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TP-69-8147/1

27 November 1972

Technical Proposal
for
TECHNOLOGY FOR IMAGERY EXPLOITATION (TIE)

[redacted]

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CLASSIFIED BY 368397
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ABSTRACT

25X1A [redacted] proposes to provide the ARGO Committee with the necessary personnel and facilities to accomplish assigned tasks concerning the exploitation of all-source, remote sensor imagery and data. Included in the proposal are sections on representative tasks, a sample work statement for the overall program, a history of [redacted] participation in this country's space photography programs and [redacted] Statements of Qualifications (separate volume). 25X1A 25X1A

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1. INTRODUCTION

1.1 Background

The United States is continually adding new satellite photography to its already impressive library of earth photography from space. The primary users of this photography are the Intelligence and the Mapping communities. These two groups have supported both the acquisition and the development of the utilization of this photography. Their interest have, understandably, been in the general areas of military intelligence and mapping. Through their efforts, great strides have been made in developing techniques and equipment for extracting, from this unique photography, information of interest to them on the identification, size and location of ground objects. Scientific personnel from these groups have examined this photography in detail searching for better ways to get more and more information from it. Their accomplishments are impressive, but because their interests were confined largely to the military intelligence and mapping fields there remains the certainty that much of this same photography can be utilized for other purposes. Studies made during the ARGO program uncovered potential uses in several areas. Many additional uses have been suggested by others. Some of the problems associated with the exploitation of this photography have been identified, and many more will be encountered. Progress in problem solving and in testing and verifying new uses has been slow. [redacted] believes that it can provide the necessary attention, personnel and experience to help solve these problems, and consequently this proposal is being offered.

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1.2 Proposal

25X1A [redacted] proposes to provide all personnel, facilities, and technical services required to accomplish specific tasks, designated by the customer, in the general area of exploitation of all-source remote sensor imagery and data. Tasks will be directed to the solution of engineering and scientific problems, and to the transfer of technology to the ARGO member agencies. Technical reports will be prepared for each task and training sessions will be conducted for agency personnel, as required. It is contemplated that the assigned tasks will require both theoretical studies and scientific experiments in the search for problem solutions. Direct assistance to agencies on special problem areas will be undertaken, as directed, but the intent will be to help the agency personnel develop new technologies and not to perform tasks within their capabilities.

It is proposed that a task type, cost plus fixed fee, level-of-effort contract be procured through the National Photographic Interpretation Center's contracting offices. A suggested work statement, including terms and conditions of the contract, is shown in Section 4.

2. [redacted] QUALIFICATIONS

2.1 General

During the past ten years [redacted] has worked with both the Department of Defense and Intelligence Agencies in the search for better ways of extracting metrical and intelligence information from satellite photography. It was obvious from the first that more was required than simple extrapolation of old ideas and methods. The scales of the precision frame photography decreased by factors from 20 to 40, yet the coverage provided by each frame opened new avenues of research. Coverage with long focal length panoramic and strip photography became available in many geographical areas of great interest, but methods of effectively extracting information from the photographs were slow, cumbersome and the results marginal. It was obvious that there were many problems to solve and many avenues of research and development to pursue; but it also was obvious that a special technical staff and special facilities would be required. [redacted] management elected to orient the major activities of the organization around the exploitation of this unique photography. An account of these activities is shown in Appendices A and B.

It becomes apparent to one examining the unclassified portion of this proposal that [redacted] interests, capabilities and image go beyond the exploitation of satellite photography. Our history of extracting meaningful data from airborne multi-sensor records goes back over ten years. Even though the primary satellite image sensors have been cameras, it is certain that future sensors will include multi-spectral cameras, radars, radiometers and others in use today plus others now in development or as yet unknown. [redacted] is keeping abreast of these new sensors and is learning how to use their records in extracting both interpretative and metrical information.

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2.2 Personnel

The acquiring and training of personnel to develop the new technologies required for exploiting this special photography has been very difficult due to the acute shortage of personnel in the required disciplines. For the past nine years [redacted] has searched through 25X1A colleges and industry for scientific personnel trained in mathematics, photogrammetry, geodesy, orbital mechanics, automatic image correlation, astronomy, photo geology, geophysics, plant ecology and other areas. It has taken as long as two years of waiting before some of the ones needed to add to the strength of our senior technical staff could be hired. An outstanding team has now been assembled that is capable of deriving many kinds of data from a variety of remote sensor records. These team members have gone through the long periods of waiting for security investigations and are now cleared to the required level of clearance.

25X1A [redacted] has probably the highest percentage of personnel with special clearances (needed for access to satellite camera records) of any industrial organization. Many of the members of [redacted] technical 25X1A staff are recognized as experts by their colleagues within their respective technical societies. Many of them are well known throughout the free world, holding positions of leadership in national and international technical organizations.

A partial list of the disciplines represented by our personnel is shown below. Some of the personnel have education and experience in more than one technical area. With the many skills available, [redacted] 25X1A is able to put together special teams capable of addressing almost any problem concerning the exploitation of multi-sensor records. A total of thirty (30) of these administrative, technical and service personnel have security clearances of the required level.

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Administration

Management
Contract Administration
Security
Controller
Secretary

Scientific and Technical

Electronic Engineering
Civil Engineering
Physics
Industrial Design
Engineering Sciences
Forestry
Wild Life Management
Geography (cultural-physical-social)
Geology (general-exploration-engineering)
Geophysics (seismology, magnetics, gravity)
Photointerpretation
Intelligence Analysis
International Relations
Psychology
Economics
History
Geodetic Science
Mathematics
Photogrammetry
Astronomy
Computer Programming/Analysis
Orbital Mechanics

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Technical Support

Surveying
Cartography
Fine Arts
Drafting
Electronics Technician
Mensuration
Photographic Processing
Photography
Printing
Technical Typing

Resumes of experience for key personnel are contained in the attached Statements of Qualifications.

2.3 Facilities

25X1A The facilities of [redacted] are ideally located for service to the many government agencies in and near Washington, D.C. [redacted] 25X1A

25X1A [redacted] location is convenient to NPIC, Fort Belvoir, Langley, Department of Agriculture, Geological Survey, Bureau of Standards, Army Topographic Command, The Pentagon, The White House, The Capitol, etc. The facility contains an image interpretation and analysis laboratory. The facilities are cleared and controlled for special security programs.

The facility's laboratory is arranged in such a manner that programs at various levels of security can be isolated. Facility work has been, and will be, coordinated with personnel working in government spaces (NPIC, DMA, etc.). This type of coordination and convenience

will allow for optimal communication and task control at the same time providing use of compatible hardware and software which is currently in use by the Intelligence Community.

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3. REPRESENTATIVE TASKS

It is recognized that varied (and, in some cases overlapping) scientific and technological interests are represented in the ARGO Committee. In addition, certain of the member agencies involved are further advanced in the use of satellite materials than others. Thus, it makes it rather difficult, at this time, to pontificate and render precise definitions for the tasks to be undertaken in this proposed program. Therefore, the task elements described below serve to suggest what [redacted] 25X1A 25X1A [redacted] feel might be representative of the types of tasks that could be included under this contract. These should in no way be construed as binding upon the customer or the contractor, but merely as examples of the activities that can be entered into.

It is most important that the initial task for this program be designated as "Preliminary Organization". This will include necessary meetings and briefings--collective and individual--with the customer and its members to define, in a reasonable and flexible way, the work to be accomplished. This task should result in an operating plan and schedule designed to guide the program efforts in a manner that will allow the best possible use of the funds, manpower and materials available.

The following includes three representative major task areas: geoscience, positioning and dimensioning and data base. These task areas are cited along with certain "task elements" that might be undertaken. In all cases, it is the intent to rigorously examine existing techniques used in the extraction and synthesis of qualitative and quantitative information inherent in imagery derived from all sources; to devise and innovate in all areas; and to provide a training vehicle for the transfer of the techniques to appropriately cleared and qualified government personnel.

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3.1 Geoscience Studies

There are many possibilities for useful tasks in this area of interest. Generally, tasks are required and should be directed to the determination of sensor utility or value for specific applications, the development of procedures and cost comparison information for various alternative methods of exploiting overhead reconnaissance, and quick reaction tests or technical support for the direct application of the imagery to priority problems. A typical progression of tasks for geoscience studies is as follows:

a. Itemize functional research areas of interest.

b. Wherever possible, group similar or analogous functional or sub-functional areas which would or could be satisfied by common imagery/data sources, geographic or otherwise.

c. Prioritize the functional area groupings into tasks.

d. Select the key process or processes by which R & D will be conducted or for which the particular study, analysis, or other implementation, is appropriate. This could include theoretical investigations, empirical-subjective research by an individual or individuals, controlled human factor testing; training programs, or equipment-aided or automated support of research effort.

e. Design study, research, or other approach and establish sub-task breakdown and level of effort required.

f. Conduct study, survey, evaluation or experiments.

g. Present results (reports, briefing, training sessions, etc.).

h. Implement results.

