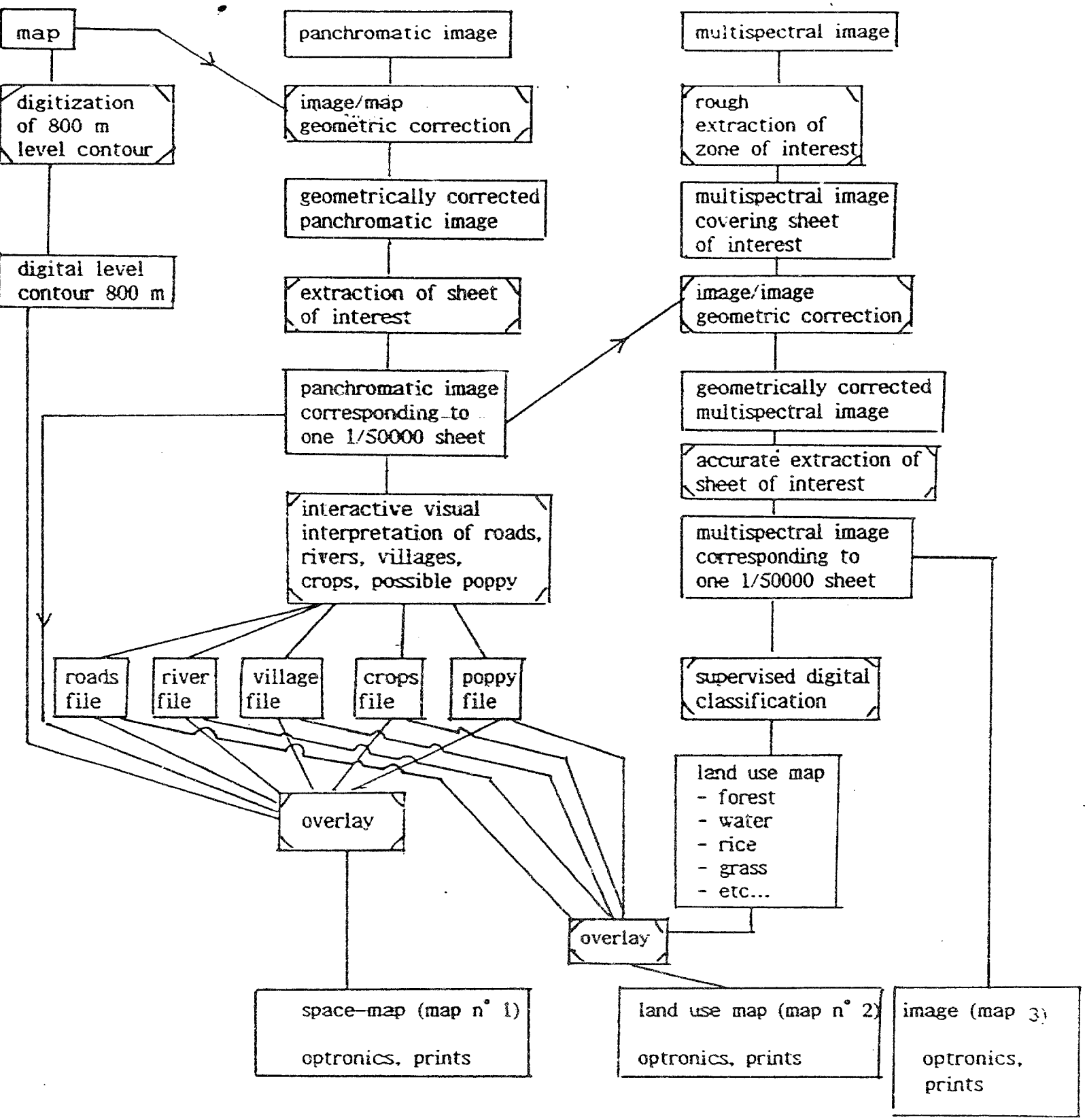


Figure 4 : Chart of image processing at AIT

: processing

: product

Appendix C. UN Expert Group meeting announcement on remote sensing of illicit narcotic crops.

UNITED NATIONS
Information Service

NATIONS UNIES
Service d'information

VEREINTE NATIONEN
Informationsdienst

For information - not an official document Zur Information - kein offizielles Dokument Pour information - document sans caractère officiel

UNIS/NAR/342
24 October 1989

EXPERT MEETING ON DETECTION OF NARCOTIC CROPS BY SATELLITE OPENS AT VIENNA

VIENNA, 24 October (UN Information Service) -- Detection of illicit narcotic crops by satellite or aerial photography is the focus of a week-long expert group meeting which opened yesterday at the Vienna International Centre.

Organized and convened by the Division of Narcotic Drugs with financial support from the United Nations Fund for Drug Abuse Control, the Expert Group Meeting on the Detection of Illicit Narcotic Crop Cultivation by Satellite aims at determining in an objective and scientific manner the feasibility and cost of identifying the coca bush, opium poppy and cannabis plant by satellite or other remote sensing technology images.

The meeting will also address the question of assessing environmental damage caused by illicit narcotic crop cultivation and estimate the cost of analysing and interpreting the information so obtained.

Welcoming the experts, Francisco Ramos-Galino, Director of the Division of Narcotic Drugs, said that before making concrete plans for interdicting illicit drug trafficking, particularly with respect to eradication of illicit narcotic plants, it was essential to have full knowledge of the extent of illicit narcotic crops and the places where they are grown.

The meeting is organized pursuant to Economic and Social Council resolution 1988/9, in which the Council requested the Division of Narcotic Drugs, in collaboration with development assistance bodies and other agencies with relevant experience to support survey and narcotic crop monitoring efforts using such technologies as high-resolution satellite imagery and aerial photography. The financing of the meeting has been made partly from the regular budget of the United Nations and partly through a special earmarked contribution received from the United States of America through the United Nations Fund for Drug Abuse Control.

Attending the meeting, which is scheduled to conclude on 27 October 1989, are experts from Bolivia, Brazil, Canada, France, India, Mexico, Pakistan, Thailand, Union of Soviet Socialist Republics, United Kingdom, United States of America as well as the Food and Agriculture Organization.

Appendix D. Satellite image spectral and spatial resolution comparisons (source: USGS).

1:50,000-SCALE (5.00 pixels/mm)

SPOT Multispectral (20 meter) merged with SPOT Panchromatic (10 meter) ground resolution

