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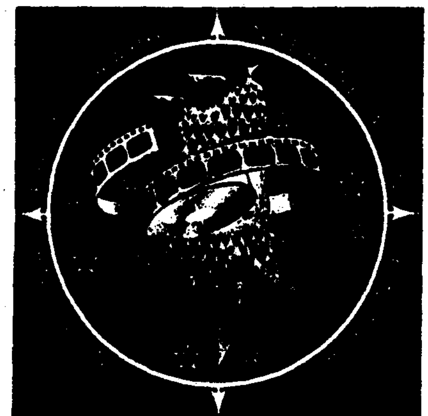

PROJECT QUILL EXPLOITATION EVALUATION REPORT

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PROJECT QUILL
EXPLOITATION
EVALUATION
REPORT

AUGUST 1965

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

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TABLE OF CONTENTS

ILLUSTRATIONS

AD HOC QUILL EVALUATION COMMITTEE

Chairman: Colonel [redacted], NPIC

Vice Chairman: [redacted], NPIC

Project Monitor: [redacted], NPIC

Members:

[redacted], CIA

[redacted] CIA

[redacted], CIA

[redacted] CIA

[redacted], DIA

[redacted], DIA

Captain John R. Jewel, U.S. Air Force

Mr. Joseph W. Grady, Dept. of the Army

Mr. Thomas P. Seymour, Dept. of the Navy

[redacted], NPIC

Captain [redacted], NRO

Major Robert M. McAllister, SAC

EVALUATION TEAMS

Guidance Team

Chief: [redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

Interpretation Evaluation Team

Chief: Major [redacted], NPIC

12 members (see Appendix A)

Technical Evaluation Team

Chief: Mr. [redacted], NPIC

4 members (see Appendix B)

Equipment Evaluation Team

Chief: Mr. [redacted], NPIC

2 members (see Appendix C)

Intelligence Evaluation Team

Chief: [redacted], DIA

4 members (see Appendix D)

Collection System Evaluation Team

Chief. [redacted] CIA

4 members (see Appendix E)

PREFACE

This is a special report on an exploitation evaluation of satellite side-looking radar imagery conducted under the direction of the Ad Hoc QUILL Committee composed of representatives from the CIA, DIA, Air Force, Army, Navy, NPIC, NRO, and SAC. The imagery was obtained from the first satellite radar mission, under Project QUILL, a research and development project of the NRO.

E X P L O I T A T I O N   E V A L U A T I O N   R E P O R T

I. PROJECT DESCRIPTION

A. Purpose

The purpose of the exploitation evaluation of Project QUILL is to determine the intelligence worth of satellite side-looking radar imagery as an information collection system (BYE #36346-65 from Director, NRO, to Director, NPIC, and BYE #41652-65, NPIC Project QUILL Evaluation Plan).

B. Objectives

1. "Assess the amenability of the QUILL High Resolution Radar products to interpretation by trained PI's to include problems associated with exploitation techniques in target detection, recognition and identification, training, and interpretation aids."

2. "Assess the limitations, advantages, and special applications of this type of satellite-derived intelligence product as a supplement to current photographic reconnaissance sensors and as a separate satellite reconnaissance sensor."

3. "Assess the benefits to be derived from various swath widths, resolutions, and beam depression angles for those applications unique to radar satellite sensors." (It is emphasized that radar sensors were examined from the point of view of image utility only. Operational problems which may be inherent to this type of sensor were not considered.)

C. Materials for Evaluation

The QUILL evaluation materials were obtained from 14 passes of Mission 2355 made over the United States [redacted] from 21 December to 24 December 1964. The mission was flown for research and engineering purposes and not for intelligence collection purposes. Consequently, some of the flight and system information and data that is required for complete interpretation was not obtained and some types of targets of current intelligence importance were not covered.

In addition, a limited amount of material was collected employing an airborne high resolution radar to map some of the target complexes contained in the QUILL product. This material was used to supplement the QUILL material employed only in the Intelligence Worth evaluation.

1. Radar Imagery Recorded

The material for evaluation, obtained from the 14 passes, was recorded by 3 methods.

a. Recovered Imagery

Physically recovered from the vehicle in the form of a Doppler History Record and converted to human readable imagery in a correlator. This material was from the first 7 passes only.

b. Transmitted Imagery

Transmitted and recorded as a Doppler History Record and fed into a correlator. This coverage was from all 14 passes.

c. Transmitted and Taped Imagery

Transmitted by data-link, recorded on magnetic tape, and later transformed into a Doppler History Record and fed into the correlator. This coverage was from all 14 passes.

2. Reproductions Received for Evaluation

Radar imagery was received in two forms:

a. Contact print on 70 mm film.

b. 2.6X enlargement on 9.5 inch film.

3. Imagery Evaluated

a. The primary evaluations were made of Recovered imagery.

b. A select sampling was made from all 3 methods of recording and was given a comparative evaluation to determine the relative losses of information.

c. The 2.6X enlargement received a technical evaluation but was omitted from interpretation evaluation because of its degradation and poor quality.

II. DISCUSSION

A. General

This discussion is a summary of the results of the efforts of 5 teams charged with attaining the objectives of the QUILL evaluation. The detailed reports of the teams are included as appendixes A thru E, which also contain results and conclusions beyond the basic objectives of the project evaluation.

B. Interpretation Evaluation (See Appendix A)

The interpretation effort involved the overlapping functional categories of mission plotting and scanning, target indexing, preliminary analysis of significant targets, and the detailed analysis of selected targets.

Mission plotting and target indexing were accomplished without difficulty with the aid of charts and maps. The continuous-scan format, the lack of atmospheric interference, and the photo/map similarity of the QUILL imagery facilitated the performance of these functions.

Target descriptive information of a general nature was readily derived during both the preliminary and the detailed analyses without the use of collateral information. The information derived from the QUILL imagery included the determination of activity levels of ports and rail yards, the occupancy of vehicle parks, and the approximate counts of aircraft at airfields. The use of collateral information and comparative visible spectrum imagery, i.e., KEYHOLE, added considerably to the reliability and the amount of detail derived from the QUILL imagery. Although targets not indicated on maps or in collateral were detected in the QUILL imagery, the derivation of substantive descriptive information was extremely difficult in many instances without the use of comparative visible spectrum imagery. The detailed analysis obtained from visible spectrum imagery was enhanced through its comparison with subsequent QUILL imagery to include target change detection.

Significant target information, such as aircraft and vessel counts, was derived from the QUILL imagery. Although this information is inherently less defined in nature than that obtained from visible spectrum imagery, this factor does not necessarily detract from the significance of the information derived from QUILL imagery.

Similar detail on most of the targets was derived from both the Recovery and Transmitted imagery. However, the degradation of the imagery from the Transmitted-tape format resulted in the loss of significant target detail.

The variables involved in the radar return from a given target and the relatively general nature of the information derived from QUILL imagery affect the accuracy of such information as aircraft and vehicle counts and functional determinations. However, reasonable estimates can be derived. The accuracy of these estimates is improved considerably through comparison with visible spectrum imagery and the maximum use of collateral information.

C. Technical Evaluation (See Appendix B)

The evaluation of the technical aspects of the QUILL material included a study of its characteristics determined by an analysis of the film quality and study of problems associated with plotting, titling, ephemeris data, and general handling.

The mensuration analysis included the determination of scale, the measurement of long distances, and the measurement of target dimensions. The QUILL mission was primarily a research and engineering test mission having no particular regard for target measurement requirements. In the majority of cases, precise measurements from QUILL imagery could not be obtained. This was partly due to the lack of reference data, such as normally received from a satellite reconnaissance mission, and partly due to the peculiarities of radar imagery. This resulted in a technically incomplete mensuration analysis. Nevertheless, the evaluation indicated that the QUILL imagery can be measured with reasonable accuracy from point to point and that the degree of measurement accuracy increases in the longer distances.

Accurate measurement of small targets is difficult because of the lack of sharpness of image edges and because of inaccuracy in establishing the image reference points of positive-return targets which are rarely imaged in their actual configuration.

The absence in the film format of mission reference data similar to that provided in the KEYHOLE program was a serious handicap to mensuration, but it is subject to ready correction through the application of techniques and equipments such as are used in other satellite systems.

D. Equipment Evaluation (See Appendix C)

The exploitation equipment currently on hand in interpretation facilities, such as the NPIC, is capable of handling QUILL mission material when it is exploited in a manner similar to a KEYHOLE read-out.

The development and installation of an in-house optical data processor (correlator) capable of enhancing target imagery detail would considerably improve the exploitation capability with regard to providing flexibility and timeliness to the detailed read-out.

In the event that a requirement for near real-time exploitation capability is generated by the collection system's real-time image transmission capability, the addition of correlating, multiple mission viewing, and automatic information retrieval would be required in the exploitation center. The nature, sophistication, and extent of such equipment would depend upon the real-time requirements, the volume and nature of the imagery of Doppler History Record received, and the type of read-out.

E. Intelligence Worth Evaluation (See Appendix D)

1. The estimated intelligence worth of a radar sensor was established through an evaluation of the following 4 major considerations.

a. The potential information collection capability of such a sensor against selected Essential Elements of Information (EEI) under certain operating conditions.

b. The advantages of the system which supplement photo sensors.

c. System limitations.

d. Special applications of such a system within selected international environments.

The collective evaluation of these considerations indicated that radar sensors could be extremely valuable as a supplemental imagery collection system during Cold War and Crisis situations and would be almost completely satisfactory as a separate system during a General War environment for the purpose of Strike Effectiveness Assessment (SEA).

2. The potential information collection capability was evaluated

for QUILL as well as QUILL-Improved (resolution approximately 10 feet in both range and azimuth) products. Furthermore, each of the preceding was evaluated as separate and supplemental collection systems. It was estimated that QUILL products were, at most, marginal information-producing materials during Cold War and Crisis situations, particularly as a separate system. However, they were estimated to be most productive for SEA during a General War environment, even as a separate system. QUILL-Improved products were considered to have substantially more information potential when compared with QUILL, particularly as a separate collection system for SEA. As a separate system, even these materials have limited information potential during Cold War and Crises; however, when employed as a supplemental system, their potential is significantly enhanced. The evaluation relative to scientific and technical information potential revealed that even QUILL-Improved products held little promise of providing anything of significance. Consideration was also given to a Post Attack Reconnaissance (PAR) mission during General War, and it was determined that the relative information potential would be almost identical to the Crisis situation.

3. The major advantages of a radar system, as a supplement to photo sensors, were considered to be threefold. They would be:

a. An essentially all-weather system.

b. A day-night system.

c. A potentially "quick response" system.

All of these advantages make a radar sensor invaluable where short response time is a major consideration.

4. The evaluation indicated a major limitation as an intelligence collection system. A radar sensor is extremely limited in providing meaningful information on previously unknown targets.

5. There were significant special applications for a radar sensor in each of the 3 international environments considered. During Cold War, changes or new construction activity could be detected, although not identified, in areas where weather or light conditions precluded photo acquisition, thereby increasing the efficiency of the operation of photo sensors for search and surveillance purposes. During both Crisis and General War, the quick-response characteristic makes its application most significant.

F. <u>Collection System Evaluation</u> (See Appendix E)

The objective of the Collection System Evaluation Team was to assess the limitations imposed upon the QUILL imagery as a result of collection equipment characteristics and to determine which characteristics might be improved in order to enhance the intelligence yield of the product.

As a result of this study, a number of system characteristics have been isolated and analyzed with regard to their influence on imagery quality and utility. To a large extent, these analyses have been subjective in nature since a sufficient quantity of QUILL data is not available.

It is clear that in order to proceed with the optimum design and development of an advanced radar system, a better quantitative understanding of the relationships between image utility and the various system parameters must be achieved. The primary parameters which require quantitative, experimental investigation are:

Range and azimuth resolution
Signal-to-Noise Ratio
Depression angle
Dynamic range
Radar frequency and polarization combinations

Although there are other characteristics which require study, it is considered essential that sufficient quantitative data be acquired on these 5 characteristics in order to design a system which would produce optimum imagery.

III. CONCLUSIONS

A. The QUILL High Resolution Radar products are amenable to interpretation by trained interpreters. Interpretation is enhanced by correlation of the QUILL products with collateral.

B. Previously known targets can be located, identified, and described, significant target changes and activities can be discerned, and previously unknown targets can be detected.

C. The analysis of QUILL imagery is enhanced significantly by variable processing with an optical data processor (correlator).

D. The exploitation of QUILL imagery on a near real-time basis with simultaneous comparison of visible spectrum imagery of selected targets is feasible.

E. In addition to the consideration of ground resolution as a separate and important factor influencing the information produced by radar imagery, the factors of dynamic range, look-angle, and frequency spectrum should also be considered.

F. A radar sensor would be of value in supplementing visible spectrum sensors in Cold War for search and surveillance purposes.

G. A radar sensor would be of definite value as a supplement to visible spectrum sensors for indications during a Crisis and for Post Attack Reconnaissance (PAR) during General War.

H. A radar sensor would be of very high value, even as a separate system, during General War for Strike Effectiveness Assessment (SEA).

I. The collection system employed on this QUILL mission represented a significant technological achievemnt. It demonstrated that very good quality radar imagery can be acquired from an orbital system during bad weather and darkness. It also demonstrated that near real-time strategic intelligence acquisition is feasible.

J. Notwithstanding the success of the collection system on this mission, it is highly probable that it can be greatly improved to produce much better imagery.

K. A QUILL-Improved system (10 feet in range and azimuth resolutions) seems justifiable.

IV. RECOMMENDATIONS

These recommendations are based on the assumption that satellite side-looking radar will be used operationally.

A. It is recommended that a thorough study be made of the requirements for the exploitation facility and exploitation procedures to include a near real-time capability.

B. It is recommended that a test program be initiated to investigate various parameters of the collection system in order to optimize the quality and utility of the resultant imagery.

APPENDIX A

INTERPRETATION EVALUATION TEAM REPORT

[redacted], NPIC, Chief

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted], NPIC

[redacted]

INTERPRETATION EVALUATION TEAM REPORT

PRELIMINARY REPORT, PHASE I

I. REFERENCE

Interpretation Evaluation Plan, Phase I

II. GENERAL

As indicated in the reference above, this report is based on preliminary analysis of data derived from Phase 1. The comments presented in Section III below will be directed only toward those aspects of the evaluation which pertain directly to the QUILL imagery (herein referred to as test imagery or imagery) plotting task. Comments related to other aspects of the evaluation are presented in Section IV and will be elaborated on in subsequent phase reports as appropriate.

III. OBJECTIVE

Plot all "Recovery" imagery, determining the complexities involved with regard to imagery format and quality, the utilization of various map formats, and handling equipment.

A. <u>Sub-Objective 1</u>

Determine the amenability of test imagery to initial orientation and subsequent scanning orientation.

1. It was determined that, given a general location for the head of each pass, it was reasonably simple to orient the initial point on most passes. Exceptions were those passes over sparsely settled areas which lacked topographic detail.

2. The continuous scan format of the imagery and the relative freedom from atmospheric interference are distinct advantages in plotting since they permit continuous map tracking and facilitate "back tracking" between well-defined points, thus permitting reasonably accurate plotting of nondescript or vague areas.