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3.1.1 Regional Resources Surveys

Experience has shown that certain basic types of geoscience data are extractable from satellite imagery (as well as non-photographic sensors). These data are listed below. In the past, they have been successfully synthesized, in various combinations, into Military Geographic Intelligence products. It is believed, but as yet untested, that these same data can be synthesized into non-military products for rapid regional surveys.

- Surface Hydrology
- Geology (litho-stratigraphic units and structural features)
- Geomorphology
- Surface Configuration
- Vegetational Types and Distributions
- Wetlands & Ecological Delineations
- Land Use
- Transportation Nets
- Planimetry
- Engineering Soils

These basic data, which are extractable from all-source materials, may be amenable to later translation into documents and maps useful in determining (for example):

- Hydrocarbon Potential
- Mineral Potential
- Forestry Potential
- Grazing Potential
- Crop Forecasts

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3.1.2 Civil Engineering

Experience has shown, in a preliminary manner, that it is possible to use rectified panoramic photography in both the making of low-order measurements and in the determination of the environmental conditions affecting the location and design of major civil works. Included among the areas in which prototype work indicates that the satellite materials particularly applicable are:

Water/Lake Surveys and Pollution Effects
Dam Site Selection and Inventory
Route and Site Selection (roads, canals, major structural complexes, etc.)
Location of Sand and Gravel Deposits
Flood Plain Delineation

3.1.3 Urban Analyses

Utilizing higher resolution satellite strip photography for interpretation, and rectified panoramic photography for the preparation of base mosaics, studies of housing quality, urban land use, and demography may be feasible on a rapid basis heretofore not possible. In this manner, estimates of conditions in previously unstudied urban areas, or in those in which the available data are outmoded owing to the dynamics of the urban flux, may be affected.

3.1.4 Ice and Snow Studies

The broad regional overview afforded by satellite coverage on a repetitive basis, suggests that it may be uniquely useful in the study of sea ice phenomena (including surface characteristics, transient features and flow patterns). Accelerating interest in high latitude regions further suggests the importance of a better understanding of sea ice and its movements as it affects surface and submarine shipping.

Satellite photography can be further exploited in terms of the hydrologic importance of massive snow accumulations in mountain systems, and the impact of the accumulations on the design of flood control systems and watershed management programs. The translation of estimated snow depth measurements and areal distribution into available water volume; further examined in terms of historical melt rates and available channel capacities, can provide data of major economic significance.

3.2 Positioning and Dimensioning

3.2.1 Accuracy of Dimensioning from Satellite Camera Records

Purpose

The purpose of this task is to analyze the photographic records from past and current satellite cameras to determine the accuracy with which dimensions of ground objects can be computed from measurements on the photographs. It has been reported previously that certain dimensions such as tree heights and river widths can be determined from satellite imagery but no comprehensive analysis has been made on all available record types covering ground objects of many sizes and shapes.

Approach

A theoretical analysis will first be made in which errors will be propagated through the mathematical model. Realistic values for measuring errors, attitude errors, ephemeris errors, etc. as determined from past experience will be used as inputs to this theoretical analysis. This portion of the task is extremely important even though it represents a relatively minor part of the entire effort. The results from these theoretical analyses will be confirmed by sample measurements on real photographs of areas where there is ground truth.

Product

The product of this task will be a final report containing a description of the theoretical analysis and the analysis using real photography, all mathematics and the results of the analyses. The report also will contain a matrix showing all satellite records examined (in the column) and a variety of ground objects (in the rows) with an accuracy figure for each intersection. A partial matrix is shown below:

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ALTITUDE-500,000 ft.

CAMERA RECORDS

GROUND ORBITS	KH-5	KH-4	KH-7
OBJECT HEIGHTS (over 75')			
OBJECT HEIGHTS (under 75')			
AREA (over 100 acres)			
AREA (under 100 acres)			

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3.2.2 Computer Programs for Dimensioning and Positioning with Satellite Photography

Purpose

The purpose of this task is to identify, obtain and modify computer programs concerned with dimensioning and positioning.

Background

During the past ten years dozens of computer programs have been prepared for classified geodetic, mapping, targeting, and dimensioning purposes. Most of these programs have high security classifications and therefore are known to very few people. The security classification on many could be removed without any danger of compromise and the programs could be made available 25X1

to a larger circle of users. Some of the programs were written for side studies and have not become a part of any production uses. These so-called "one-shot" programs can perform useful computations and should be made available. Many of these, and even production, programs have been lost and others will be lost unless a concentrated effort is made to preserve them.

Approach

Personnel who have been involved with the analysis, writing or using of these programs over the past 5 to 10 years will be assigned to determine the status of all programs that can be located in the various classified government agencies. The programs will be examined for purpose, currency, operating condition, available documentation, etc. Those programs which are considered worthy of keeping will be code-checked more thoroughly, provided with operating instructions, described in detail, listed and adequately documented. A catalog of these programs will be prepared and a master set of cards and/or tapes will be assembled.

Products

Final report describing the work performed
A catalog of all programs and subroutines
Adequate documentation
A master file of cards and tapes

3.3 Data Base

The purpose of this task is to define, design, and begin to create a research data base which would result in a common, unified, and systematic means by which all of the various ARGO participants could utilize overhead recon imagery and collateral data. The development of such a base would include consideration of such factors as:

- Imagery Collection/Mission Planning
- Geographic and functional areas of interest (classification system)
- Mosaicking and imagery/data formatting
- Data/Imagery indexing, search, storage and retrieval
- Integration of recon-derived information with other collateral data inputs (truth, auxiliary data, other sources)
- Interrelation with photogrammetric/mensuration software
- Facility, personnel, and training requirements
- Future "operational" functional implementation for all agency participants

It is anticipated that considerable use of NPIC's facilities, equipment, and software would be made during the development of the data base. [redacted] imagery data base inputs would also be considered.

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4. SAMPLE WORK STATEMENT

The following is a sample work statement which includes a definition of the scope of the proposed work, a description of how the tasks will be defined, sets staffing and funding limitations, and defines reporting procedures.

STATEMENT OF WORK

Title: Technology for Imagery Exploitation (TIE)

A. GENERAL

The contractor will provide the personnel, facilities, and best efforts consistent with the established level of funding, for the solving of scientific and engineering problems and for the transferring to the customer the technology concerning the exploitation of remote sensor imagery and data.

B. SCOPE

The contractor will perform specific tasks concerning both the quantitative and qualitative aspects of remote sensor imagery and data. These tasks will include, but not necessarily be limited to, consideration of the following factors:

1. type of sensors--spectral region, scales, distortions, format and resolution.

2. acquisition factors--altitude, attitude, weather, time and frequency.

3. subjects of interest--as defined by ARGO, other member agencies.

4. problems--detection, identification, location, size, status, condition, and forecasting.

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In regard to the above factors, the contractor will be required to perform a variety of tasks including, but not necessarily limited to, the following:

1. basic and applied research
2. development of exploitation techniques, procedures and hardware performance specifications
3. technical and economic trade-off analyses
4. concept development, testing and verification
5. exploitation system design
6. training
7. system implementation and support

The contractor will provide scientific expertice to include, but not necessarily be limited to, the following disciplines:

Electronic Engineering
Civil Engineering
Physics
Industrial Design
Engineering Sciences
Forestry
Wild Life Management
Geography (cultural-physical-social)
Geology (general-exploration-engineering)
Geophysics
Photointerpretation
Geodetic Science
Mathematics
Photogrammetry
Astronomy
Computer Programming/Analysis
Orbital Mechanics
Photographic Processing

In performing approved tasks, the contractor shall maintain close liaison with the customer so as to assure that those specific technical areas of particular concern to the customer are adequately covered. The tasks will be undertaken on the basis of guidelines jointly developed by the customer and the contractor. These guidelines will include the priorities that are to be applied to certain tasks, and the problems that will be most critical in future customer activities. In satisfying task requests, emphasis will be on technical quality as well as on timeliness of response.

C. TASKS

Specific tasks will be defined and mutually agreed to by the customer and the contractor at the beginning of the contract. Expected technical results, work schedule, and the level of effort will be specified and agreed to prior to commencement of work, and a task order(s) will be issued by the contracting officer. A separate technical task will be established for the purpose of providing the contractor with engineering man-hours to be used during task definition meetings, for providing special briefings, and for participation in discussions appropriate to the technical areas specified herein.

In addition to the above tasks, the contractor shall develop and maintain the capability of providing scientific information on a quick response basis to be known as a Quick Reaction Response (QRR). The QRR is defined as a response estimated to require not more than 80 hours of a scientist's or engineer's time plus necessary support. The customer will assign a priority relative to other work assigned under this contract. The form and level of detatil in responding to inquiries shall be as mutually agreed.

In performing the foregoing work, the contractor will utilize, in addition to the information already available to it, such classified and unclassified information as made available by or pursuant to a request by the customer.