Bands 3, 2, 1, and Pan

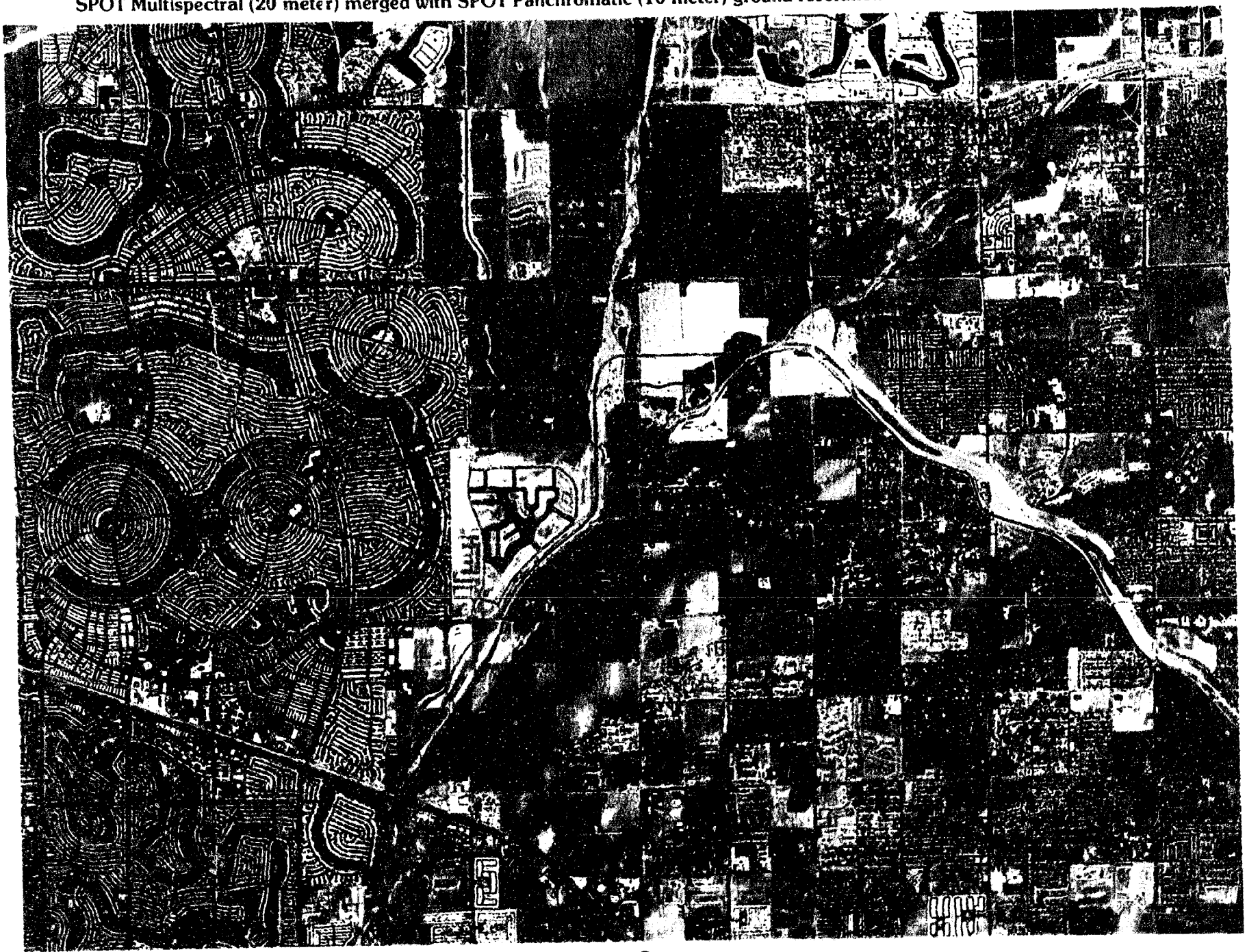


Image © 1987 CNES

Sun City

1:50,000-SCALE (5.00 pixels/mm)

Landsat TM (30 meter) merged with SPOT Panchromatic (10 meter) ground resolution

Bands 4, 3, 1, and Pan

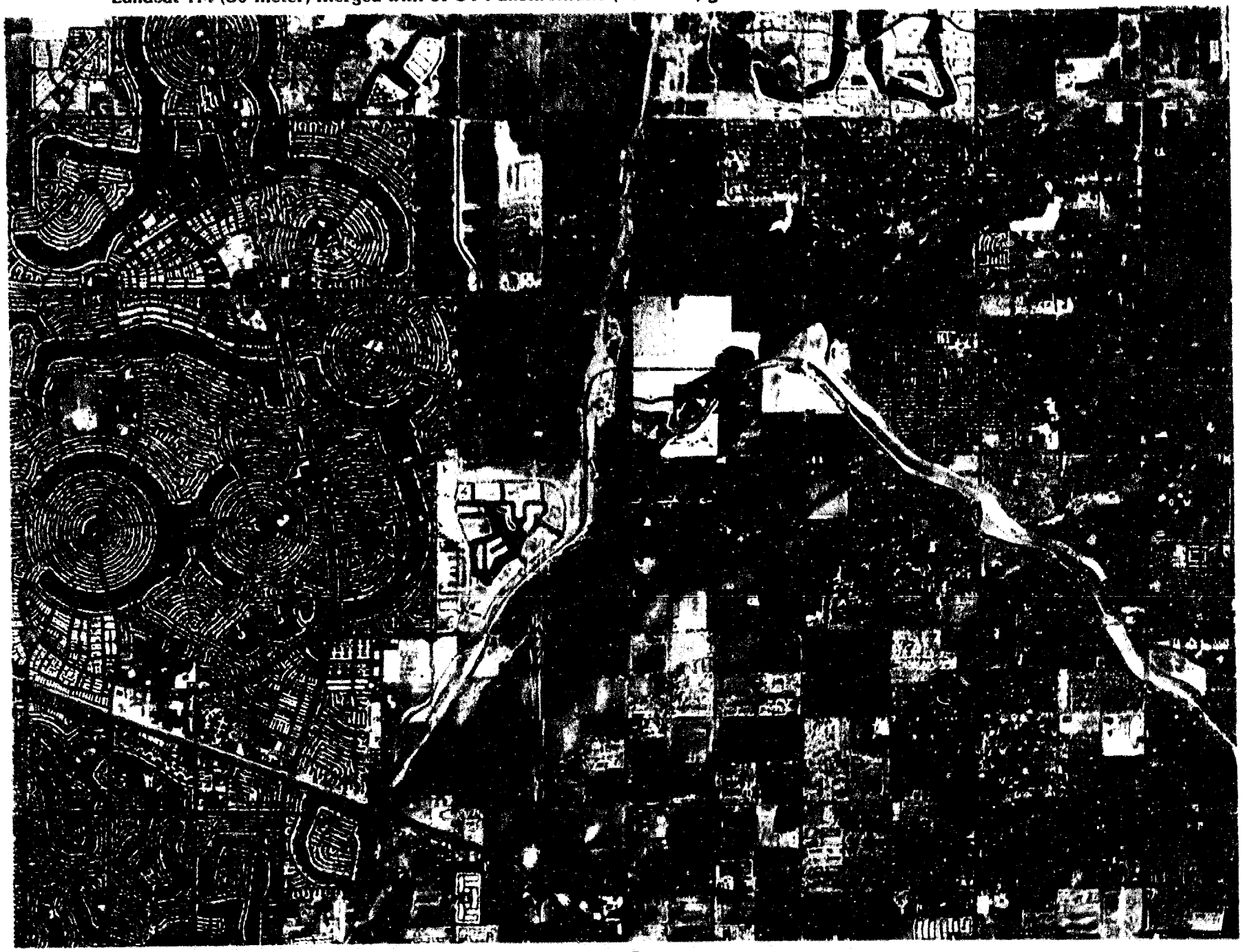


Image c 1987 CNES

Sun City

Landsat Multispectral Scanner (MSS) 75 meter ground resolution Bands 4, 2, and 1

Sun City and Northwest Phoenix

1:100,000-SCALE (3.33 pixels/mm)

Landsat Thematic Mapper (TM) 30 meter ground resolution Bands 4, 3, and 1

Sun City and Northwest Phoenix

Appendix E. 1. Space shuttle photography acquisition information.

E. 2. Large format camera photography acquisition - Chicago aerial survey.

SPACE SHUTTLE HAND-HELD EARTH OBSERVATIONS PHOTOGRAPHY COMPOSITE COVERAGE MAP

STS-1 THROUGH 61-C

APRIL 12, 1981 THROUGH JANUARY 18, 1986

CAMERAS

Linhof Aero Technika 45 and Hasselblad EL/M cameras were used to obtain hand-held Earth Observations photographs on the first twenty-four shuttle missions, STS-1 through STS 61-C. These missions began on April 12, 1981 and ended on January 18, 1986. Most of the film used during the missions was Kodak Ektachrome, although a few rolls of Aerochrome Infrared and panchromatic black and white film were tested for effectiveness. The Linhof camera had interchangeable 90mm and 250mm lenses. The Hasselblad cameras had interchangeable 80mm and 250mm lenses on the first flight, STS-1. All later flights carried interchangeable 50mm, 100mm, and 250mm lenses.

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COMPOSITE COVERAGE MAP DESCRIPTION

The Composite Coverage Map shows the locations (dots) of approximately 32,000 hand-held Earth Observations photographs obtained during the first twenty-four missions. Most of the positions represent photographic center points which have been located on a map. When a photograph could not be located, it is represented by the nadir position of the Orbiter at the time the photograph was exposed.