3. The narrow swath width of the imagery is a disadvantage in plotting since it precludes accurate plotting of coverage in those areas where identifiable features occur infrequently or where map detail is lacking. This disadvantage is offset in large part by the continuous-scan format.

4. The lack of appreciable effect from obliquity serves as an advantage in plotting with the Richardson viewer in that the imagery may be scanned either horizontally, vertically, or diagonally, thus facilitating image-to-map orientation.

5. The composition and normal quality of the imagery lend themselves to plotting because the features normally used for orientation are prominent on the imagery. These are, in most cases, the features which are prominent on most map series. This feature is discussed in more detail in Sub-Objective 2 below.

B. Sub-Objective 2

Determine the adaptability of test imagery to plotting techniques, utilizing various map series.

1. The basic map used in Phase 1 was the USAF Operational Navigation Chart (ONC) (1:1,000,000) supplemented by AMS Series 1301 (1:1,000,000), USAF Pilotage Charts (1:500,000), AMS Series V501 (1:250,000), US Air Target Charts, Series 200 (1:200,000), and USGS Topographic Series (1:24,000).

2. While the basic map (ONC) was adequate for plotting most passes it was found to have serious shortcomings with regard to desolate areas due to the lack of terrain detail portrayed. The most satisfactory map for plotting such area coverage was AMS Series V501, primarily because of the topographic detail portrayed.

3. It was determined that a much higher degree of accuracy in plotting coverage limits could be achieved on all passes utilizing AMS Series V501 and the USGS Topographic Series. Two map detail factors contributed to this accuracy -- the obvious increase in detail of naturally occurring features and the higher degree of similarity between patterns and shapes of man-made features portrayed on those maps and the patterns and shapes portrayed on the imagery.

4. The primary advantage in using the Air Target Charts, Series 200, was the ease in correlating specific returns on the imagery with the radar-return annotations on the charts. This advantage is more useful in locating specific points in large complexes and in identifying isolated returns, assuming that a general location is known, than in mission plotting.

C. Sub-Objective 3

Determine the adaptability of the test imagery to the various items of equipment and techniques utilized in normal plotting and scanning processes.

1. Two primary items of equipment, the Richardson Viewer and the Richards GFL-940 Light Table with B&L Zoom Mono Viewer, were utilized during Phase 1.

2. Though both items of equipment were utilized initially, the Richardson Viewer was utilized almost exclusively in those areas where the image quality was reasonably good. It was necessary in some cases where the quality deteriorated (pass 9) to use the light table in order to delineate image limits. The deterioration was manifested as a darkened area which necessitated adjustment of illumination under sharp focus. A displacement or inversion of the image format added to the problem but was resolved through combined viewing utilizing both viewing devices.

3. The Richardson Viewer affords the distinct advantage of rotating the imagery to an attitude which will orient best with maps and other graphic orientation aids which may be used in the plotting task.

4. Utilization of both the Richardson Viewer and the Richards 940 Light Table in combination permits the plotting team to simultaneously scan two variations in density, thus insuring easier extraction of image limits in areas of varying tone. This technique has greater significance in target scanning and detailed studies and will be commented on in detail in subsequent phase reports.

5. Initial difficulty was encountered in mounting the film for viewing. It was found that when the film is viewed so that the format titling data (word RECOVERY and pass number) reads properly the terrain image is reversed. This probably can be corrected without difficulty.

6. The scribed reference points annotated by TID along the film border were most helpful in Phase 1 and will be extremely useful in Phase 2. A similar titling system keyed to sensor-induced fiducial marks appears advisable.

7. The most satisfactory enlargement factor utilized on the Richardson Viewer is 15X. This factor permits observation of good detail at an adequate scale. It was found that

at 30X a diffusion of light through the brighter image areas caused an excessive loss of detail and hindered detailed plotting. The 5X position offered no advantage over the 15X and was more difficult to work with due to the relatively smaller scale.

8. It was found that etching the limits and centerline of the imagery on the viewing screen so that they could be used as reference points in locating and plotting returns expedited and simplified the plotting task. The etched lines superimposed over the projected imagery need not be positioned with a high degree of accuracy since they are used as a general guide to help locate more definitive points.

9. Some difficulty was encountered initially as a result of shifting or offsetting of the image track in range due to changes in Pulse Repetition Frequency (PRF). This range shift does not present a serious plotting problem when detected. However, if it is not recognized at the point of occurrence it could lead to difficulties. Since PRF changes are made by the operator, this problem can be avoided by furnishing the plotting teams with the locations of such changes.

IV. PRELIMINARY OBSERVATIONS

Incident to the conduct of Phase 1, certain observations not directly applicable to the plotting task were made. These are presented below as preliminary observations and will be evaluated further in subsequent phases.

A. Light Diffusion in Bright Image Areas

As indicated previously, some loss of definition was experienced at 30X apparently due to a diffusion of light passing through the lighter images, causing them to fuse together. This may be corrected to some degree through fine illumination control but may be best resolved by strictly controlled printing on paper format. This should only be necessary for detailed analysis.

B. Tone Contrast

While related to some degree to the problem outlined in A above, this comment is directed to the use of various (at least 2) density duplicate positives for MCI scanning and limited detailed studies. Significant loss of detail was noted in several instances on both light and heavy (relative) density duplicate positives. Since significant targets will image to varying degrees across the entire spectrum of the dynamic range of the system, from negative (dark) returns such as airfield runways and, presumably, silo covers flush with the ground to positive (bright) returns such as tall missile gantries and most buildings, it appears essential that the first and second phase read-out teams should utilize at least 2 density variations to insure maximum extraction of data.

V. SUMMARY

Preliminary analysis of the results of Phase 1 indicates that no significant problem areas exist with regard to accomplishing the plotting task involved in the exploitation of this type imagery operationally. In fact, certain advantages, such as continuity of scan and lack of atmospheric interference, are apparent.

INTERPRETATION EVALUATION TEAM REPORT

PRELIMINARY REPORT, PHASE II

I. REFERENCES

A. Interpretation Evaluation Plan, Phase II

B. Preliminary Report, Phase I, QUILL Imagery Interpretation Evaluation

II. GENERAL

This report is based on preliminary analysis of data derived from Phase II. The comments presented in Section III below will be directed only toward those aspects of the evaluation which pertain to the performance of first and second phase mission read-out functions utilizing the "Recovery" imagery. The comments presented in Section IV below will be directed toward those aspects of the evaluation which pertain to the relative amenabilities of the various types of QUILL imagery (Transmitted, Transmitted-taped, and Recovery) to those same functions. Comments related to other aspects of the evaluation are presented in Section V and will be elaborated on in subsequent phase reports or in the final report as appropriate.

III. OBJECTIVE 1

Scan selected passes of "Recovery" imagery to determine the extent to which normal first and second phase target reporting information can be derived, to include location and identification of both known and previously unknown targets, description of targets including significant changes, and description of activity such as air, naval, and ground order of battle information (See Table 1 for list of target types).

A. Sub-Objective 1

Determine the amenability of test imagery to location and identification of previously known targets, utilizing only map and series 200 target sheet references:

1. It was determined that target areas are readily located under most conditions. Notable exceptions are relatively small target areas located in larger areas of high return where imagery detail was either in smaller negative return areas or melded in smaller high return areas. It was found that railroads, which are commonly used in locating known target areas, are not readily discernible when they fall perpendicular to the flight path.

2. Ability to identify targets once the target location was determined varied with the type target, target environment, and the angle at which it was viewed by the sensor. Most known targets in rural areas were readily identifiable--some by association with surroundings, and others by recognition of features imaged. Airfield runway and taxi strip patterns of improved surfaces were identifiable. Port facilities, military installations (in rural areas), railroad classification yards, and some major utilities such as power plants were identifiable. Industries could generally be classified as heavy, light, or processing-type facilities and specific functional areas identified in many cases. POL storage was identifiable in those areas which were reasonably free of clutter. While most bridges were identified, several are not discernible at their known locations. This is apparently due to their environment and angle in reference to the sensor combined with their shape, a relatively low deck-type bridge in each case.

B. <u>Sub-Objective 2</u>

Determine the extent to which target descriptive information on known targets can be derived without the use of collateral information other than maps, series 200 target sheets, and standard PI keys.

1. Target descriptive data, while somewhat general in nature, can be derived in most cases as indicated below:

a. The most significant facilities at strategic airfields are discernible to the extent that hangars/ maintenance buildings, parking aprons, secured storage and alert ramps, electronic facilities, and some aircraft can be described as such with reasonable confidence. Reasonably accurate aircraft counts are obtainable in open, known parking areas.

b. A similar degree of detail is discernible in most port facilities where piers, wharves, and quays are readily distinguished and accurate shipping counts are obtainable. Some broad categoric identifications of shipping can be made without measurements and can be refined with accurate mensural data. Heavy construction and transloading equipment tend to clutter the image and interfere with interpretations in those cases where they predominate.

c. The approximate size of railroad classification yards can be determined and reasonably accurate estimates regarding the number of trains and cars can be derived.

The approximate speed and direction of travel of moving trains can be obtained when the angle of incidence and speed is sufficient to cause a Doppler effect displacement.

d. Military installations which normally form recognizable patterns, apart from those in built-up areas, can be described. Activity such as vehicle estimates in motor pools is extremely difficult without specific information regarding vehicle park locations.

e. Surface-to-air missile site locations are discernible, with guidance areas giving strong returns, while actual launch positions are manifested as negative targets due to the lack of reflecting structures. Analysis of Cleveland area SAM sites indicates that revetted launch positions would be imaged as positive returns.

f. POL storage facilities are readily discernible, and the extent of associated refinery facilities can be ascertained. In many cases, it is possible to differentiate between full and partially full floating top tanks.

C. Sub-Objective 3

Determine the amenability of the test imagery to the recognition and description of previously unknown targets without the use of collateral photography:

1. Those targets which are manifested on the test imagery as strong positive returns or which appear as a pattern which is indicative of their function or significance are discernible and in most cases were reported on by the analyst. Targets such as airfields (improved surface), small port facilities, shipping, bridges, railyards, new roads, power plants, POL storage, and various industries were readily identified. Significant details were derived to the same extent as with previously known targets of comparable structure with certain exceptions. Industrial facilities could be classified as light, heavy, or processing installations. However, specific functions could not be ascribed to many target components, and limits of specific plant areas remained ill-defined until collateral photography was utilized. This is due primarily to the lack of firm patterns of such facilities and the normal close association of various types of industries in larger industrial complexes.

2. The degree to which previously unknown targets covered by a given mission or pass can be recognized and described depends primarily on the target environment. Those targets which are isolated or contrast with their surroundings are

easily discerned while targets occurring in large complexes or which blend with their surroundings are frequently very difficult to recognize and analyze. Several factors predominate in effecting the latter condition. They are:

a. The high degree of "clutter" in signal returns from large complexes.

b. The nature of the signal return or lack of return from a given target.

c. The automatic compensation (automatic gain control) within the sensor which tones down the signal return from high return areas, (i.e. large complexes) and causes a loss of resolution in negative or small return targets (i.e. airfields and unrevetted missile sites) which are associated with those areas.

D. Sub-Objective 4

Determine the effect which utilization of collateral and comparative photographic coverage has on locating and identifying targets on test imagery:

1. Information of any nature which assists in defining exact locations of targets and in further defining the physical limits of the target, as well as indicating specific functions, is useful. Comparative photography proved an invaluable aid in confirming the location and identification of suspect targets. This is especially true in complexes where separation of individual target areas on the test imagery is extremely difficult without comparative conventional photography. In one instance, a surface-to-air missile site annotated on the 200 series target chart could not be discerned on the test imagery while an associated control/guidance area was identified, though both facilities were covered. Conventional coverage of the site revealed that the launch area had been dismantled while the guidance/control area remained. This is indicative of the value of utilizing comparative imagery of various types to detect changes as well as to identify target components.

2. In those areas where no conventional photography or other collateral was available, many "suspect" targets remained in that category, whereas in each case where specific collateral or conventional photography was available it was possible to confirm or refine initial tentative identifications or to negate the specific return as a significant target. A particular example is an automobile junkyard which was manifested as a very bright return area at a location which was indicated as

a cultivated area on the map used. Conventional photography permitted identification of the junkyard, and it was negated as a suspect significant target.

E. Sub-Objective 5

Determine the extent to which target descriptive information derived from test imagery can be enhanced through utilization of collateral data including comparative conventional photography.

1. As was the case in target location and identification, collateral information and comparative conventional photography proved invaluable in describing the various targets covered. It is possible in many cases to associate individual signal returns on the test imagery with individual structures or parts on conventional photography. Knowledge of the ascribed functions of specific targets and target components permitted appreciable refinement of test imagery analysis.

2. Analysis of relatively static installations such as POL refineries was considerably enhanced by using comparative photography. It was possible in the case of refinery installations to confirm the analysis from test imagery that certain storage tanks were partially full, floating top tanks. The construction of additional storage tanks was apparent from comparison of test imagery with conventional photography. It became possible to differentiate between various functional facilities in the refinery imaged on the test imagery by comparing previously nondescript target returns with images on the conventional photography. Such refinements can be accomplished to a greater extent in less complex installations.

3. Significant activity can be determined to a considerable degree with the use of comparative conventional photography. As indicated previously, new construction and dismantling and destruction of facilities can be ascertained, assuming the change takes place between the various dates of target coverage. In addition, it is possible to ascertain the status of military installations with regard to the presence of vehicles and aircraft at those installations at the time of coverage. Two examples are:

a. Identification of military vehicle parks from installation plans and conventional photography permitted the conclusion (not arrived at in the analysis from test imagery without collateral) that vehicles were present in those areas when covered by the test imagery. Without such comparison, the area could not be identified as a vehicle park on test imagery.

b. Initial analysis of the test imagery covering several airfields revealed the presence of suspect aircraft in apparent aircraft parking areas. Comparison with conventional photography confirmed these estimates in each case but one, where it was found that the suspect aircraft images were probably vehicles or small structures. In addition, it was possible to locate additional aircraft on the test imagery after determining the extent of the parking areas from conventional photography.

IV. OBJECTIVE 2

Compare the Recovery (R), Transmitted (T), and Transmitted-taped (TT) imagery obtained on selected passes to determine the adequacy of each to furnish first and second phase missions read-out information on typical targets and to determine the relative advantages of each type imagery.[1]

A. Sub-Objective 1

Determine the amenability of each type test imagery to target recognition during normal mission scanning:

1. The analysis conducted during preceding portions of this evaluation was derived from recovered test imagery. This imagery is considered adequate to permit performance of the interpretative functions listed in Table 2, within the context of the discussions presented thus far. It was determined, as indicated in Table 2, that each of the types of imagery were generally adequate for target recognition scanning with each having certain relative advantages and disadvantages as follows:

a. Use of Recovery imagery is particularly advantageous in scanning for targets which are imaged as positive signal returns. This imagery was determined to be the best in 5 out of 9 scanning type functions

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[1]Recovery imagery was recorded on photographic film from a cathode ray tube in the vehicle and processed after recovery, transmitted imagery was transmitted by wide-band data link to a ground station and processed, and transmitted-taped imagery was transmitted as above and tape recorded for later processing.

as indicated in Table 2.

b. Use of Transmitted imagery was found to be particularly advantageous in scanning for targets which are imaged as negative signal returns or dark toned areas, though loss of specific resolution is apparent. The resultant tone leveling of the positive signal returns caused negative return targets such as airfields ~~to~~ become more apparent. This imagery was determined to be the best in 4 out of 9 scanning-type functions, as indicated in Table 2.

c. While the Transmitted-taped imagery was determined to have a slight advantage over the Transmitted imagery in two instances, as indicated in Table 2, it was found to have serious limitations. Reduction in overall contrast made it most difficult to perform normal scanning functions.

