DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER GEODESY, INTELLIGENCE AND MAPPING
RESEARCH AND DEVELOPMENT AGENCY
FORT BELVOIR, VIRGINIA 22060

IN REPLY REFER TO

ENGGM-

22 June 1966

SUBJECT: Planning for PG System Data Tests

TO: Chief of Engineers
ATTN: ENGTE-T
Department of the Army
Washington 25, D. C.

1. Reference [redacted] received 9 June 1966, which requests "DIA be provided with an outline plan of your objectives for the testing of a calibrated PG System when available."

2. Based on expectation of successful calibration of the PG-1 instrument, or successful calibration of one of the other instruments very early in the PG series, this agency undertook development of an exhaustive, highly rigorous Pilot Data Reduction Test to (1) develop optimum data reduction processes for these materials and (2) to determine the maximum geometric integrity inherent in PG system data and materials. Briefings on this Pilot Test have been held for OCE, DIA, and selected ACIC personnel. Independent of this Pilot Test, we have also contracted with [redacted] for development of necessary processing routines to allow reduction of PG materials in the UPDRAMS. A secondary purpose of the [redacted] work is to provide us a check of the Pilot Data Reduction Test results and analyses.

3. As the referenced DIA message states, there have been "difficulties encountered in calibration of PG-1." In effect, the PG camera system manufacturer has reported complete failure to date of his attempts to achieve calibration of the PG-1 instrument. Reduction of calibration measurements from the PG-2 instrument is currently underway at Itek. However, because the reasons for the system malfunctions and resultant calibration failure of PG-1 have not yet been isolated, and because the PG-2 instrument was scheduled for delivery the week ending 17 June, there is reason to question whether successful calibration of the PG-2 instrument will be achieved. This analysis of the situation was confirmed by Messrs. [redacted] of Itek during a conference at [redacted] on 10 June 1966.

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4. In view of the events concerning the PG-1 and PG-2 and the further fact that the follow-on J-3 system is now scheduled for delivery at about the same time as PG-5, we have reconsidered our plans for experiments and tests using PG materials. The uncertainties thrown into the PG System program by the failure of PG-1 have required that we develop contingency plans, one or more of which will apply depending on future developments. The following comprise our best judgement as to the proper alternative courses of action:

a. PG-1 - The camera manufacturer has furnished us all data and documentation related to his calibration test. These data together with photography and data produced when PG-1 is flown will be examined and evaluated to determine whether they are of sufficient value to warrant performance of our original Pilot Data Reduction Test and/or the [redacted] approach. If possible and warranted, one or both of the tests will be performed. If the data are of such nature and quality as to preclude performance of the tests, the tests will not be attempted; instead, attempts will be made to determine the major sources of system malfunction. In any case, ~~in conjunction with AMS,~~ an attempt will be made to compile a portion of a 1:250,000 orthophotomap using the materials. The effort spent on this compilation test will be directly proportional to the determined quality of the photography and "Calibration" data produced during the system test flight.

b. PG-2 - Our plans are exactly the same as for the PG-1 instrument. However, if the PG-1 data is run through the Pilot Data Reduction Test, we will not repeat the test using PG-2 data. Instead, we will proceed directly to a test compilation.

c. PG-3 - If either PG-1 or PG-2 is successfully calibrated to such extent that the Pilot Data Reduction Test can be performed, the test will not be repeated on PG-3. Instead, PG-3 flight data will be run directly through the UPDRAMS using the [redacted]-developed routines. On the other hand, if neither PG-1 nor PG-2 is successfully calibrated but PG-3 is, then the PG-3 flight data will be run through the Pilot Data Reduction Test. Finally, if PG-3 is not successfully calibrated, then the materials will be analyzed as described in 3a above.

d. PG-4 - This copy has been withdrawn by the Contracting Officer and reverts to a simple KH-4 reconnaissance package.