MAP FUNCTION

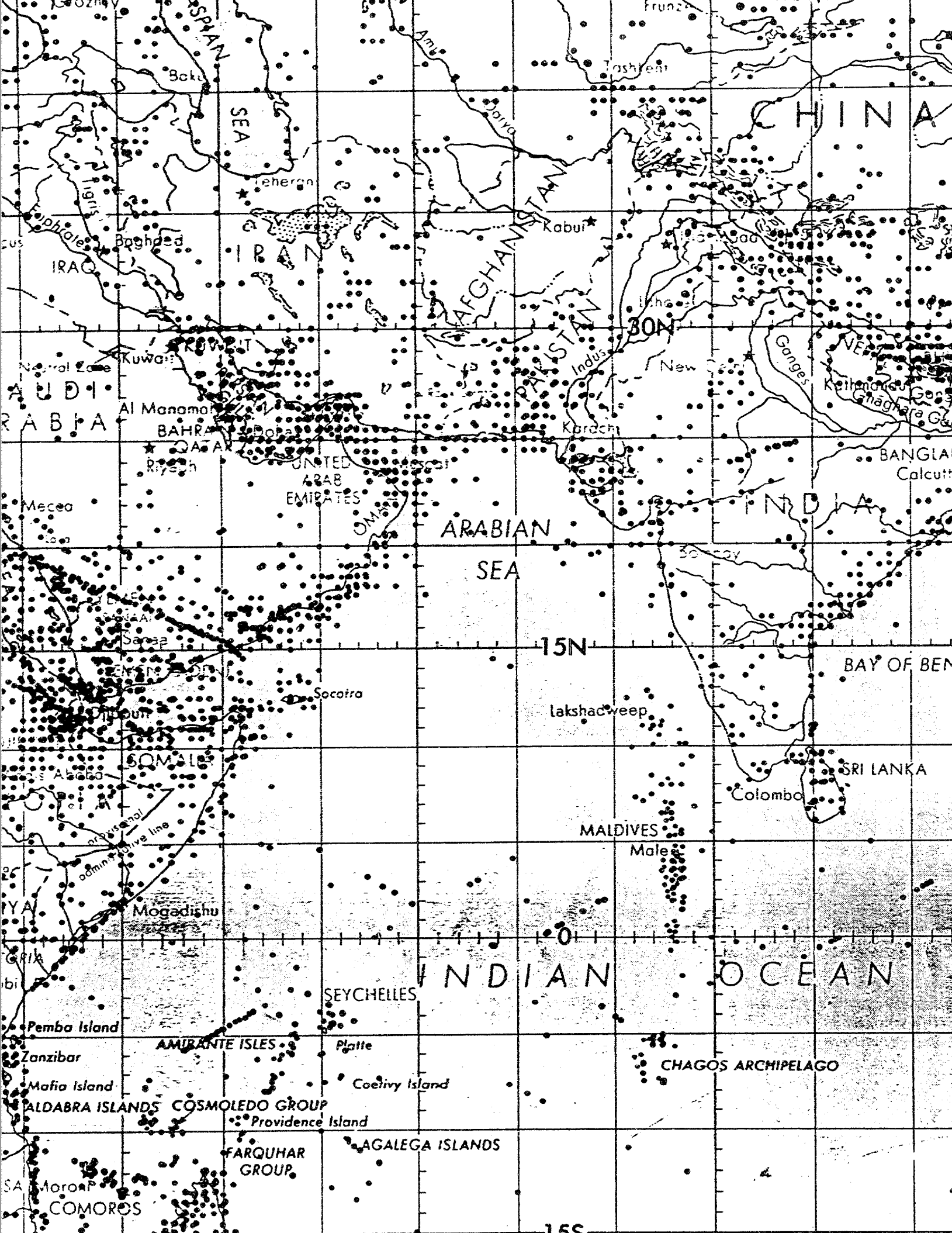
The purpose of this composite map is to show the density and distribution of hand-held photographic coverage of the world during Missions STS-1 through 61-C. It is designed to serve as a general guide to available photography and as an aid in planning hand-held Earth Observations photographic coverage for future Space Shuttle missions. However, in order to identify and select photography that may be useful for specific applications, it is necessary to search individual mission maps and catalogs for roll and frame numbers.

PHOTOGRAPH SOURCES

Earth viewing Shuttle photography may be obtained from the following sources:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
Telephone: (605) 594-6151

Technology Applications Center
University of New Mexico


CHINA
Baku
Tashkent
Tehran
Kabul
IRAN
IRAQ
Baghdad
AFGHANISTAN
PAKISTAN
Indus
Ganges
Kathmandu
Kuwait
KUWAIT
Al Manamah
BAHRAIN
Doha
QATAR
Riyadh
UNITED ARAB EMIRATES
Karachi
New Delhi
INDIA
BANGLADESH
Calcutta
Mecca
ARABIAN SEA
Sanaa
Socotra
Djibouti
Lakshadweep
SOMALIA
Colombo
SRI LANKA
MALDIVES
Male
Mogadishu
INDIAN OCEAN
SEYCHELLES
Pemba Island
Zanzibar
AMIRANTE ISLES
Platte
CHAGOS ARCHIPELAGO
Mafia Island
Coetivy Island
ALDABRA ISLANDS
COSMOLEDO GROUP
Providence Island
AGALEGA ISLANDS
FARQUHAR GROUP
Moroni
COMOROS
30N
15N
0
15S

Background

Astronauts have used hand-held cameras to photograph the Earth for nearly 25 years, beginning with the Mercury missions in the early 1960's. Since 1981, Space Shuttle astronauts have taken more than 37,000 photographs with the Hasselblad Model 500 EL/M and the Aero Linhof Technika 45 hand-held cameras. About 85 percent of these photographs are Earth-looking views. The rest show satellite deployments, extravehicular activities, and astronaut activities in the cabin.

Astronauts are trained in scientific observation of geological, oceanographic, environmental, and meteorological phenomena. They are also instructed in the use of photographic techniques and equipment. Training helps the astronauts make informed decisions on which areas and phenomena to photograph. Specific areas of scientific interest are selected before each flight by a group of scientists. The astronauts receive intensive training and in-flight aids to help them locate these sites.

Photographic Characteristics

Most of the photographs are in natural color, although a limited amount of black-and-white film has been used with polarizing filters. Beginning in 1983, a small amount of color infrared film was tested on some missions.

Three lenses (50 mm, 100 mm, and 250 mm) on the Hasselblad cameras and two lenses (90 mm and 250 mm) on the Aero Linhof camera offer a wide variety of both areal coverage and spatial resolution. The Shuttle flies at different altitudes; for example, on the first 24 missions, the altitude range was between 204 and 555 km, (110 and 300 nautical miles), which adds to this variation. Table 1 offers a guideline to the areal coverage provided by the photographs.

Table 1.- Approximate distance across a vertical photograph taken from an altitude of 296 kilometers (160 nautical miles)

Camera	Lens	Distance	
		Kilometers	Nautical miles
Hasselblad	50 mm	325	175
	100 mm	165	90
	250 mm	65	35
Aero Linhof	90 mm	310 × 395	170 × 215
	250 mm	110 × 145	60 × 75

A rule of thumb is that the 100-mm lens offers spatial resolution similar to that of the Landsat multispectral scanner (approximately 80 m) and the 250-mm lens has resolution similar to that of the Landsat thematic mapper (approximately 30 m).

For most Shuttle missions, the orbital tracks cover the tropical and temperate regions of the Earth between 28° N. and 28° S. latitude. Nine Space Transportation System (STS) missions have flown at higher latitudes, with the orbits of STS Missions 9, 41-G, 51-B, and 61-A extending to 57° N. and 57° S. latitude. Repeat coverage of an area is obtained by acquiring photography on several missions and/or by taking photographs from different viewing angles during a single mission.

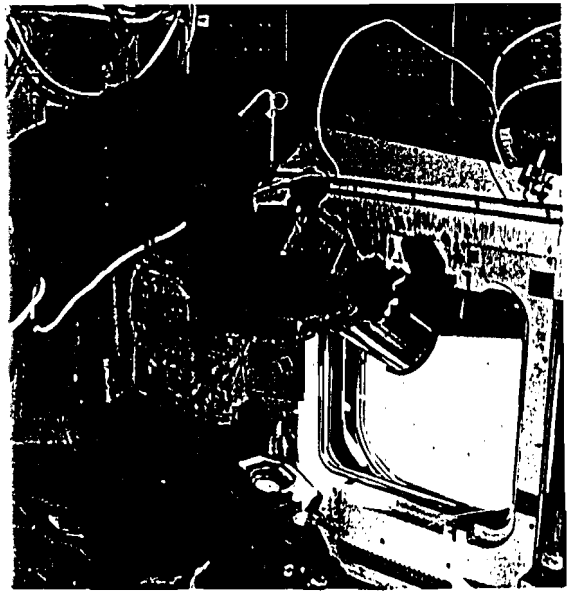
As a result of the Earth's rotation and the Shuttle's orbit duration (approximately 90 minutes), an area may be photographed at different Sun angles during a single mission.

Stereoscopic coverage is available for a number of areas.