2. The shortcomings of the recovered and transmitted imagery can be reduced to some degree in each case through variation of image tones by manipulation of illumination while viewing, through film processing, or by multiple processing of the data film in the correlator.

B. Sub-Objective 2

Determine the extent to which target description information can be derived from each type of imagery.

1. The amount of detail derived is directly dependent on ground resolution and contrast. These two factors were the primary consideration in arriving at the following results.

a. Since the recovery imagery offered the best resolution and could be manipulated so that specific target detail could be enhanced, it was determined to be best suited for extraction of descriptive information.

b. The transmitted imagery was found to be adequate in most instances as indicated in Table 2. In those instances where it was found to be lacking, it was determined that acceptable results could be achieved with detailed study.

c. The transmitted-taped imagery was determined to have serious limitations due, primarily, to a lack of resolution and a relative lack of image firmness, in that detail tended to blend together.

2. Significantly, it was determined that the transmitted imagery is adequate for obtaining target descriptive information

and that the transmitted-taped imagery, while considerably less useful, will furnish limited descriptive data of a general nature.

C. Sub-Objective 3

Through direct comparison of the 3 types of test imagery determine the relative utility of each for performance of first and second phase mission read-out functions:

1. A representative list of functions performed is presented in Table 2. As indicated, a ranking of first, second, or third was assigned to each type imagery for each function. Point values were assigned to each ranking assigned by each analyst and then totaled for a given function, thus resulting in the final ranking as indicated.

V. PROBLEMS

Incident to the conduct of Phase II of the Interpretation Evaluation, several problems were encountered and resolved through application of special imagery processing and through adaptation of available equipment. A brief discussion of these problems and the solutions employed is presented here for the information of the evaluation teams concerned:

A. The problem of imagery density or contrast alluded to earlier was reduced considerably by the production of 5 variations in density of specific target areas directly from the correlator (precision optical processor). Employment of this process permitted the presentation of a much wider portion of the dynamic range of the original record. The advantage derived was of sufficient magnitude to indicate the desirability of systematically accomplishing this process for high-priority targets.

B. Some difficulty was encountered in analyzing bright returns due to the diffusion of excessive light. A polaroid copy camera was utilized to produce a positive print in an attempt to "stabilize" the bright returns. The results were very satisfactory. In addition, it was found that considerable time could be saved by producing polaroid photos of areas on test imagery and conventional photography for hasty comparison.

C. In order to achieve the desired degree of flexibility in comparing test imagery with conventional photography, 2 Richardson viewers were utilized side by side. Though difficult to work with because of their size, this method of comparison furnished the desired flexibility and was extremely beneficial. The success achieved indicates the desirability of a comparative viewer having a dual viewing system with each viewer mechanism individually controlled for maximum flexibility of magnification and orientation.

VI. SUMMARY

It can be stated that preliminary analysis of the results of Phase I and II of the Interpretation Evaluation indicates the following:

A. Significant known targets can be located, identified, and generally described utilizing QUILL imagery.

B. Previously unknown targets of similar nature can be detected utilizing QUILL imagery.

C. Target identification and analysis is considerably enhanced when QUILL imagery is compared with conventional photography.

D. The degree of definition obtained from QUILL imagery permits gross assessment of target changes.

E. When used in conjunction with conventional comparative photography, QUILL imagery can reveal significant changes in activity.

TABLE 1

TYPE TARGETS REPORTED

1. Airfields
2. Military Installations
3. Surface-to-Air Missile Sites
4. Ports
5. Industry
6. Major Utilities
7. Railroad Marshalling Yards
8. Rail Activity
9. Urban Complexes
10. Miscellaneous Transportation Facilities

TABLE 2

RESULTS OF COMPARATIVE ANALYSIS

The following chart depicts the first and second phase read-out functions attempted throughout Phase II and details the relative rankings assigned the 3 types of imagery in evaluating their relative amenability to the performance of such functions.

	RELATIVE RANKING		
READ-OUT FUNCTION AND TYPE TARGET	TRANS	TRANS-TAPED	RECOVERED
Locating Airfields	1	3	2
Describing Major Airfield Facilities	2	3	1
Obtaining Approximate Aircraft Count	2	3-B	1
Locating SAM Sites	2-A	3-C	1
Locating Port Facilities	1	3-A	2
Describing Port Facilities	2	3-A	1
Obtaining Approximate Vessel Count	2-D	3-B	1
Identifying Bridges	2	3-A	1
Tracking Roads	1	3	2
Tracking Railroads	1	3	2
Locating Marshalling Yards	2	3	1
Describing Marshalling Yard Activity	3-B	2	1
Identifying Power Lines	3-A	2	1
Detecting Moving Trains	3	2	1
Recognition of POL Storage	3-A	2	1
Estimating POL Tank Count	3-A	2	1

TABLE 2.(Continued)

READ-OUT FUNCTION AND TYPE TARGET	RELATIVE RANKING		
	TRANS	TRANS-TAPED	RECOVERED
Identifying Partially Full Flotation Tanks	3-A	2	1
Locating Normal MCI Targets within a Complex	2	3	1
Locating Normal MCI Targets in Rural Areas	3	2	1

A - Could not be performed in 1 case of 7
B - Could not be performed in 2 cases of 7
C - Could not be performed in 3 cases of 7
D - Could not be performed in 4 cases of 7

INTERPRETATION EVALUATION TEAM REPORT

PRELIMINARY REPORT, PHASE III

I. REFERENCES

A. Interpretation Evaluation Plan, Phase III

B. Preliminary Report, Phase I, QUILL Imagery Interpretation Evaluation.

C. Preliminary Report, Phase II, QUILL Imagery Interpretation Evaluation.

II. GENERAL

A. This report is based on preliminary analysis of data derived from Phase III. The comments presented in Section III below will be directed toward those aspects of the evaluation which pertain to the derivation of information necessary to the conduct of detailed analysis from QUILL imagery. The various techniques discussed in references B and C were employed during this phase, and the conclusions presented in reference C are supported by the findings of Phase III.

B. It should be noted that the "detailed" analysis discussed herein is a limited term applied here to conduct of the analysis performed and does not refer to the amount or type of information derived.

III. OBJECTIVE

Determine the extent to which significant target information can be derived from test imagery through the application of detailed analysis.

A. Sub-Objective 1

Determine the extent to which significant target information can be derived without the use of collateral data.

1. In those instances where the target functions were known as a result of initial target identification, a considerable amount of target detail was derived. The extent of this detail decreased as more complex targets were studied. Industrial plants involved in mechanical production were more accurately described than the more complex chemical processing industries.

2. When functions were not known initially, it became more difficult to determine the extent and relationship of facilities though in some cases functions could be determined through the application of normal analytical techniques.

3. All target reports prepared without the use of comparative imagery or other collateral were general in nature in describing facilities but were more specific in estimating the activity levels of such targets as airfields, ports, and railyards. Examples of the type information derived without collateral data are presented in column 2 of Table 3.

B. Sub-Objective 2

Determine the extent to which significant target information can be derived from test imagery with the full exploitation of collateral data:

1. The utilization of comparative imagery and other collateral data in the conduct of detailed analysis resulted in the derivation from test imagery of a considerable amount of significant target information not previously derived. Collateral data permitted identification of specific functional components and determination of changes such as expansion or removal of facilities. Accurate location of aircraft and vehicle parking areas on comparative imagery permitted correlation with test imagery, thus resulting in more accurate estimates of activity levels. Detailed comparison of test imagery with comparative imagery is readily accomplished and is essential to the full exploitation of test imagery where a maximum amount of target descriptive information is desired. Examples of the type information derived with the use of collateral data, compared with that derived without collateral, are presented in Table 3.

C. Sub-Objective 3

Determine the relative amenability of the 3 test imagery formats (Recovery, Transmitted, and Transmitted-taped) to detailed interpretation.

1. The extraction of information on all target elements, ranging from bright positive signal returns to very subtle tone differences in negative return areas, required imagery manipulation across the entire dynamic range of the data record. The recovery data record afforded the best base of manipulation with the optical image processor (correlator). As a result, more detail was discernible in comparing 5 images of a given target, produced at 5 different correlator settings. This technique was effective in complex target areas where it permitted differentiation between positive returns which had blended together on the original test materials. It was also possible to discern subtle

tonal changes in weak return areas using this technique.

2. Since the Transmitted and Transmitted-taped data records were the result of weaker signal returns and apparently influenced by atmospheric conditions they did not offer as wide a latitude for image processing. The Transmitted imagery did provide much of the essential target information that could be derived from analysis of the recovery imagery. However, some loss of significant information, such as individual aircraft returns and target element delineation, was experienced in some cases. The Transmitted-taped imagery was degraded to the extent that a significant amount of target detail was lost. Though preliminary analysis was refined to a limited degree utilizing this imagery, it required time-consuming comparison with comparative photography and was considerably less reliable than the information derived from the Recovery and Transmitted imagery. It should be noted that the significance of the limitations of the Transmitted and Transmitted-taped imagery in relation to the Recovery imagery, with regard to detailed analysis, depends upon the type and amount of information desired. Table 4 illustrates the relative degree of information obtained on selected targets from each type imagery.

IV. SUMMARY

The application of detailed imagery analysis techniques permitted refinement of preliminary analysis and increased the reliability of information derived. Reasonably definitive information was derived from both Recovery and Transmitted imagery through application of these techniques while the quality of the transmitted-taped imagery limited detailed exploitation.

TABLE 3

COMPARISON OF INFORMATION DERIVED WITH AND WITHOUT COLLATERAL DATA

Type Target	Information Derived without Collateral	Additional Information Derived with Collateral
Airfield	Approximate runway dimensions, general extent and location of facilities such as taxiways, parking aprons, secured areas and housing, and hangar/maintenance buildings, and estimated aircraft count.	More specific extent and location of facilities and refined aircraft count. Identification of electronics locations, weapons storage areas, POL storage, and miscellaneous facilities.
Military Installation	General patterns and inaccurate building counts. Limited identification of functional areas.	Refined building counts by type of building. Discernment of "new" construction, identification of vehicle parks, and estimated vehicle counts. Discernment of ammo storage area. Refined identification of functional areas.
Surface-to-Air Missile Installations	Confirmed presence of facilities in known guidance area. Tentative identification of known launch area. Uncertain negation of abandoned launch area.	Confirmed presence of individual guidance facilities. Identification of known launch area. Negation of abandoned launch area.
Port Facilities	General description of piers, transshipping area, and number of large vessels.	Identification of and determination of activity on building ways. Location of heavy loading equipment. Significant changes in facilities and number of vessels present.

TABLE 3. (Continued)

Industrial Areas	Extent of facilities, indications of activity levels, and general description of major components with limited reliability of identifications.	Significant changes in extent of facilities, refined activity estimates, and confirmed/corrected identification of major components.
Railroad Marshalling Yards	Identification of large (6 plus tracks) railyards and gross estimates of yard capacity and activity levels.	Refined estimates of capacity and activity levels, and changes in capacity and associated facilities. Identification of smaller (4-6 track yards).

TABLE 4

SUMMARY OF DATA DERIVED-SELECTED TARGETS

Target Information Required	Recovery	Transmitted	Transmitted-Taped
I. Wurtsmith AFB			
A. Determine runway serviceability	yes	yes	yes
B. Identify Major Facilities	yes	yes	yes
C. Discern Major Changes	yes	yes	Prob
D. Identify & Count Aircraft			
1. Main Parking Apron	3 hvy, 3 med, 2 poss med, 16 poss small.	3 hvy, 5 prob a/c (med hvy)	8 prob a/c
2. Alert Apron	4 psns prob occ, 4 psns poss occ, 1 vacant	5 psns poss occ, 4 poss undetermined	2 returns from area, occupancy undetermined
3. Other	None	None	None
E. Identify & Count Vehicles Adjacent to Taxiway	13 prob vehicles/ sheds	4 groups u/i objects	4 groups u/i objects
F. Locate Electronics Facilities (known)	Yes	Yes	Yes
II. Mothball Fleet and Port, Wilmington, N.C.			

TABLE 4.(Continued)

A.	Locate Major Facilities	Yes	Yes	Yes
B.	Discern Major Changes	Yes	Yes	No
C.	Count Ships in Storage	Approximately 127	At least 120	Estimated 100
D.	Identify Other Shipping	1 ship, 1 small vessel	1 prob ship	Undetermined
E.	Discern Ship Construction/ Repair	None apparent in yard	None apparent in yard	Undetermined

INTERPRETATION EVALUATION TEAM REPORT

FINAL REPORT

I. REFERENCES

A. Interpretation Evaluation Plan

B. Preliminary Report, Phase I

C. Preliminary Report, Phase II

D. Preliminary Report, Phase III

II. GENERAL

This report is designed to present the results of the QUILL imagery "Interpretation Evaluation" conducted by the National Photographic Interpretation Center. It summarizes the evaluation plan employed and the conduct of the various phases of the plan, details of which are available in References A through D.

III. EVALUATION PLAN AND CRITERIA

A. The evaluation was conducted in 4 phases designed to test the amenability of QUILL imagery to the functions involved in extracting intelligence information from imagery, including analysis of such information, as well as recording and dissemination of the data derived. The first 3 phases involved the overlapping functional categories of mission plotting and preliminary target location, mission scanning and preliminary analysis of significant targets, and detailed analysis of selected targets. The fourth phase involved the evaluation and refinement of data derived from the previous phases.

B. The criteria established for the evaluation were designed to insure valid testing of the QUILL imagery within the limits of the evaluation objectives. These criteria are as follows:

1. Utilization of the QUILL "Recovery" imagery as the basic subject material.

2. Selection of typical strategic targets as subjects for analysis.

3. Concentration of analysis on known targets for which "Truth Data" was available.

4. Confirmation of analysis by duplicate analysis and utilization of "Truth Data."

5. Employment of experienced interpreters both with and without previous radar imagery interpretation experience.

6. Maximum utilization of collateral material in each phase after completion of initial analysis without collateral.

IV. EVALUATION ANALYSIS

A. The significant aspects of the evaluation are summarized in phase order as follows:

1. Phase I

a. The mission plotting and preliminary target locating functions were accomplished without significant difficulty. The continuous scan imagery format, relatively free of atmospheric interference, and the similarity of the imagery detail to that found on most maps permits ready orientation and plotting (Figure 1).

b. While there is a slight "Oblique" appearance to the imagery it is quickly adjusted to. The lack of appreciable "Oblique" effect permits rotation of imagery to any orientation for comparison with other imagery or collateral data.

c. Target returns presented by the imagery are readily equatable to the radar return annotations on Series 200 Target Charts. The narrow (10 NM) swath width of the test imagery causes difficulty in maintaining orientation over desolate areas and may result in only partial coverage of large targets. However, this disadvantage is largely overcome by the continuous scan format.