e. PG-5 - If PG-1, PG-2, or PG-3 is successfully calibrated to such extent that the Pilot Data Reduction Test can be performed, the test will not be repeated on PG-5. Instead, PG-5 flight data will be run directly through the UPDRAMS using the [redacted]-developed routines. On the other hand, if neither PG-1, PG-2, nor PG-3 is

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successfully calibrated but PG-5 is, then a judgement will have to be made whether or not to run PG-5 flight data through the full Pilot Data Reduction Test. This judgement will depend on two factors: (1) How many further PG systems will be flown, and (2) the status of the J-3 system. It is not possible now to predict what the decision will be since PG-5 is not scheduled for delivery until mid-summer of 1967.

5. Attached are summaries of both the Pilot Data Reduction Test and the less extensive [redacted] Test. It is believed that these summaries, together with the information detailed in paragraphs 2, 3, and 4 above, comprise the data requested by DIAMC in their 9 June message.

[redacted]

1 Incl
as

Colonel, CE
Commanding

[redacted]

ARMY PLANS
FOR
PG TEST AND EVALUATION

I. INTRODUCTION

The Panoramic Geometry (PG) series of cameras constitute the first attempt at developing a cartographic capability with the panoramic cameras of the KH-4 satellite reconnaissance system. The procedure currently being tested for establishing geometric quality into the panoramic camera consists of adding a dot reseau along each edge of the exposure and one (or more) collimators to trace out the path of the lens perspective center. Since the degree of success which can be achieved by this attempt to calibrate the KH-4 camera system will have a marked influence on future decisions regarding additional calibration attempts and the possible need for separate MC&G acquisition systems, the Army plans to rigorously test and evaluate the PG photography in order to positively ascertain the ultimate capabilities of this system for mapping purposes, the optimum procedures for utilizing these materials in the data reduction process, and to gain significant information regarding the calibratability of panoramic camera systems.

II. BACKGROUND

There has been considerable controversy regarding the improvement in cartographic capability which will be gained by the incorporation of the PG calibration devices in the KH-4 panoramic camera system. This non-agreement between cognizant authorities and the influence an evaluation of this first calibration attempt will have on future MC&G acquisition system decisions, has motivated the Army to develop test procedures which will unquestionably define the ultimate capabilities of the PG system and allow the optimum utilization of this photography in the mapping data reduction process. The Army's PG test and evaluation plans therefore are not only aimed at rigorously testing the calibrated system as it is designed, but are flexible enough to accommodate most foreseeable contingencies with respect to the possible failure in achieving the desired degree, or any degree, of calibration. In this way it is hoped to attain the maximum results from the test and evaluation of this photography with a minimum amount of failure risk.

III. TEST AND EVALUATION PLANS

The overall concept in testing the PG materials divides into two distinct approaches and involves the independent efforts of two Contractors, Itek and [redacted] On one hand the Army is

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vitally interested in determining the ultimate capability of the PG system. To achieve this goal Itek Corporation was awarded a contract to develop a plan of procedures for the pilot data reduction test of the PG photography and a sophisticated block adjustment program to triangulate and analyze the PG test data. However, in addition to determining its ultimate capability, the need exists for incorporating the PG materials into the Army's data reduction program. This aspect of the PG test and evaluation plan was given to [redacted] because of their past intimate association with the development of present data reduction procedures. Naturally, the two Contractors' efforts will be somewhat correlated in that the Itek work must consider the data reduction aspects and the [redacted] effort will necessarily consider the cartographic evaluation of the PG materials.