Uses for the Photography

The Shuttle hand-held photography fills a niche between the coverage provided by aerial photography and that of unmanned satellite scanners and complements these two familiar formats with additional information. The ability of the trained astronaut to rapidly identify and photograph important phenomena on the Earth makes the Shuttle photographs unique. Near-real-time information exchange with the crew facilitates the recording of current events of environmental, geological, oceanographic, and meteorological importance.

Photographing at various Sun angles highlights different geologic features and takes advantage of sun glint to show intricate ocean structures and land/water interfaces. Critical environmental monitoring sites are photographed repeatedly over time; some have photographic records dating back to the Gemini and Skylab missions. Earth-limb pictures taken at sunrise and sunset document the changes in the Earth's atmospheric layering. Volcanic activity is monitored in cooperation with the Scientific Event Alert Network of the Smithsonian Institution. Meteorological phenomena are monitored and photographed during Space Shuttle missions. Documentation of hurricanes, thunderstorms, squall lines, island cloud wakes, and the jet stream, complements meteorological satellite data by offering better resolution and stereoscopic coverage of such phenomena. The photographs can be used in geologic mapping and in updating existing maps.



STS 51-B Commander Bob Overmyer photographing the earth. (51B-05-000)

Obtaining Information on Space Shuttle Hand-Held Photography

Each frame of the hand-held Shuttle photography has a set of descriptors to help the user understand the photographic content. This information is available in a set of catalogs or through an automated data base search.

- **Catalogs** — Catalogs of the photography for each Space Shuttle mission can be obtained by contacting the Earth Resources Observations System (EROS) Data Center.
- **Data Base** — A computerized data base containing more than 15 descriptors for each frame of Shuttle Earth-looking photography has been compiled. A data base query can be made through the EROS Data Center.
- **Viewing Centers** — The photographs can be viewed on microfilm at National Cartographic Information Centers; the Technology Application Center, University of New Mexico; the Lunar Planetary Institute, Houston, Texas, and the Library of Congress, Washington, D.C.
- **Video Disk** — The Earth-viewing photography from the first 24 STS missions is available on a video disk through the Smithsonian Institution, Washington, D.C.

Ordering Photographs

Prints, slides, and transparencies of STS Earth-looking photography are distributed through three agencies. The primary source of the data is:

Eros Data Center
User Services Section
Sioux Falls, South Dakota 57198
Phone: (605) 594-6151
FTS: 784-7151

Other sources are:

Technology Applications Center
University of New Mexico
Albuquerque, New Mexico 87131
Phone: (505) 277-3622

and

Media Services Branch
Still Photography Library
NASA/Lyndon B. Johnson Space Center
P.O. Box 58425, Mail Code AP3
Houston, Texas 77258-8425
Phone: (713) 483-4231

A user may contact these agencies for ordering assistance, price lists, and order forms. To order a picture, submit the Shuttle mission number, the film roll number, and the frame number.

If the interest lies in a specific area, a listing of available photographs can be obtained through the EROS Data Center. Submit the geographic name (i.e., country, island chain, ocean, or sea) and the latitude and longitude coordinates for the area of interest.

The Space Shuttle Earth Observations Project Office recommends that a user visit one of the viewing centers to select the photograph best satisfying his or her requirements before ordering a photograph.

NASA
National Aeronautics and Space Administration

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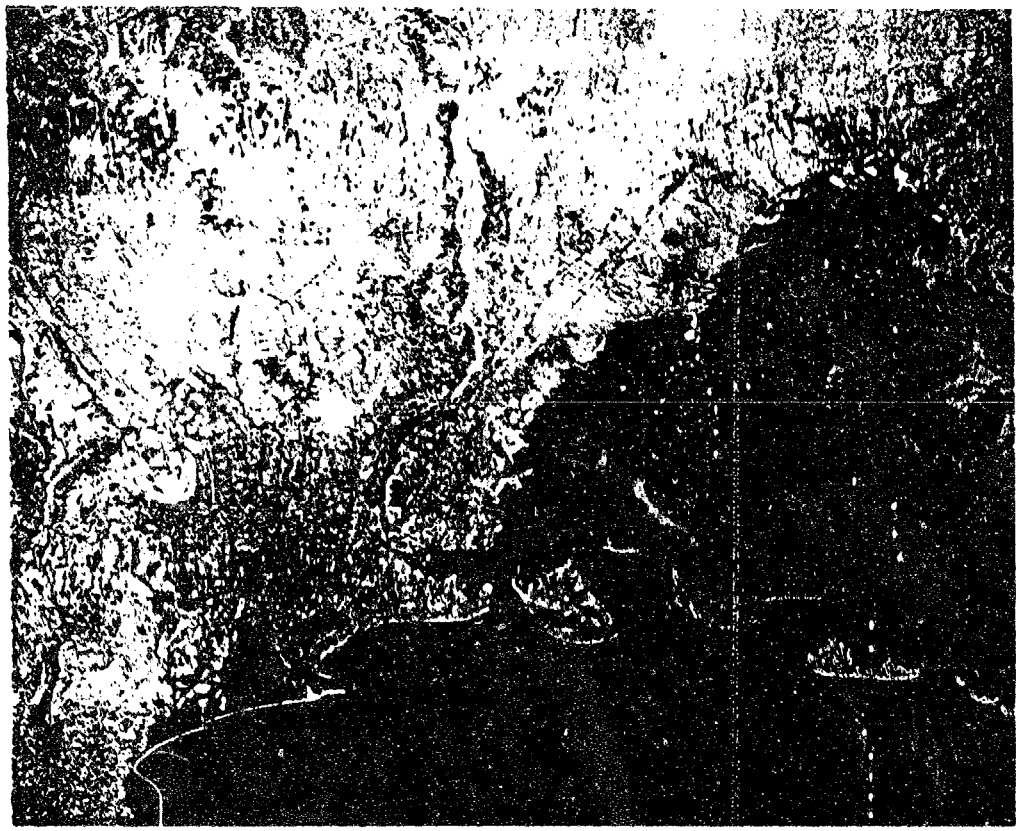


Fig. 9 S30-95-116. The primary port of Pakistan, Karachi, is located at the western end of the mouths of th Indus River. The intertidal mangroves of the Indus River mouth bars are the darker areas to the right. Karachi is well delineated in the left center of this color infrared photograph. Center-point is 25.0°N 67.0°E. This photograph was taken at 0537GMT on 7 May 1989 from an altitude of 177 nm.

