~~TOP SECRET~~
SPECIAL HANDLING

PRO H6B

BYE 16691-69

Cy 1 4 pgs

DEPARTMENT OF THE AIR FORCE
DIRECTORATE OF SPECIAL PROJECTS (OSAF)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

17 March 1969

REPLY TO ATTN OF: SP-1

SUBJECT: NPIC Attitude Measurement Requirements for HEXAGON

TO: MEMORANDUM FOR BRIGADIER GENERAL BERG

1. THE DNRO asked in Whig 7791 that NPIC Attitude Measurement Requirements for HEXAGON and NRO Plans to meet them be reconfirmed, and that a Document be prepared which reflects the agreed statement of NPIC Requirements and corresponding planning performance of HEXAGON Hardware.

2. REQUIREMENTS

NPIC has requested that the HEXAGON System provide attitude data with an absolute accuracy of at least three arc-minutes in all axes. (Reference [redacted]). NPIC also desires that the attitude data be available at NPIC no later than the time photography is delivered.

Positioning Requirement

The three arc minutes absolute is a valid goal if positioning is a requirement. Whether positioning from the HEXAGON materials is a requirement or not is a matter which SAFSP cannot confirm.

Monoscopic Measurement Requirements

The monoscopic measurement geometry results, for the worst case, in a one percent error in the measurement of Horizontal Dimensions and two percent error in the Measurement of Vertical Dimensions, where the absolute attitude error is 10 to 12 arc minutes.

Stereoscopic Measurement Requirements

The Stereoscopic Measurement Geometry is constrained so that an absolute attitude error makes a small contribution to the measurement error. Relative attitude errors cause an apparent scale difference. The horizontal and vertical measurement errors are approximately

~~TOP SECRET~~
SPECIAL HANDLING

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

2 1/2 percent for a relative attitude error of 15 arc minutes. NPIC submits that even though the HEXAGON Attitude System theoretically meets the stereoscopic measurement requirements, the system should provide sufficient accuracy to satisfy the monoscopic measurement requirements for the following reasons:

A. Accurate attitude measurement is required for use with the one-half frame of monoscopic coverage which occurs at the Start and Stop of each camera operation and the monoscopic coverage which would occur if one of the panoramic cameras fail during the mission.

B. Stereoscopic measurement requires additional reduction time and NPIC does not anticipate having sufficient stereo measuring equipment in the center to permit stereo measurements to be made. The SPO suggests, on the other hand, that the half frame of monoscopic coverage at the stop and start of each camera operation can be considered as wastage or bonus coverage and no known target will intentionally be covered monoscopically. Since this is so, a degraded attitude measurement capability during the time malfunctions occur may be acceptable.

Ancilliary Requirements

There was general agreement regarding the following aspects related to attitude measurements.

A. The currently available time measurements are adequate.

B. More frequent measurement might be desirable for diagnostic purposes but a frequency of measurement of once per camera frame is adequate for normal operations.

C. The attitude measurement can be arbitrarily made at the start, center or end of photography, although there is a mild preference for measurement at the center of photography.

3. ALTERNATIVES

There are several ways to provide positioning information such as using the HEXAGON Mapping System or improving maps in the area of interest to the point where they are sufficiently accurate. However, these solutions do not satisfy the NPIC Timeliness Requirement. In addition, the HEXAGON Mapping System will not necessarily be turned on at the same time as the panoramic camera.

There are several techniques which could be used to make rapid attitude measurements which can be used for either positioning or dimensioning. The possible approaches are:

A. Retain the current design; that is, record information from the present satellite vehicle horizon sensors and gyros. This will provide attitude data within a relative accuracy of approximately 3 arc minutes (2σ) in all axes and an absolute accuracy of 24 arc minutes (2σ) in pitch and roll and 30 arc minutes (2σ) in yaw. This does not meet the positioning requirement stated by NPIC.

B. Incorporate more accurate instrumentation for the present horizon sensors. This could provide absolute attitude data to an accuracy of 10-12 arc minutes (2σ). This would satisfy the requirement for monoscopic dimensioning as stated by NPIC.

C. Incorporate an already developed Sun Sensor to calibrate out the gyro drifts and horizon sensor biases. This could provide 3 arc minutes (2σ) accuracy in absolute attitude but might be affected by horizon uncertainty and has limited growth potential.

D. Measure apparent star motions with a solid-state star field comparator and gyros. This could provide 2.2 arc min (2σ) accuracy in absolute attitude but a new star comparator will have to be developed.