A. Itek Contract

When knowledge was obtained regarding the forthcoming issuance of the PG system and that Itek would be involved with the calibration of these materials, it was decided that this company would be in the best position to perform an in-depth analysis of this system and evaluate its ultimate capabilities. In addition, they had proposed the development of a sophisticated block triangulation program which would simultaneously adjust the PG and frame index photography, allowing the incorporation of any-and-all auxiliary data and constraining the solution to orbital dynamics. This program will utilize time as the primary independent variable to functionally relate all parametric and observational data. The basic goal of the Itek contract is to develop this adjustment program for an 18-photo block of photography (eight pan models and one frame model), and to use the program with both fictitious and real (when it becomes available) data to mathematically analyze the PG system. The purpose of the adjustment program is to generate (densify) the ground coordinates and variance-covariance error matrices of selected photo pass points. The investigation, then, consists essentially of comparing the computed coordinates with known values (surveyed or map control), and through analysis of any deviations and the error matrices arrive at an evaluation of the PG system's cartographic capability. The vehicle for producing the data to be analyzed is the pilot data reduction of the PG materials, for which a test plan is also being developed under the Itek contract. This pilot data reduction test plan will stipulate the overall material and data flow and specify the specific operations and computational steps to be performed. The Itek test plan currently calls for redundant mensurations to be made on the test photography. This redundancy of data not only permits the ultimate capability of the PG systems to be determined, but

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will allow more comprehensive analyses to be made by providing a sufficiently wide variation in density and distribution of the data to be manipulated by the triangulation program. The overabundance of test data permits the program to simulate a number of pilot tests under different conditions without the need to re-measure the photography. The knowledge gained from these simulations should supply significant information about the PG system's geometric integrity and could have an impact on the operational data reduction program.

Although the points generated by the triangulation program will ultimately be utilized as control for the map compilation process, their primary function will be as inputs to the analytic evaluation. The analytic analysis, as opposed to the production of a map product, is considered the best indication of the PG system's capability, since it allows an evaluation of just this system without the variables introduced by the compilation equipment. However, the production of orthophotos by the Universal Automatic Map Compilation Equipment (UNAMACE) will be performed and these UNAMACE outputs evaluated in order to determine the capability of the PG system in terms of the ultimate map product. Specifically, the results to be obtained from the Itek contract will include: an eighteen photo block adjustment program, an analytic analysis using this program with fictitious data, a PG coordinate transformation program, the pilot data reduction test plan, and the analytic analysis of the PG system with the triangulation program using real data obtained from the pilot test. In addition, the Corps of Engineers will prepare an evaluation report on the map products obtained from the test.

The Itek pilot data reduction test summarized above will require a considerable expenditure of effort on the part of the Army Map Service. However, the importance of obtaining an unquestionable evaluation of the PG system and the overall knowledge to be gained from the test is deemed sufficient justification for this expenditure. It is estimated that the performance of the pilot data reduction test will require the measurement of approximately 22,000 points and about 2,200 point transfers. These mensuration operations will require about 4,000 man-hours of effort and nearly six months elapsed time. It should be noted here that this is a test, and under normal operational conditions, the mensuration effort should be considerably reduced - perhaps by as much as one half - for the eighteen photo block being considered.

B. [redacted] Investigations

[redacted] has been intimately involved in assisting the Corps of Engineers to develop the Universal Photogrammetric Data Reduction and Mapping System (UPDRAMS). This system was designed to

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accept a wide range of mapping and reconnaissance photographic inputs, with primary emphasis placed on the reduction of covert satellite photography. In their activities related to the development of UPDRAMS, [redacted] became involved with developing procedures and techniques needed to reduce panoramic photography of the KH-4 system. It is, therefore, a natural continuation of investigative effort that [redacted] experiment with and analyze the PG photographic materials for the primary purpose of developing procedures and programs which will enable the reduction of these materials by UPDRAMS. Although the [redacted] effort is aimed at developing an operational capability at AMS (as opposed to test results), the necessary investigations leading to this capability will include a cartographic evaluation of the PG system which will serve as a back-up to the sophisticated Itek study.