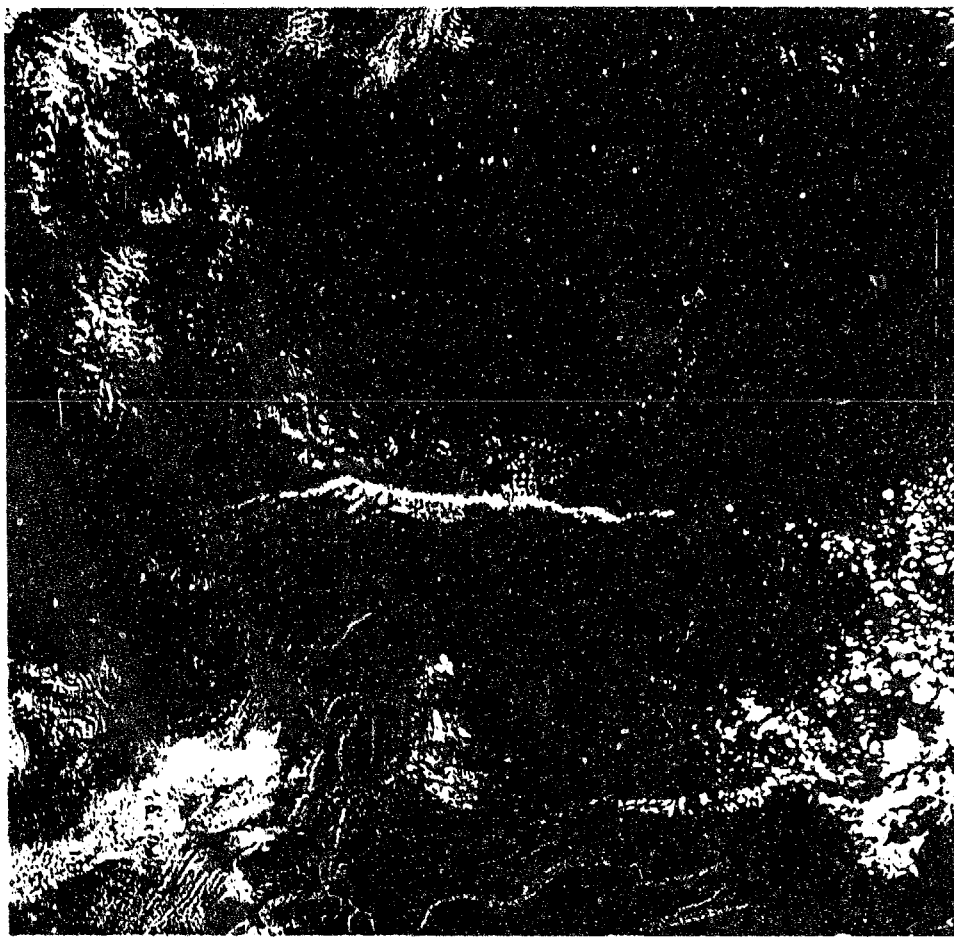
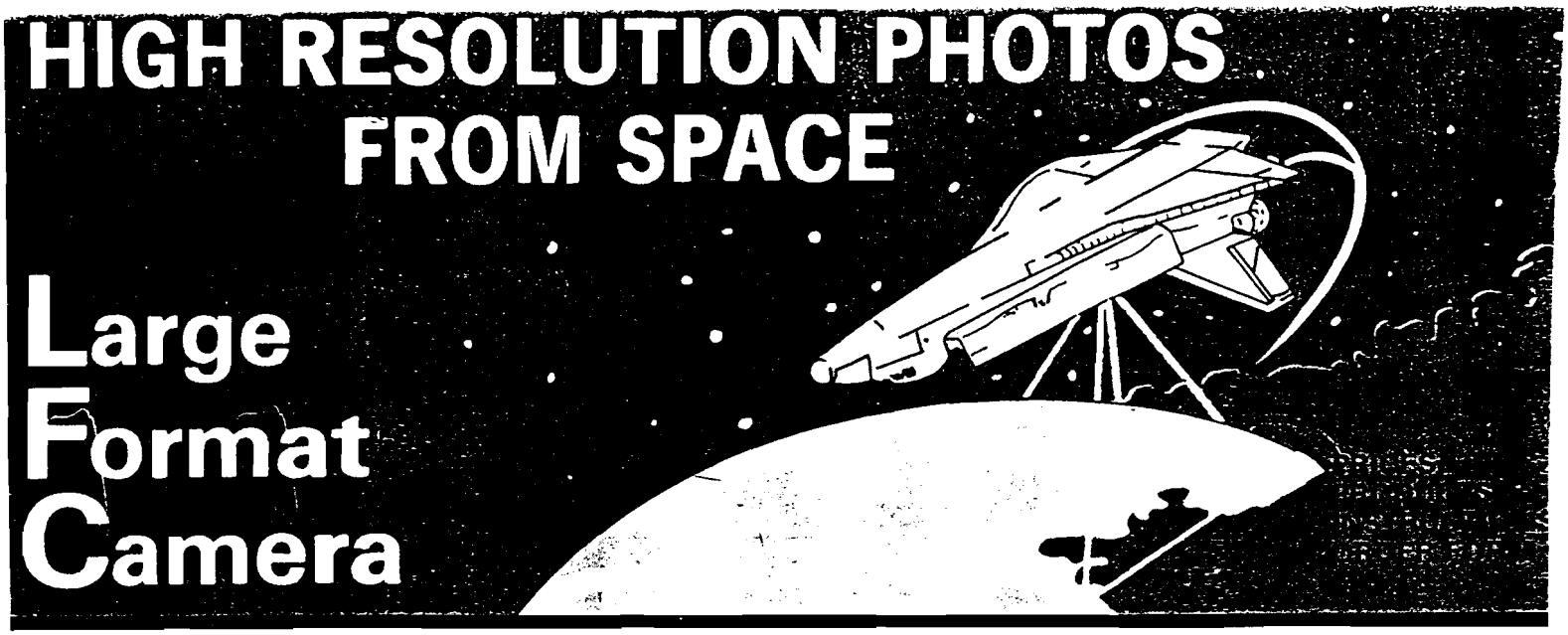


Fig. 10 S30-88-00K. One of the last great reserves of closed-canopy tropical hardwood (dipterocarp) forests is found on Borneo. Previous Space Shuttle missions have documented large-scale deforestation in both the Indonesian (Kalimantan) and Malaysian (particularly in Sabah (North Borneo)) portions of Borneo. The extent of deforestation here, primarily for timber export to Japan (Sabah) and clearing for transmigration (Kalimantan), is still

hampered by smoke and humidity hazes prevalent during

HIGH RESOLUTION PHOTOS FROM SPACE



Large Format Camera

LFC DEPT.
CHICAGO AERIAL SURVEY, INC.
2140 Wolf Road
Des Plaines, IL 60018 USA

Bulk Rate
U.S. Postage
PAID
St. Petersburg, Fl.
Permit No. 1030

Phone (312) 298-1480
TELEX 754439 UD

- Imagery from space, useable with many conventional mapping instruments.
- Including black and white, color, and color infrared high resolution photos.
- Individual frames cover up to 65,000 sq.mi. (167,000 sq. km.)
- Stereo coverage with up to 80% overlap.

CAS

51

CHICAGO AERIAL SURVEY, INC.

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PRODUCT AND PRICE LIST

he photographic products listed below will be made from a Master Duplicate (first generation copy) f the original LFC film exposed during STS Mission 41-G during October, 1984. Prices are subject change and apply only to the experimental photography from STS Mission 41-G.

CONTACT PRINTS	CODE	U.S. $ PRICE
9 x 9 inch (23 x 23 cm) Black and White	01	55
9 x 18 inch (23 x 46 cm) Black and White	02	65
9 x 9 inch (23 x 23 cm) Color	03	70
9 x 18 inch (23 x 46 cm) Color	04	80

ENLARGEMENTS	CODE	PRICE
Black and White, up to and including 2X or 18 x 18 inch (46 x 46 cm) print size	05	65
Black and White, up to and including 3X or 27 x 27 inch (69 x 69 cm) print size	06	80
Black and White, up to and including 4X or 36 x 36 inch (91 x 91 cm) print size	07	95
Black and White, over 4X enlargement or > 36 x 36 inch (91 x 91 cm) print size, per square foot (per 930 square cm)	08	12
Color, up to and including 2X or 18 x 18 inch (46 x 46 cm) print size	09	120
Color, up to and including 3X or 27 x 27 inch (69 x 69 cm) print size	10	150
Color, up to and including 4X or 36 x 36 inch (91 x 91 cm) print size	11	180
Color, over 4X enlargement or larger than 36 x 36 inch (91 x 91 cm) print size, per square foot (per 930 square cm)	12	20

ROLL FILM DUPLICATION	CODE	PRICE
Black and White Positive from B & W negative; 20 frames minimum, per frame	13	11
Black and White Negative from B & W negative; 20 frames minimum, per frame	14	13
Black and White Panchromatic Negative from color positive; 20 frames minimum, per frame	15	13
Color Positive Transparency Duplication, 20 frames minimum, per frame	16	18

SINGLE FRAME POSITIVE TRANSPARENCIES	CODE	PRICE
Black and White 9 x 9 inch (23 x 23 cm) Contact Diapositive; 7 mil base; base up	17	65
Color 9 x 9 inch (23 x 23 cm) Contact Diapositive; 7 mil base	18	80
Color 9 x 18 inch (23 x 46 cm) Duplicate Transparency; 4 mil base	19	95
Black and White 9 x 18 inch (23 x 46 cm) Duplicate Negative; 4 mil base	20	70
Black and White 9 x 18 inch (23 x 46 cm) Panchromatic Negative from Color Transparency	21	85
Black and White 9 x 9 inch (23 x 23 cm) Contact Diapositive; 7 mil base; emulsion side up (includes internegative)*	22	95
Black and White 9 x 18 inch (23 x 46 cm) Film Diapositive; 7 mil base	23	70

ACCESSION AID	CODE	PRICE
Microfiche of selected Mission Ephemeris Data, Geographic Descriptors, and Footprint Maps showing Locations Frame-by-Frame (shipping included)	99	5

econd generation film diapositives prepared with emulsion-to-emulsion contact during film xposure result in a correct-reading **base-side up** product. If an emulsion-side up product is equired, it will be a third-generation copy since an internegative must be made as well.