2. Phase II

a. In order to assess the value of the test imagery in affording the basis necessary for locating specific target areas, identifying targets, and describing significant facilities and activity more accurately, a sequence of analysis was prescribed. These functions were first attempted without the use of collateral other than maps and target charts. Having accomplished this for all of the functions, the analyst then repeated each step with the use of full collateral.

b. It was determined that significant information could be derived from the test imagery without the use of collateral. However, it was possible in each instance to extract information more rapidly and to derive more detail when collateral data, particularly comparative photographic coverage, was utilized (Figure 2). In those areas where no comparative photography or other collateral was available, many "Suspect" targets remained in that category whereas in those cases where such data was available it was possible to confirm or refine initial, tentative identifications or to negate the specific return as a significant target.

c. A comparison of the 3 formats of test imagery (Recovery, Transmitted, and Transmitted-taped) with regard to performing the Phase II functions outlined above was performed. Significantly, it was determined that the "Transmitted" imagery generally compared favorably with the "Recovery" imagery though some image quality loss was apparent.

d. Targets were located and identified with reasonable accuracy in most cases. The ease with which target identification is made is largely dependent on the target environment and sensor-viewing angle as well as the actual composition of the target.

e. A reasonable amount of general target descriptive information is obtainable during preliminary analysis on such targets as: Airfields, ports, military camps, some industries, and rail transportation facilities. Major target components can be equated to specific signal returns, and estimates of activity levels can be derived in some cases (Figures 3 through 6). Aircraft and vehicles were discerned in known parking areas though some of the aircraft in such areas were not discerned. Accurate vehicle counts were not obtainable but reasonable estimates could be arrived at. Ships were discernible in ports and underway offshore (Figure 7). Approximate train and car counts were derived from preliminary analysis of railroad marshalling yards. Rail traffic can be discerned under some conditions, and estimates of train speed as well as direction can be derived. Comparison of target coverage from the test imagery with earlier photography revealed changes such as new construction and aircraft and vehicle position changes.

3. Phase III

The application of detailed analysis techniques to selected targets resulted in refinement of data derived during Phase II and in the derivation of previously undetected information. The close correlation of target returns depicted on the test imagery with comparative photography permitted more accurate aircraft, vehicle, train, and ship counts. The techniques also permitted a more accurate determination of the extent and location of target components such as electronics facilities, ammunition storage areas, airfield POL storage areas, and missile launch facilities. While the test imagery does not furnish sufficient data for detailed description of previously unknown facilities it was possible to correlate much of the data derived from detailed analysis of conventional photography with the signal returns and thus frequently detect even subtle target changes. Detailed analysis of major targets was considerably enhanced through utilization of varying correlator-produced reproductions of test imagery designated to present a cross section sampling of the entire dynamic range of the original data record film.

V. SUMMARY AND CONCLUSIONS

A. Since QUILL imagery lacks the detail and resolution obtainable in conventional photography and presents a target return which is influenced by a number of variables, some of which were unknown, no attempt was made to evaluate the test imagery in terms of what could be derived from conventional photography. The evaluation was designed to determine what information could be derived from QUILL imagery, utilizing all available exploitation resources. The analysis conducted and the conclusions arrived at are presented in this context.

B. It is apparent that certain significant information can be derived from QUILL imagery. This information is inherently more general in nature than that normally derived from conventional photography. However, this factor does not detract from the significance of the information that is derived. The plural involved in a given target area return and the relatively general nature of the information derived from QUILL imagery affect the accuracy of such information as aircraft and vehicle counts or functional determinations, but, normally, reasonable estimates can be derived. The accuracy of these estimates can be considerably enhanced through comparison of the QUILL imagery with conventional photographic coverage and full exploitation of other collateral data.

C. The relative lack of interference from atmospheric conditions, the capability to furnish near real-time analysis of target areas, and the amenability of QUILL imagery to correlation with conventional photography combined with the results of the various analysis conducted during this evaluation produce the conclusions listed below:

1. Previously known targets can be located, identified, and described.

2. Significant target changes can be discerned.

3. Previously unknown targets can be detected.

4. Significant Air, Naval, and Ground Order of Battle information can be derived.

5. Correlation with conventional photography considerably enhances exploitation.

6. Employment as an indicator sensor, to detect areas for exploitation by more specific sensors, and in change detection is indicated.

7. Exploitation of QUILL imagery on a near real-time basis with simultaneous comparison of conventional photography of selected targets is feasible.

APPENDIX B

TECHNICAL EVALUATION TEAM REPORT

[redacted], NPIC, Chief

[redacted] NPIC

[redacted] NPIC

[redacted], NPIC

[redacted], NPIC

[redacted]

I. GENERAL

The Technical Evaluation Team performed studies and tests on QUILL materials with regard to the titling of the film, handling of the materials, plotting, film evaluation, mensuration analysis, determination of scale, and the measurement of targets. Of these tasks, those concerned with mensuration are the most important to the evaluation objectives.

II. TITLING

The test material used contained insufficient titling for operational use. Titling data should be placed on the border of the film, preferably the far-range side. The titling should be readable when the imagery is in proper viewing orientation and should include the following data:

A. Mission number

B. Revolution number

C. Date of acquisition

D. Orbital direction (ascending, descending)

E. Security classification

F. Index marks and number

III. PACKAGING AND LABELING OF MATERIAL

The imagery from each revolution should be placed on a separate spool. If more than one acquisition of imagery is obtained on a single revolution, the parts should be separated by 2 feet of "idents" which indicate the end of one part and the beginning of another part. The second and subsequent parts should contain index marks and numbering that are a continuation of the first part of that revolution. The film from each revolution should contain a minimum of 6 feet of leader and trailer, both of which should contain:

A. Mission number

B. Revolution number

C. Date of acquisition

D. Security classification

E. Type of reproduction (Transmitted, Transmitted-taped or Recovery)

The flange of the spool, the container, and the cover should each be labeled identically. The label should contain the following information:

1. Mission number

2. Revolution number

3. Date of acquisition

4. Security classification

5. Type of reproduction

The labels should be color coded to conform to existing practice (i.e., green for original negative, red for duplicate positives, blue for work copy, and so forth).

IV. PLOTTING

The area covered by the test material was plotted on 1:1,000,000 WAC sheets. The radar imagery is readily adaptable to current procedures for plotting photography. No special templates were required. Insufficient ephemeris data was available to compare planned coverage versus actual coverage. Overlays to a 1:9,000,000 base map were prepared depicting all previous satellite photographic coverage of the same areas for photo interpretation use.

V. FILM EVALUATION

The film received was evaluated in a manner similar to that of visual photography. A physical evaluation of the material indicated that although care was taken in the reproduction of the material, the negatives and positive transparencies were of sub-standard photographic quality compared with other photographic material received by NPIC. The 2.6x enlargements were of such inferior quality that they were considered of little value. Areas of soft focus occurred in these enlargements which would adversely influence the PI evaluation if used. A substantial difference in density and contrast can be obtained by adjusting the correlator, which in turn affects the interpretability.

VI. MENSURATION ANALYSIS

It was first necessary to attempt to acquire a thorough understanding of the geometric characteristics of the QUILL radar system and of the supporting data regarding the conduct and performance of the test mission. It was soon obvious, as attested to by [redacted] that little consideration had been given to the possibility that there would be an interest in exploiting metrical information from the material. Consequently, there was a definite lack of supporting data necessary to extract measurements therefrom. Some of the necessary data was subsequently made available. Knowing what is needed, much of the data could be provided in the future. The inherent characteristics of the radar system results in a non-uniform scale of the imagery. The scale differs in transverse, or range, direction from that in the azimuth direction. In addition, operational adjustments made in flight and correlator manipulation also affects the scale. Other factors affecting the ability to extract measurements include flare of the return, the lack of image sharpness of the edges of objects, and the difficulty of distinguishing the radar return from the various parts of an object, such as the roof from the base of a building. Availability of accurate maps or charts is most beneficial in determining scale and identifying objects. Manipulation of the correlator produces a considerable change in measurements. Available measuring instruments were utilized satisfactorily, with the main improvement suggested being a larger field of view to locate and identify objects to be measured.

VII. SCALE DETERMINATION

Several areas, one from each of 4 passes, were chosen for mensuration tests. Good maps and ground truth data were available for these areas. The scale of the radar imagery was determined by 2 methods.

A. Computed Scales

These were determined from nominal values of attitude, earth radius, vehicle velocity, incidence angle compensating for earth curvature, film velocity, and format width.

1. The azimuth scale was determined as follows. Knowing the on-off times of the operation, the average altitude (H), radial distance and inertial velocity (V) were determined from the orbital ephemeris. The ground velocity (Vg) was calculated from:

$$Vg - (V) \left(\frac{R}{R+H \sec 35^\circ}\right)$$

where R = earth radius

The azimuth scale was computed as the ratio of the velocity of the processor output film (Vf) to the ground velocity Vg. A nominal Vf = 0.729 inches/sec was used.

$$\text{Azimuth Scale} = \frac{Vf}{Vg}$$

2. The range scale was determined from:

$$\text{Range Scale} = \frac{Rs/\cos B'}{Wf}$$

where

R_S = slant range interval = 5.95nm

B' = incidence angle = ($B-\alpha/2-\phi$)

B = beam depression angle = 55°

d/2 = half of the vertical beamwidth = 1.5°

ϕ = earth curvature $\approx$ 1.5°

Wf = format width = 27.4nm = 1.08 inches

B. Scales from Maps

Scale numbers were obtained by calculating the distance between points

$$D = (X^2 + Y^2)^{\frac{1}{2}}$$

and computing the ratio of photo distance to map distance multiplied by map scale.

$$\text{Photo Scale} = (\text{map scale}) \left(\frac{PD}{MD}\right)$$

The scales obtained by the 2 methods were in agreement to within 1 percent for 3 of the areas and to within 2 percent for the fourth area.

C.

Pass	Area	Azimuth Scale Measured	Azimuth Scale Computed	Range Scale Measured	Range Scale Computed
9	Phoenix	1:394542	1:399142	1:664500	1:652232

Pass	Area	Azimuth Scale Measured	Azimuth Scale Computed	Range Scale Measured	Range Scale Computed
14	Richmond	1:399700	1:401837	1:655400	1:653583
24	Chicago	1:399440	1:399557	1:653040	1:652232
30	Wurtsmith AFB	1:403750	1:401822	1:645875	1:652232

In actual operational use, good maps of the area covered may not exist; thus the computed scale will have to be utilized. It is felt that scale can be determined to an accuracy of 2 percent or less, depending upon the accuracy of the mission data.

VIII. MEASUREMENTS

Measurements were made of a variety of distances from 3,900 feet in length up to several miles in an assortment of directions. These measurements were then compared with scaled map distances. Errors ranged from a fraction of 1 percent to over 10 percent, the bulk of the measurements being in error less than 3 percent. A lesser number of measurements were made of smaller cultural features, such as buildings, bridges, and a race track. These objects ranged from 75 feet to several hundred feet in size. The error in measurements of these features was excessive, several being over 100 percent and many being greater than 25 percent in error. (Table 5).

IX. REQUIREMENTS FOR DATA

In the course of the technical evaluation, the need for certain supporting data crystallized.

A. A precise frequency time track accurately imaged on the film would provide the basis for measuring the film speed, which would be used to determine the azimuth scale. The time track would also provide a base for aligning the film in a comparator, and for zeroing the instrument when making measurements.

B. A time word recorded periodically from which GCT time or system time could be recovered with an accuracy of ±5 milliseconds would provide a means of correlating imagery with the orbital ephemeris and known changes in the system's operating sequence.

C. Some means of calibrating or establishing the accuracy of the beam depression angle, film speed, pulse rate frequency, and so forth, would in turn contribute to improving the accuracy of derived dimensional data.

D. A more frequently recorded ephemeris, such as a 4 second instead of a 1 minute interval, containing the following items of suggested accuracy. (The asterisk designates items in addition to those provided on the test mission.)

1. GCT - ±5 milliseconds
2. System time - ±5 milliseconds
3. Latitude of vehicle nadir - 1/10 minute
4. Longitude of vehicle nadir - 1/10 minute
*5. Latitude of beam incidence - 1/10 minute
*6. Longitude of beam incidence - 1/10 minute
7. Altitude - ±1,000 feet
8. Radial distance - ±1,000 feet
*9. Slant range - ±1,200 feet
*10. Ground range - ±600 feet
11. Inertial velocity - 1 foot/second
*12. Ground velocity - 1 foot/second
13. Flight path angle - 1/10 minutes
14. Azimuth - 1/10 minutes

E. Attitude data of the vehicle accurate to about ±15 minutes of arc.

F. A listing of the sequence of operation including operating on/off times, pulse rate frequency, and any adjustment or change made during operation.

X. CONCLUSIONS

A. A method should be devised to affix a series of index marks to the Doppler Record to insure that all reproductions contain index marks in the identical location relative to the imagery regardless of azimuth scale variations.

B. Both a time word and time frequency track is needed on the Doppler Record that can be reproduced on the photo reproductions. These should appear on the edge opposite the titling and be machine readable.

C. Maps, visual photography, or other collateral are mandatory in extracting reliable mensural data.

D. Instruments and techniques are currently available for plotting and measuring radar imagery. Some instrument modifications are suggested.

E. More supporting data can be provided than was available for the test mission, to aid in mensuration.

F. The radar imagery can be exploited to obtain measurements. However, the accuracy of such measurements will not approach the accuracy of those obtainable from visual photography.

G. The accuracy of long distances is greater than that of shorter distances.

H. It is possible to obtain better quality photo images of the Doppler Record.

I. NPIC should receive the original Doppler Record and install a correlator so that reproductions of various density and contrast can be produced for maximum exploitation.