E. Measure apparent star numbers with a vidicon star sensor. This could provide 2.5 ar min (2σ) accuracy in absolute attitude. Development of this device entails some risk since the sensitivity may be marginal.

F. Incorporate a gimballed star tracker. This could provide 2.1 arc min (2σ) accuracy in absolute attitude. This accuracy is easily achieved but weight and costs are high.

4. The impact of the various possible changes is summarized as follows:

~~TOP SECRET~~
SPECIAL HANDLING

		Effectivity	Development Cost	Recurring Cost
Improve present attitude system to approximately 12 arc minutes		First Vehicle	$150K	Negligible
Develop & Incorporate	LMSC or ITEK Star Scanner	Vehicle 7	$ 4 M	$ 240 K
Develop & Incorporate	Sun Sensor	Vehicle 7	$ 2.5 M	$ 270 K
Develop & Incorporate	Gimballed Star Sensor	Vehicle 7	$ 4.5 M	$ 800 K

5. There are promising Technical Developments under way (such as SPARS) which could be used as a basis for the development of a 3 arc minute Attitude Sensor. It is probable that a more optimum system could be defined as we gain more information from these Technical Development Programs, and it is therefore to our advantage to defer a decision to select a specific approach as long as possible. If a go-ahead were given in October 1969, we would expect to meet the Seventh HEXAGON Vehicle.

6. The Aerospace Study on this subject is attached for your information.

JOHN L. MARTIN, JR.
Major General, USAF
Director

1 Atch
2 cys Aerospace Report
[redacted]
BYE 109-017008-69

~~TOP SECRET~~
SPECIAL HANDLING

[redacted]

PRO-A-6B

~~TOP SECRET~~
TOP SECRET

BYEMAN
CONTROL SYSTEM

~~IS~~ NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

T

6 May 1969

MEMORANDUM FOR THE CHAIRMAN, COMIREX

SUBJECT: NPIC Attitude Measurement Requirements for HEXAGON

This memorandum is in response to your request that NRO investigate options to meet the NPIC request for attitude data accurate to 3 arc-minutes absolute accuracy in all axes. NPIC also desires that the attitude data be available at NPIC no later than the time photography is delivered.

The rationale for the NPIC attitude request is as follows:

Positioning Requirements - The three arc-minutes accuracy is a valid goal if positioning is a requirement. Whether positioning from HEXAGON materials by NPIC and not using the SI photography is a requirement or not is a matter NRO cannot confirm. The attitude of the SI camera system will be 3 arc-seconds and it would appear that this is the system that should be used for positioning.

Monoscopic Measurement Requirements - The monoscopic measurement geometry results, for the worst case, in a one percent error in the measurement of horizontal dimensions and two percent error in the measurement of vertical dimensions, where the absolute attitude error is 10 to 12 arc-minutes.

Stereoscopic Measurement Requirements - The stereoscopic measurement geometry is constrained so that an absolute attitude error makes a small contribution to the measurement error. Relative attitude errors cause an apparent scale

~~HANDLE VIA~~

~~TOP SECRET~~
TOP SECRET
~~BYEMAN CONTROL SYSTEM~~
~~NO FOREIGN DISSEM~~

CONTROL NO BYE 12817/69
COPY 1 OF ___ COPIES
PAGE 1 OF 4 PAGES

difference. The horizontal and vertical measurement errors are approximately two and one-half percent for a relative attitude error of 15 arc-minutes. NPIC submits that even though the HEXAGON attitude system theoretically meets the stereoscopic measurement requirements, the system should provide sufficient accuracy to satisfy the monoscopic measurement requirements for the following reasons:

Accurate attitude measurement is required for use with the one-half frame of monoscopic coverage which occurs at the start and stop of each camera operation and the monoscopic coverage which would occur if one of the panoramic cameras fails during the mission.

Stereoscopic measurement requires additional reduction time and NPIC does not anticipate having sufficient stereo measuring equipment in the center to permit stereo measurements to be made. The NRO suggests, on the other hand, that the half frame of monoscopic coverage at the stop and start of each camera operation can be considered as wastage or bonus coverage and no known target will intentionally be covered monoscopically. Since this is so, a degraded attitude measurement capability during the time malfunctions occur may be acceptable.

Ancillary Requirements - There is general agreement regarding the following aspects related to attitude measurements:

1. The currently available time measurements are adequate.

2. More frequent measurements might be desirable for diagnostic purposes but a frequency of measurement of once per camera cycle is adequate for normal operations.

3. The attitude measurement can be arbitrarily made at the start, center, or end of photography, although there is a mild preference for measurement at the center of photography.

