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PROPOSAL FOR DEVELOPMENT OF CHANGE-DETECTOR EQUIPMENT

[redacted]

20 January 1962

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SECTION I - INTRODUCTION

The photo-interpreter in an information processing system must search a photograph, compare it with other photographs of the same area and with surrounding areas, and compile data that will finally be fitted together carefully for an appraisal of the strategic, tactical, and logistic significance of any changes that have occurred between the photographs.

Screening aids offer the greatest potential for the improvement of photo-interpreter performance in the analysis of surveillance data. These devices, while leaving the job of interpretation to the human, provide a machine method to reduce greatly the search time of the photo-interpreter; thus, they enable him to handle large amounts of data in a given time or reduce the time required to obtain a given piece of intelligence.

A device that will automatically register, compare, and display data from two perspective views of a common area taken at different times exemplifies a screening aid that will assist the photo-interpreter. Such a device allows the interpreter to locate changes between scenes quickly and, subsequently, to determine the nature of the change (for example, the addition of new objects to the scene, the change in positions of objects within the scene, and the removal of objects from the scene). A change detector screening aid also provides a basic device around which other screening aids can be added to improve performance further.

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[redacted] This program comprises the design, fabrication, and evaluation of a change-detector screening aid that will provide the capability described above. The equipment will consist of a console containing comparator and display units. The

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comparator unit will contain the necessary components to perform the functions of automatic registration and comparison of image data from roll film. The display unit will provide the components required to display the scenes being compared as well as the output comparison data and controls required to operate the console. Described herein are some of the operational uses of the device, the basic technique proposed, and a summary of recent studies and problems that remain to be solved.

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SECTION II - CONCEPT OF CHANGE DETECTION

1. STRATEGIC AND COMBAT CONSIDERATIONS

Surveillance is conducted primarily to determine the location of the enemy and chart his movements. Today, the development of an adequate strategic and combat surveillance capability has become a serious problem confronting the Military because of the advent of missiles, satellites, and nuclear warheads together with the development of innovations in tactics and strategy created by the use of the new weapons.

Prior to and during any war, strategic intelligence must be gathered concerning the capabilities, limitations, vulnerabilities, and probable actions or reactions of foreign or enemy nations. Satellites are now used and will continue to be used for surveillance. Intelligence concerning topology and military geology can now be obtained by the use of visual sensors. In the near future, [redacted] technology will be available to permit the use of such sensors in satellites and very high altitude aircraft. The imminence of hostilities, for example, can be measured by comparisons of data obtained from repeated looks at large geographical areas.

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As a global satellite surveillance system is developed and as space flights become more frequent and routine, there will be an increasing amount of strategic surveillance data available for interpretation. Automatic devices are required that will screen and therefore reduce the amount of data to be interpreted. The key to this process is a technique that detects the positions within pictures where changes have occurred when compared to pictures taken previously of the same area. In some instances, where the low resolution of pictures makes detail interpretation impossible and would normally obscure changes, this technique will reveal general areas of change. Subsequent reconnaissance missions

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can then be performed to obtain more detailed pictures from which specific changes can be determined.

During general or limited war the combat surveillance problem is becoming increasingly important. Timing has become critical since armies can now move rapidly and contain integral capabilities for air transportation. Targets now move constantly, employing camouflage, night, or bad weather to avoid detection. Thus, the timely location of targets and the resulting shift of the defense posture require quick decisions and actions. This can be accomplished only by more rapid, complete, and precise intelligence.

Present tactics and organization require a dual capability for the Army, namely, strategic and tactical mobility. The role of tactical aviation for close support will become partly the responsibility of surface-launched missiles and surveillance systems organic to the ground forces. All surveillance functions have become more difficult because of the high mobility possessed by the enemy. This mobility will continue to increase with time, hence profitable targets will remain profitable only for short periods. The total enemy situation observed or sensed at any given time may change in minutes. Even now, the existing data-gathering capabilities exceed the capacity to process this information. The systems currently under development are planned to gather larger amounts of data, making the problem truly difficult. The information-processing system must be built to exploit the capabilities of both men and machines. The system must be matched at one end with the data-gathering capability of surveillance and other intelligence sources and at the other end with the basic information required for a command decision.