TABLE 5

MENSURATION DATA

Pass 9 - Phoenix

Pass 14 - Richmond

Pass 24 - Chicago

Pass 30 - Wurtsmith AFB

TABLE 5. (Continued)

PASS 09 - PHOENIX

MEASUREMENT	MEASURED MAP DISTANCE		MEASURED COORDINATES MICRONS		DISTANCE MEASURED SCALES FT	DISTANCE COMPUTED SCALES FT	ERROR MEAS SCALES %	ERROR COMP SCALES %
	(IN)	FT	X	Y				
1	1.88	3917	1184	1548	3707	3658	5.4	6.6
2	3.63	7563	2452	2996	7261	7171	4.0	5.2
3	5.43	11312	3641	4571	11023	10883	2.6	3.8
4	6.94	14458	5078	5621	13906	13746	3.8	4.9
5	19.97	41604	6981	18489	41306	40609	0.7	2.4
6	22.47	46812	8337	20746	46496	45720	0.7	2.3
7	22.33	46520	12191	19919	46201	45520	0.7	2.1
8	19.81	41270	10785	17544	40714	40114	1.3	2.8
9	19.00	39583	14609	16582	40796	40317	3.1	1.8
10	22.48	46833	16073	19087	46521	45954	0.7	1.9
11	22.93	47770	19896	18212	47323	46886	0.9	1.8
12	20.44	42583	18479	15884	42085	41731	1.2	2.0
13	15.60	32499	15012	10139	29430	29283	9.4	9.9
14	22.49	46853	8371	20798	46617	45839	0.5	2.2
15	21.01	43770	9518	19185	43600	42908	0.4	2.0
16	19.75	41145	10794	17724	41087	40479	0.1	1.6
17	18.49	38520	11979	16169	38508	37994	0.03	1.4
18	17.72	36916	13412	15073	37163	36731	0.7	0.5
19	2.54	5292	1356	2247	5203	5126	1.7	3.1
20	2.53	5271	3855	814	5296	5342	0.5	1.3
21	3.58	7458	2443	3184	7627	7528	2.3	0.9
22	5.67	11812	6278	4150	12161	12104	2.9	2.5
23	5.10	10625	7752	1659	10666	10758	0.4	1.2
24	7.63	15896	11581	2475	15931	16069	0.2	1.1
25	8.01	16687	10137	4683	16868	16871	1.1	1.1
26	10.75	22395	6678	10618	24708	24349	10.3	8.7
REYNOLDS METALS PLANT								
2-3	0.176	367	339	86	477	481	30	31
3-4	1.132	2358	622	1123	2577	2537	9.3	7.6
4-5	0.385	802	698	162	970	978	21	22
5-6	0.318	662	223	473	1071	1053	62	59
7-2	0.741	1544	333	659	1500	1476	2.9	4.4
FAIR GROUNDS (RACE TRACK)								
1	0.642	1337	711	58	929	939	31	30
2	0.437	910	120	334	744	732	18	20
COUNTRY CLUB								
1-2	0.995	2073	1605	313	2187	2207	5.5	6.5
2-3	0.995	2073	611	1080	2483	2446	20	18
3-4	0.995	2073	1477	301	2021	2039	2.5	1.6
4-1	0.948	1975	447	1061	2384	2345	21	19

TABLE 5. (Continued)

PASS 09 - PHOENIX (Continued)

MEASUREMENT	MEASURED MAP DISTANCE (IN)	MEASURED MAP DISTANCE FT	MEASURED COORDINATES MICRONS X	MEASURED COORDINATES MICRONS Y	DISTANCE MEASURED SCALES FT	DISTANCE COMPUTED SCALES FT	ERROR MEAS SCALES %	ERROR COMP SCALES %
SPORTSMAN'S PARK								
1	0.497	1035	375	103	534	538	48	48
2	0.248	517	57	94	218	215	58	58
PASS 14 - RICHMOND								
1	5.26	10958	2371	4680	10531	10509	3.9	4.1
2	6.23	12979	3133	5505	12528	12504	3.5	3.7
3	7.61	15854	4388	6696	15502	15477	2.2	2.4
4	7.72	22905	85	10598	22786	22722	0.5	0.8
5	13.56	28250	1262	12988	27973	27896	1.0	1.3
6	15.18	31624	2160	14601	31519	31434	0.3	0.6
7	7.55	15729	4613	6752	15726	15701	0.02	0.2
8	8.20	17083	9918	4994	16862	16897	1.3	1.1
9	9.81	20437	12512	5527	20255	20307	0.9	0.6
10	13.86	28875	14429	10131	28849	28870	0.09	0.02
11	16.21	33770	17666	12051	34752	34781	2.9	3.0
12	11.93	24854	17920	3584	24725	24837	0.4	0.07
13	14.12	29416	21191	4280	29265	29399	0.5	0.06
14	15.72	32749	23613	4723	32580	32728	0.5	0.06
15	17.94	37374	28450	1845	37508	37705	0.4	0.9
16	21.78	45374	33451	5493	45416	45634	0.09	0.6
17	21.79	45395	33442	5475	45395	45613	0.00	0.5
18	22.56	46999	35884	739	47071	47322	0.1	0.7
19	23.05	48020	36759	64	48191	48448	0.4	0.9
20	23.81	49603	37813	1222	49643	49907	0.08	0.6
21	21.64	45083	32174	7526	45177	45371	0.4	0.6
22	21.74	45291	31244	9202	45489	45662	0.4	0.8
23	17.63	36729	28862	1275	37937	38138	3.3	3.8
24	14.73	30687	23509	480	30837	31002	0.5	1.0
25	13.08	27250	20936	43	27447	27594	0.7	1.3
26	12.78	26625	19005	4659	26854	26967	0.9	1.2
27	11.74	24458	15772	6564	25034	25103	2.4	2.6
28	9.84	20500	15299	1814	20433	20536	0.3	0.2
29	7.74	16125	12242	1196	16254	16337	0.8	1.3
30	6.15	12812	9785	774	12935	13003	1.0	1.5
31	4.83	10062	5001	3643	10214	10220	1.5	1.6
LENGTH OF BRIDGES								
1	0.423	881	541	171	799	802	9.3	9.0
2	0.809	1685	391	278	788	788	53	53
3	0.691	1440	459	301	884	884	39	39
4	1.483	3090	1605	743	2641	2648	14.5	14.3
5	0.479	998	548	283	941	943	5.7	5.5
6	1.263	2631	1008	1286	3064	3061	16.5	16.3
7	0.764	1592	704	506	1427	1428	10.4	10.3
8	1.247	2598	1088	1135	2826	2824	8.8	8.7
9	0.784	1634	846	237	1221	1225	25	25
10	0.851	1773	1104	88	1459	1467	17.7	17.3

TABLE 5. (Continued)

PASS 24 - CHICAGO

MEASUREMENT	MEASURED MAP DISTANCE		MEASURED COORDINATES MICRONS		DISTANCE MEASURED SCALES	DISTANCE COMPUTED SCALES	ERROR MEAS SCALES	ERROR COMP SCALES
	(IN)	FT	X	Y	FT	FT	%	%
1	6.76	13520	10365	122	13580	13591	0.4	0.5
2	6.51	13020	9919	311	13011	13021	0.07	0.01
3	5.79	11580	8902	173	11668	11676	0.7	0.8
4	7.25	14500	11088	183	14530	14541	0.2	0.3
5	11.46	22920	17546	153	22987	23005	0.3	0.4
6	5.27	10540	7811	84	10234	10242	2.9	2.8
7	7.12	14240	10905	107	14287	14298	0.3	0.4
8	18.57	37140	26703	244	34985	35012	5.8	5.7
9	5.04	10080	7331	84	9606	9613	4.7	4.6
10	8.27	16540	12656	101	16580	16593	0.2	0.3
11	4.66	9320	6862	42	8989	8996	3.5	3.5
12	7.75	15500	11945	213	15655	15667	1.0	1.1
13	4.11	8220	6342	81	8310	8316	1.1	1.2
14	6.88	13760	10477	56	13725	13736	0.2	0.5
15	14.12	28240	140	12244	26240	26203	7.1	7.2
16	13.10	26200	578	11941	25601	25565	2.3	2.4
17	17.51	35020	184	15917	34111	34063	2.6	2.7
18	13.15	26300	122	12460	26702	26664	1.5	1.4
19	18.58	37160	182	16944	36312	36261	2.3	2.4
20	4.89	9780	32	4437	9508	9495	2.8	2.9
21	12.50	25000	106	11398	24426	24392	2.3	2.4
22	7.97	15940	82	7475	15526	15504	2.6	2.7
23	11.95	23900	111	10917	23395	23362	2.1	2.2
24	3.51	7020	20	3361	7203	7193	2.6	2.5
25	10.92	21840	133	10042	21521	21491	1.5	1.6
26	9.74	19480	26	8543	18308	18282	6.0	6.1
WASHINGTON PARK RACETRACK								
11	1.212	2424	1018	861	2277	2276	6.1	6.1
12	0.383	766	319	393	940	939	22.7	22.6
MENDEL HIGH SCHOOL AND PALMER PARK								
21-22	1.296	2592	788	308	1214	1214	53.2	53.2
22-23	0.637	1274	229	527	1168	1167	8.3	8.4
23-24	1.296	2592	625	297	1037	1037	60.0	60.0
24-21	0.637	1274	995	205	1375	1376	7.9	8.0
BUILDING								
31-32	0.150	300	70	66	168	168	44.0	44.0
32-33	1.078	2156	851	937	2297	2295	6.5	6.4
33-34	0.100	200	21	46	103	102	48.5	49.0
34-31	1.041	2082	548	649	1651	1649	20.7	20.8
31-35	0.783	1566	343	228	664	664	57.6	57.6
35-36	0.149	298	78	126	289	289	3.0	3.0
BUILDING								
41-42	0.042	84	9	70	191	150	127.4	78.6
42-43	0.611	1222	811	207	1151	1152	5.8	5.7
43-44	0.037	74	14	52	112	112	51.3	51.3
44-41	0.611	1222	815	209	1158	1158	5.2	5.2

TABLE 5. (Continued)

PASS 24 - CHICAGO (Continued)

MEASUREMENT	MEASURED MAP DISTANCE		MEASURED COORDINATES MICRONS		DISTANCE MEASURED SCALES FT	DISTANCE COMPUTED SCALES FT	ERROR MEAS SCALES %	ERROR COMP SCALES %
	(IN)	FT	X	Y				
BUILDING								
51-52	0.231	462	16	78	168	168	63.6	63.6
52-53	0.690	1380	929	230	1313	1314	4.8	4.8
53-54	0.229	458	13	45	97	97	78.8	78.8
54-51	0.688	1376	928	216	1301	1302	5.4	5.4
BUILDING								
61-62	0.282	564	39	187	404	403	28.4	28.5
62-63	0.166	332	242	20	320	320	3.6	3.6
63-64	0.280	560	17	159	342	341	38.9	39.1
64-61	0.166	332	189	35	259	259	22.0	22.0
BUILDING								
71-72	0.270	540	127	168	396	396	26.7	26.7
72-73	0.440	880	400	200	677	677	23.1	23.1
73-74	0.270	540	120	249	557	556	3.1	3.0
74-75	0.441	882	394	113	570	571	35.4	35.3
BUILDING								
81-82	0.246	492	396	3	519	519	5.5	5.5
82-83	0.091	182	12	45	97	97	46.7	46.7
83-84	0.248	496	398	18	522	523	5.2	5.4
84-81	0.090	180	9	63	136	135	24.4	25.0
BUILDING								
91-92	0.092	184	3	144	309	308	122.3	121.7
92-93	0.261	522	561	8	735	735	40.8	40.8
93-94	0.092	184	12	122	261	261	41.8	41.8
94-91	0.261	522	555	9	727	728	39.3	39.5
DIAMETERS OF SMALL OIL TANKS								
101	0.041	82	26	0	34	34	59	59
102	0.042	84	0	44	94	94	12	12
DIAMETERS OF MEDIUM OIL TANKS								
111	0.073	146	40	0	52	52	64	64
112	0.075	150	0	61	131	131	13	13
DIAMETERS OF LARGE OIL TANKS								
121	0.096	192	61	0	80	80	58	58
122	0.094	188	0	92	197	197	4.8	4.8
PASS 30 - WURTSMITH AFB								
1	0.061	318	251	16	335	333	5.3	4.7
2	2.64	13749	1310	6543	13973	14108	1.6	2.6
3	0.061	318	276	64	390	389	22.6	22.3
4	2.64	13749	1586	6479	13889	14021	1.0	2.0
5	0.058	302	234	88	362	361	19.9	19.5

APPENDIX C

EQUIPMENT EVALUATION TEAM REPORT

[redacted] NPIC, Chief

[redacted], NPIC

[redacted], NPIC

I. PURPOSE OF REPORT

This report is an evaluation of equipment requirements for the exploitation of QUILL-type material. The evaluation is primarily based on the experience gained during the evaluation of the first QUILL mission by the NPIC Interpretation and Mensuration teams. It also includes comments on future equipment requirements based on the assumption of possible operational concepts regarding the utilization of reconnaissance radar.

II. EQUIPMENT USED

The major items of equipment used by the Interpretation and Mensuration teams were standard Richardson Rear Projection Viewers, B & L Zoom 70 Stereomicroscope (in monoscopic mode) on Richards GFL-940 Light Tables, and Mann & Nistri Comparators. This equipment was utilized in a manner similar to the way it is used in reading out normal photographic missions.

III. EXPLOITATION OF DATA

If we assume that the primary usefulness of reconnaissance radar is to collect information during bad weather conditions and darkness it can then be assumed that radar reconnaissance would be used primarily during crisis periods (when the higher-resolution camera systems could not be used). If radar is considered primarily as a crisis management tool, then the exploitation of radar data must be performed on a near real-time basis. A near real-time exploitation capability implies a very high degree of automation in the exploitation equipment. This high degree of automation will affect film processing and reproduction, viewing and interpretation, mensuration, collateral support, and reporting. Each of these functional categories of exploitation is discussed below in relation to a real-time exploitation capability.

A. Film Processing and Reproduction

The first film record produced by the radar system is called a Doppler History Record or, for short, the "Data Film." This is not an interpretable film record, in the normal sense, since it contains only diffraction patterns of radar reflections from various targets. To obtain an image-type film the data film must be processed on an optical (or electronic) correlator which provides, as an end product, an exposed but undeveloped negative (in a cassette). This image negative is then processed (developed, fixed, washed, and dryed) by normal photo lab procedures. Then, the required number of duplicate positive transparencies can be reproduced in the normal manner. For a real-time capability, however, the exposed negative produced by the correlator would have to be processed in a fully automatic, photo-processing and duplicating system integrated with the correlator. In addition to rapid access to the image film for interpretation, the PI may also require rapid laboratory production of density-sliced reproductions of selected target areas. He may also require rapid reproduction of paper prints on high contrast paper in order to enhance certain target characteristics. Whatever the requirements for photo processing may be, the PI will have to have immediate response to his needs.

B. Interpretation

If real-time read-out of QUILL-type material is not required, current and projected types of interpretation equipment and procedures would generally be adequate, with 2 exceptions.

First, the equipment to be used must make it easier to compare collateral photography with the radar imagery. For this first QUILL evaluation, the comparison was performed by placing 2 Richardson projectors side-by-side. However, if 4 or 5 mission coverages were to be compared this procedure would become very unwieldy. Comparison of previous target coverage (particularly photographic) is considered mandatory in order to extract the maximum information from the radar imagery. Therefore, some type of multi-mission comparison viewers are believed to be necessary for the full utilization of QUILL-type material.

Second, the radar interpreter should be able to request and use re-correlated imagery of selected target areas because any one image recording from the correlator will not contain all of the information on the data film due to a dynamic range limitation of the recording film. Re-correlating radar data film imagery would be analogous to density slicing by normal photo lab procedures by varying the exposure. The use of re-correlated imagery does not imply that a correlator be operated by the interpreter if real-time exploitation is not a requirement, but that a correlator should be available so that the interpreter can request re-correlated imagery.