There are several ways to provide positioning information such as using the HEXAGON mapping system or improving maps in the area of interest to the point where they are sufficiently accurate. However, these solutions do not satisfy the NPIC timeliness requirements. In addition, the HEXAGON mapping system will not necessarily be turned on at the same time as the panoramic camera. The several techniques which could be used to make rapid attitude measurements which can be used for either positioning or dimensioning are:

1. Retain the current design; that is, record information from the present satellite vehicle horizon sensors and gyros. This will provide attitude data within a relative accuracy of approximately 3 arc-minutes (2) in all axes and an absolute accuracy of 24 arc-minutes (2) in pitch and roll and 30 arc-minutes (2) in yaw. This does not meet the positioning requirement stated by NPIC.

2. Incorporate more accurate instrumentation for the present horizon sensors. This could provide absolute attitude data to an accuracy of 10-12 arc-minutes (2). This would satisfy the requirement for monoscopic dimensioning as stated by NPIC.

3. Incorporate an already developed sun sensor to calibrate out the gyro drifts and horizon sensor biases. This could provide 3 arc-minutes (2) accuracy in absolute attitude but might be affected by horizon uncertainty and has limited growth potential.

4. Measure apparent star motions with a solid-state star field comparator and gyros. This could provide 2.2 arc-minutes (2) accuracy in absolute attitude but a new star comparator will have to be developed.

5. Measure apparent star numbers with a vidicon star sensor. This could provide 2.5 arc-minutes (2) accuracy in absolute attitude. Development of this device entails some risk since the sensitivity may be marginal.

6. Incorporate a gimballed star tracker. This could provide 2.1 arc-minutes (2 σ) accuracy in absolute attitude. This accuracy is easily achieved but weight and costs are high.

The impact of the four major options on the HEXAGON system is summarized as follows:

		Effectivity	Development Cost	Recurring Cost
Improve present attitude system to approximately 12 arc-minutes		1st Vehicle	$150K	Negligible
Develop and Incorporate	LMSC or ITEK Star Scanner	Vehicle 7	$ 4M	$240K
Develop and Incorporate	Sun Sensor	Vehicle 7	$2.5M	$270K
Develop and Incorporate	Gimballed Star Sensor	Vehicle 7	$4.5M	$800K

Should USIB determine that the NPIC attitude requirement can only be satisfied by incorporation of a system with an accuracy of better than 12 arc-minutes, it would be advantageous to delay definition of the system until October 1969. This would permit a more optimum system definition since it could take advantage of the additional information which will be available from technical development programs such as the stellar precise attitude reference system (SPARS).

RUSSELL A. BERG
Brigadier General, USAF
Director

PRO A6b

Handle via BYEMAN
Control

~~TOP SECRET~~
~~HEXAGON~~

7

18 June 1969

MEMORANDUM FOR: Director, National Reconnaissance Office Staff

SUBJECT: NPIC Attitude Measurement Requirements for HEXAGON

REFERENCE: NPIC Attitude Measurement Requirements for HEXAGON, Director, NRO Staff, to Chairman, COMIREX, 6 May 1969, BYE-2263-69

1. Following receipt of the 9 June memorandum from the Director, NRO, on the subject of HEXAGON over-runs, with particular emphasis on reassessment of the need for the 12-inch SI camera, we requested NPIC to complete a thorough review of its attitude accuracy requirement. Attachment A, which was part of the NPIC reply to our request, we are now forwarding to you on the basis of its pertinence to your 6 May memorandum to this office (see reference).

2. We note that your 6 May memorandum did not require an urgent reply but we feel that with the possibility of further review of HEXAGON upon us, as suggested in Mr. Froehlke's 13 June memorandum to Dr. McLucas, you might need all available information at this point in time.

3. This office agrees with the NPIC premise that there may be frequent occasions when accurate measurements are required on a timely basis. We support, therefore, the need to provide attitude data

BYE-2278-69
Copy 1

~~HEXAGON~~
~~TOP SECRET~~

Handle via BYEMAN
Control

accurate to better than 12 arc-minutes. We note also that purely for mensuration purposes the 3-inch focal length camera would be preferred to the 12-inch SI. The chances of getting conjugate imagery are increased with the smaller camera. Should any mission be flown without an index camera it would be necessary to add a star scanner or one of the other options outlined in your memorandum.