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D. STAFFING AND FUNDING

The staffing and funding will be for a period of performance of twelve (12) months. The level of funding may vary from year to year. The funding will cover technical and support manpower and the necessary computer services and support materials to accomplish the anticipated work load.

The contractor will submit a staffing plan for each approved task. It is understood and agreed that the contractor shall: 1) except for reasons beyond its control or because of the needs of the tasks as they develop, utilize in the performance of the work, the services of persons identified in the staffing plans or other persons equally qualified for the specific task; 2) provide the Agency with notification of any circumstances which necessitate a significant deviation from the staffing plan; 3) follow generally the approach toward the conduct of the work outlined in the task order(s); 4) obtain the specific approval of the customer before undertaking any foreign travel under this contract; and 5) devote to the work the approximate level of effort by contractor personnel as specified in the staffing plan, or their dollar value equivalent.

25X1A [redacted] will serve as the Contracting Officer's Representative and will assign Government technical monitors for special tasks as required. The contractor will assign an over-all program manager to act as a focal point for the communication between the customer and the contractor.

E. REPORTS

Throughout the performance of this program, the contractor will maintain close liaison with the customer.

Beginning thirty (30) days from the effective date of this contract, the contractor will provide the customer with written monthly status reports, in ten (10) copies each. In addition, it is anticipated that from time to time the customer may request oral briefings on those findings which warrant attention. The time and format of the oral briefing(s) will be arranged by the customer in consultation with the contractor.

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In addition to the foregoing reports, the contractor will, upon completion of each task order, submit to the customer the following reports:

1. A draft task report for customer technical and editorial review, in ten (10) copies.

2. Following the receipt of the customer's approval and/or modifications of the draft task reports, the contractor will submit ten (10) copies of the task report.

3. A final oral briefing on the task will be presented if requested by the customer. The time and place of the briefing will be arranged by the customer in consultation with the contractor. The requirement for a final oral briefing may be waived by the contracting officer, if it is determined that the oral briefing is not appropriate to a specific task.

5. PROGRAM MANAGEMENT

This program will be administered at staff level of the [redacted] The position of the [redacted] and the organization of [redacted] to department level, are shown in the Statements of Qualifications.

5.1 Program Organization

The program manager for this effort will be [redacted], Manager, Special Projects Office. He will have complete responsibility and accountability for the management of the work, including planning, technical performance, and cost and schedule control for all program functions. He will be the primary point of contact to the customer. He will be assisted by the technical personnel at [redacted] from which he will form special teams to address assigned tasks. Individual names of these technical personnel are included in the Statements of Qualifications.

5.2 Schedule

Separate work scheduled will be prepared for each assigned task and submitted to the COR for approval.

5.3 Manpower Requirements

The estimated level of effort for a twelve (12) month period will be submitted under separate cover upon request.

25X1A 3. EXPERIENCE IN SATELLITE PHOTOGRAPHY EXPLOITATION

3.1 History

In this section and the next is a short history of the work performed by 25X1A in the general area of satellite photography exploitation. The first part is a narrative telling how and why certain avenues of research were undertaken and the results achieved. It attempts to show the chronological development of the work, first in the general area of mapping and geodesy and then in the general area of surface environmental and geoscience analysis.

The second section contains resumes of representative tasks. It is the classified portion of the Statements of Qualifications.

Over ten years ago 25X1A 25X1A was instrumental in generating a proposal for the construction of a camera system, orbiting the earth in a satellite, for the determination of ground point positions on a world-wide basis. Upon the successful adoption 25X1A of that system was given the responsibility for the design, implementation, and testing of the complete ground data reduction system. Equipment such as the Coordinate Readout Matcher or 25X1A CRM (for determining the photo coordinates of UTM grid intersections on 1:250,000 scale maps), the Stellar Coordinate Reader or SCR (for measuring, semi-automatically, the coordinates of stellar imagery), a storage and

25X1A retrieval unit for [redacted] photo chips, and others were designed and built. Some 46 computer programs, ranging from coordinate transformation and correction programs up to the OREAXE (for determining camera attitude from stellar measurements) and Differential Orbit Improvement or DOI Programs (for the determination of an orbit ephemeris from photo coordinates and corresponding ground control data), were prepared. Upon successful orbiting 25X1A of the initial [redacted] missions, the entire data reduction system--procedures, equipment, and computer programs--was tested and then turned over to the Army Map Service for production use.

The initial testing of the [redacted] system indicated that the potential 25X1A accuracy of that system had not been attained. Therefore, [redacted] under- 25X1A took studies which led to large improvements in the accuracy of the [redacted] 25X1A system. These studies indicated two major routes to follow: (1) the incorporation of improved observations in quality, quantity, and variety; and (2) the improvement of the data reduction programs. It was found, for example, that by including observations in the Southern Hemisphere (not originally done) a threefold improvement of the orbit in the Southern Hemisphere would be obtained. In addition, it was suggested that pass points and partial control (sea shore points) and ground tracking observations (radar, 25X1A [redacted] cameras, doppler, etc.) be employed. The principal data reduction program, the DOI itself represented a considerable improvement of the original version prepared by the Smithsonian Astrophysical Observatory. However, a series of studies indicated that it could be still further improved by (1) incorporating the above new types of observations, (2) including datum shifts, (3) expanding the air drag and gravity models, and (4) providing for simultaneous adjustment of all five successful [redacted] missions. As a result of 25X1A those studies a new program, the RECAP program, was prepared and a continuing effort to improve, update, and provide for more ease and sophistication in the operation of that program was undertaken. Finally, to aid in the testing of the RECAP program, a fictitious data generator program, FIDAGE, was prepared. The most recent studies by [redacted] the so-called Ultimate Accuracy 25X1A Studies, showed that, with the additional observations and the new RECAP program, the full potential of the 25X1A [redacted] system could be achieved.

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As a result of its successful implementation of the [redacted] data reduction system, [redacted] was given a task to design a data reduction system capable of handling photography from any satellite camera system. Thus, the Universal Photogrammetric Data Reduction and Mapping System, the UPDRAM System, evolved. [redacted] prepared a complete outline of the UPDRAM System, including flow charts (and narrative) depicting operational procedures, equipment functions, material flows, storage and retrieval operations, and software (computer programs). Specifications for all equipment were prepared. An exhaustive study of storage and retrieval systems, both existing and under development, was carried out and experiments were completed in order to validate the efficacy of the adopted storage and retrieval system. Also, numerous point transfer studies were undertaken in support of the UPDRAM System design. A task was carried out to determine the expected production rates of the various equipments of the UPDRAM System in order to establish the most effective equipment mixes for various types of satellite photography. Finally, a series of Operational Procedures Manuals was prepared, the purpose of the manuals being to provide production personnel with complete instructions for the operation of the UPDRAM System. Although [redacted] did not construct any of the equipment for the UPDRAM System, it did prepare a number of the key computer programs. These included programs in support of the photo inventory and geodetic control inventory (storage and retrieval programs) and a Mission Reduction Program. The Mission Reduction Program would apply all necessary corrections and transformations to photo coordinate measurements, extract from the geodetic control inventory all necessary ground control information, format the resulting data for the RECAP Program, and then take the resulting data from the RECAP Program to update the geodetic control inventory.

Although the ultimate objective of the UPDRAM System was to be able to handle future camera systems designed specifically for mapping, several existing camera systems employed for reconnaissance offered mapping possibilities. Therefore, Autometric began a series of tasks whose aim it was to provide a means for production mapping with reconnaissance type photography.

This photography is, generally, of two types: (1) the prime intelligence photography, mainly panoramic but some strip, of very long focal length; and (2) the terrain index photography, frame photography of very short focal length [redacted]. The tasks were directed towards both types of photography. A series of studies was carried out with the terrain index photography to determine its accuracy--in particular, to determine if it had sufficient accuracy for the production of 1:250,000 scale maps--and, then, to develop production mapping procedures for that photography. Because of its high resolution, a major effort was undertaken to develop production mapping procedures for the KH-4 panoramic photography. Panoramic photography, because of the dynamic manner in which it is exposed, has generally been considered to have very poor accuracy. However, [redacted] was able to develop post flight calibration procedures which made possible accurate mapping with panoramic photography with virtually no ground control. In addition, [redacted] designed, and evaluated the results of, the Engineering Tests for panoramic photography on the Universal Automatic Map Compilation Equipment or UNAMACE (the principal item of equipment in the UPDRAM System). Finally, [redacted] prepared the Absolute Orientation and UDAP programs (to generate panoramic photography input parameters for the UNAMACE) and the PASOUT program (for the post flight calibration of panoramic photography). [redacted] also carried out studies and experiments which led to the development of post flight procedures for the [redacted] strip camera systems.