Dr. Kraft estimates, for example, that the field army intelligence requirements in a highly mobile war may dictate the data processing of as high as 100,000 pictures daily.[a] Present estimates of interpretation

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[a] Dr. Conrad Kraft, "Possible Solutions for Minimizing Time Delay and Errors in Data Utilization." Proceedings of the National IAS/ARMY Aviation Meeting (UNC). April 13-14, 1961, Washington D. C.

rates indicate that as many as 12,000 man-years of work would be required to analyse this amount of film for a years' combat.

The data interpretation of imagery in these amounts is well beyond the capacity of the trained personnel available to the United States. The training of large numbers of interpreters alone is not an adequate solution to this problem. The solution will be found only in the utilization of better methods of employing machines to aid photo-interpreters in handling large amounts of data while leaving the final integration of the data to the photo-interpreter.

Machines can be built that possess capabilities greater than man in memory, data handling, and the rapid transfer of data. Thus, a simple and direct approach is the utilization of semitrained personnel to operate simple but reliable equipment that can detect rapidly and accurately any changes that have occurred in two views of a common area taken at different times. This approach permits the skilled, highly trained photo-interpreter to concentrate on the details of the changed areas, where the highest probability of significant data exists.

2. MILITARY APPLICATIONS

Comparisons of repeated looks of a common area reveal three types of image changes: (1) the addition or movement of objects into the area, (2) the removal of objects from the area and, (3) the movement or repositioning of objects within the area. Knowledge of the types of changes with identification of the objects concerned yields intelligence for a variety of military situations pertaining to enemy capabilities, limitations, and vulnerabilities. The measure of transportation and other activities is useful as an indicator of forthcoming action.

Activity can be defined, in general, as the number of changes taking place in a given area of interest. Thus, counts of changes per unit area constitute a measure of activity. However, the changes measured must

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be of military significance if the intelligence derived from such measures is to be useful in military decisions.

The imminence of hostilities for a general war can be measured by examination of enemy activity over large areas. Supply area activity, the location of new construction, and the relocation of military targets can all be used to predict the coming of a general war. A change detector can be used to screen the vast amounts of data required to obtain an over-all imminence-of-war indication rapidly enough to permit defensive actions.

Enemy intentions toward a limited war can be judged from changes of such items as the image background and motion. The most reliable indication of a danger situation can be provided by a combination of the parameters of motion appearing simultaneously, or in a logical sequence, starting with slower motions (in central or remote areas), followed by a convergence toward areas where an order of battle is being formed for the instant of strike. A reliable danger count would be a summation of changes as they appear simultaneously or as new changes are added to those already existing. Figure 1 exemplifies the use of a change detector to detect vehicle movement within an area.

The continued observation and subsequent measurement of changes that have occurred in the terrain itself can be used to locate new bunkers, munition dumps, camouflaged areas, and new missile launching sites.

For quantitative bomb damage assessments a change detector can be used to compare the reconnaissance pictures taken before and after a strike. Repeated comparisons of detail pictures of a combat area can be used to plot an enemy order of battle since the movement and relocation of various military targets, personnel, and the construction of foxholes and bunkers can be quickly located and recorded.

The use of a change detector to locate the position of newly laid mine fields is a promising concept. In many cases where great effort has not