4. Please advise me if any other details or further discussion of the problem would be helpful to you at this time.

William A. Tidwell
Chairman
Committee on Imagery Requirements and Exploitation

Attachment to BYE-2972/69

ATTACHMENT A

1. [redacted] of NPIC presented to COMIREX on 5 September 1968 a non-technical statement of NPIC's attitude accuracy requirements for HEXAGON with the request that COMIREX affirm the community requirements for accuracy and timeliness of mensuration. At the end of his presentation he passed out a Working Paper, dated 4 September 1968, which gave the details of his briefing.

2. In essence, [redacted], speaking for NPIC, indicated:

a. NPIC had two categories of measurement which were regularly performed:

(1) Positioning of points, such as specific targets, with reference to an accuracy commensurate to orbital parameters. This would require an attitude accuracy from HEXAGON of at least three arc minutes in pitch, roll and yaw with respect to local vertical reference.

(2) Dimensioning of objects, both in the horizontal and vertical. An attitude accuracy from HEXAGON of ten to twelve arc minutes would be required for monoscopic coverage, while fifteen arc minutes would suffice for stereoscopic coverage.

b. NPIC had discussed these matters with SAMSO on 6 and 7 August 1968. SAMSO officers expressed the belief that all measurements made from HEXAGON imagery should be limited to stereo imagery. NPIC disagreed because of the belief that there would probably be some objects imaged on monoscopic coverage requiring mensuration. Also NPIC didn't believe there was sufficient stereo mensuration equipment available to meet expected needs if all HEXAGON imagery was in stereo. (This matter is now under study at NPIC in an attempt to devise means to meet such stereo requirements, if necessary.) At that time SAMSO also recommended use of the stellar index package for those requirements which could not be met by their planned Attitude Reference System (ARS). NPIC believed this was impractical due to a number of reasons: The physical location of the SI package in relation to the main camera; the fact that the SI camera may not always be operated in conjunction with the main camera and when it was there would only be conjugate imagery approximately half the time; there would be a burdensome requirement to perform relative orientations between the SI and the main system; and finally the fact that receipt of the SI package film after the fourth bucket would preclude obtaining accurate measurements until several weeks after the last of the mission film was obtained.

Attachment to BYE-2972/69

c. NPIC also recommended to COMIREX that consideration should be given to providing some means of recording attitude data and then transmitting it by telemetry or tape so that it is received together with the main camera film. This would permit accurate measurements during first- and second-phase readout minimizing or eliminating remeasurement, reidentification, and reassessment of PI information. Also, the attitude data could be reduced only once for the benefit of the entire community.

d. NPIC pointed out that the CIA Imagery Analysis Service has endorsed NPIC's recommendation that the main camera attitude accuracy requirement be at least three arc minutes in all axes.

3. COMIREX did not support NPIC's requirements as listed. Specifically, COMIREX declared:

a. DOD Mapping Agencies and not NPIC should be responsible for positioning. This means that ICRS and NRO positioning support required for mission planning on the KH-8 where timeliness is essential for new targets, would have to come from the Mapping Agencies in the future, and thus NPIC did not need three arc minutes.

b. There was no requirement for timely accurate measurement during first- and second-phase readout. Accurate measurements were required only within the third-phase reporting period, and response time was not a factor. HEXAGON criteria called for achieving ten to twelve arc minutes. TOPOCOM and others in the community had stereo measuring equipment and could be called upon to do measurement tasks when and if NPIC found itself equipment-limited. The SI package which covered about half the number of targets covered by the main camera could be used in those cases. There was no requirement for three arc minutes accuracy on the part of Departmental PI activities. Finally, although it would be nice to have, the community did not require a one-time reduction of attitude data, delivery of that data with the corresponding main camera film, and could accept a situation of continually reporting out refined measurements.

4. In response to a COMIREX request, NRO provided a cost statement (General Berg's memo of 6 May 1969) with regard to providing varying degrees of attitude accuracy. COMIREX, by memo of 19 May 1969, asked NPIC for comments on Berg's letter which are provided herewith as follows:

Attachment to BYE-2972/69

a. The design criteria is now stated as 15 arc minutes for the ARS instead of the ten to twelve arc minutes previously understood by NPIC and so reported to COMIREX by [redacted].

b. All proposals made by General Berg are acceptable in varying degrees of desirability, with the expenditure of $150,000 to achieve twelve arc minutes recommended by NPIC.

5. At the latest COMIREX meeting held on 5 June 1969, Col. [redacted], Chairman of the MC&G Working Group, read a memo from Dr. McLucas requesting DOD affirmation of the need for the SI package in HEXAGON. NPIC believes that mapping and charting elements can provide sufficient justification within terms of their own requirements. However, NPIC also believes that:

> The intelligence community could probably derive some value from imagery acquired on the Index camera of areas not covered by the main camera. Admittedly, this would be over areas of minimal interest to the intelligence community, but it could serve to provide a data base which might be of value in the event of an unforseen crisis in those areas. Indeed, NPIC by Message to NRO dated 2 June 1969, requested two copies of SI material to take care of this eventuality in addition to its possible use in mensuration.

