☐ SECRET ☒ CONFIDENTIAL 997385 ☐ UNCLASSIFIED

CONTRACT INSPECTION REPORT

CONTRACT NO.

TASK NO. 99

25X1

TO:

ENGINEERING SECTION/CB/PD/OL

DATE: 23 September 1965

INSPECTION REPORT NO. *(If final, so state)*: 4

ESTIMATED COMPLETION DATE: 30 September 1965

NAME OF CONTRACTOR

25X1

TYPE OF COMMODITY OR SERVICE

Automatic Image Recognition by Coherent Optical Techniques

THE CONTRACTOR IS ON SCHEDULE ☐ YES ☒ NO

PER CENT OF WORK COMPLETED - 85%

PER CENT OF FUNDS EXPENDED - 80%

THE CONTRACTOR WILL PROBABLY REMAIN WITHIN ALLOCATED FUNDS ☒ YES ☐ NO IF ANSWER IS "NO" ADVISE RECOMMENDATION AND/OR ACTION OF SPONSORING OFFICE. ON REVERSE HEREOF. IF KNOWN, INDICATE MAGNITUDE OF ADDITIONAL FUNDS INVOLVED.

HAS AN INTERIM REPORT, FINAL REPORT, PROTOTYPE, OR OTHER END ITEM BEEN RECEIVED FROM THE CONTRACTOR DURING THE PERIOD? ☐ YES ☒ NO *(If yes, give details on reverse side.)*

HAS GOVERNMENT-OWNED PROPERTY BEEN DELIVERED TO CONTRACTOR DURING THIS PERIOD? ☐ YES ☒ NO *(If yes, indicate items, quantity, and cost on reverse side.)*

INCENTIVES

IS THIS AN INCENTIVE CONTRACT ☐ YES ☒ NO
IF YES, CHECK TYPE
☐ COST ☐ PERFORMANCE ☐ DELIVERY

NOTE:
USE REVERSE SIDE FOR COMMENTS.
FINAL REPORT MUST CONTAIN INCENTIVE EVALUATION.

OVERALL PERFORMANCE OF CONTRACTOR

1. ☐ OUTSTANDING
2. ☐ EXCELLENT
3. ☐ ABOVE AVERAGE
4. ☒ AVERAGE
5. ☐ BELOW AVERAGE
6. ☐ BARELY ADEQUATE
7. ☐ UNSATISFACTORY

IF OVERALL PERFORMANCE OF CONTRACTOR IS UNSATISFACTORY OR BARELY ADEQUATE, INDICATE REASONS ON REVERSE SIDE.

RECOMMENDED ACTION

☒ CONTINUE AS PROGRAMMED

☐ WITHHOLD PAYMENT PENDING SATISFACTORY PERFORMANCE

☐ TERMINATE

☐ OTHER *(Specify)*

IF TERMINATION IS RECOMMENDED OR IF THIS IS A FINAL REPORT PUT COMMENTS ON REVERSE IN NARRATIVE FORM ON CONTRACTOR'S PERFORMANCE AND CERTIFY THAT ALL DELIVERABLE ITEMS UNDER THE CONTRACT HAVE BEEN RECEIVED. THESE INCLUDE, WHERE APPLICABLE, THE FOLLOWING:

ITEM	REC'D	DOES NOT APPLY	ITEM	REC'D	DOES NOT APPLY
PROTOTYPES			MANUALS		
DRAWINGS AND SPECIFICATIONS			FINAL REPORT		
PRODUCTION AND/OR OTHER END ITEMS			SPECIAL TOOLING		
			OTHER GOVERNMENT PROPERTY		

DATE OF LAST CONTACT WITH CONTRACTOR: 30 August 1965

SIGNATURE OF INSPECTOR

25X1

DIVISION: P & D S

INSPEC

SIGNATURE OF APPROVER

FORM 10-64 1897 USE PREVIOUS EDITION ☐ UNCLASSIFIED ☒ CONFIDENTIAL ☐ SECRET (12-36)

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Automatic Image Recognition by Coherent Image Techniques

25X1 [redacted]

Progress Report No. 7

Financial Status

Amount Authorized

Estimated expenditures through 8 August 1965

Funds Committed

Funds Remaining

[redacted] 25X1

Technical Status

Attached is a technical progress report which consists of a summary report presented to the sponsor's technical representative during his visit on August 19.