SECTION II - CONCEPT OF CHANGE DETECTION

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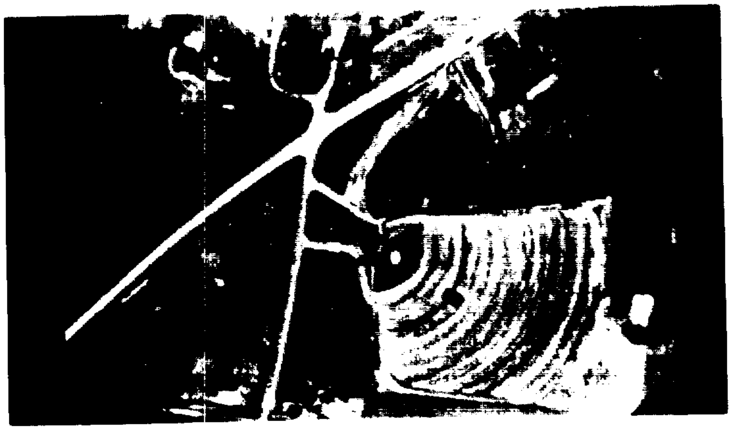
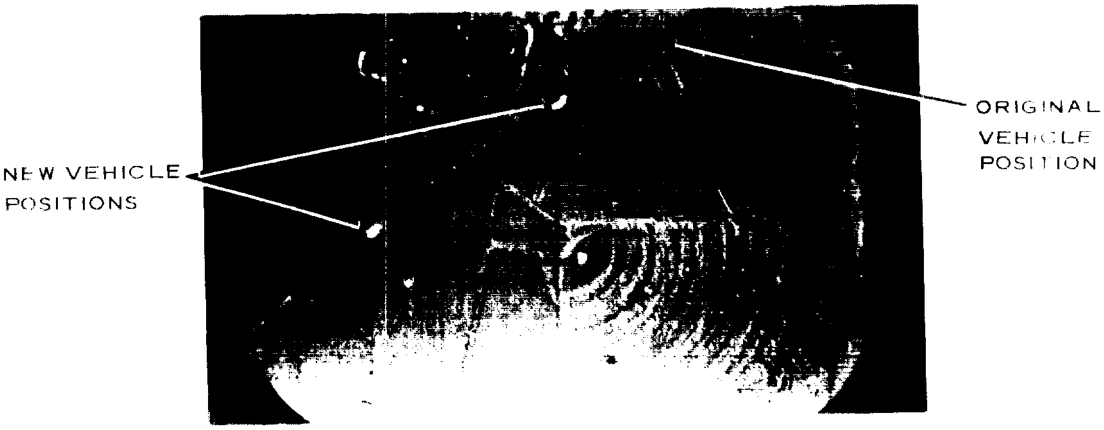


REFERENCE SCENE

COMPARISON SCENE



CHANGE DISPLAY

Figure 1 - Detection of Vehicle Movement

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been expended to hide the mines, a simple comparison in a change detector of the area at different times will easily detect the addition of the mines. Figure 2 shows a typical example of the use of a change detector for the location of newly laid mines. For those cases where previous reconnaissance pictures are not available or where great care has been taken to hide the mines, the use of camouflage detection film with a change detector can be used to locate spoil lines left by the burial of the mines themselves or to locate differential growth in the mined areas. Processed camouflage detection film shows highly infrared-reflective objects as red (e.g., healthy foliage), green objects that are not highly infrared reflective as blue-green (e.g., unhealthy foliage, which, although still green, has lost most of its infrared reflectivity), and brown or red objects, which are not highly infrared reflective, as yellow or brown (e.g., the dead foliage of most plants).

Sod covering mines, for example, will experience healthier growth than the surrounding area, while patrol or egress paths through a mine field will normally scar the vegetation, causing a decline in growth. Thus, pictures of mine fields made with camouflage detection film, taken even after the planting of mines, will exhibit the differences in growth so that the normal identifying mine field patterns can be observed.

3. COMPARISON OF VARIOUS METHODS OF CHANGE DETECTION

There are three basic methods of detecting changes between two scenes of overlapping data. The first, the side-by-side or juxtaposed method, is the current operational technique and consists of the intermittent scanning of two images of the same area placed side-by-side in front of the observer. The pictures are scanned alternately until the observer recognizes that data exist in one scene and not in the other. He must alternately store and compare as much data as he is capable of handling.