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LFC TECHNICAL NOTES

(The following information is compiled from data available from NASA and other sources and is provided for informational purposes only.)

INTRODUCTION

The Large Format Camera (LFC) provides high quality metric stereo photography from space. Unlike electro-optical data collected by Landsat and other scanner-based systems, sophisticated computer processing is not necessary to produce the photographic image. The LFC photographs are sized for use on standard mapping instruments, including the simplest stereoscopic viewers.

Scales of the film images range from near 1:750,000 to about 1:1,200,000. These high-resolution photographs can be enlarged 10 times or more with little loss of image quality. In most cases, the photographs are useable for mapping applications at scales up to 1:50,000.

As described in the product list and ordering instructions, a wide variety of film and paper print products are available on standard orders. Custom services are available for special items, (e.g., mounting photos, oversize transparencies etc.)

In the following paragraphs the LFC system, operation, and mission objectives are described.

THE LFC PAYLOAD

The Large Format Camera (LFC) payload consists of a camera system (lens cone and film magazine, electronics assembly, and nitrogen gas supply assembly) and, attached to it, an Attitude Reference System (ARS) (stellar camera array with its support structure, environmental enclosure, and electronics assembly).

LFC SPECIFICATIONS

Film Format Size	- 9 x 18 inches (23 x 46 cm)
Lens Focal Length	- 12 inches (30.5 cm)
Lens Aperture	- F/6.0
Film Capacity (Thin-Base Film)	- 4000 ft (1219 meters)
(Frames of Photos)	- 2400 (approximately)
Exposure Range	- 4 ms to 32 ms (1/250 sec to 1/31.25 sec)
Exposure Interval Range	- 7.5 sec minimum
Ground Resolved Distance (Low Contrast)	- 65 feet (20 meters) at 160 nautical miles (n.mi.) altitude
Ground Coverage at Typical Altitudes	- 120 x 240 n.mi. at 160 n.mi. altitude 222 x 444 km at 296 km altitude

LFC DESCRIPTION

The LFC is a high altitude aerial mapping camera scaled up to operate from Earth-orbital altitudes. It is bigger, more stable, more precise, and more technologically advanced in optics and electronics than its airborne predecessors.

LFC CAPABILITY

The aspheric lens system of the LFC focuses an orthogonal image, free from spherical aberration, on a 9 x 18 inch focal plane. Photographs are made with the long axis of the film parallel to the ground track. This is done to provide an opportunity for adequate image-motion compensation within the camera. The camera body is pressurized by the nitrogen gas supply. This helps to stabilize the film and provides an atmosphere in which a relative vacuum can be created to momentarily press the film onto the platen during an exposure. During the exposure pulse, the platen moves the film at exactly the correct speed (electronically controlled) to cancel the image smear that would otherwise be caused by the movement of the Shuttle over the Earth. To acquire stereo pairs of photography, exposures may be timed to provide forward overlaps of 80, 70, 60, or 10 percent. In the 80-percent mode, each pair of photos would have a base height ratio of 1.2, which should allow photogrammetric perception of heights as small as 30 meters (plus or minus 15 meters) at a map scale of 1:50,000

ANCILLARY DATA

Each frame of LFC film is imprinted with data referenced to time of exposure. The data includes a Reseau grid, fiducial marks, mission and frame numbers, Julian Day, and Greenwich Mean Time, all keyed to the precise center of the exposure pulse. Each pair of frames of the ARS is also imprinted with a Reseau, a frame pair number, and time.

OPERATION

The LFC is monitored by the Shuttle Orbiter's general purpose computer, and the data transaction signals are relayed to the operations center at the Lyndon B. Johnson Space Center (JSC) in Houston These signals (38 data channels) include flags and operational parameters that enable the Principal Investigator and his associates to monitor and command the LFC from the ground. The crew of the Orbiter also has access to critical items of information about the system, and can operate the cameras through a stand-by system on board.

FILM TYPES

Five types of Kodak film (three sections of black and white, a section of aerial color, and a section of high-definition color infrared) were spliced together to fill the LFC film magazine in order to evaluate the camera's optical properties at several spectral wavelengths. The ARS stellar cameras have only one type of black and white Kodak film.

OBJECTIVES

Mission 41-G Objectives were:

1. Verification of the mechanical, thermal, electrical, and electronic operation of the LFC/ARS system in Earth orbit.
2. Operation of the LFC with four types of film over cloud-free land areas to obtain data for analytical evaluation of mapping capabilities of the camera.

RESULTS AND USES

Mission 41G (the first experimental LFC flight) encountered extraordinary cloud cover, particularly in the northern hemisphere. However, many cloud-free areas were photographed in the northern hemisphere as well as in the near-equatorial regions and the southern hemisphere. While 20-30% clouds renders conventional aerial photography almost useless, the huge area covered on each LFC frame allows large areas between clouds or larger cloud-free parts of each photograph to be used for mapping.

A gross stereo model on a typical high altitude aerial photography (60% overlap, scale = 1:58,000) covers approximately 40 square miles (100 sq. km.). The typical LFC stereo model (60% overlap, scale = 1:750,000) encompasses about 14,000 square miles (36,000 sq. km.)! The efficiency of using LFC coverage is apparent, especially in regions with limited ground control.

Specific applications for LFC photographs include but are not limited to

- topographic mapping
- planimetric mapping
- land use mapping
- hydrologic studies
- natural resource inventory
- minerals exploration

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Appendix F. 1. Soyouzkarta (from Soviet KOSMOS) imagery of Afghanistan/Pakistan.

F. 2. Soyouzkarta photography acquisition information - Contitrade Services Corp.

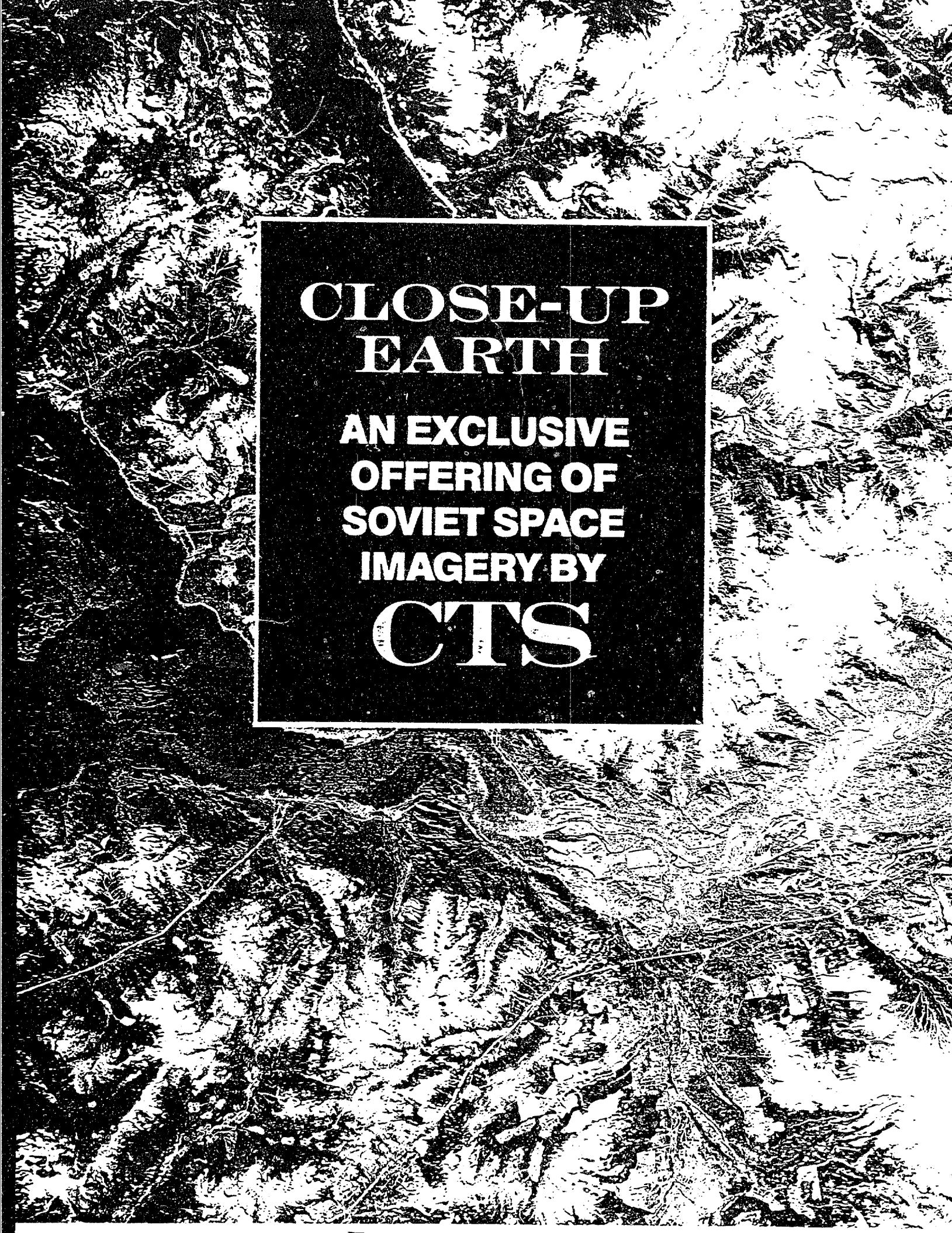
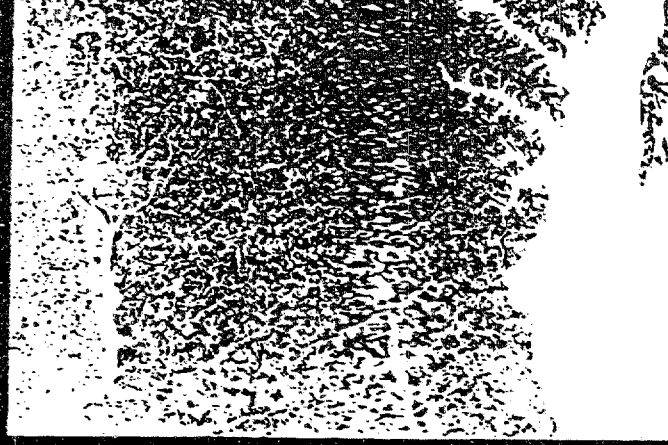