With the exception of the [redacted] System, all satellite camera systems now flying were designed for reconnaissance. Thus, though major errorts have been undertaken for the employment of photography from such systems for mapping, such photography is not as suitable as would be photography designed for mapping. Therefore, very shortly after the [redacted] program was underway, [redacted] began studies directed towards the design of a camera system specifically for mapping. These studies, culminated in the report, An Optimum Cartographic Collection System, contained equations, graphs, tables,

and so on, which could be employed for designing an optimum mapping camera system. In addition, a number of support studies were carried out to determine the optimum design, and the attainable accuracy, of stellar attitude camera systems. The studies resulted in the recommendation of design parameters for several mapping systems. One of those recommended systems has since been adopted for the terrain index camera for a new reconnaissance system.

Because of its experience in the design of the UPDRAM System, and its intimate knowledge of the has just recently completed the task of designing a new data reduction system, the Advanced Map Data Reduction System, for the production of 1:50,000 and 1:250,000 scale maps from New Search photography. investigated equipment, computer programs, and operational procedures--both existing and under development--in order to design a number of alternative data reduction systems. Then, based on error propagation and cost/effectiveness studies, a system design was selected and complete description of that system, along with equipment specifications, was prepared.

has been active in widening the state-of-the-art in satellite image interpretation for the geosciences since early 1964. The company's first program in determining the information content of satellite imagery was initiated as a result of the experiments performed during the research and development of the mapping system. The purpose of the program was to determine the environmental data content of the imagery of the KH-5 and KH-4 Systems. The study involved the interpretation and mensuration of natural and man-made phenomena and detail. The general areas of interest included geology, vegetation and land-use, show and ice cover, cloud cover and urban features.

The study indicated that satellite imagery contained useful data although an exact measurement of the interpretability was not ascertained. It was recommended that additional work be accomplished in order to determine

the ability of photo interpreters to produce accurate and complete terrain and cultural products.

The program Evaluation of Experimental Strategic Military Geographic Intelligence from Short Focal Length Satellite Imagery was initiated in late 1964 as a result of the first program. The study had three basic objectives: (1) the construction of an uncontrolled mosaic of a continent; (2) the derivation and compilation through photo-interpretation of basic geoscience data of the entire continent without the aid of collateral materials; and (3) the synthesis of the basic data into military geographic intelligence overlays.

The continent of Africa was selected as the study area. The continent was divided into 12 sections each covered by a mosaic and 8 overlays. The mosaic sheets were produced from 6 KH-5 [redacted] missions. The imagery was selected in such a manner as to minimize cloud cover. The mosaic was constructed at a scale of 1:4,000,000 and then enlarged for presentation to a scale of 1:2,000,000. The geoscience overlays were compiled through stereoscopic interpretation of the enlarged KH-5 frames. The military geographic intelligence overlays were then synthesized from the interpreted data. 25X1A

The conclusions of the study were that valuable and highly useful geoscience data and military geographic intelligence could be obtained from satellite imagery. It was recommended that the imagery of the KH-5 system and all other satellite systems be utilized to expand the interpretation state-of-the-art and that an experiment be performed with the imagery of the KH-4 system to obtain data for military and civil engineering.

The program Use of Satellite Photography for Military and Civil Engineering Purposes was initiated in 1966. The objectives of the study were to ascertain the amounts and type of civil and military data, required for major works, that can be extracted from KH-4 satellite imagery.

The first phase of the program required the systematic interpretation of satellite imagery covering a broad distribution of geographic, climatic and physiographic regions.

The second phase required the construction of a semi-controlled mosaic of a 10,000 square mile area in [redacted] From the mosaic and imagery interpretation an effort was made to acquire reliable engineering design information. These data were used to select alternate military highway routes between two points and five hasty-type airfields.

The third phase required the interpretation and mensuration of engineering data along a major proposed highway route. This data was then evaluated and compared with engineering data prepared for development of the route.

The expertise acquired during the program was then directed to the detailed definition of an organization that will make pragmatic everyday use of satellite photography for preliminary engineering design purposes in support of field army requirements.

The development of the state-of-the-art was brought to the attention of the President's Scientific Advisor Committee in 1967. This office initiated Project ARGO which brought together scientists from government agencies to study the potential of satellite imagery for earth resource development. [redacted] supplied its facilities, managerial talents and general satellite interpretation knowledge to the group. The personnel of [redacted] conducted an orientation course for the scientists at the initiation of the project. Following that phase the company supplied the logistical support necessary for successful completion of the program.

During the same period that ARGO was being performed personnel of [redacted] were involved in a project to select a series of routes of communication in the Sudan for the U. S. Strike Command. The effort involved

the construction of a 1:1,000,000 mosaic and several 1:250,000 mosaics of the country. The objective of the study was to determine the best supply routes between Port Sudan, on the Red Sea, and Khartoum. A series of geoscience overlays was prepared and the best routes were selected. These routes were then studied in detail and a series of military geographic intelligence overlays was prepared. In addition, a study of the rail, port and airfield facilities was made. Plans were constructed showing what improvements would be required for use in the event the STRICOM had the need to operate in the theater.

25X1A In 1968 undertook a program for the development of a Terrain Study Prototype for the U. S. Army Engineer Topographic Laboratory. This program was designed to illustrate, through an operational test, the effectiveness of using a combination of satellite imagery and collateral materials for the solution of regional military problems relating to terrain and the natural environment. The study was addressed specifically to problems concerning military geographic intelligence and irregular force operations.

The program required the production of basic geoscience overlays at scales of 1:250,000 and 1:50,000. This data was then synthesized into military geographic intelligence overlays suited for tactical and strategic planning. The study illustrated that KH-4 can be enlarged to a scale of 1:50,000, yet retain sufficient ground resolution allow stereoscopic interpretation.

Also in 1968, work on the Classified Automated Military Geographic Intelligence System (CAMGIS) was initiated and completed. This ground data handling system configuration is based upon the aforementioned exploitation work with classified satellite systems over the past eight years and describes a complete classification, indexing, accession, storage, and retrieval system which the Army can implement to produce military geographic intelligence on a world-wide basis.

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This system spells out a two year and five year development cycle
25X1D including the use of [redacted] frame camera system and includes facility equipment, personnel, and cost estimates for the establishment of such an Army satellite intelligence exploitation capability.

25X1A [redacted] conducted the Terrain Study Prototype of North Korea for the Engineer Topographic Laboratory. The principal objective of that program was to develop a terrain study prototype covering North Korea. The end products of the program were a set of briefing aids and graphics designed to demonstrate the feasibility of utilizing satellite photography for the production of terrain data at small, medium and large scales.

The effort included the construction of three mosaics with basic terrain data interpretation. The study also included the production of a 1:12,500 city plan and a 1:3,500 scale port plan from
25X1D [redacted] satellite imagery.

25X1A In 1967 [redacted] entered into a time and materials contract with the Advanced Research Projects Agency to provide photo-interpreters for the Terrain Atlas Nuclear Test Detection Program. One phase of the program provided two photo geologists to interpret satellite imagery over potential test sites in the Soviet Union. The mission of the geologists was to interpret satellite imagery and correct the geology, soils, vegetation and geomorphology overlays that were to be presented as atlases of potential test areas. A total of 13 atlases were revised during the two year term of the contract.

The second phase of the contract required the services of a third geologist. The objectives of the study were to determine the quantitative aspects and the physical configuration of geologic formations through the use of a projection stereoplotter. In addition, the task was to determine

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the feasibility of utilizing the stereoplotter as a tool for photo geology. The project explored the feasibility of using the projector to record dip and strike, measure strategraphic sections and delineate formational contacts of geologic structures. The final task of the program involved an evaluation of the data gained from the experiments for this scientific value and accuracy, as well as to ascertain the utility of the data in the ARPA Terrain Atlas Program.

Because of an increased interest in additional sensors to be employed in satellite operations, [redacted] embarked upon a series of studies designed to evaluate and validate the techniques used throughout the intelligence community for exploitation of conventional and unconventional imagery. The purpose of these studies was to insure that future systems carried the optimum sensor package for the maximum information content. These studies involved exploitation systems analyses, an evaluation of screening and targeting techniques and a design of human factor testing procedures to validate conclusion of the studies. 25X1A

The first of this type of study was a basic human factors test experiment with image interpreters utilizing both infrared and optical photography, collected during both daylight and night hours, in order to produce an interpretation manual of typical imagery targets. This general work was followed by an investigation of specific areas of intelligence value, training implications, mensuration and exploitation techniques and equipment for unconventional sensor use against specific NPIC Essential Elements of Information. Sensor outputs studied included color, camouflage detection, laser line scan and passive radiometry.

Following these studies, [redacted] engaged in a comprehensive study of the intelligence value of satellite imagery (both line scan and photographic) against one particular set of targets--Mobile Ground Radars. This study analyzed the relationships of interpreter performance, target ground resolution and intelligence analyst estimation. 25X1A

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A number of human factors problems occurred in the previous efforts, resulting in several Photo Interpreter Performance analyses conducted by [redacted] personnel for NPIC. The first involved a determination of the resolution/performance relationship using as stimulants various combinations of stereo/non-stereo/color/black and white imagery. Tasks included test design, test administration, analysis of test results and overall coordination of efforts of other contributing contractors and NPIC personnel. An investigation of training and training requirements was indicated by the results of the study described above. This was accomplished with the aid of NPIC interpreters throughout the experimental phase. Following this, a complete analysis of the imagery exploitation and collateral data support process of NPIC was conducted.