[redacted] The evaluation of the PG materials to be conducted by will, like the Itek study, concentrate on an analytic analysis. The effort will consist of developing techniques and preprocessing programs to compensate systematic effects in the PG system based on the camera configuration and calibration data actually obtained (as opposed to the design criteria). Specifically, the PG calibration data will be utilized to account for film distortion and image motion compensation. Although the best of several approaches contemplated cannot be ascertained until the test photography is actually obtained, film distortion will probably be corrected by performing either a least squares six parameter fit of measured reseau points to calibrated reseau points in groups of four, or the performance of a least squares n^{th} order polynominal fit of all reseau points; and image motion compensated by performing a fit of photo imagery measurement to the measurements of the principal point trace, or by performing a fit of the principal point trace to the function $\Delta X = IMC \sin\theta$, or by simply utilizing the calibrated value of the IMC constant. The programs developed through these investigations will then be used to analyze the PG photography in order to determine its accuracy and geometric fidelity.

As opposed to Itek's sophisticated block adjustment program, the [redacted] PG cartographic evaluation effort will consist of relatively simple one model analytic tests and therefore have a relatively small associated development risk. Similar programs have been developed by [redacted] for the existing uncalibrated KH-4 panoramic photography and are being used for its evaluation at the present time. Using the one model analytic programs, resections and relative orientations will be performed and the patterns of residual errors analyzed. The results of this investigation will be a quantitative evaluation of the PG materials from both a relative and an absolute sense. In addition, the degree of improvement in cartographic capability

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(if any) in the PG system will be ascertained by comparing the photographic residuals with and without incorporation of the calibration data and by comparing the PG test results with those obtained from an evaluation of the uncalibrated panoramic system. A large enough statistical sample of photography will be evaluated in this manner to insure reliable evaluation results, but the overall magnitude of the investigative effort will be relatively small compared to the Itek test plans.

[redacted]s performing other investigations which are directly associated with UPDRAMS, but related to the PG cartographic evaluation. One is an investigation of block adjustment techniques aimed at determining optimum triangulation procedures with satellite photography. Although this study will be performed with-or-without the existence of a PG system, it should serve as a valuable back-up to the triangulation program being developed by Itek. Another [redacted] investigation related to the PG system test and evaluation is their modification of the UNAMACE preprocessing programs. This effort will allow the utilization of the additional data provided by the PG materials in the compilation phase of the data reduction system.

IV. SUMMARY OF BASIC TEST PLANS

In summary, the Army's test and evaluation program depicted above consists of a parallel approach to the PG problem. On one hand we have [redacted] performing one more step in a long continuous development program aimed at achieving an AMS operational capability with the PG materials. On the other hand we have Itek developing procedures and programs specifically aimed at testing and evaluating the PG systems with a different and more sophisticated approach in order to determine the maximum capability of the PG system. This two-pronged approach has several distinct advantages. First, the Itek work offers the possibility of getting maximum benefit from the PG calibration data. Second, the high risk associated with achieving success with a program of this magnitude and complexity is offset by the availability of the [redacted] block adjustment and single model analytic programs to provide a back-up cartographic evaluation of the PG materials. It is felt that this approach will provide greater assurance of a successful test and the ultimate promise of an optimum PG data reduction capability.

V. CONTINGENCY PLANS

Although the overall plans for test and evaluation of the PG materials are based on successfully achieving fabrication, calibration, and test photography with the PG system, the effect of failure of any or all of these important operations on the test plans must be considered. Of principal concern is the impact produced by the inability

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to ascertain the degree of success achieved by the PG calibration devices installed in the panoramic camera. In other words, the question "What is the effect and what tests can be performed if the PG system cannot be calibrated?" must be answered. Since the reasons for not obtaining a successful calibration cannot possibly be known before the fact, the definite effects produced by this occurrence can only be estimated. However, in light of the important need to obtain an evaluation of the PG system, plans have been developed to enable a quantitative analysis of this system in the contingency that the calibration devices do not meet the design specifications or that the system is uncalibratable. Under these conditions the originally planned rigorous tests would neither be fruitful or warranted, and the depth and quantity of analyses would necessarily be curtailed.