The second method is the apparent motion, or flicker, method, since any change occurring in the scene will have an apparent motion or flicker to

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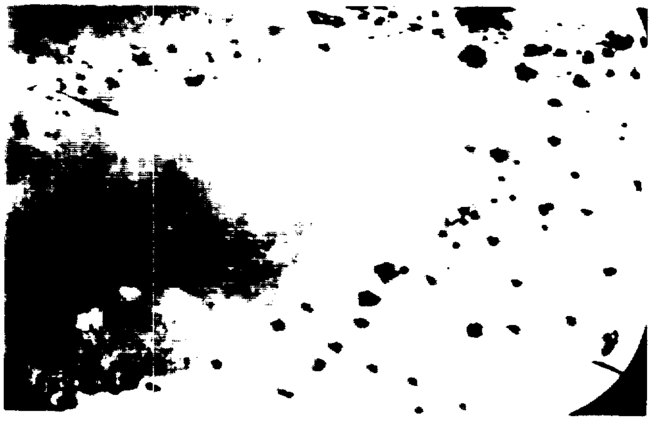
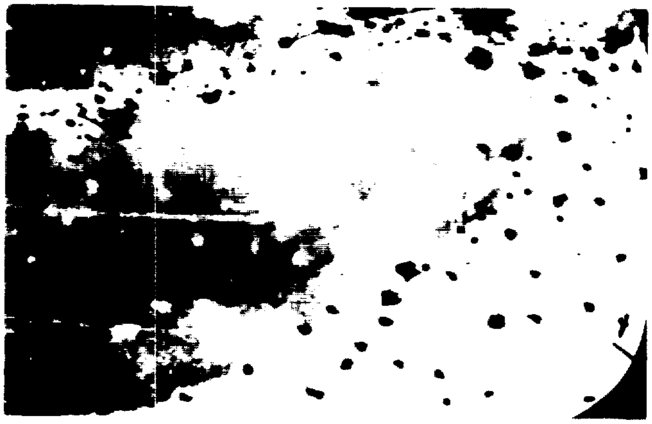
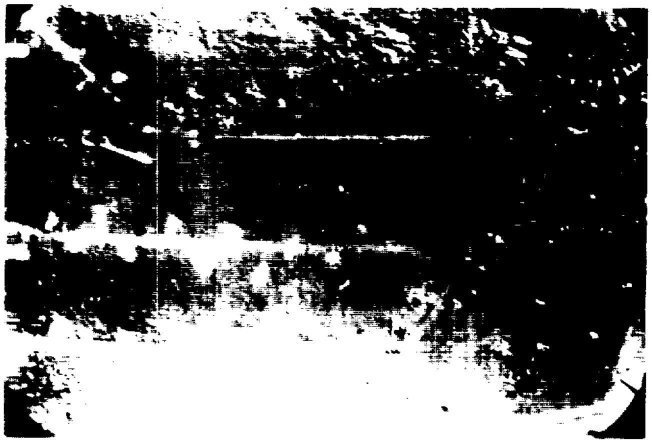


REFERENCE SCENE



COMPARISON SCENE



CHANGE DISPLAY SHOWING MINE PATTERNS

Figure 2 - Detection of Mines

the observer. The method consists of the presentation of old and new images in registry and in alternating sequence at approximately 1-1/2 cps.

The third technique is the "difference" or "overlay" method and consists of the optical or electrical mixing of positive and negative images of the old and new scenes. The optical method produces the quotient of the two transparencies, while the electrical method normally produces the difference between the two images.

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The three methods were compared for various types of changes and display magnification by Dr. Conrad Kraft [redacted][a] Changes in the number, size, and position of targets were independent variables while (1) the time required to detect the changes and (2) the errors in the changes were the dependent variables. Fifteen trained observers were used on each of the three methods. The number of false reports of targets that were not changed were determined.

The differences between the three methods proved to be highly significant. Figure 3 shows the average time required to locate as many as six changed objects within a scene for the various methods of change detection; the juxtaposed method is approximately three times longer than the difference or flicker method. The averages for all groups of changes are 58.5, 19.7, and 22.5 sec, respectively. Although the display size did not appear to affect the detection time of the side-by-side method, it affected significantly the difference and flicker methods.