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Because of the growing concern for the knowledge of the resolutions required to identify certain targets and the relationship of resolution to interpreter preformance, [redacted] undertook an additional series of studies designed to determine this relationship and define the resolution required to identify certain ground targets, based on increased sensor capabilities. Various targets such as mobile radars and missile sites, and ground sites of both the targets were used in these studies. Controlled test programs were designed and administered to experienced photo interpreters. Based on the performance of the interpreters, certain ground resolutions were established providing the answers to the current Essential Elements of Information required for each target type.

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The need for the development of a practical means for implementing inspections which could contribute to the verification of arms control agreements led to [redacted] involvement in a program to compare satellite imagery with conventional aircraft imagery. This comparison was accomplished to see if the conventional aircraft imagery (specially flown to simulate the satellite photography) could compare with the aircraft imagery in the information content. In this program [redacted] analyzed and compared satellite imagery using qualitative and quantitative measures including

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standard photo interpretation techniques, modulation transfer functions, granularity and density measures. The results of this program indicated that large scale satellite imagery and large scale aircraft imagery were compatible in information content whereas the small scale imagery from both sources did not compare.

In addition to the specialized types of R & D conducted for NPIC, a complete systems analysis of the NPIC exploitation capability and data flow was also conducted. Recommendations (some of which have since been implemented) included those concerning personnel organization/teaming relationships, equipment utilization, software utilization, data base mechanisms (access, storage, and retrieval), geographic vs. functional targeting intelligence inputs/outputs, and training.

25X1A Since 1970 [redacted] has performed varied R & D tasks for a continuing NPIC program "Basic Research in Precise Measurement". The objective is to determine the precision of mensuration and to assist in improving the accuracy of mensuration through a variety of techniques. Areas investigated to date include:

1. Reticle Design
2. Viewing Illumination
3. Film Stability on Measuring Devices
4. Human Engineering Instrumentation Design
5. Design and Development of Semi-Automatic Pointing Devices

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Continued services have been supplied to various members of the intelligence and mapping community. Much work is performed on a

stand-by consultant basis. Rather than detail each and every task--let it suffice to state that the skills of [redacted] personnel have been in continued demand and continue to satisfactorily meet the requirements of varied R & D programs. Of particular note is the nature of these task--by and large work performed is in support of real needs--only infrequently are "study" contracts obtained; rather immediate and practical problems are signed on, and thus very little "blue-sky" performance is tolerated or permitted. 25X1A

Such problem solving R & D activities are currently being undertaken in the following areas:

- Coherent Side Looking Radar Exploitation (ocean and land surveillance).
- Underwater Camera System Analysis
- Radar Target Location
- Orbital Computer Programming
- Human Factors Testing for Near-Real-Time Sensor Exploitation
- Training Package and Photo-Interpretation Key Design and Production
- Photogrammetric/Computer Systems Analysis

This rather comprehensive account of [redacted] experience in satellite imagery exploitation was given to show the depth of our involvement in many facets of this work in the classified area. In a separate volume, Statements of Qualifications, is shown [redacted] experience in lesser classified and unclassified programs. 25X1A 25X1A

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3.2 Contract Descriptions

In this section will be found resumes of representative classified tasks. They are presented here to show in limited detail the kinds of problems associated with satellite photography that have been addressed by [redacted] during the past 15 years. Each of these tasks has been fully documented for the original customer.

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Title: The Differential Orbit Improvement Program, DOI II

Job No.: 106-1

Objectives: To prepare an improved version of the DOI Program.

Approach: The Differential Orbit Improvement Program, DOI, had been prepared by the Smithsonian Astrophysical Observatory in computer machine language, which severely limited its use. As a first step, the program was rewritten in FORTRAN II language for the IBM 7090 computer at the Army Map Service, incorporating linking so that the entire program could be run at one time. Sophisticated gravity and air drag models were added to the program which, originally, included only empirical parameters.

Results: The improved version of the DOI Program, the DOI II, with complete documentation, were delivered.

Title: Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS)

Job No.: 106-3

Objectives: To present a detailed description of the UPDRAM System, including the flow of materials through the system.

Approach: The UPDRAM System was first divided into five phases; (1) materials preparation and storage, (2) evaluation, (3) mensuration, (4) map compilation, and (5) computation. Each of the five phases was further subdivided into individual functions. Detailed descriptions of each of the functions within each phase were then prepared, each function description being accompanied by a detailed function flow chart. Finally, detailed Technical Requirements for each piece of equipment in the system, with the exception of the off-the-shelf items, were prepared.

Title: Storage and Retrieval System Study

Job No.: 106-6

Objectives: To determine an effective storage and retrieval system for multi-volume photographic materials and geodetic data supplied to and generated by the Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS).

Approach: Storage and retrieval systems, both operational and those under development by governmental agencies and commercial firms, were evaluated using the following criteria: (1) type, quantity, and form of material used in the system; (2) characteristics of the master file; (3) system performance; and (4) utilization of present system components to devise a suitable storage and retrieval system for the UPDRAM System.

Results: A Photographic Record Storage and Retrieval System and a Geodetic Data Storage and Retrieval System were recommended, the former based on bin storage of the original negatives, the latter on scroll storage on Kalvar employing the Command Retrieval Information System (CRIS).

Title: The Universal Photogrammetric Data Reduction and Mapping System, Production Analysis

Job No.: 126-8

Objectives: To provide a complete production analysis of the Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS) including the production scheduling of material, data, and personnel as a continuous flow between and within each piece of equipment in terms of quantities or rates of production.

Approach: The production rate of each piece of equipment in the UPDRAM System on a unit basis was first determined. These production rates were then expanded to 1000 photographs for the triangulation and orbit adjustment function and to such production rates for each piece of equipment as would keep the Universal Automatic Map Compilation Equipment busy full time in the mapping function. The production scheduling for the triangulation and orbit adjustment of a single complete mission was then determined. Finally, production rates and scheduling for the production of 1,000,000 square miles of mapping at scales of 1:50,000 and 1:250,000 were computed.

Results: The production analysis was presented in the form of tables and charts, providing criteria (1) for determining the relative numbers of balance of equipment and personnel for optimum operation with designated input materials, and (2) for the selection of input material configurations for optimum production.

Title: System Mathematical Analyses and Computer Programming

Job No.: 126-13

Objectives: To prepare the computer programs necessary to implement the Computer Support function of the Universal Photogrammetric Data Reduction and Mapping System.

Approach: Four programs were completed. They were (1) an Absolute Orientation Program, (2) a Photo Inventory Storage and Retrieval Program, (3) a Control Point Inventory Storage and Retrieval Program, and (4) a Mission Reduction Program. The purpose of the Absolute Orientation Program, whose analysis was developed under Job No. 126-22, is to perform a relative orientation, absolute orientation, and non-conformal adjustment of a stereo pair of frame or panoramic photographs to ground control. The photo inventory programs store new photo records (data) on the photo inventory tapes, update the photo records already on the photo inventory tapes, and retrieve photo records from the photo inventory tapes. Similarly, the control point inventory programs store new point records on the control point inventory tapes, update the point records already on the control inventory tapes, and retrieve point records from the control point inventory tapes. The Mission Reduction Program accepts photographic measurements, ground control data, camera position and attitude data, camera calibration data, evaluation data, and so on; performs a least squares adjustment of that data constrained to an orbit; and produces a final Mission Photo Inventory Tape for merging into the Master Photo Inventory Tape.

Results: The computer programs, in FORTRAN IV, and complete program documentation were delivered.

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Title: Investigation of Photographic Recording of Geodetic Control

Job No.: 126-15

Objectives: To establish and evaluate procedures for the acquisition, identification, marking, and formatting of photo-identifiable geodetic control to be placed in the Geodetic Control File of the Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS).

Approach: Studies were conducted and tests performed to:

(1) determine storage scale and format for photo imagery of geodetic control,

(2) determine techniques and equipment for preparing photographic records,

(3) determine selection criteria for terrain points,

(4) establish control density requirements, and

(5) investigate storage and retrieval practices.

An area within the continental United States of suitable size for test purposes was selected, and geodetic control information within that area suitable for use in establishing the Geodetic Control File was collected. A sample Geodetic Control File was then prepared.

Results: Suitable procedures for the preparation of a Geodetic Control File were developed.

Title: Information Content of Certain Reconnaissance Satellite Imagery.