25X1 [redacted]
8/30/65

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Automatic Image Recognition by Coherent Optical Techniques

Summary Technical Status

Section A - Theory

The main problem considered here was to find if there were any theoretical limitations to the recognition process in handling large amounts of highly detailed information or recognizing objects of any degree of complexity. This was broken into 4 problems:

A - 1 Maximum Information Content of a Photograph or Filter

Calculation shows that the upper limit of detail in the negative which the process can handle is 2000 lines per millimeter. At the present time there are few lenses or emulsions which will realize as much as 200 lines per millimeter, and therefore the process is not a limiting factor in any photograph we can make.

There is no problem in attaining the necessary information content in the filter. The two technical difficulties are resolution and dynamic range. The resolution of the filter material has to be adequate to record the interference lines produced by the two-beam process. This is usually in the range of 120 lines per millimeter and is easily recorded on high resolution materials. Unfortunately, these materials have a short dynamic range which makes it necessary to adjust the exposure fairly exactly to obtain the desired selectivity in the filter, but this is not a limitation on information content.

A - 2 Minimum Size of Detectable Objects

As the size of an object in a negative decreases the amount of light which it passes decreases in proportion to its area. At some size the object will pass so little light that even after it is concentrated into a recognition spot this energy will not be appreciably higher than the surrounding noise level and the object cannot be detected. Theory shows that for aerial negatives having an average "noise" this minimum size is .3 mm or .012 inch. For fine-grained films the minimum size would be even less, and for noise-free subjects such as printed copy the minimum size is much less.

A - 3 Modulation Transfer Function of the Optical System

The problem was to find if the recognition process imposed impossible requirements on the optics. The requirements placed on each of the optical elements in the recognition system and the filter making subsystem were analyzed separately. Theory and experiment both show that there is no practical difficulty in realizing a transfer function that is high enough for any practical application. The only serious problem is keeping the lenses and other optical parts clean during the life of the system.

A - 4 Obtainable Signal-to-Noise Ratios

Aerial photographs contain objects containing all sorts of detail as well as grain which together create the optical equivalent of noise. The SNR can be calculated only in closed form for specified signal shapes and for certain spectral densities or noise. Making logical assumptions for the area of the object, film graininess and other variables, it is possible to calculate a SNR of about 15 db. Translated into optical terms this is adequate for detection and appears to agree with experimental findings.

A - 5 Relative Merits of Phase (PPR) and Amplitude (Photographic) Filters

So far as theory is concerned, there is little difference between the two kinds of filters. Ideally, the matched filter should consist of two parts, the signal-passing portion and the noise-rejection portion. It is possible to calculate that the signal-passing portion is identical in operation for a filter made by either the photoplastic or photographic process. It has not been possible to calculate the effect of noise-rejection portion, but this is rarely used anyway.

The conclusion to be drawn from the five theoretical studies is that the processes is capable of much more than we need, the real problems are materials and technique.

Section B - Equipment

Several practical operating problems were considered:

B - 1 Effect of Glass Plates

It is sometimes convenient to use object transparencies or spatial filters on glass photographic plates, will irregularities in the glass be a problem? For small areas, such as one-inch square spatial filters, the errors found in most glass photographic plates have little effect on the recognition system. Over large areas commercial photographic plates contain surface irregularities that result in wavefront deformations which reduce the S/N ratio and cause a loss of detection. This difficulty can be eliminated by placing the film or plates in a liquid gate or by making the transparencies on microflat glass.

B - 2 Effect of Vibration

The 20-foot optical bench was vibrated in a rather severe manner and the recognition system operated throughout the tests with no change in adjustments necessary afterwards. Vibration does not appear to be a problem if the system is properly designed.

B - 3 Reducing the Amplitude of the Reference Beam

Several means of beam attenuation appear equally satisfactory if the attenuators are placed at the focal point of the second lens. Satisfactory attenuation was obtained with a series of gelatin filters, a circular wedge and two crossed polarizers mounted on flat glass plates.

B - 4 Liquid Gates

For film we have tested, equally good results were obtained with or without liquid gates.

In review, none of the equipment problems appear serious and simple solutions were found for the four studied.