Figure 4 shows the omission errors for the various change detection techniques. The data indicate that positional changes are the most difficult to detect. For the side-by-side method as many as 99-percent errors can be expected with change targets of four-minute size with no display magnification. The error percentage can be reduced to 60 and 37, respectively, when display magnifications of 4 and 8 are used. When

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[a] Ibid.

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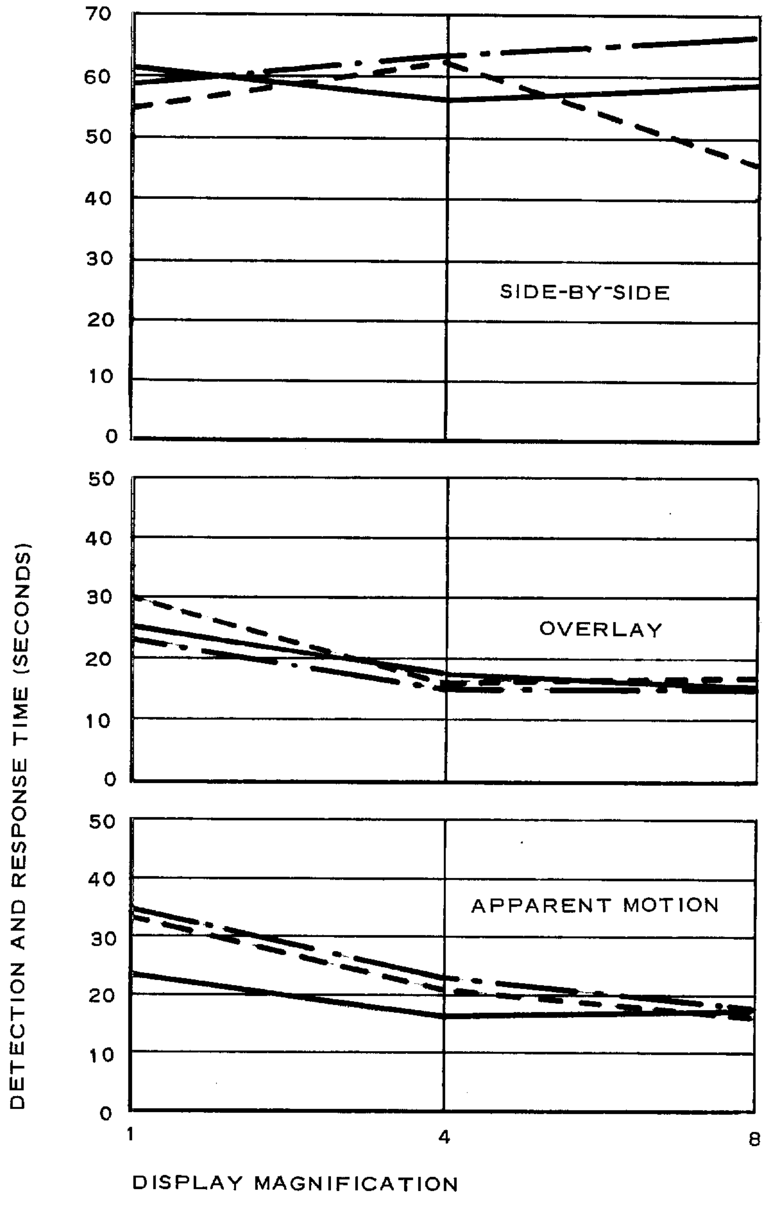