CLOSE-UP
EARTH
AN EXCLUSIVE
OFFERING OF
SOVIET SPACE
IMAGERY BY
CTS

Image Subject: **EARTH**

Location: **USER SPECIFIED**

Resolution: **5 METERS OR FINER**



Washington, D.C. Area

Possum Kingdom Reservoir, North Central Texas

Puget Sound, State of Washington

Tokyo Bay

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Alpine Mountain Range, Italy

What makes this image of a mountain range, taken from space by an orbiting satellite, different from all other space imagery? ***Availability and resolution!***

ContiTrade Services Corporation, under terms of a trade agreement with USSR FTO Soyuzkarta, has exclusive rights to market high resolution Soviet satellite imagery within the Western Hemisphere, with limited exceptions in Latin America. This high resolution imagery may be purchased for all parts of the world, with exception of the USSR and Socialist nations.

Products from two camera systems are available: the KFA-1000 and the recently declassified MK-4 camera.

KFA-1000 has resolution of 5 meters, but some independent investigators have reported resolution as fine as 2 meters or less. Objects as small as individual trees and automobiles in parking lots are recognizable. KFA-1000 imagery is recorded on 30 x 30 centimeter film and returned to Earth for processing. Original scale of the recorded film is about 1/250,000, so each frame covers an area approximately 60 x 60 miles.

KFA-1000 photographic images are available either in panochromatic or spectrozonal color. Spectrozonal film is dual emulsion and records light in 570-670 and 670-810 nanometer ranges. All materials are first generation derivatives from original negatives.

Products are available as black and white or color film positives or negatives, as well as paper prints. Photographic scales range from 1/250,000 to 1/24,000.

MK-4 is a true multispectral cartographic camera with a resolution of 6 meters. Data are recorded on four separate film bases simultaneously in a variety of spectral bands, ranging from the lower part of the visible spectrum into the near infrared. Original film is 19 x 19 centimeters in size. Data recorded at an original scale of about 1/700,000 may be enlarged without loss of resolution or rectification to a scale as large as 1/24,000. MK-4 has 25 fiducial points and may be obtained in a variety of photographic products, either black and white or false color.

KFA-1000 and MK-4 products are available from extensive banks of archival data. Most were recorded after 1986. Products from archives generally are delivered within three weeks of date order is received. Where data are not in archives, ContiTrade Services will contract to acquire coverage for a future delivery date at no extra cost to the customer. Special order conditions are negotiated on a case by case basis.

ContiTrade Services requires customers to sign a license agreement regarding reproduction of the satellite imagery. Advance payment required for all imagery where prior credit is not arranged.

A variety of derivative products are being developed, including high resolution digitized CCTs of KFA-1000 and MK-4 film products. These are digitized without loss of resolution or rectification and formatted to be compatible with Eosat and SPOT digital products.

For further details, contact:

ContiTrade Services Corp.
277 Park Avenue
New York, N.Y. 10172
Phone: 212/207-5550
Fax: 212/935-5787

ContiTrade Services Corp.
2000 South Main
Fort Worth, Texas 76110
Phone: 817/923-8301
Fax: 817/923-2515

CONTITRADE SERVICES CORPORATION

2000 SOUTH MAIN
FORT WORTH, TX 76110

TELEPHONE (817) 923-8501
FAX (817) 923-2515

September 15, 1989

Dear Sir:

I wish to make you aware of the ultrahigh resolution satellite photography ContiTrade Services Corporation is now marketing. Through a trade agreement signed with FTO Soyuzkarta, ContiTrade Services Corp. now markets in the western hemisphere five meter resolution photography from both the KFA-1000 and MK-4 cameras.

Our coverage is extensive, our computer searches quick and efficient, and our delivery time is generally three weeks. We believe these data are the finest commercial satellite data available, and believe they may successfully be used in cartography, G.I.S., and urban planning as well as the more traditional uses of satellite data.

Although the original data are in a photographic format, we have successfully digitized them without loss of resolution or quality. Both photographic and digital products may be obtained.

Should you desire new coverage, we will commission to provide this, meteorological conditions permitting, within sixty days and deliver the product to you at the same price as archival data.

After you have had a chance to look over these materials, I will call to discuss how these materials may meet your needs.

Sincerely,

Velon H. Minshew, Ph.D.

VHM/ss
Encl.

CONTITRADE SERVICES CORPORATION
DIGITAL PRODUCTS PRICE LIST

All prices are US dollars.

KFA-1000*	Ca. 50 x 50 miles
1 Band	$2560
2 Bands	$3050
MK-4**	Ca. 100 x 100 miles
1 Band	$2050
2 Bands	$4050
3 Bands	$5520
KATE-200***	Ca. 150 x 150 miles
1 Band	$1550
2 Bands	$2550
3 Bands	$3550

All data are 6250 BPI CCTS in a format compatible with EOSAT TM data.

*Digitized at Five (5) micron pixel element size
**Digitized at three (3) micron pixel element size
***Digitized at ten (10) micron pixel element size

All digital products are made from first generation film positives or from original film negatives.

CONTITRADE SERVICES CORPORATION
KFA-1000 PRICE LIST
Resolution 5-7 Meters

277 Park Avenue
New York, NY 10172
(212) 207-5550
Fax (212) 935-5787
Telex 422 542

2000 South Main
Fort Worth, TX 76110
(817) 923-8301
1-800-343-8650
Fax (817) 923-2515

PRODUCT CODE	DESCRIPTION		UNIT PRICE	PRICE PER SQ.KM
B&W				
1.	Film Positive	1/220-270,000 (30x30cm)	$ 800	$0.12
2.	Film Negative	1/220-270,000 (30x30cm)	$ 855	$0.13
3.	Pos. Contact Print	1/220-270,000 (30x30cm)	$ 340	$0.05
4.	Positive Print	1/125-135,000	$ 510	$0.09
5.	Paper Print	1/50,000	$ 870	$0.13
COLOR				
6.	Film Positive	1/220-270,000 (30x30cm)	$ 980	$0.15
7.	Film Negative	1/220-270,000 (30x30cm)	$1050	$0.16
8.	Pos. Contact Print	1/220-270,000 (30x30cm)	$ 450	$0.07
9.	Positive Print	1/125-135,000	$ 620	$0.10
10.	Paper Print	1/50,000	$1100	$0.17

(Scale of original negative is variable due to differing altitudes of satellites carrying the cameras. They can be rectified to a specific scale upon request.)