Section C - Automation

If the system is ever to be used economically it must be automated to perform the search and recognition mechanically. There are many problems to automation and only the following were studied:

C - 1 Accuracy of Filter Alignment

If spatial filters are to be changed mechanically we must know the tolerance on their location. Small errors of alignment, less than .001 inch had negligible effect. For average size objects, an error of $\pm$ .002 inch reduced the recognition signal to 80 percent of its normal value. These values are within the tolerance of automatic equipment.

C - 2 Orientation Tolerance

A rotation error of one-half degree between the image and filter results in negligible signal loss. A two-degree angle error reduces the signal to 80 percent of its normal value.

C - 3 Scale Tolerance

The curve of magnification error between the object and spatial filter as a function of signal intensity has a practically flat plateau at zero error and essentially linear slopes. A size difference of 2 percent results in little loss of signal. Another way of describing the magnification or scale tolerance is that the signal drops to 80 percent of maximum when the magnification is varied $\pm$ 3 percent and falls to 50 percent with a change in size of $\pm$ 6 percent. For variations of less than 1 percent the loss of signal strength is negligible.

C - 4 Time Constant for a Scale and Orientation Search

This is based on the time to perform the scale (magnification) and orientation (rotation) search of the photograph and indicates the time to process one negative. Using the rotational and scale tolerances derived earlier, it appears that the search time for a typical aerial negative is about two minutes including the time to change transparencies.

C - 5 Use of Photoplastic Film for Filters

The signal-to-noise ratio of the recognition signal is equal for equivalent silver and PPR spatial filters. The red-sensitive PPR material has low transmission for red light and the signal is attenuated by this absorption. The processing time as well as alignment of the finished filter is much faster for the PPR. The PPR (red-sensitive) requires less exposure time than a satisfactory silver material and it is reusable.

C - 6 Real-Time Filter Generation

We redefined "real-time" to mean a short time rather than instantaneous. The total elapsed time to make a silver-bearing filter on Kodak 649 material was 2 minutes exposure plus one-hour processing. The total elapsed time to make a PPR filter of the same subject was 10 seconds exposure plus 20 seconds charging time and a fraction of a second development time. The film could be precharged reducing the time to practically the exposure time.

C - 7 Television Readout of Recognition Signals

A mechanical readout is essential and a television type system appears most suitable. This work not yet completed.

In review, answers or at least partial answers have been found to several of the problems of automating the system and adapting it to operate in real time. Considerably more work on automation remains to be done, but no serious problems have been uncovered.

Section D - Problems of the Photograph

This section was concerned with problems such as how well low-contrast and camouflaged targets could be detected, also how well a filter made from a vertical photograph would detect an oblique image of the same object.

D - 1 Effect of Target Size

The optimum signal-to-noise ratio for aerial photographs was obtained with objects close to 5 mm size using our 20-foot bench, as predicted by the "f-400 rule". Objects much smaller than 2 mm gave poor recognition on this bench, but when processed on another instrument with shorter focal length lenses gave good recognition. The entire transparency could not be covered at one time on the smaller instrument.

D - 2 Effect of Multiple Identical Targets

Multiple, identical targets in the same photograph can result in loss of detection signal for some of these targets. If vehicles are oriented at certain small angles to each other resulting in phase interference in the most important parts of the diffraction pattern, then one or more of these vehicles will produce a weak signal. Close-packed vehicles lose part of their outline and the inner vehicles show some loss of detection. In none of the cases tested did the relative signal strength fall below 47 percent of that of a single vehicle.

D - 3 Multiple-Object Filter

For simple objects such as characters on a noise-free background, 20 or 30 can be used in one filter, certainly as many as 10. For more complex objects such as vehicles on a noisy background, the present limit appears to be three or four. The signal-to-noise ratio decreases as the number of objects in the filter increases. The number of false-alarms for similar objects increases as the number of objects in the filter increases. The magnification and orientation tolerances are tightened slightly as the number of objects increases. The use of a filter containing four objects should reduce the search time to nearly one-quarter that of using four separate filters.

D - 4 Effect of Shadows

Small, sharp shadows around a vehicle outline it, increasing the contrast with its surroundings and improving recognition. In general, recognition is better in photographs taken on sunny days than cloudy days when there are no shadows. On the other hand, a low sun will produce long distorting shadows which will reduce the recognition. We have no good numerical results on this effect at present.