Job No.: 126-16

Objectives: The purpose of the program was to determine the environmental data content of the imagery of the KH-5 and KH-4 satellite systems. The program's interpretation and mensuration efforts involved a sampling of the spectrum of natural and man-made phenomena and detail. The general areas of interest included:

- Geology
- Land Use
- Snow and Ice Cover
- Clouds
- Urban Features

Approach: In order to determine the value of satellite photography and its possible application to the disciplines of geology, and resources exploration, an initial review of all pertinent geologic and geomorphologic criteria was conducted. Those essential elements that were considered to be interpretable from satellite photography were isolated. The terrain elements were then compiled into target lists to serve as interpretation guides.

Imagery was selected and interpreted. These interpretations were then compared with collateral data for accuracy and data content.

Results: The study indicated the satellite imagery contained much useful data although an exact measurement of the accuracy and completeness of the study results could not be ascertained without further research.

It was recommended that additional research be carried out in order to determine the system's utility to produce an accurate and complete product.

Title: Systems and Combinations Adapted to the Acquisition of Control Geometrically Distributed over the Land Masses of the World

Job No.: 126-17

Objectives: To investigate methods for improving the results obtainable with the [redacted] satellite photography.

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Approach: The initial data reduction and testing of the [redacted] photography indicated that the potential accuracy of that system had not been attained. Therefore, studies were undertaken to determine ways of improving the observations (in quality, quantity, and variety) and of improving the data reduction programs, in particular the DOI program. Tests were undertaken in which observations in the Southern hemisphere and ground tracking observations [redacted] were incorporated, and the value of datum shifts in the DOI program was investigated.

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Results: It was recommended that ground control be as well distributed as possible in making orbit adjustments, that ground tracking observations be incorporated whenever possible, and that pass points and partial control points (sea shore points) be employed. It was further recommended that the DOI program be expanded to include datum shifts. (This latter recommendation was implemented under Job No. 126-23, which resulted in the RECAP Program.)

Title: An Optimum Cartographic Collection System

Job No.: 126-18

Objectives: To determine the parameters of an optimum cartographic collection system operating in a satellite orbiting the earth and capable of acquiring photography suitable for topographic mapping and point location.

Approach: The requirements, both in content and in accuracy, for topographic maps at large and medium scales (1:50,000 and 1:250,000) meeting military needs, and the requirements for point location, were first established. The parameters of cartographic collection systems were then developed. The functional relationships between these parameters and the accuracy, content, and ground coverage of a cartographic collection was developed and presented both in the form of equations and in graphical form (using the graphs, trade-offs between the various parameters can be determined). The parameters of a number of existing and proposed systems were evaluated with respect to their ability to meet the requirements of content and accuracy for large and medium scale mapping and for point location. The costs--including development, equipment, booster, launch and recovery, data reduction, and map production--of each of the existing and proposed systems were considered.

Results: An optimum cartographic collection system was selected.

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Title: The Universal Photogrammetric Data Reduction and Mapping System, Optimum Operating Procedures

Job No.: 126-19

Objectives: To determine optimum operating procedures to be employed in the various operational segments of the Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS) for each of several specified categories of input photography.

Approach: A detailed analysis of the UPDRAM System, as defined in Job No. 106-3 and employing the production analyses developed under Job No. 126-8, was developed. The resulting optimum operating procedures were then presented in three volumes, the first presenting a narrative of those procedures, the second containing detailed operational flow diagrams, and the third showing time, manpower, equipment, and material requirements.

Results: Optimum operating procedures for the UPDRAM System were produced.

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Title: Preparation of Operational Programs for the Universal Automatic Map Compilation Equipment

Job No.: 126-22

Objectives: To develop procedures for the determination of input parameters for the compilation of panoramic photography on the Universal Automatic Map Compilation Equipment (UNAMACE), and to determine the adequacy of the UNAMACE operational programs with panoramic photography.

Approach: The analyses employed in the UNAMACE operational programs were investigated. Procedures for the determination of panoramic photo input parameters--based on the transformation of the panoramic photographs to equivalent frame photographs, the relative and absolute orientation of the stereo model formed by that photography, and the non-conformal adjustment of that model to ground control--were developed and tested.

Results: The analyses employed in the UNAMACE operational programs were found to be adequate. The procedures for determining input parameters for the compilation of panoramic photography on the UNAMACE were found to be satisfactory and it was recommended that they be programmed for production use (such a program was later completed under Job No. 126-13).

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Title: Refined Consolidated Adjustment Program, RECAP

Job No.: 126-23

Objectives: To produce a computer program capable of adjusting two or more orbital missions simultaneously.

Approach: Analyses, program design, and program preparation were undertaken to produce a computer program having the following features:

(1) Adjust up to 20 missions simultaneously, but not exceeding a total of 120 adjustable orbital parameters;

(2) handle up to 3725 solution parameters;

(3) employ a gravity model with the capability of using spherical harmonic coefficients of order 18 and degree 18;

(4) accept as input data: radar observations, range-rate (Doppler) observations, ground based camera observations, and orbiting camera observations including complete and partial (sea shore points) ground control and conjugate imagery from separate missions; and

(5) provide as output: orbital parameters for each mission, ephemerides for each mission, coordinates of unknown ground points, corrections to ground tracker coordinates, time bias correction between ground tracker clocks and vehicle clocks, datum shift information, and two residual presentations, sensor and orbital.

In addition, the FIDAGE program, capable of producing fictitious data suitable for testing the RECAP program, was prepared.

Results: The RECAP and FIDAGE programs, in FORTRAN IV for the IBM 7094, and complete program documentation were delivered.

Title: The Evaluation of the Hipernas IIB Inertial Navigation System, The evaluation of a Mapping Satellite for Controlling a Rapid Combat Mapping System USQ-28, and Rectification of Side-Looking Radar by means of High Altitude Photography.

Job No.: 126-24

Objectives: To determine the quality of a map compilation for a specified block of terrain in which little or no previous ground control is available.

Approach: In the first study errors were generated in a sample ground control network with the aid of a simulation model made for the Hipernas IIB inertial navigation system. These errors were then used to perturb a real set of control points associated with real photography. An orthophoto produced in this manner with the use of the B8-Stereomat was then compared with the unperturbed orthophoto to determine and quantitatively analyze the magnitude of the errors introduced by the inertial navigation system. In the second study, pertaining to the geodetic mapping satellite, a similar approach was used insofar as an orthophotograph was the final product of this phase. However, in this situation, the errors were propagated indirectly from a physical model consisting of a pair of overlapping satellite photographs to the ground control through the intermediate media of conventional altitude photography. In the final study the high altitude photograph, or a small sector thereof, was enlarged to the scale of the photographic presentation of the side-looking radar. The SLR was oriented in the plane of the horizon and rectified by comparison with the high altitude enlargement by a manual process which seeks to match detail, one small area at a time. Finally, a best visual match was made between the two film transparencies, the SLR copy superimposed on the enlarged KH-5 photography.

Results: The studies indicated that the qualify of map compilation could be improved by the use of inertial navigation equipment and/or satellite altitude photography.

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TOP SECRET

Title: Evaluation of Experimental Strategic Military Geographic Intelligence from Short Focal Length Satellite Imagery

Job No.: 126-25

Objectives: 1) The construction of a mosaic covering the Continent of Africa;

2) The derivation and compilation, through photo-interpretation, of basic geoscience data covering the continent;

3) The synthesis and compilation of military geographic intelligence overlays from the basic geoscience data.

Approach: This program was conducted without the aid of collateral materials. The area studied was divided into 12 sections, each covered by a mosaic sheet and 8 overlays. The mosaic sheets were produced from six missions and the imagery was selected in such a manner as to minimize cloud cover. The mosaic was constructed at a scale of 1:4,000,000 and then reduced, for presentation purposes, to 1:2,000,000.

The geoscience overlays were compiled through stereoscopic interpretation of the enlarged satellite frames. The military geographic intelligence overlays were then synthesized from the data compiled above.

Results: It was concluded in this study that geoscience and military geographic intelligence could be derived from satellite imagery and it was recommended that other systems be used to obtain preliminary data for military and civil engineering.

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Title: An Analysis of Stellar Attitude Determination by Physical Simulation

Job No.: 126-29

Objectives: To perform studies concerning the precision of attitude determination by means of a metrical camera photographing stars as a function of the number of stars and the distribution of stars.

Approach: Stellar photographs were first taken with the [redacted] Zenith Camera. Some fifty star images on the resulting plates were then identified and measured. The attitude, and the precision of that attitude, were then determined for four subsets of well distributed stellar images and for ten subsets of the fifty stars arranged in other patterns.

Results: Graphs, depicting the precision of camera attitude as a function of the number and distribution of measured stellar images, were presented.