Add $125 Shipping & Handling for each order. (All prices are U.S. Dollars)

MK-4 PRICE LIST

Resolution 5-8 Meters

277 Park Avenue
New York, NY 10172
(212) 207-5550
Fax (212) 935-5787
Telex 422 542

2000 South Main
Fort Worth, TX 76110
(817) 923-8301
1-800-343-8650
Fax (817) 923-2515

PRODUCT CODE	DESCRIPTION			UNIT PRICE	PRICE PER SQ.KM
Single Band					
11.	Film Positive	1/900,000	(18x18cm)	$1050	$0.05
12.	Film Negative	1/900,000	(18x18cm)	$1110	$0.05
13.	Film Neg-Pos. Set	1/900,000	(18x18cm)	$1190	$0.05
14.	Pos. Contact Print	1/900,000	(18x18cm)	$ 210	$0.01
15.	Positive Print	1/500,000	(36x36cm)	$ 300	$0.01
16.	Paper Print	1/250,000		$ 440	$0.02
3 Bands					
17.	Film Positive	1/900,000	(18x18cm)	$2520	$0.11
18.	Film Negative	1/900,000	(18x18cm)	$2660	$0.12
19	Film Neg-Pos. Set	1/900,000	(18x18cm)	$2860	$0.13
20.	Pos. Contact Print	1/900,000	(18x18cm)	$ 420	$0.02
21.	Positive Print	1/500,000	(36x36cm)	$ 600	$0.26
22.	Paper Print	1/250,000		$ 880	$0.04
Color Spec.					
23.	Film Positive	1/900,000	(18x18cm)	$1950	$0.09
24.	Film Negative	1/900,000	(18x18cm)	$2070	$0.09
25.	Film Neg-Pos. Set	1/900,000	(18x18cm)	$2250	$0.10
26.	Pos. Contact Print	1,900,000	(18x18cm)	$ 700	$0.03
27.	Positive Print	1/500,000	(36x36cm)	$1020	$0.05
28.	Paper Print	1/250,000		$1600	$0.07
Color Syn.					
29.	Film Positive	1/900,000	(18x18cm)	$3220	$0.14
30.	Film Negative	1/900,000	(18x18cm)	$3470	$0.15
31.	Film Neg-Pos. Set	1/900,000	(18x18cm)	$3800	$0.17
32.	Pos. Contact Print	1/900,000	(18x18cm)	$ 750	$0.03
33.	Positive Print	1/500,000	(36x36cm)	$1070	$0.05
34.	Paper Print	1/250,000		$1600	$0.07

(Scale of original negative is variable due to differing altitudes of satellites carrying the cameras. They can be rectified to a specific scale upon request)

Add $125 Shipping & Handling for each order. (All prices are U. S. Dollars)

CONTITRADE SERVICES CORPORATION
KATE-200 PRICE LIST
Resolution 15-30 Meters

PRODUCT CODE	DESCRIPTION		UNIT PRICE	PRICE PER SQ. KM
Single Band				
35.	Film Positive	1/1,350,000 (18x18cm)	$ 230	$0.01
36.	Film Negative	1/1,350,000 (18x18cm)	$ 250	$0.01
37.	Film Neg-Pos. Set	1/1,350,000 (18x18cm)	$ 280	$0.01
38.	Pos. Contact Print	1/1,350,000 (18x18cm)	$ 100	$0.01
39.	Positive Print	1/700,000 (36x36cm)	$ 140	$0.01
40.	Paper Print	1/350,000	$ 220	$0.01
3 Bands				
41.	Film Positive	1/1,350,000 (18x18cm)	$ 550	$0.02
42.	Film Negative	1/1,350,000 (18x18cm)	$ 580	$0.02
43.	Film Neg-Pos. Set	1/1,350,000 (18x18cm)	$ 630	$0.03
44.	Pos. Contact Print	1/1,350,000 (18x18cm)	$ 210	$0.01
45.	Positive Print	1/700,000 (36x36cm)	$ 310	$0.01
46.	Paper Print	1/350,000	$ 470	$0.02
Color Spec.				
47.	Film Positive	1/1,350,000 (18x18cm)	$ 450	$0.02
48.	Film Negative	1/1,350,000 (18x18cm)	$ 480	$0.02
49.	Film Neg-Pos. Set	1/1,350,000 (18x18cm)	$ 510	$0.02
50.	Pos. Contact Print	1/1,350,000 (18x18cm)	$ 200	$0.01
51.	Positive Print	1/700,000 (36x36cm)	$ 280	$0.01
52.	Paper Print	1/350,000	$ 420	$0.02
Color Syn.				
53.	Film Positive	1/1,350,000 (18x18cm)	$ 690	$0.03
54.	Film Negative	1/1,350,000 (18x18cm)	$ 750	$0.03
55.	Film Neg-Pos. Set	1/1,350,000 (18x18cm)	$ 790	$0.03
56.	Pos. Contact Print	1/1,350,000 (18x18cm)	$ 235	$0.01
57.	Positive Print	1/700,000	$ 300	$0.01
58.	Paper Print	1/350,000	$ 450	$0.02

(Scale of original negative is variable due to differing altitudes of satellites carrying the cameras. They can be rectified to a specific scale upon request.)
Add $125 Shipping & Handling for each order. (All prices are U.S. Dollars)

CONTITRADE SERVICES CORPORATION

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2000 SOUTH MAIN
FORT WORTH, TX 76110
(817) 923-8301
FAX (817) 923-2515
1-800-343-8650

SOYUZKARTA DATA SEARCH

MAIL TO: Company _____
Contact _____
Address _____
Phone _____ Fax _____

SEARCH INFO:

Date of Request ____ / ____ / ____
Country to search _____

Period of Acquisition: From ____ / ____ / ____
To ____ / ____ / ____
All Coverage ____

Maximum Acceptable Cloud Cover: 10% ____ 25% ____ ≥25% ____

COORDINATES:

Latitude/Longitude Single Point Search

Point 1
Latitude ____ D ____ M N / S
Longitude ____ D ____ M E / W
Radius (km) _____

Point 2
Latitude ____ D ____ M N / S
Longitude ____ D ____ M E / W
Radius (km) _____

Point 3
Latitude ____ D ____ M N / S
Longitude ____ D ____ M E / W
Radius (km) _____

Point 4
Latitude ____ D ____ M N / S
Longitude ____ D ____ M E / W
Radius (km) _____

Latitude/Longitude Regional Coverage Search

1 Latitude ____ Deg ____ Min N / S
Longitude ____ Deg ____ Min E / W

2 3

2 Latitude ____ Deg ____ Min N / S
Longitude ____ Deg ____ Min E / W

3 Latitude ____ Deg ____ Min N / S
Longitude ____ Deg ____ Min E / W

1 4

4 Latitude ____ Deg ____ Min N / S
Longitude ____ Deg ____ Min E / W

Soyuzkarta Grid Reference Map

Area 1. Numeric _____, Alphabetic _____

Area 2. Numeric _____, Alphabetic _____

Area 3. Numeric _____, Alphabetic _____

Area 4. Numeric _____, Alphabetic _____

BEST AVAILABLE COPY

CONTITRADE SERVICES CORPORATION

NEW YORK OFFICE
277 PARK AVE.
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FAX (212) 935-5787
TELEX: 422542

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2000 SOUTH MAIN
FORT WORTH, TX 76110
(817) 923-8301
FAX (817) 923-2515
1-800-343-8650

SOYUZKARTA DATA PURCHASE

PURCHASER:
Company _____
Contact _____
Address _____
Phone _____ Fax _____

SHIPPING ADDRESS:

_____
_____
_____
_____

FILM NO.	FRAME NO.	PRODUCT CODE	NO. OF EACH	UNIT PRICE	TOTAL PRICE

SPECIAL ACQUISITIONS:
For initiating a special acquisition,
please call 1-800-343-8650

TYPE OF PAYMENT: TOTAL ORDER $ _____

___ Check / Money Order, enclosed

___ Purchase Order

COMMENTS or SPECIAL INSTRUCTIONS:

_____
_____
_____
_____

BEST AVAILABLE COPY

Appendix G. Landsat 4/5 worldwide reference system scene centers for Afghanistan and Pakistan.

PATH 160
65°
PATH 15
70°
75°
PATH 15
SOCIALIST REPUBLICS
KYZYL KUM
KOKAND
KASHGAR
35
AFGHANISTAN
PAKISTAN
QUETTA
MULTAN
HYDERABAD
JODHPUR
MUSCAT
OMAN
IND