TYPES OF CHANGE

———	NUMBER
– – –	SIZE
—·—	POSITION

NOTE

TARGET DISPLAY SCALE = 4 MINUTE UNITS
AVERAGE REPORTING TIME = 8 SECONDS

Figure 3 - Time Required for Various Methods of Change Detection

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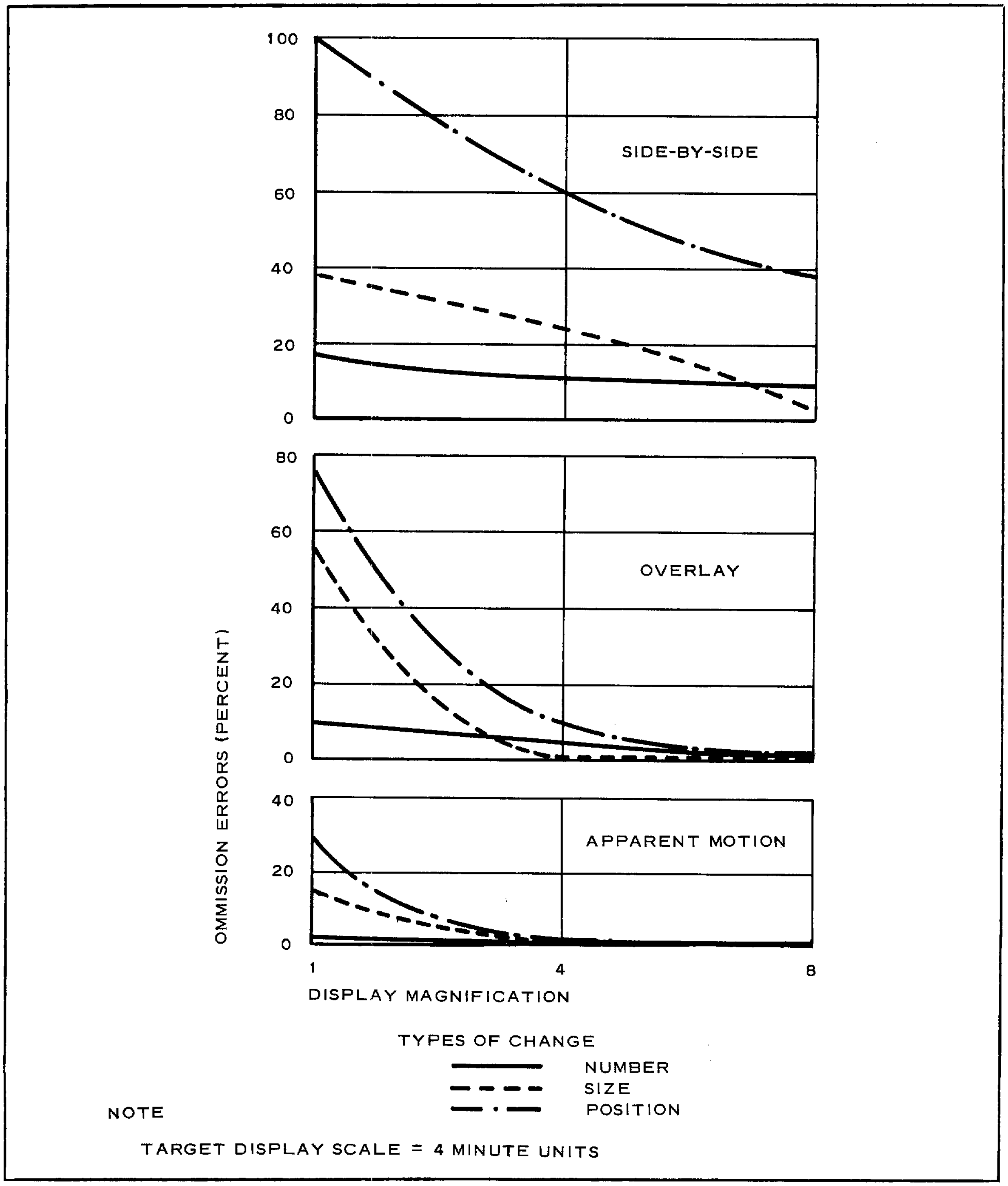