6. It should be made perfectly clear that NPIC was and is providing its opinions without regard to cost factors. NPIC realizes that cost factors can preclude community decisions to provide what is best for photo interpretation. However, NPIC would be derelict in its obligation to the intelligence community if it were not to state its beliefs for consideration.

~~TOP SECRET~~

PROJ

HANDLE VIA BYEMAN CONTROL SYSTEM

~~ISI~~ NATIONAL RECONNAISSANCE OFFICE

WASHINGTON, D.C.

THE NRO STAFF

4 September 1969

MEMORANDUM FOR THE CHAIRMAN, COMIREX

SUBJECT: NPIC Attitude Measurement Requirements for HEXAGON

REFERENCE: A. BYE 12817/69
B. BYE 2278/69

This memorandum is to inform you of current efforts by the NRO to provide attitude data for the HEXAGON prime sensor.

Based on your memorandum of 18 June 1969 (reference A) and previous discussion of the various options for attitude data (reference B), the NRO is proceeding with development of a 12 arc minute (2 sigma level) capability with rapid readout. Current investigations indicate that the presently programmed attitude system should provide pitch to 9 arc minutes, roll to 7 arc minutes, and yaw to 10 arc minutes at the one-sigma level. It appears feasible to improve this system at minimal cost to achieve 12 arc minutes at the two-sigma level in pitch and roll, but it is unlikely that significant improvement can be made in the yaw value.

There is no program to provide 3-inch focal length frame camera for HEXAGON. The 12-inch focal length stellar-terrain camera presently under development is programmed for launch on the seventh HEXAGON vehicle.

LEW ALLEN, JR.
Colonel, USAF
Director

~~HEXAGON~~

HANDLE VIA BYEMAN CONTROL SYSTEM

EXCLUDED FROM AUTOMATIC REGRADING
DOD DIRECTIVE 5200.10 DOES NOT APPLY

CONTROL BYE 13143/69
COPY 2 OF 2 COPIES
PAGE 1 OF 1 PAGES

969 04 003

~~TOP SECRET~~

HANDLE VIA BYEMAN CONTROL SYSTEM

~~ISI~~ NATIONAL RECONNAISSANCE OFFICE

WASHINGTON, D.C.

PRO A 66

THE NRO STAFF

3 September 1969

MEMORANDUM FOR COLONEL ALLEN

SUBJECT: HEXAGON Attitude Requirement

BACKGROUND

The message from [redacted] at TAB B inquires as to NRO action with regard to providing attitude data for the prime HEXAGON sensor and references a memorandum from Mr. Tidwell. The referenced memorandum at TAB C is more than a little ambiguous but taken in context with its attachment indicates that the practical absolute attitude requirement for the HEXAGON prime sensor is 12 arc minutes. More accurate attitude (the three arc minute requirement) should be satisfied using conjugate imagery with the stellar-terrain camera. It appears practical at this time to tweak up the present horizon sensor-gyro to approach the 12 arc minute figure for about 150-300K. Alternatives (Star Scanner, Sun Sensor, Gimballed Star Sensor) have been estimated at 2.5 - 4.5M for development and 240 - 800K recurring (TAB D).

DISCUSSION

In a telecon yesterday, Col Buzard indicated [redacted] had gotten some bad information. Maj Johnson called Mr. [redacted] today and said that [redacted] was satisfied with the current effort to achieve the 12 arc minute attitude. The memo to Chairman, COMIREX, at TAB A summarizes our current efforts, thereby informing the community and providing for feedback.

RECOMMENDATION

That the memo at TAB A be signed and presented to the Chairman, COMIREX, by Col Sweeney on 4 September.

ROBERT A. SCHOW, JR.
Major, U. S. Army

[redacted]

Atchs
TAB A, Prop Memo (BYE 13143/69)
TAB B, [redacted]
TAB C, BYE 2278-69
TAB D, BYE 12817-69

(PROTOTOP SECRET)

HANDLE VIA BYEMAN CONTROL SYSTEM

~~TOP SECRET~~

EXCLUDED FROM AUTOMATIC REGRADING DOD DIRECTIVE 5200.10 DOES NOT APPLY

CONTROL NO Internal
COPY 1 OF 2 COPIES
PAGE 1 OF 1 PAGES