If the interpretation of QUILL-type material must be performed on a real-time basis, the current interpretation equipment and procedures are inadequate. A real-time interpretation capability will probably require a facility which includes, as primary equipment, a highly automated comparison viewer and a direct viewing PI-operable data film correlator for the interpretation of enhanced portions of the first generation record. In addition, the facility will probably have to have an automated storage and retrieval system for the recall of pertinent collateral film and other information and equipment which will permit the interpreter to report the interpreted target data on a near real-time basis. The interpretation facility would also have to be supported by immediate-response mensuration equipment and by immediate-response reproduction facilities.

C. Mensuration

Experience obtained during the current evaluation indicates that the mensuration equipment now used (the Nistri and Mann Comparators) is adequate with regard to the accuracy of long-distance measurements. For short measurements, such as building dimensions, the inaccuracies were not due to the equipment but to the operator's inexperience in recognizing which radar "blobs" to measure. This inexperience in interpreting magnified radar-image detail considerably increased the measurement time compared with mensuration photography. Therefore, it is assumed that operator training in radar interpretation will increase the accuracy and decrease the measurement time, using currently available equipment.

IV. GENERAL CONCLUSIONS

Conclusions on the adequacy of the equipment for the exploitation of QUILL-type materials must be based on 2 different assumptions of operational use:

A. Real-time read-out will not be required.
B. Near real-time read-out will be required.

If the time allowed for read-outs is no more critical than the time allowed for normal photographic mission read-out and reporting, then the current equipment is generally adequate for exploiting QUILL-type material. There are, however, several improvements to current equipment which would enhance the quality and the ease of read-out, as discussed in section III B.

If near real-time read-out (a few minutes) is a strict requirement, current equipment and facilities are totally inadequate for exploiting a large volume of QUILL-type material. Real-time interpretation of transmitted imagery implies that the video signal be transmitted from the collection system to the interpretation facility for processing and immediate interpretation on a direct-viewing correlator. No quick reaction capability for exploiting strategic reconnaissance materials of this type is known to exist. However, it is within the state-of-the-art to develop such a capability within about 2 years if a major effort is expended.

V. RECOMMENDATIONS

As indicated previously, a judgment on the adequacy of current equipment to exploit QUILL-type materials is almost wholly dependent on the operational use of the radar. This, in turn, dictates the allowable time for read-out.

If real-time read-out is going to be a requirement, it is strongly recommended that immediate attention be given to the development of a quick-reaction exploitation facility. It is estimated that the required lead time to develop such a facility is about 24 to 30 months.

APPENDIX D

INTELLIGENCE EVALUATION TEAM REPORT

[redacted] DIA, Chief

[redacted], NPIC

[redacted], CIA

Maj. Robert M. McAllister, SAC

Capt. Edward Couto, SAC (Alternate)

I. REFERENCES

A. COMOR-D-13/36, subject: Elements of Information, dated 19 February 1965.

B. NIC No. 4-651, subject: USIB General Indicator List, dated 26 September 1964.

C. SAC statement of Strike Effectiveness Assessment requirements.

II. OBJECTIVE

The objective of this report is to estimate the intelligence worth of a radar sensor.

III. SUMMARY

A. The estimated intelligence worth of a radar sensor was established through an evaluation of the following 4 major considerations.

1. The potential information collection capability of such a sensor against selected essential elements of information (EEI) under certain operating conditions.

2. The advantages of the system which supplements photo sensors.

3. System limitations.

4. Special applications of such a system within selected international environments.

The collective evaluation of these considerations indicated that radar sensors could be extremely valuable as a supplemental imagery collection system during Cold War and Crisis situations and would be almost completely satisfactory as a separate system during a General War environment for the purpose of Strike Effectiveness Assessment (SEA).

B. The potential information collection capability was evaluated for QUILL as well as QUILL-Improved (resolution approximately 10 feet in both range and azimuth) products. Furthermore, each of the preceding was evaluated as separate and supplemental collection systems. It was estimated that QUILL products were, at most, marginal information-producing materials during Cold War and Crisis situations, particularly as a separate system. However, they were estimated to be most productive for SEA during a General War environment, even as a separate system. QUILL-Improved products were considered to have substantially more information potential when compared with QUILL, particularly as a separate collection system for SEA. As a separate system, even these materials have limited information potential during Cold War and Crisis. However, when employed as a supplemental system, their potential is significantly enhanced. The evaluation relative to scientific and technical information potential revealed that even QUILL-Improved products held little promise of providing anything of significance. Consideration was also given to a Post Attack Reconnaissance (PAR) mission during General War. It was determined that the relative information potential would be almost identical to the Crisis situation.

C. The major advantages of a radar system, as a supplement to photo sensors, were considered to be threefold. It would be:

1. An essentially all-weather system.

2. A day-night system.

3. A potentially "quick response" system.

All of these advantages make a radar sensor invaluable where short response time is a major consideration.

D. The evaluation indicated 1 major limitation as an intelligence collection system. A radar sensor is extremely limited in providing meaningful information on previously unknown targets.

E. There were significant special applications for a radar sensor in each of the 3 international environments considered. During Cold War, changes or new construction activity could be detected, although not identified, in areas where weather or light conditions precluded photo acquisition, thereby increasing the efficiency of the operation of photo sensors for search and surveillance purposes. During both Crisis and General War, the quick-response characteristic makes its application most significant.

IV. CONCLUSIONS

A. A radar sensor could be of some value as a supplement to photo sensors during Cold War for search and surveillance purposes.

B. A radar sensor could be of definite value as a supplement to photo sensors for indications during a Crisis and for Post Attack Reconnaissance (PAR) during General War.

C. A radar sensor would be of very high value, even as a separate system, during General War for Strike Effectiveness Assessment (SEA).

D. A QUILL-Improved system (10-foot range and azimuth resolution) seems justifiable.

V. DISCUSSION

A. Information Collection Potential

1. Approach

a. Operating Environment Selection

The Intelligence Evaluation Team selected Cold War, Crisis, and General War as representative international environments for estimating the potential of a radar sensor as an information collection system. For each of these environments, a collection mission was selected; i.e., Search, Surveillance, and Technical Intelligence during Cold War; Indications during a Crisis; and Strike Effectiveness Assessment (SEA) and Post Attack Reconnaissance (PAR) during General War.

b. EEI Selection and Analysis

Within the context of each collection mission, a selection was made from references A, B, and C, of Essential Elements of Information (EEI) which were considered to be representative of the subjects and questions which could confront a photo interpreter under the preceding operating conditions. (Tables 6, 7, 8, 9, and 10.) These EEI were submitted to the QUILL Imagery Interpretation Evaluation Team for its analysis and estimate as to whether QUILL or QUILL-Improved products (resolution approximating 10 feet in both range and azimuth) could provide the EEI as specified, both as a separate system or as a system supplementing current photo sensors. Its estimate was requested in terms that the products could either "probably," "possibly," "probably not," or "not" provide the EEI as specified.

c. Data Evaluation and Statistical Presentation

The Intelligence Evaluation Team reviewed and evaluated the EEI analysis performed by the Interpretation

Team. An effort was made to determine the best estimate as to whether QUILL or QUILL-Improved products would provide the EEI under the varying circumstances previously described. The results of this evaluation were reduced to statistical representations of the percentages of EEI which might be provided under the prescribed circumstances (Attachments 12 and 13). The collection missions for Technical Intelligence and Post Attack Reconnaissance (PAR) were not graphically presented. There was little promise of even QUILL-Improved products providing any significant information for Technical Intelligence. Therefore, it was dropped from further consideration. A review of the EEI for PAR revealed they were essentially identical to those for Indications. Therefore, the results relative to Indications are equally applicable to PAR.

2. Limiting Factors

a. The Imagery Interpretation and Intelligence Evaluation Teams' lack of experience with radar imagery.

b. The extremely small number of samples, involving only 8 photo interpreters, used in estimating radar sensor capabilities relative to EEI.

c. The substantial number of EEI and circumstances other than those prescribed which were excluded from consideration.

d. The fact that the effect of the human factor element on the PI analysis was not included.

3. Conclusions

a. As a Separate Collection System (Attachment 12).

(1) QUILL

(a) Search/Surveillance: Estimated to be limited as a meaningful information collection system.

(b) Indications: Same as stated for Search/Surveillance above.

(c) Strike Effectiveness Assessment: Estimated to be most promising as an information collection system.

(2) QUILL-Improved

(a) Search/Surveillance: Estimated to have possible potential as a very productive collection system; much better than the QUILL-type products.

(b) Indications: Same as stated for Search/ Surveillance above.

(c) Strike Effectiveness Assessment: Estimated probably to approach being 100 percent productive as an information collection system.

b. As a Supplemental Collection System (Attachment 13).

(1) QUILL

(a) Search/Surveillance: Estimated to have much more potential in collecting meaningful information than as a separate collection system. However, it is estimated, at most, to be only marginally productive in this mode.

(2) QUILL-Improved

(a) Search/Surveillance: Estimated to have probable potential as a very productive information collection system.

(b) Indications: Estimated as probably being most profitable as an information system.

B. Advantages over Photo Sensors

1. Weather Penetration

In practically all cases, a radar system, unlike photo sensors, is able to acquire meaningful imagery when heavy cloud conditions exist. Therefore, it is essentially an all-weather imagery collection system.

2. Self-Illumination

Unlike the photo sensor, a radar provides its own source of illumination. Therefore, it can be used as an imagery collection system 24-hours a day, 365 days a year, anywhere on the globe.

3. Timeliness

In contrast to the photo sensor, a radar system, through its electronic characteristics, can potentially provide raw information on a near real-time basis.

C. Limitations

1. General Descriptive Detail

A radar system can apparently only provide a general description of installations and their equipment. Therefore, it is extremely limited in providing significant information about targets which were previously unknown.

2. Other

There are many technical and other operational limitations which have not been included in this evaluation.

D. Special Applications

1. Search/Surveillance During Cold War Environments

A radar system could be employed to provide certain search/surveillance EEI on areas where weather or light conditions preclude their acquisition by photo sensors. It could detect or negate either changes or new construction activity in these areas, such as the Kamchatka Peninsula, where poor weather prevails, or the northern regions of the USSR, where poor light conditions often prevail. Although specific identification of these changes could not be made, at least it could be determined whether additional imagery collection is currently required. Such an application could bring about a more efficient employment of current, as well as future, photo sensors.

2. Indications During Crisis Environment

A radar system has an extremely valuable application during this situation based upon its inherent "quick response" capabilities. The system response would not be hampered by weather or light conditions. Because of its electronic characteristics, the system can potentially provide raw information on a near real-time basis -- a major consideration during a Crisis.

3. Strike Effectiveness Assessment (SEA) During General War Environment

Same as stated for Indications above. Furthermore, a radar system has the estimated capability of satisfying practically 100 percent of the overall SEA requirements.

TABLE 6

SEARCH AND SURVEILLANCE EEI DURING COLD WAR

1. Identification of newly constructed single silo offensive missile sites of a known configuration in a known complex.

2. Same as 1 above, except of an unknown configuration.

3. Same as 1 above, except at a previously unknown location.

4. Same as 1 above, except of an unknown configuration at a previously unknown location.

5. Identification of newly constructed soft offensive missile sites of a known configuration in a known complex.

6. Same as 5 above, except of an unknown configuration.

7. Same as 5 above, except at a previously unknown location.

8. Same as 5 above, except of an unknown configuration at a previously unknown location.

9. Determination of the construction status of hard offensive missile sites.

10. Same as 9 above, except for soft sites.

11. Distance between offensive missile sites within ± 100 feet.

12. Determination of occupancy status for hard offensive missile sites.

13. Same as 12 above, except for soft sites.

14. Identification of newly constructed permanent SA-2 and SA-3 sites.

15. Same as above, except in field deployed mode.

16. Determination of occupancy status for permanent SAM sites.

17. Identification of newly constructed Tallinn-type sites.

TABLE 6. (Continued)

18. Determination of occupancy status for Tallinn-type sites.

19. Identification of newly constructed vertical static test stands.

20. Identification of newly constructed horizontal test cells.

21. Identification of newly constructed airfields, 5,000 feet or more in length.

22. Determination of the construction status of airfields.

23. Determination of the number of heavy and medium bomber aircraft deployed at airfields.

24. Location of aircraft at airfields.

25. Identification of newly constructed Ground Zero at known nuclear weapons test sites.

26. Same as 25 above, except at a previously unknown location.

27. Detection of a surface or near surface detonation of a nuclear device at known nuclear weapons test site.

28. Same as 27 above, except at a previously unknown location.

29. Detection of an underground nuclear test at a previously known site.

30. Same as 29 above, except at a previously unknown location.

31. Identification of newly constructed gaseous diffusion plants.

32. Determination of the construction status of gaseous diffusion plants.

33. Identification of newly constructed plutonium production reactors.

34. Determination of the construction status of plutonium production reactors.

35. Identification of newly constructed national or regional nuclear weapons storage sites.

36. Determination of the construction status of 35 above.

37. Identification of newly constructed Type III nuclear weapons storage bunkers.

TABLE 6. (Continued)

38. Determination of the construction status of 37 above.

39. Determination of the number of submarines present in port.

40. Location of submarines in port.

41. Identification of submarines underway out of port.

42. Determination of the number of surface combatant vessels in port.

43. Identification of newly constructed naval missile support installations.

44. Determination of the construction status of 43 above.

45. Identification of submarines newly under construction.

46. Identification of newly deployed TALL KING radars.

47. Identification of newly deployed TOKEN-type radars.

48. Identification of newly constructed Hen House-type structures.

49. Determination of the construction status of 48 above.

50. Identification of newly constructed Dog House-type structures.

51. Determination of the construction status of 50 above.

52. Identification of newly constructed triad-type electronic facilities.

53. Determination of the construction status of 52 above.

54. Determination of the number of tanks/SP guns within a known armored garrison.

55. Determination of the quantity of major equipment (tanks, trucks, artillery pieces) within known military installations.

56. Determination of the level of occupancy of known military installations.

TABLE 7

TECHNICAL INTELLIGENCE EEI DURING COLD WAR

1. Determination of the inside diameter of silo launch facilities within ± 1 foot.
2. Determination of the thickness of a silo door within 6 inches.
3. Determination of the number of stages of an offensive ballistic missile.
4. Determination of the diameter of a ballistic missile within ± 6 inches.
5. Determination of the number of engines on a ballistic missile.
6. Determination of the shape of the reentry vehicle.
7. Determination of the aircraft fuselage width within ± 1 foot.
8. Determination of the aircraft wingspan size within ± 5 feet.
9. Determination of the number of engines on aircraft.
10. Determination of the type of engines on aircraft.
11. Determination of the dimensions of wind tunnels within ± 2 feet.
12. Determination of the amount of electrical power supplied to AE production facilities.
13. Determination of the submarine length overall within ± 6 inches.
14. Determination of the submarine beam dimensions within ± 6 inches.
15. Determination of radar reflector dimensions within ± 1 foot.