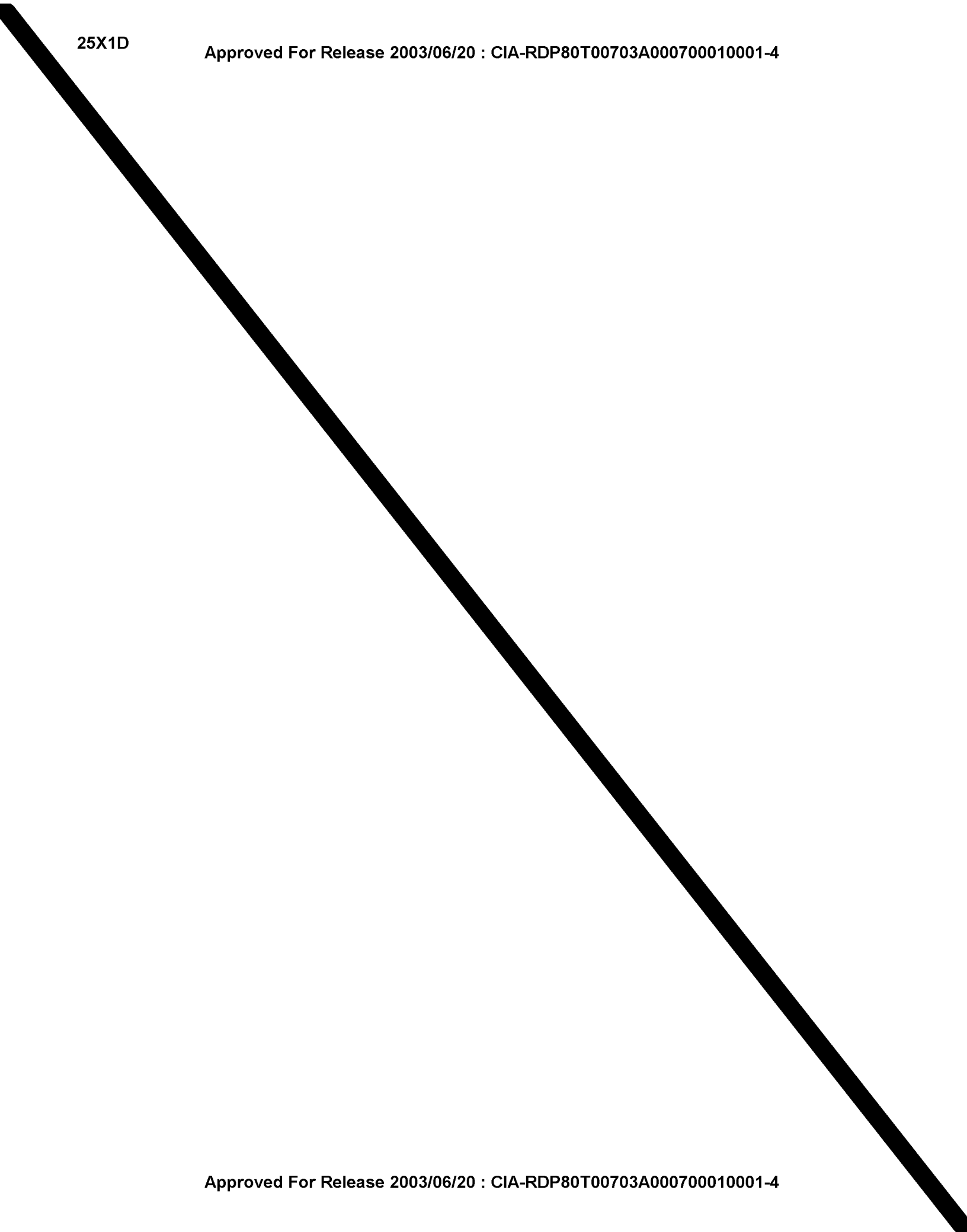
Title: UNAMACE Engineering Test Addendum

Job No.: 126-31

Objectives: To determine the capabilities of the Universal Automatic Compilation Equipment (UNAMACE) when employing panoramic photography taken from satellite altitudes.

Approach: Orthophotographs and drop line contour plots were produced by the UNAMACE at scales of 1:250,000 (with contour intervals of 100 feet and 200 feet) and 1:100,000 (with a contour interval of 50 feet), from contact diapositives and 3.3X enlarged diapositives respectively, of selected stereo pairs of panoramic photographs taken with the KH-4 camera system. The production rates and number of stops during UNAMACE operation were noted and the accuracy and quality of the orthophotographs and drop line contours were determined.

Results: Orthophotographs produced by the UNAMACE at a scale of 1:250,000 will meet National Map Accuracy Standards, and the UNAMACE is capable of producing drop line contours at a contour interval of either 200 feet or 100 meters meeting National Map Accuracy Standards, when adequate ground control is available. Further, when 3.3X enlarged KH-4 panoramic photography is employed, orthophotographs produced by the UNAMACE at a scale of 1:100,000 will meet National Map Accuracy Standards and the UNAMACE is capable of producing drop line contours at a contour interval of either 100 feet or 30 meters.



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Title: Studies of Photo Interpreter Performance as a Function of Resolution, Stereo, and Color

Job No.: 165, 2241

Objectives: To determine the relationships between interpreter performance and photographic ground resolution.

Approach: Human factors studies were performed to determine the resolution performance relationships. [redacted] assisted in the ground truth data collection phases of the studies. [redacted] administered the tests to NPIC photointerpreters, assisted on the test design and analysis and served as overall coordinator between the other contributing contractors and NPIC personnel. 25X1A 25X1A

Results: Two studies were published: The Analysis of Missile Sites as a Function of Photographic Ground Resolution (S) and The Measurement of Photographic Images by Human Operators (U).

In the missile study a specific range of ground resolution was determined as providing the answers to the Essential Elements of Information that were asked of the subjects. A missile key was also published on the sites used in the study.

In the measurement study, errors were demonstrated by subject and total subjects for different geometric shapes as a function of edge spread and contrast.

Title: Positional and Dimensional Error Analysis of Objects Calculated from Panoramic and Strip Photography

Job No.: 170

Objectives: To prepare an analysis directed towards calculating the effects of interior and exterior orientation errors in panoramic and strip camera systems upon the length or height of a ground object.

Approach: The panoramic and strip camera observations are first reduced to equivalent frame observations so that the theory or central projection can be applied. Both an accuracy study and a precision study were then performed. In the accuracy study, parameters of interior or exterior orientation are perturbed and the affects of those perturbations on ground dimensions are noted. In the precision study, errors in interior or exterior orientation parameters are propagated through the appropriate transformations.

Results: The analyses are presented.

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Title: Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS) Operational Procedures Manual

Job No.: 194-9

Objectives: To present procedures for the operation of the Universal Photogrammetric Data Reduction and Mapping System.

Approach: A complete operational procedures manual for mapping from the following satellite photography was prepared:

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[redacted]

The procedures were prepared in separate volumes, each volume describing operating procedures for a major operational segment of AMS (e.g., planning, photo preparation, control, stereo compilation, planimetric compilation). Each major work operation description begins at the top of a page with a descriptive title. Associated with this title is the name of the operational segment that will be responsible for performing the work described. The operation is then described in narrative fashion supported by complete flow charts.

Results: The UPDRAMS Operational Procedures Manual was completed and delivered.

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Title: Use of Satellite Photography for Military and Civil Engineering

Job No.: 1215

Objectives: The objective of this program was to ascertain the amounts and type of civil and military engineering data, required for major works, that can be extracted from satellite imagery.

Approach: The first phase of the program required the systematic interpretation of satellite imagery covering a broad distribution of geographic, climatic and physiographic regions.

The second phase required the construction of a semi-controlled mosaic of a 10,000 square mile area in [redacted] From the mosaic and imagery interpretation an effort was made to acquire reliable engineering design information. These data were used to select alternate military highway routes between two points and five "hasty" airfields.

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The third phase required the interpretation and mensuration of engineering data along a major proposed highway route. This data was then evaluated and compared with engineering data prepared for development of the route.

Results: The data acquired during the course of the program was then applied to the formation of an organization that will make pragmatic everyday use of satellite photography for preliminary engineering design purposes in support of field army requirements.

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Title: Investigation of Systematic Panoramic Distortions

Job No.: 1221

Objectives: To continue the work begun under Task 126-10-5 in order to determine if, in fact, a calibration procedure could be devised which would remove the systematic errors from KH-4 panoramic photography and, if so, to determine the effectiveness of that procedure.

Approach: Seven consecutive frames each of forward and aft KH-4 panoramic photography (and the corresponding terrain index photography) exposed over an adequately controlled and mapped area were employed to determine the calibration constants for the two cameras involved. Then, two additional photographs each of forward and aft photography taken with the same cameras but exposed several days later over another adequately mapped area were employed to determine if the calibration constants determined for the two cameras were, indeed, valid. As a first step the image coordinates of ground control points, the format edge, fiducial marks, and time marks were measured on all photographs. Those measurements were preprocessed by fitting to the format edge and scaling to the fiducial marks. A relative orientation between the panoramic and terrain index photographs was performed and the panoramic photo coordinates were transformed to equivalent frame photo coordinates. Then, resections of the equivalent frame photo coordinates to highly weighted ground control were performed. Photo residuals of the resection runs were fit to polynomials, the coefficients of those polynomials forming the basis of the camera calibration. That calibration was then applied to the additional photographs and the precision of the additional photographs was determined.

