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

RESEARCH INSTITUTE FOR GEODESTIC SCIENCES

Brief and Evaluation of

- Project [redacted]
A Plan for Evaluating the Accuracy of a Multiple Orbit Adjustment

By

Itek Corporation

BRIEF

The purpose of this project was to present a test procedure with methods and techniques for evaluation of accuracies obtained in a simultaneous adjustment of data from more than one photographic satellite mission. The requirement for a Test and Evaluation Plan became evident when it was determined that a complete void existed in the area of testing the results from a simultaneous, multi-mission adjustment of all BAFF missions. While this plan is presently directed toward the multiple orbit adjustment of the existing BAFF photography, it is designed to be sufficiently general to be applied to any photogrammetric adjustment employing orbital constraints. The approach employed consists of a series of discrete phases. The first step concerns the generation of an ephemeris from a reduction of the materials. Through an analyses of the residuals generated on mission data, systematic errors can be recognized and removed. After the systematic errors have been resolved, the adjusted exposure station data will be used to compute the positions of known geodetic control points with associated error propagation parameters. The evaluation of the predicted errors in comparison with the known true positional error represents the final phase of the testing effort. The author has arranged the report to highlight the actual methods and techniques for the testing and evaluation outlined in Section XII, Test Procedures. In recognition of the importance of the statistical nature of the plan, all attempts have been made to establish a mathematical and philosophical ground work for the final description of the plan. The discussion presented on the accuracy and precision significance of the adjustment problem is both comprehensive and pertinent to the problem at hand. In recognition of the peculiarities of the multi-mission reductions of BAFF missions, many expansive and time consuming statistical tests for the goodness of fit of residuals could be performed. The Students "t"

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Brief and Evaluation of

- Project LUCAS -
A Plan for Evaluating the Accuracy of a Multiple Orbit Adjustment

By

Itek Corporation

BRIEF

The purpose of this project was to present a test procedure with methods and techniques for evaluation of accuracies obtained in a simultaneous adjustment of data from more than one photographic satellite mission. The requirement for a Test and Evaluation Plan became evident when it was determined that a complete void existed in the area of testing the results from a simultaneous, multi-mission adjustment of all BAFF missions. While this plan is presently directed toward the multiple orbit adjustment of the existing BAFF photography, it is designed to be sufficiently general to be applied to any photogrammetric adjustment employing orbital constraints. The approach employed consists of a series of discrete phases. The first step concerns the generation of an ephemeris from a reduction of the materials. Through an analyses of the residuals generated on mission data, systematic errors can be recognized and removed. After the systematic errors have been resolved, the adjusted exposure station data will be used to compute the positions of known geodetic control points with associated error propagation parameters. The evaluation of the predicted errors in comparison with the known true positional error represents the final phase of the testing effort. The author has arranged the report to highlight the actual methods and techniques for the testing and evaluation outlined in Section III, Test Procedures. In recognition of the importance of the statistical nature of the plan, all attempts have been made to establish a mathematical and philosophical ground work for the final description of the plan. The discussion presented on the accuracy and precision significance of the adjustment problem is both comprehensive and pertinent to the problem at hand. In recognition of the peculiarities of the multi-mission reductions of BAFF missions, many expansive and time consuming statistical tests for the goodness of fit of residuals could be performed. The Students "t"