TABLE 7. (Continued)

16. Determination of radar reflector shape.

17. Determination of the type of ground force equipment.

18. Determination of the dimensions of ground forces equipment within ± 6 inches.

TABLE 8

INDICATIONS EEI DURING CRISIS

1. Detection of extensive vehicular activity within nuclear weapons storage sites.

2. Detection of MR/IRBM units moving into known fixed field launch sites.

3. Detection of widespread placement of offensive missiles on launchers and associated equipment.

4. Detection of widespread placement of defense missiles on launchers.

5. Determination of the number of heavy and medium bombers deployed at airfields.

6. Determination of the number of fighters deployed at airfields.

7. Detection of weapon-loading activity at airfields.

8. Determination of the number of submarines present in ports or dispersed areas.

9. Determination of the number of submarines absent from normal port.

10. Detection of the departure from known garrisons of major ground force units.

11. Determination of the number of transport aircraft at bases near airborne units.

12. Determination of the equipment and aircraft activity patterns at airfields.

13. Determination of the location of aircraft on the airfield.

14. Determination of weapon-loading activity at submarine bases.

15. Determination of the activity level at railroad marshalling yards and depots.

16. Detection of the widespread dispersal of aircraft and naval vessels

TABLE 8. (Continued)

from their normal bases.

17. Detection of ground force troop units and equipment assemblying near airfields.

18. Detection of the dispersal of tactical aircraft to secondary airfields.

19. Detection of substantial augmentation of fighter aircraft on strip alerts.

20. Detection of the removal of MR/IRBM equipment from known storage depots.

TABLE 9

STRIKE EFFECTIVENESS ASSESSMENT EEI DURING GENERAL WAR

1. Locate AGZ relative to DGZ within ± 200 feet.

2. Determine the diameter of the crater (smallest crater 2,200 feet) within ± 100 feet.

TABLE 10

POST ATTACK RECONNAISSANCE EEI DURING GENERAL WAR

1. Determination of activity within known offensive missile sites.

2. Determination of activity within known defense missile sites.

3. Determination of activity within known nuclear weapons storage sites.

4. Detection of the placement of offensive missiles on launchers and associated equipment.

5. Detection of the placement of defensive missiles on launchers.

6. Determination of activity at known bomber bases.

7. Determination of activity at known tactical airfields.

8. Determination of the number of heavy and medium bomber aircraft at home bases.

9. Determination of whether gaseous diffusion plants are operating.

10. Determination of whether plutonium production reactors are operating.

11. Determination of submarine activity at home ports.

12. Determination of the number of submarines in home ports.

13. Determination of weapon-loading activity at submarine bases.

14. Identification of submarines underway out of port.

15. Determination of activity level at railroad marshalling yards and depots.

16. Detection of ground force troop units assembly areas.

17. Determination of activity at known ground force installations.

18. Determination of occupancy status of known ground force

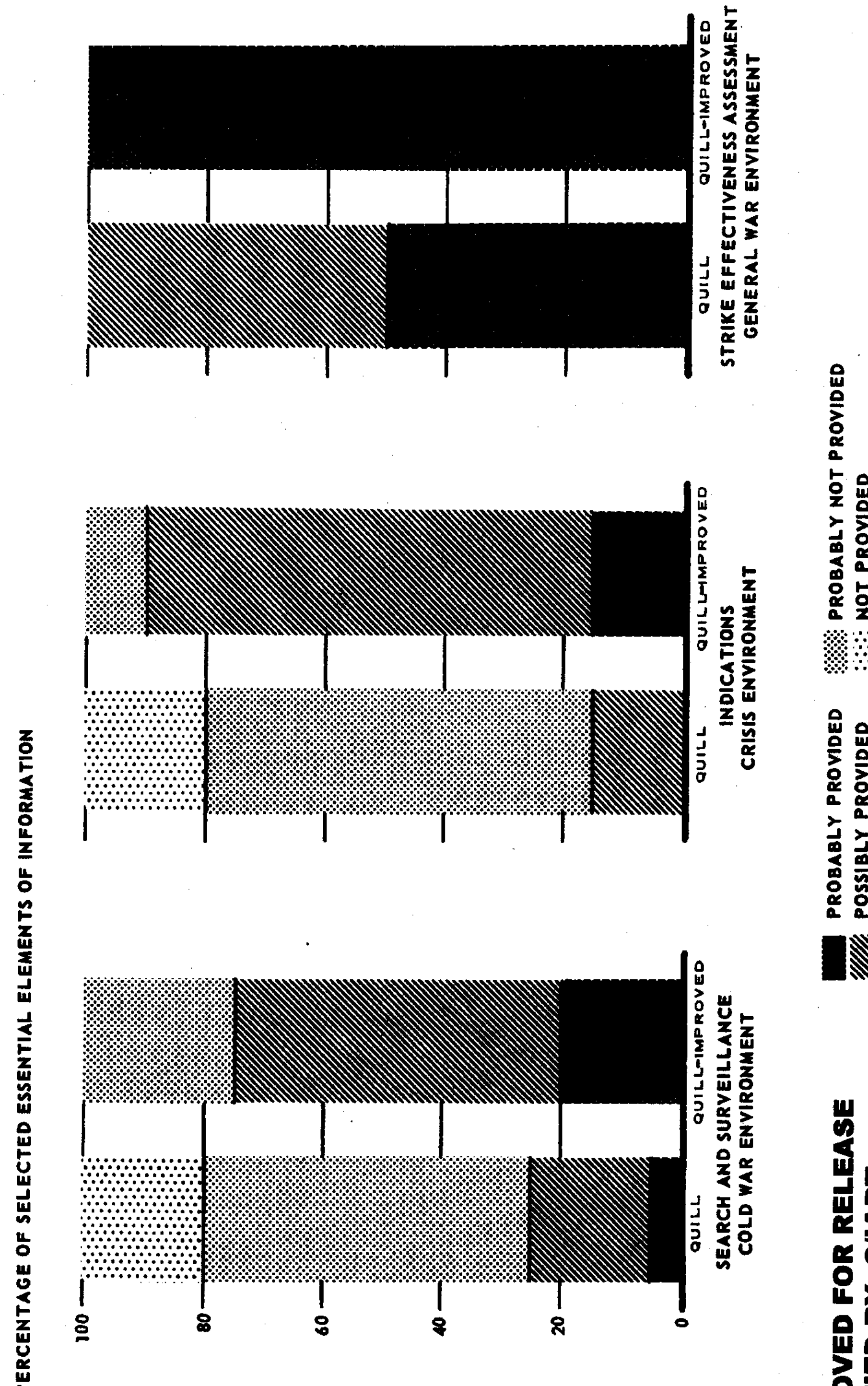
TABLE 10.(Continued)

installations.

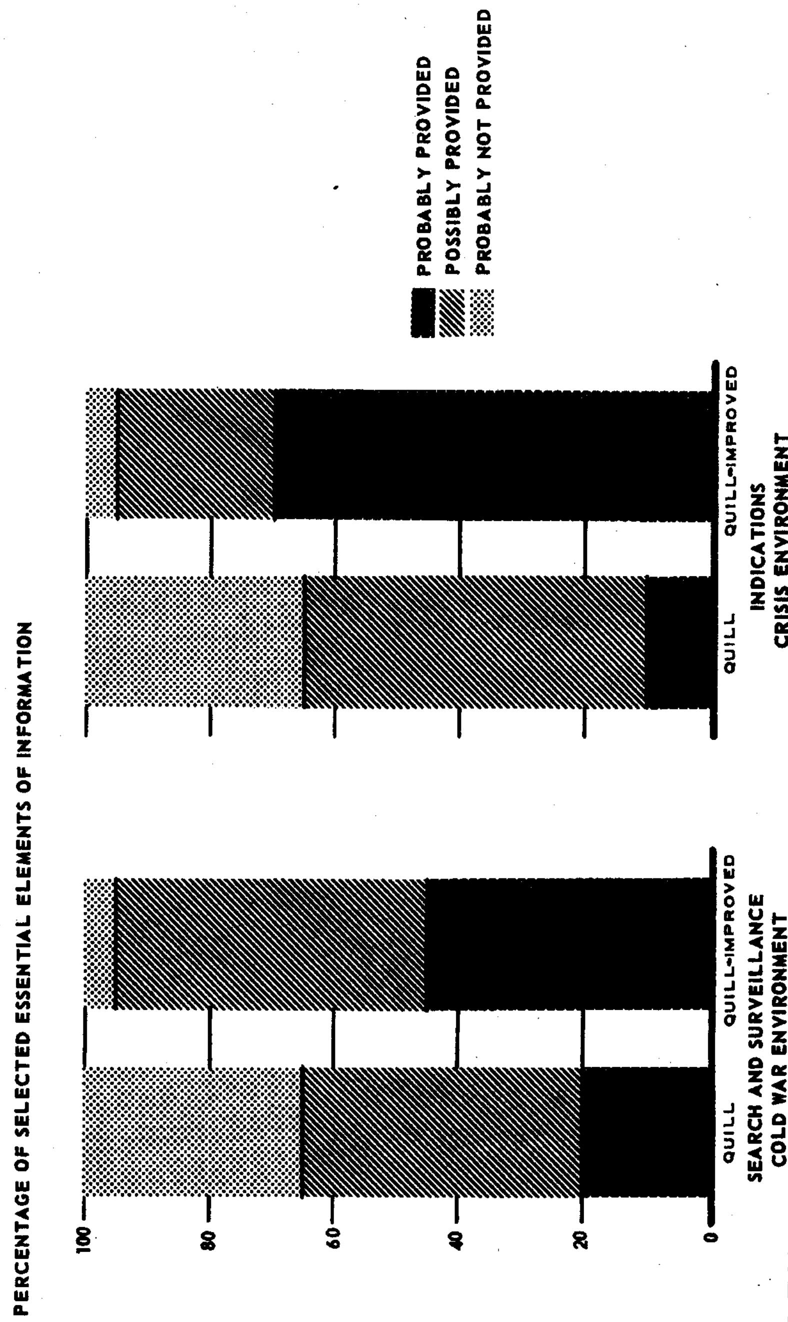
19. Determination of activity at known missile storage depots.

20. Detection of new construction activity for offensive missile systems.

ESTIMATED SHORT TERM POTENTIAL OF QUILL VS QUILL-IMPROVED AS A SEPARATE INFORMATION COLLECTION SYSTEM



ESTIMATED SHORT TERM POTENTIAL OF QUILL VS QUILL-IMPROVED AS A SUPPLEMENTAL INFORMATION COLLECTION SYSTEM



APPENDIX E

COLLECTION SYSTEM EVALUATION TEAM REPORT

Chief, [redacted] CIA

[redacted], CIA

Lt. Cmdr. T. R. Legett, U.S. Navy

[redacted]

SUMMARY

The successful orbital performance of the QUILL system and subsequent analysis of the collected data has indicated that satellite side-looking radar systems may have significant potential, particularly as supplementary sensors, for intelligence collection. Although the current evaluation has also included a limited amount of radar imagery of finer resolution than the QUILL product, it has not been possible to obtain a quantitative measure of the influence of the various important radar system parameters, such as resolution, swath width, and depression angle, on ultimate intelligence utility of the radar product for various classes of targets. Accordingly, an experimental program which consists of collecting data employing an airborne radar with an appropriate variation of parameters, both in the radar and the processing system, and subsequent analysis and interpretation is recommended.

I. INTRODUCTION

When attempting to assess the future utility of radar-derived imagery, it is important to take full account of the unique nature of the process. Unlike optical photography, in the case of side-looking radars the radar scene is actively illuminated with coherent microwave energy. The implications of this fact are profound. Although, as the QUILL product evaluation has tended to show, at relatively course conventional photographic imagery, high resolution radar imagery of cultural targets is an unique form of imagery which cannot in general be regarded as equivalent to optical photography. Operational side-looking radar systems have produced imagery from which considerable utilization and interpretation experience has been gained. However, the resolution exhibited by these systems has generally been on the order of 50 feet. There is no comparable body of experience relative to the rather small quantity of finer resolution imagery (approaching 5 feet by 5 feet); consequently, quantitative data on the characteristics of such radar-illuminated scenes together with a quantitative measure of image quality as a function of resolution is not available at the present time. Another consequence following from the basic principles of side-looking radar systems is that the systems design parameters under the control of the engineer are greater in number and in many cases different in character than in the comparable photographic situation.

In the case of optical photography, a vast body of knowledge has been accumulated over the years--both quantitative and qualitative in character--and in the final analysis, it is this experience which makes possible the intelligent formulation of requirements and the development of useful photographic systems. For example, the general nature of scenes as they appear in high altitude photography is common experience to a large part of the user community. (It is worthy to note, however, that even now it is not an easy matter to achieve a consensus on the utility of various camera system improvements.) The effect of such things as sun angle, haze, image scale vs. granularity, and effect of image degrading sources on the utility of photography are all relatively well understood.

Finally, the subtle relationship between photographic resolution and image utility has been the subject of considerable experimentation. An analogous situation does not exist for high resolution, side-looking radar-derived imagery.

Under the circumstances outlined above, a prerequisite to a side-looking radar development program beyond QUILL must be a vigorous 2-point program:

A. A broad effort to acquaint the user community with the high resolution side-looking radar sensor as an intelligence collection tool, with the objective of fostering a careful development of relevant requirements.

B. An aggressive effort to develop both qualitative and quantitative data relating design parameters to image utility. This will provide information that is essential for the specification of system parameters for future configurations.

II. RELEVANT SYSTEM PERFORMANCE PARAMETERS

The purpose of this section is to briefly delineate the technical performance parameters which provide quantitative measures of certain system characteristics and to discuss the significance of these technical quantities in a manner directed toward the intelligence-oriented user.

First, let us consider a particular group of parameters, all of which are specific characteristics of the "ambiguity function" of the radar system. These are: Azimuth and range resolution and level of ambiguity. The "ambiguity function" of the system is simply the response of the radar system to a "point" target; i.e., a target which has small physical extent compared with the resolution capability of the overall system (including any subsequent processing). The ambiguity function is the radar analog to the familiar "impulse response" of a linear time-invariant electrical network and to the familiar spread-function of an optical system. Its use is strictly correct only in linear time-invariant radar systems, but it is nevertheless useful when used with caution in the presence of receiver nonlinearities. The ambiguity function unavoidably has some energy at positions far removed from the origin (i.e., the coordinates of the true "point" target). However, it is possible to exercise some control over this energy distribution in the design process, subject to a number of constraints which will not be discussed in this report.[1]

The "azimuth" resolution of the system is simply the "width" of the cross section (parallel to the vehicle flight path) of the 2-dimensional ambiguity function. The "range" resolution is the width of the orthogonal cross section. The most commonly used measure of resolution is the "half-power" width, although other measures (such as "radius of gyration" or equivalent rectangle") are more useful from the analytic viewpoint. In this report, the half-power width definition of resolution will be employed. These widths are largely determined by the design of the system, but will also be affected by phase errors, non-linearities, and radar and processor adjustments which degrade the 2-dimensional transfer functions of key elements. In the QUILL system, the azimuth resolution ranged from 10 to perhaps 25 or 30 feet in azimuth (for the physically recovered data), with resolution being locally of the order of 7 to 10 feet in certain isolated samples of imagery. Ground-range resolution was on the order of 75 feet. The technology required to obtain resolution on the order of 5 to 10 feet in both range and azimuth is available.