Results: The procedures developed for the calibration of KH-4 panoramic photography were, indeed, effective in removing a significant amount of distortion from that photography.

Title: Weighted Least Squares Adjustment of Pan, Strip and Frame Camera Data Collected over Short Arcs by an Orbiting Vehicle.

Job No. 1226

Objectives: To prepare computer programs suitable for the performance of error analyses of mapping systems in orbit.

Approach: Studies were performed to determine an optimum orbit constraint over a distance of 600 miles. It was found that third degree polynomials gave an error of less than one meter when fit to fully perturbed Keplerian orbits. The PHANTOM Program, a least-squares adjustment program capable of handling panoramic and strip photography as well as frame photography, was then prepared employing polynomial constraints for camera position and attitude. Finally, the PIDGEN program, which generates fictitious data for input to PHANTOM as a function of Keplerian orbit parameters, was prepared.

Results: The PHANTOM and PIDGEN programs, along with complete documentation, were delivered.

25X1A
25X1A

Title: PG Analysis

Job No.: 1227

Objectives: To develop the preprocessing techniques required for the reduction of PG panoramic photography (a modified KH-4 panoramic camera system), to determine the effectiveness of the calibration of that photography, and to determine the accuracy of that photography.

Approach: Computer programs required for the reduction of the PG panoramic photography were prepared. One forward and one aft photograph, exposed over a well controlled area [redacted] were selected and measured. The panoramic photo coordinates were preprocessed and then transformed to equivalent frame photo coordinate; resections with highly weighted ground control were performed, and the photo residuals from those resections were analyzed to determine the magnitude of the remaining distortions and the accuracy of the photographs.

25X1A

Results: The calibration of the IMC traces was found to be invalid (i.e., the calibration was not repeatable). However, by employing measurements of the reseau holes and the IMC traces, a major portion of the systematic error was removed from the PG photography and its accuracy was found to be somewhat better than conventional KH-4 panoramic photography.

25X1
25X1A

Title: Human Factors Support Services

Job No.: 3261

Objectives: To provide services to [redacted] to accomplish three specific tasks; Photo Interpreter Performance Mission, Stereo Evaluation and Factors Study, and The Relative Accuracy of Mensuration. 25X1A

25X1 Approach: [redacted] personnel were responsible for gathering the test stimulus material (satellite photography, KH-4,
25X1D [redacted] annotating and locating the targets, training and administering the tests. There were over a thousand targets analyzed for use on the tests. All the work was accomplished.

25X1A Results: [redacted] provided inputs to all the final reports. [redacted] 25X1A published two Task Analysis reports on the flow of satellite file and data handling of the imagery by the photointerpreters to produce the OAK, OAK supplement and detailed reports and mensuration film handling procedures of the Photogrammetric Branch within NPIC.

Title: Imagery Experimentation Support

Job No.: 2272, 2319

Objectives: To determine the intelligence value of satellite imagery (both line-scan and photographic) for military targets, from the relationship of interpreter performance, target ground resolution, and intelligence analyst estimates.

Approach: The techniques used were the same as in 165 and 2241.

Results: Published Study, The Analysis of Radar Sites as a Function of Photographic Ground Resolution (S).

This study was similar to the missile study in that ground resolutions for the requirements were demonstrated. The latter job 2319, is currently in process with the analysis of Ground Order of Battle Targets as a function of photographic ground resolution and various line-scan parameters.

Title: Terrain Study Prototype

Job No.: 1278

Objectives: The principle objective of this program was to develop a prototype terrain study. The program was designed to illustrate, through an operational test, the effectiveness of using a combination of satellite imagery and collateral materials for the solution of regional military problems concerning terrain studies. The study was addressed specifically to problems concerning military geographic intelligence and irregular force operations.

Approach: The program was conducted in three tasks:

(1) The first task required the construction of a mosaic using KH-4 panoramic imagery. A series of geoscience overlays was then compiled covering the mosaic, through the stereoscopic interpretation of the satellite panoramic imagery. Upon completion of the basic overlays the data was synthesized into five military geographic overlays.

(2) The second task required the production of basic geoscience overlays at an enlarged scale of 1:50,000.

(3) The third task encompassed the checking of data developed in Tasks I and II using collateral materials in the form of National Intelligence Survey reports.

Results: The conclusions of the study were:

(1) The KH-4 panoramic photography affords wide areal coverage and contains adequate ground resolution characteristics so as to allow an interpreter to extract a sufficient level of continuous terrain detail to meet the requirements of the DIA Guide to the Production of Terrain Studies.

(2) KH-4 panoramic imagery can be enlarged to a scale of 1:50,000. At this scale sufficient ground resolution is maintained to allow stereoscopic interpretation of a geoscience "data base", from which military geographic intelligence overlays for guerrilla operations can be produced.

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25X1A

(3) It was shown that KH-4 panoramic photography can be enlarged approximately 8X to a scale of 1:20,000. At this scale considerable ground resolution is lost, however, the imagery can be used to formulate preliminary or contingency defense plans in conjunction with previously compiled, smaller scale, military geographic intelligence.

25X1
25X1A

25X1A
25X1A

Title: The Analysis and Data Reduction of Strip Photography

Job No.: 1283

Objectives: To develop, program, and test data reduction techniques for strip photography; to analyze the results of those tests; and to prepare a production program for the determination of strip photography input parameters for the analytical plotters.

25X1D

Approach: The PASOUT program, a computer program capable of transforming [redacted] strip photography measurements to an equivalent frame photograph and then performing a relative orientation between that photograph and the terrain index photograph, was prepared. Several sets of strip photographs and their corresponding terrain index photographs were selected, measured, and run through the PASOUT program and the Single Camera Resection Program. The data from those runs, plus a large amount of data from another task, were analyzed to determine the validity of the data reduction techniques.

Results: The techniques described above were validated. However, the ground control was not of sufficient accuracy to determine the quality of the strip photography. In addition, some of the strip photography included large timing errors. A production program for mapping from strip photography was described in detail.

25X1
25X1A

Title: Extension and Application of Multiple Orbit Short Arc Error Analysis Program (PHANTOM)

Job No.: 1288

Objectives: To develop the analysis and necessary computer programs that would enable the user to determine the relative accuracy with which a network of control over a region 500 miles on a side could be established from a set of photographic records collected by a specific camera system in orbit and then to apply the derived techniques to a variety of mapping systems defined by the Army.

Approach: The PHANTOM program and its associated data generator, PIDGEN (both prepared under Job No. 1226), were modified as required and several supplementary programs were prepared. Photograph and ground data were then generated for some eleven different camera systems and configurations using the PIDGEN program. The data for each system, each covering an area 500 miles square, were then adjusted and the errors propagated employing the PHANTOM program.

Results: The results of the adjustments of the eleven mapping systems were tabulated and presented graphically in order that a comparison of the relative accuracies of the various systems could be made.

Title: FT-15 - A Comparative Analysis of Photographic Quality

Job No.: 2319-1

Objectives: To provide a valid and precise expression of the amount of information available in satellite and aircraft imagery.

To compare the information available in each type of imagery and provide an indication of the amount of Arms Control information which can be expected from large and small scale presentations.

Approach: To satisfy these objectives, Autometric performed a qualitative and quantitative analysis of KH-4, [redacted] and aircraft imagery. This analysis consisted of: 25X1D

1. Image interpretation
2. Modulation Transfer Functions
3. Granularity Measurements
4. Density Measurements

Results: [redacted] 25X1D

The small scale KH-4 and aircraft imagery were not comparable.

25X1
25X1A [redacted]

Title: Data Analysis and Interpretation

Job No.: 3229-1/1301-1

Objectives: This project was a service program for the ARPA Terrain Atlas for Nuclear Test Detection Program.

Approach: The program required two photo-geologists to interpret satellite imagery over potential nuclear test sites in the Soviet Union. The two geologists interpreted the imagery and corrected the collateral data where discrepancies were detected.

The program disciplines were geology, soils, vegetation and landforms. A total of 13 atlases were revised over the two-year term of the contract.

Title: Data Analysis and Interpretation

Job No.: 3329-2/1301-2

Objectives: The objectives of the study were to determine the quantitative aspects and the physical configuration of geologic formations through the use of satellite imagery with a projection stereoplotter. In addition, the task was designed to determine the ability of a stereoplotter to fulfill the requirements of a geologic study and to determine the ability of a geologist, untrained in the operation of a stereoplotter, to operate a stereoplotter and produce an accurate geologic interpretation.

Approach: The initial phases of the study were directed to the feasibility of using the imagery with projection-type stereoplotters to record dip and strike, measure strategraphic sections and delineate formational contacts of geologic structures. This was followed by a series of tests to determine time requirements and the problems involved in recording the structural attitude of key geologic formations in four test areas.

The final phase of the program was designed to evaluate the information gained from the tests for scientific value and accuracy and to ascertain if the data could be utilized in the ARPA Terrain Atlas Program.