A. Evaluation of Calibration Data

Since a knowledgeable and experienced Contractor has been assigned to calibrate the PG system, it is not considered necessary or even adviseable to duplicate his calibration analysis nor to question the validity of his conclusions with respect to whether or not the calibration devices meet the design specifications. It is assumed here that a calibration report by the Contractor will be made available to the codeword mapping community. However, if such a report is not issued, it may be worthwhile to analyze the calibration data for the purpose of discovering the degree of failure of the calibration from both a relative and absolute sense and to possibly pinpoint the causative factors of non-calibration. The analysis of the calibration data would basically consist of a plot of the comparator coordinate values and a determination of the magnitude of the disparaties between the design criteria and actual data.

B. Post Mission Evaluation

There are a number of tests which could be performed on the PG test photography - assuming that it was flown over an area covered by large scale mapping. As mentioned earlier, the degree of rigorousness of these tests and the magnitude of effort would be sharply curtailed if the PG system is non-calibratable. However, a definitive and informative evaluation of the system in both a relative and absolute sense could and should be performed. First of all, the calibration data can be measured and analyzed in a manner similar to the calibration evaluation to determine the calibration characteristics under operational

conditions and, again, to measure the degree of failure of the calibration. The results of this analysis in terms of the degree of consistency of the calibration data and its possible use for correcting systematic effects will define the depth of analyses which can be performed on the photography itself.

The successful accomplishment of the pilot data reduction test developed by Itek is dependent on having their panoramic transformation and block adjustment programs produce valid results. Since these programs' operations are based on utilizing the geometric fidelity introduced by the calibration devices, the successful operation of these programs depends on the fact that these devices meet their design specifications. Thus, if these criteria are not obtained, it appears that the benefits to be gained from the Itek pilot data reduction test would be minimal and the overall test plan should be abandoned. The majority of the PG evaluation would then be performed using the [redacted] programs.

The effect of non-calibration on the analyses to be performed by [redacted] should be minor. Since their programs will utilize only that portion of the calibration data which is useful, the [redacted] effort will more-or-less be the same as that planned for a successful PG system (see paragraph III. B.), except that the test effort itself will be the minimum needed to arrive at conclusive results. Thus, all available calibration data which can be utilized for correcting systematic effects will be incorporated into the [redacted] analysis. If none of the calibration data is useable, the analysis will be based on evaluation programs developed for the present system. Therefore, an absolute quantitative evaluation of the PG system will still be obtainable from the [redacted] programs regardless of the state of calibration achieved. It is considered that the analysis of one or two models from each of the several passes over controlled areas should suffice for this evaluation.

C. Qualitative Analysis

As in the pilot data reduction test plan, the primary evaluation of the PG system for a non-calibratable situation will be dependent on an analytic analysis. However, it would still be worthwhile to carry out the data reduction process through the production of map products by the UNAMACE. The operational flow of materials would be handled as depicted by the Itek pilot data reduction test plan, but using the reduced test concept. This procedural flow should produce information from two standpoints. First, it will show the effects

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of the data reduction process on the PG materials, i.e., loss of calibration markings and imposed reseau, size of pug holes needed, etc. Secondly, it will show the effects of the calibration markings on the data reduction operations, i.e., loss of correlation by the UNAMACE caused by the IMC traces and/or the imposed reseau, appearance of undesirable IMC traces on the orthophoto, etc. One, or at most, two test models run through the data reduction process should be sufficient to produce the desired information.

VI. SUMMARY

Based on the above, it can be seen that the Army is planning a comprehensive and rigorous test of the PG system. The importance of achieving optimum and unquestionable test results is recognized and reflected in the development of the Army's test plans. All conceivable contingencies are taken into account such that even under adverse conditions a valid and absolute evaluation of the PG materials can be performed.