D - 5 Effect of Target Aspect

This has not been completed, but the results indicate that variation in aspect angle up to 20 degrees is not serious for the recognition of vehicles.

D - 6 Target Obscuration - Effect of Low-Contrast

With negatives showing no scratches or flaws, images of objects at extremely low-contrast are located at the same signal-to-noise ratio as obtained in normal contrast negatives. Good recognition was obtained for images that had a density difference from the background of 0.15 or less. The intensity of the recognition signal is less in low-contrast pictures, but the noise also is smaller. Scratches and defects become more serious as the contrast of the negative is reduced. If the contrast is low due to camouflage, then the signal will be weak and the noise normal. Recognition under these conditions could be difficult.

D - 7 Dazzle Camouflage

Dazzle camouflage produces strong diffraction noise. If the average frequency of this noise is close to that of the chief spatial frequency of the target, then the target may be obscured by noise and be undetectable by this process. The presence of confusing background actually reduces the intensity of the recognition signals. This is not understood at present.

D - 8 Overlap or Partial Concealment

Good recognition was obtained when up to 60 percent of the target was obscured. Some recognition was obtained for targets 80 percent obscured. These recognitions are possible only when the target has average or high contrast and the background is the same. Low-contrast targets with noisy camouflage becomes more difficult.

D - 9 System Evaluation

This term is intended to include all of the factors in this section and the problems of design and automation. As seen in this section, it is possible to have objects too small to detect in a particular equipment and some kinds of camouflage are effective in confusing the instrument. On the other hand, the process has shown good performance on low-contrast and partially hidden objects. There is every indication at present that the process should find any object a human operator would normally find. An exception to this is deliberate camouflage which may alert a human operator to look for additional clues. Human beings have intelligence to cope with all sorts of difficult situations when necessary and the recognition process has no intelligence.

The present evaluation is that the recognition process appears adequate to handle many search and detection problems.

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Automatic Image Recognition by
Coherent Image Techniques

25X1 [redacted]

Progress Report No. 6

Financial Status

Amount Authorized

Estimated expenditures
thru 4 July 1965

Funds Committed

Funds Remaining

[redacted] 25X1

Technical Status

The engineering progress report for the period 13 June 1965 to 9 July 1965 is attached.

25X1 [redacted]
7/12/65

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Automatic Image Recognition by Coherent Optical Techniques

Progress Report No. 6

Experimental studies conducted during this reporting period include work with liquid gates on the 20-foot optical bench, multiple object filter tests, test of first aerial films supplied and additional studies on the effects of obscuration.

The liquid gate problem has been solved to our satisfaction and the large gate is now usable at least over the central 2 1/2 inch diameter area. Some liquids tested exhibited extreme temperature sensitivity which produced refractive index stratification and resulted in an effect exactly like astigmatism. A suitable liquid was located.

The alignment tolerances for a multiple object filter were described previously as being quite critical. We have discovered some errors in the manner in which these experiments were conducted and a new test was made on the alignment tolerance of the entire pattern of ten objects with the filter and not the alignment of one object with the filter. The conclusions now reached are that the x and y displacement tolerance of multiple object filters is the same as single order filters. The rotation and magnification alignment tolerances are the same if the filter is made in the same diffraction order. In general, multiple object subjects will require a higher order filter. Since the higher order filter has "spots" at greater radial distances from the axis, the rotation and magnification tolerances are reduced proportionately.

The first aerial photographs supplied were duplicate negatives and were apparently produced by the reversal process. These films lacked the relief characteristic found in most photographic images. The assumption that the reversal process was probably employed would account for the loss of this feature. Recognition obtained on the submitted film was poor. Recognition on contract prints from the aerial negatives was considerably improved, but still less than anticipated. Spatial filters made from sharp originals such as models and cutouts gave slightly better recognition than filters made from images taken from the aerial film. Some original negatives were supplied and upon inspection they appear to not only have the desired relief effect, but are also somewhat sharper in detail. Filters are now being made and recognition studies will be well underway during the early part of the next reporting period.

If negatives are in perfect condition, with no scratches or flaws, this recognition process will locate images of objects at extremely low-contrast and at the same signal-to-noise ratio as obtained in normal contrast negatives. Good recognition was obtained for images that had a density difference from the background of .15 or less.

During the next reporting period, it is planned to work with the supplied aerial negatives and begin planning the experiments with the image orthicon read-out.