The "level of ambiguity" refers to the presence of unwanted energy, and in particular to local spurious peaks, distinct from the mainlobe of the radar system's ambiguity function. In the QUILL system, the ambiguity function consisted of a number of equispaced peaks, symmetric about the main peak, with levels that were designed to be some 35 db below the mainlobe peak under normal operating conditions. Half of these ambiguous peaks were sharply focused, and the remainder were defocused. Ambiguous peaks, or target indications, appearing at the correct azimuth coordinate but incorrect range coordinate are known as "range" ambiguities, while those at correct ranged but incorrect azimuths are referred to as "azimuth" ambiguities. The QUILL data yielded one of each type, each being generated under conditions unusually favorable to its appearance. With sufficient collateral data, together with imagery interpretation experience, it is possible to identify ambiguities as such and

1. This subject, as well as other details of radar design and performance analysis, is treated in the QUILL Engineering Evaluation Report and its references.

reduce the possibility of erroneous intelligence extraction. Azimuth ambiguities appear only in conjunction with the properly-imaged target complex, while range ambiguities always arise from an object which does not appear elsewhere in the imagery. Consequently, range-ambiguities may be less acceptable than are azimuth ambiguities. The level below which the ambiguity is restrained helps in part to establish the dynamic range capability of the radar system, although many other factors also enter.

The signal-to-noise ratio of the radar system is determined in part by a proportionality factor which enters into the specification of the "height" of the peak of the ambiguity function. Signal-to-noise ratios for point targets with specified radar cross-sections and for extended terrain with specified reflection coefficient can each be defined and controlled. The output signal-to-noise ratio may be limited by elements in the receiver and recorder having insufficient dynamic range. It appears practical to design satellite radar systems to have signal-to-noise ratios from 5 to 10 db higher than is characteristic of the QUILL results, with some possibility of realizing an improvement of 15 db through the use of increased transmitter power and improvement in the receiver noise figure.

Certain aspects of the radar ambiguity function cause the designer to limit the width of the illuminated swath to a value which may be unsatisfactory for certain applications. The illuminated swath width in the QUILL experiment was 10 nautical miles. For a given system configuration, the swath width is directly proportional to the azimuth resolution, this being roughly 7.5 feet in the QUILL case. Thus, the swath width may be increased at the expense of azimuth resolution. Finally, multi-channel receiver schemes may be employed to provide a brute-force solution to the swath-width problem which, though inelegant and perhaps massive, nevertheless, can permit swath widths of many tens of miles. Swath width requirements can only be formulated in terms of specific missions and knowledge of likely spatial distributions of target complexes associated with these missions.

The "dynamic range" of the output imagery refers to the ratio of the maximum intensity of a strong-target indication to the intensity of the noise-induced background. Ignoring the effects of "laser noise" in the optical processor associated with the radar system, this dynamic range is greatest in the optical image at the processor output, prior to recording of this image on photographic film. Of course, the dynamic range is dependent upon the target complex being viewed. When the latter was an industrial complex, the image dynamic range of the QUILL system was about 30 db. This dynamic range is not preserved on most of the film outputs but can be, either through use of large-dynamic-range fine grain films or through generation of output transparencies at several exposure levels. The latter was proven to be useful in the QUILL evaluation. Finer-resolution images are likely to have larger inherent dynamic ranges, which can be preserved through provision of adequate dynamic range in the critical receiver and recorder elements.

Highly reflective targets cause signals in the receiver to exceed the linear operating regions of critical elements. Restricting the excursion of large signals via gain reduction in the receivers causes "weak" targets to vanish into the noise levels of these elements. The use of an AGC circuit in the radar permits one to make optimum use of the available (normally insufficient) dynamic range by matching the gain to average local reflectivity conditions. In any system likely to be realized in the foreseeable future, strong-target returns will be limited. The limiting process may lead to the generation of false-target indications which are quite distinct from those induced by ambiguity considerations. The relative levels of these false-target indications can be controlled in the design process. An auxiliary effect of strong-signal limiting is a relative suppression of the strengths of weak target indications in close proximity to the strong-target return. Depending upon system configuration, this suppression can take either of 2 forms: It may operate over a thin constant-range strip, spread about the azimuth-location of the strong target, or it may operate over a 2-dimensional region centered on the strong target. The key to controlling this suppression again lies in specification of adequate dynamic range for elements in the receiver/recorder chain. The QUILL system employed a conventional CRT-film recorder with a dynamic range of approximately 20 db. A laser-film recorder, developed for side-looking radar application, has demonstrated 35 db dynamic range.

III. FACTORS INFLUENCING ABILITY TO SEE TARGETS

A large number of factors influence the ability of the interpreter to see target indications of intelligence interest. These factors may be divided into 2 distinct categories: The "controllable" ones which are in the hands of the system designer and uncontrollable factors which are related to the target complex and intervening conditions.

A. Controllable Factors

This category, which includes all of the performance parameters discussed in Section II, as well as others, are listed below:

1. Azimuth resolution
2. Range resolution
3. Ambiguity levels: "Focused"
   "Defocused"
4. Signal-to-noise ratio: Point target
   extended terrain
5. Dynamic range: Of optical image
   Of film record
6. Swath width
7. False-target levels due to nonlinearities
8. Degree of small-target suppression: 1-dimensional
   2-dimensional
9. Radar system depression angle
10. Center frequency
11. Polarization
12. Presence of "coherent breakup" of targets

Items 1 through 8 on this list are parameters which are evident from the output imagery alone. The remainder have an effect on image quality via the dependence of radar reflectivity itself on depression angle, frequency and polarization, and through the frequency sensitivity of the "coherent breakup" process. A careful examination of reflectivity data on a fine-resolution basis, coupled with further study of the break-up process and means of circumventing it, is required.

B. Uncontrollable Factors

Into this category, we group the following:

The general target-field reflectivity distribution, including orientation of "directional" targets and the presence of target cover.

Target motion

Weather conditions

Surface conditions

Spurious motions of the radar-bearing vehicle

Target motions lead to both defocusing and displacement of point-target images. In certain situations, the displacement can be used as a measure of speed. Isolated targets can be refocused for individual study.

Weather and surface conditions did not appear to seriously alter the quality of the QUILL imagery in most cases, although rainfall effects were discernible on one pass.

The situation requires careful review if other frequencies are contemplated.

Spurious attitude motions of the radar-bearing vehicle lead to map distortion through action of the clutterlock circuitry. These can be monitored, and with system accuracy.

IV. EXPERIMENTAL PROGRAM RECOMMENDATIONS

A quantitative measure of the influence of various radar system parameters on the quality and utility of radar imagery is an essential prerequisite for the design and deployment of an optimum high resolution follow-on to the QUILL system. The major parameters of interest are:

A. Range and azimuth resolution, not necessarily of equal magnitude.

B. Signal-to-noise ratios for point targets and extended tarrain.

C. Radar depression angle.

D. System dynamic range.

E. Radar frequency and polarization combinations.

It is recommended that an experimental program directed toward the attainment of an understanding of the impact of these parameters on the ultimate image utility for various classes of targets be initiated.

(Not all of these parameters need be investigated to the same depth nor with an uniform degree of quantitative experimentation; however, all are key parameters at the disposal of the system designer.) Without such information, however, it will not be possible to generate system specifications with adequate assurance that specific intelligence collection objectives can be reliably attained.

The required radar imagery can be obtained using a currently available aircraft-mounted side-looking radar with some reasonable modifications. The radar has a resolution capability on the order of 5 by 5 feet. This product could be progressively degraded in resolution (independently in both dimensions) to provide appropriate material for studying the joint effect of these parameters. In addition, data could be taken on important target classes employing various depression angles (the range of 30 to 60 degrees is suggested). The use of various frequencies, along with appropriate processing, should provide useful information for solving the "coherent breakup" problem by frequency averaging. The use of a laser-film recorder for increased system dynamic range will attack the small target suppression problem and other effects due to system nonlinearities.

For analysis and interpretation of the radar imagery, it is necessary to maintain a group of trained interpreters to serve as subjects for the experimentation. This group need not necessarily be large, but the composition of the group must remain relatively constant because training and experience will be a key to the successful conduct of these experiments. It is recommended that a group of the NPIC photo interpreters who have participated in the QUILL evaluation be designated for this purpose and that a significant percentage of their time be made available. The further training of these interpreters and the planning and conduct of the testing should be conducted in close consultation with specialists knowledgeable in the field of psychophysical testing, as experience in comparable programs utilizing photographic imagery has shown that inexpert design and administration of performance tests can lead to invalid or inconclusive results.

A program of approximately one year could lead to significant and useful results. An initial one month planning period followed by approximately 3 months of appropriate PI training while concurrently proceeding with acquisition of the initial test materials should be sufficient preparation for the initiation of experimentation. The subsequent 8 months will be used to complete a series of testing cycles with provisions for obtaining additional test material as required. While this will almost certainly not be a sufficiently extensive program to study in detail all aspects of this problem, we will certainly be in a vastly better position than we are now to make an intelligent judgement with regard to exploitation of side-looking radars for intelligence collection.

1.3 Program Objectives

Primary Mission Objective   The primary objective of the orbital flight was to [redacted]. For the purpose of this demonstration a resolution goal of [redacted]

Secondary Mission Objectives   A number of secondary objectives of scientific and/or engineering significance were also established. Among these are the following:

- Quantitatively [redacted], with emphasis on azimuth-dimension behavior:
- [redacted] posed by:
  - Payload design parameters
  - Payload in-flight performance
  - Vehicle attitude behavior
  - Atmospheric conditions
  - WBDL design and performance
- Determine the reasons for any observed anomalous performance of the system:
- Collect data on target-field reflectivity.
- Develop engineering data useful for aerospace radar system designs.
- Demonstrate the capability of the ground recording equipment to [illegible] received via the WBDL.

Primary Vehicle Objectives The launch phase primary vehicle test objective was to inject th[redacted] (SS-01A) into a near circular orbit so that the satellite altitude would b[redacted] 13 nautical miles when passing between 30^{o}N and 70^{o}N geodetic latitudes with an [redacted] 0.25 degrees.

The orbit phase primary vehicle test objectives were:

- o To maintain, during the minimum orbit life of[redacted] stabilized horizontal attitude with the following tolerances (-Z axis up and -X axis forward):
  - Deadband 0.15 ± 0.07 degrees, all axes
  - Bias uncertainty ± 0.4 degrees, all axes
  - Maximum pitch rate 0.002 degrees/second
  - Maximum roll rate 0.005 degrees/second
  - Maximum yaw rate 0.003 degrees/second
- o To yaw the vehicle to a bias angle of 2.44 ± 0.3 degrees to the left and to the right in response to commands.
- o To provide electrical power to sustain payload and vehicle life for a minimum of 65 orbits.
- o To command and control vehicle and payload operation.
- o To obtain data required for the generation and verification of commands to control vehicle and payload operation.

The recovery phase primary vehicle test objectives were:

- o To orient the SS-01A to a [redacted], separate the [redacted] the capsule so that its re-entry trajectory falls within a predetermined recovery area.

- To recover the [redacted] with its payload by air or surface units deployed for that purpose.

1.4 Mission Description

The mission of Vehicle 2355 was to place in orbit a [redacted], side-looking radar system payload in order to obtain a high resolution terrain map. The payload was to be operated in realtime under command of the Vandenberg and New Hampshire Satellite Tracking Stations. Operation of the payload was to be limited to the Continental United States. The SS-01A vehicle was to be injected into a near circular orbit so that the altitude over the areas to be recorded would be approximately 130 nautical miles. Precise attitude stabilization of the vehicle would then orient the radar antenna so that the main lobe of the radar beam would be at a fixed depression or look angle of 55° from the horizontal, thereby illuminating a swath approximately [redacted]

The data obtained from the payload was in the form of target echoes which were synchronously demodulated to preserve both phase and amplitude of the signals. These signals, which constitute the raw radar map Data or doppler history of the illuminated terrain, were [redacted] Simultaneously, these signals were transmitted over the Wide Band Data Link to the tracking stations where they were again recorded photographically on film by ground based recorders and also electronically on wide band magnetic tape recorders. The film recorded in the satellite was to be recovered in the Pacific Ocean area by means of air catch of a recovery capsule. Figure 1.4 portrays the ... and the tracking stations zero and five degrees elevation circles of coverage.

1.5 System Description

The satellite vehicle utilized for this mission consisted of the following subsystems:

- Subsystem A (SS/A) - Structural
- Subsystem B (SS/B) - Propulsion
- Subsystem C (SS/C) - Electrical
- Subsystem D (SS/D) - Guidance and Attitude Control
- Subsystem C & C - Command and Control
- Payload Subsystem
- Recovery Subsystem

The above subsystems are described in some detail in Part II, Para. 2.1, Satellite System Engineering; Para. 2.2, Radar Payload; and Para. 2.3, Test, for the Recovery Subsystem. Since the Recovery Subsystem was GFE, the effort was limited to test on that subsystem, and the configuration description is confined to the information considered necessary for understanding of system operation.

The satellite structure forward of the standard Agena vehicle interface housed and supported the guidance system components, the radar payload and associated power equipment and the recovery capsule.

The radar payload was developed for satellite application by Goodyear Aerospace Corporation from the AN/UPQ-102 side looking doppler radar utilized in the RF-4C aircraft. The radar components include: (1) a Transmitter-Modulator, which is basically a high power R.F. pulse amplifier; (2) an RF-IF unit, which generates a low power RF pulse for the transmitter and receives and compresses the reflected radar pulse; (3) a Reference Computer which generates timing and control signals, RF pulses for transmission, synchronously demodulates the received intermediate frequency to provide video data and performs electronic beam steering to a zero doppler position; (4) a Power Control Unit, which controls and switches power and generates regulated voltages necessary for the radar; and (5) a Recorder which records the received video from the Reference Computer on film by exposure from the face of a cathode ray tube. The film, containing the doppler history of each target, is returned by the recovery capsule. Simultaneously the video data from the Reference Computer is transmitted by means of an R.F. data link to the tracking stations, and recorded in a similar film recorder.

The high power output pulse of the radar was transmitted through a flat, phased array, antenna mounted on the side of the satellite with the beam oriented perpendicular to the vehicle longitudinal axis and at a 55 degree depression angle below horizontal. The beam width was .346 degrees in the azimuth direction and 2.9 degrees in the vertical direction at the half power points. The satellite was rotated 180 degrees after injection into orbit (positioned for recovery pitch down) and was stabilized in a horizontal plane. During the payload operating passes the horizon sensors were disconnected and the satellite was precisely stabilized under fine attitude control by the inertial reference package gyros. The system was supplied electrical power by three silver-zinc batteries, the output of which was converted and regulated as required. The electrical capacity of the batteries limited the duration of the mission. The vehicle was commanded through an S-Band beacon and returned data through two VHF telemetry links and the wide band UHF data link.

After separation of the recovery capsule the vehicle was re-stabilized in the horizontal plane and the payload was operated through the data link until power depletion on orbits 72 - 73. The orbit decayed and the vehicle re-entered on orbit 333 at 1027Z, 11 January 1965.