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significance test for mean and F-ratio significance test for variance are sufficiently elegant to meet all demands for error analysis and do not place a tremendous computational burden on the user. The aspects of these two tests that have led the Contractor to this choice concern the "safety factors" built into the tests used and the fact that the tests can be used with confidence even if the distributions are non-normal. In addition to a statistical discussion, the contents of Appendix B help to represent the supporting mathematics - equations and formulae - necessary for a complete set-up of the testing and evaluation program. The description of the actual test procedures used in assessing the accuracies obtainable from a simultaneous multi-mission adjustment is in sufficient detail to be immediately applied to the BAFF data reductions and general enough to be applied to future analyses. The test is aimed at determining the accuracy of a point on the ground that was positioned by photogrammetric intersection from two or more exposure stations whose positions have been obtained from the orbit adjustment. A brief emphasis is made by the Contractor concerning the problems of comparative evaluations of multi-mission reductions utilizing RECAP and TRACE. The difficulties of such comparative analyses become immediately apparent even with the few comments made by the author. In order that systematic errors be detected, the observation residuals are divided into subsets based on some physical characteristic and then a comparison is made of the mean and variance of each subset to an equivalent statistic for the full set of residuals. The residuals for range, tracking cameras, control points, and relative geometry points are generated, collected separately, and then the two statistical tests - Student's "t" and "F-ratio" - applied. A tabular display (an example is contained in Appendix A of report) represents the failure, magnitude and frequency for a particular characteristic residual and permits further analysis for systematic error identification and subsequent re-adjustment. These systematic errors, of course, can be mission dependent, datum dependent, tracking instrumentation dependent or a combination of dependent errors. The Contractor was not to provide a means for identifying the characteristic of every possible error source seen in a particular residual analyses. The author has, however, provided the guidelines needed for making a logical deduction of a particular systematic error. Although the user is extremely capable in the technological area of the processing, transfer, and measuration of photogrammetric data, the Contractor has outlined procedures for these particular items to insure that such procedures are standardized for the test. Computation of the check point positions and propagation of errors through the associated variance - covariance matrix provides the data needed for subsequent accuracy analysis statements. A check of such position statements against the known time check point positions will provide the needed information to determine whether or not all systematic errors in exposure station positions have been reduced below a random error noise level. The sample of the computed check point positions fall

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within a particular probability ellipsoid (a 90% probability ellipsoid was chosen by the Contractor) then the coordinates of any unknown points can be computed and with a high degree of confidence. In other words, all the systematic errors have been eliminated and a true accuracy statement for this point is available, which of course is the whole purpose for the generation of the Test and Evaluation Plan. Nothing in this plan reflects an original mathematical formulation to solve this problem. The plan does, however, represent a refreshing approach to a serious problem which has been neglected for too long.

EVALUATION

The Test and Evaluation Plan contained in the final report represents an excellent vehicle for analyzing the simultaneous multiple-mission adjustments of the DAFF missions and any future reductions. This general critique statement includes each and every aspect of the report. Although specific formulations, tables, examples, and descriptions were made by the author, the plan is really designed to place flexible guidelines as to the final evaluations, methods, and techniques and enables the user to bring to bear on the problem of DAFF mission analyses, the maximum in-house talents and experience. Notations on specific items should be made. The statistical tests suggested by the Contractor will surely be adequate for evaluation for goodness of fit and overall systematic error elimination. Since these tests are probably a little different than those normally used, it is worth noting that particular advantage realized in this problem of multi-mission reductions. The main point is that a high confidence in results of the analyses is possible even if the data tested is a possible non-normal distribution. The problem of comparing REGAP and TRACE reductions is important to the immediate analyses of DAFF missions and it had been hoped that the plan would include in a more definitive fashion a procedure to perform this comparison. However, in noting the extreme complexity of such analyses, the plan provided will represent the departure point for comparative analyses and this deficiency is not in any way seriously detrimental to the content and ultimate purpose of the plan. The report did not cover every possibility that may be encountered in systematic error definitions. The very scope of the problem is much too difficult to adequately present in this report because of the severe complexity of the analyses. Those items listed in the treatment of a parameter dependent systematic errors are more than adequate for the needed error analyses. The sequence of the treatment for errors are such that the elimination of the possible larger sources are considered first and subsequent error sources systematically eliminated. The sections covering the actual DAFF-type data used and the techniques employed in reductions analyses provide the needed guidelines for a planned, deliberate, and consistent approach to the problem. An excellent vehicle for arriving at an accuracy evaluation for a mission or particular portion of a mission is present in the comparative checks between computed positions

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and accuracies and known values for the same points. This report represents a most significant tool for evaluation of DAFT and other missions and has been needed for too long. The current status of the reductions of AEM indicates that the availability of a Test and Evaluation Plan at this time is not only opportune, but necessary. The Contractor's conclusions are anti-climatic in light of the excellent presentation. The recommendations are equally well-founded and they follow logically from the body of the report. An investigation of the ultimate accuracies of existing material with additional analyses of future inputs of other control may, as stated, enable a significant by-product to be produced - a plan for control enhancement to be formulated from conclusions of the study and analyses.

The Test and Evaluation Plan presented in the report is excellent in content and in presentation. It is recommended that this report be accepted. Also it is recommended that efforts be initiated to put the recommendations made by the Contractor into a definitive study plan.

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Captain,
Research Institute for
Geodetic Sciences

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