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~~(C)~~ NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

RDA 66

BYE 50302-66
27 September 1966

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MEMORANDUM FOR: Director, National Reconnaissance Office

SUBJECT : Automatic Satellite Attitude Determination

1. The National Photographic Interpretation Center is herewith expressing a strong requirement for consideration of means by which the elements of exterior orientation of satellite photographic reconnaissance cameras can be determined automatically during orbital flight.

2. Specifically, the Center's need is for data to accurately determine the pitch, roll, and yaw of the camera station at the instant of exposure, to determine rates about the three axes, to correlate the attitude data with the specific photographic event, and to permit the utilization of the data for the timely production of dimensional intelligence.

3. During the past year, the Center has been presented evidence of the technological capability for including automated attitude determination equipment in satellite photographic vehicles. Although such information has been primarily the product of a single contractor, the Center's requirement is solely for consideration of the concept involved rather than the means of automatically providing accurate attitude data.

4. From the Center's viewpoint, the Hexagon and Dorian satellite reconnaissance programs appear to be most promising for inclusion of an automated attitude determination technique. Because these programs are still in an early developmental stage, adequate time hopefully remains to consider the application of such automated techniques before design decisions are made which might preclude its inclusion. In the interest of standardization of ground data handling methods, it is desirable that this approach be considered for all future satellite reconnaissance systems and possibly even as a retrofit to existing systems as major block changes are planned.

5. To support the Center's viewpoint, an investigation was initiated to determine NPIC's requirement for timely, accurate attitude data.

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The following results are based on theoretical computations for system parameters equivalent to proposed Hexagon parameters, on statistical data derived from a system providing a ground resolution equivalent to that expected from the Hexagon system, and on data derived from systems which presently provide attitude data.

a. Assuming an altitude of 90 nautical miles, an obliquity angle of 45 degrees, and a ground resolution of three feet at nadir, computations show that attitude errors of 15 minutes of arc in pitch, roll, and yaw (total attitude error of 22 min. 13 sec.) will not be the major contributor to the overall error if the distance to be measured is less than 230 feet or if the height is less than 115 feet. A sample of mensuration requests during first phase readout shows that from 200 to 1,000 objects must be measured with 96 percent of the objects less than 1,000 feet in length. Also a sample of roll angle distribution for a search type system shows that over 5-degree intervals, the look angle is equally distributed out to 45 degrees.

b. In order that attitude is not the major source of error for dimensions up to 1,000 feet, the NPIC requirement for attitude accuracy is 3 minutes of arc in pitch, roll, and yaw or a total combined tolerance of 4 min. 50 sec. of arc.

c. Because attitude data is not readily available during the first phase readout, nominal attitude values are used to compute ground dimensions. When compared to attitude data derived from stellar photography, the nominal pitch and roll values were in error by greater than 15 minutes of arc for more than 25 percent of the frames for which stellar data was available. Yaw values were in error by greater than 15 minutes of arc for more than 54 percent of the cases.

d. To obtain attitude for present programs, the reduction of 400 frames of stellar photography requires from 96 to 120 manhours at a cost of approximately $5,000. This figure does not include costs of the stellar cameras, film, processing, titling, calibration, etc. Reduction of stellar photography can provide attitude to an accuracy from 1 to 3 minutes of arc if a sufficient number of well-defined, well-distributed star images are recorded. The star images, however, are usually streaked, mis-shaped, or distributed in flared areas where measuring the images is difficult and time consuming. The

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cycling rate of the stellar camera is such that one stellar frame is recorded for every seven primary frames in one system, necessitating the use of interpolative values for the intervening frames, and one stellar frame per main frame in another system, thus negating the detection of rate changes. Because stellar reduction is dependent on system time, any clock failure or time recording failure precludes the reduction of stellar data.

e. Similarly the reduction of 2,900 frames of horizon photography requires 290 manhours at a cost of approximately $2,900 (excluding cost of horizon cameras and film). Because the horizon and fiducials are not always well-defined or sharply imaged, the pointing errors are increased. Yaw cannot be readily determined from horizon photography.

6. To fully exploit all reconnaissance photography, the NPIC installed 175 remote computer access stations as part of the basic structure of Building 213. The selection of NPIC's electronic computer was based largely on its real time interrupt capability to handle inputs from remote stations. The Center has invested more than $3,000,000 in the development of precise computer affiliated mensuration equipment, including that remotely located and functioning in various building components. Also near completion is a computer program which considers the effects of all sources of error (camera attitude, geometric fidelity, ephemeris data, earth curvature, refraction, film stability, instrumentation errors, and even human pointing errors). The economical and practical use of the state of the art equipment and the sophisticated photogrammetric reduction programs depends on the provision of accurate and timely digital data to support their operation. The economical and practical use of the recovered photography depends largely on the capability of timely and accurate interpretation in response to immediate requests from the intelligence community. In addition the benefits which will be achieved by allowing the Center to make more efficient use of its technological capability, the cost effectiveness of a major portion of the Center's activities will be greatly enhanced, a constant goal in the management operations of the Center.

7. The NPIC considers dimensional intelligence an integral part of photo interpretation. To consider dimensional intelligence anything less than integral is to deny the photo interpreter a completeness in the performance of his responsibility to the intelligence community, that

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of providing exact information about activities of interest. This is acutely evident when considering the availability of ground resolutions which permit the derivation of technical intelligence data. With dimensional data to determine, augment, or corroborate size, capacity, and capability, photo interpretation advances beyond detection and possible or probable identification to the stage of exact intelligence, stressing closest conformity to the truth. With respect to exact intelligence and to maintaining a potential commensurate with system capabilities, the NPIC considers improvements in the accuracy and timely availability of attitude data as logically and technologically essential. The concept of recording a larger quantity of higher quality attitude data on both the photography and a separate recoverable record is indeed advantageous to the maximum utilization of NPIC's capabilities. With accurate data stored in the computer at the time the photography is received, the 175 remote stations could, for the first time, readily provide for the first phase OAK reports measurements of the same accuracy as those now produced, often weeks later, in detailed reports. With other community members receiving the same attitude data from the same source by the same reduction technique, the extensive duplication of effort in data reduction could be eliminated. Also differences in photo derived measurements which often occur as a result of differences in attitude values could more easily be resolved.

8. It is envisioned that much of the actual measurement work now performed by photogrammetrists in support of the photo-interpretation operation in the Center will be done by the interpreters themselves as a result of being able to have the mensural data presented to them in their work areas. In addition to increasing the timeliness and efficiency of the reporting, the savings in manhours of work and reducing the complexity of the measurement operation will tend to alleviate recruitment problems for scarce photogrammetric talent and would materially assist the Center in meeting its manpower needs.

9. NPIC is currently undergoing a systems analysis of its data handling operation, with particular emphasis on digital information. United Aircraft Company's Corporate Systems Center is performing this analysis and it is interesting to note the comment in their report of August 19, 1966 concerning Attitude and Position Information.

> "A matter of real concern in utilizing imagery received from satellite platforms is a knowledge of the exact position and attitude of the camera at the time the image was made. Accurate data on this subject, prior to film arrival at NPIC, can markedly reduce the problems of target prediction, assignment and scheduling and make much more accurate the limited measurements made during immediate readout."

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10. The NPIC urgently needs any practical means for allowing the automation of those tasks which lend themselves to such techniques if it is to maintain its previously established performance levels in terms of completeness of reporting. The particular technique described here appears to have promise and your favorable consideration of this requirement is requested.

Arthur C. Lundahl

ARTHUR C. LUNDAHL
Director

Attachment

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