NOTE

TARGET DISPLAY SCALE = 4 MINUTE UNITS

Figure 4 - Omission Errors for Various Methods of Change Detection

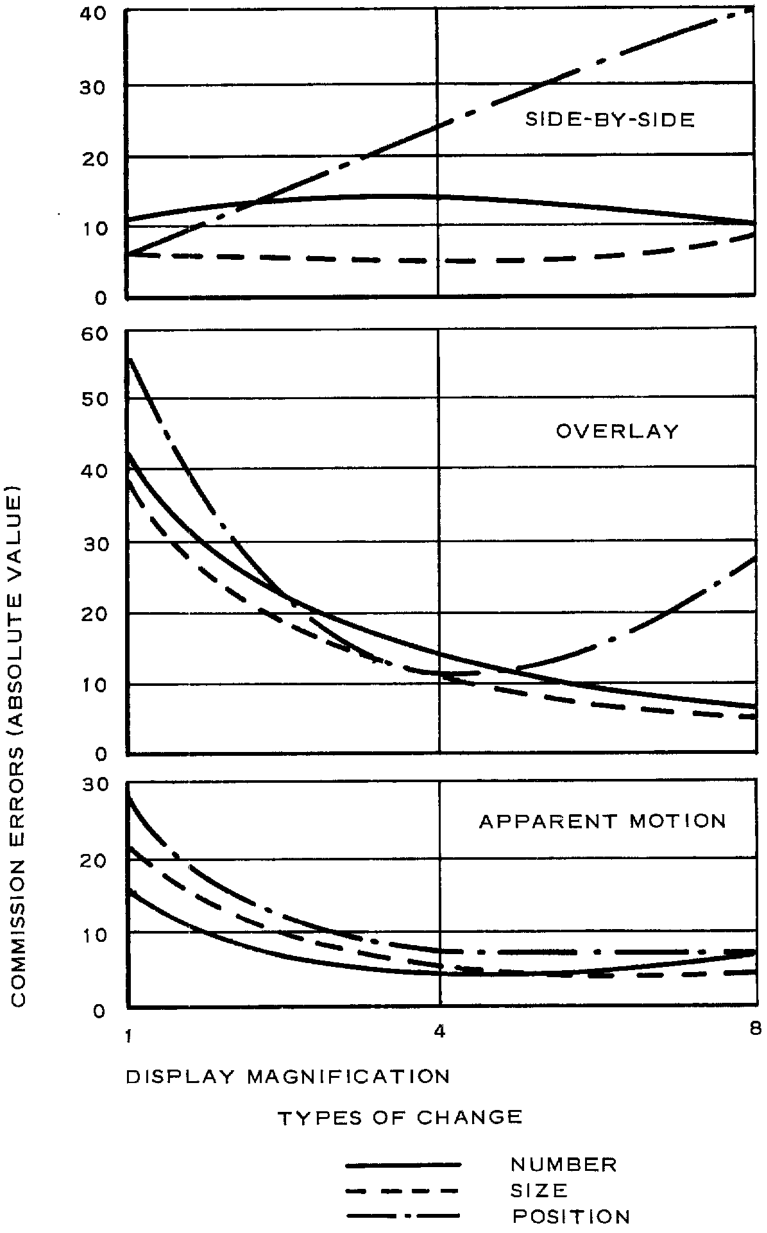
changes are caused by the addition of targets, the display size has little effect. The difference and flicker methods however, have minimum omission errors when a display magnification of 4× is used.

The number of falsely detected changes, called commission errors, are shown in Figure 5. The efficiency of the various methods can be obtained by combining the detection times and the errors as shown in Figure 6. For the experiments performed by Dr. Kraft the difference and flicker methods were essentially the same.

Consider a typical global satellite surveillance system, operating at an altitude of 150 naut mi and with a 24-in.-focal-length camera, designed to obtain a complete mapping of the USSR and China every 30 days. Such a system will generate at least 46,500 pictures each month. If a cloud cover of 0.66 is assumed, the number of frames will have to be increased to 140,000 pictures.

Consider a field-army battle-front situation with daily reconnaissance of an area of 100 by 300 naut mi from an altitude of 2,000 ft using a 9-in. film format and a camera focal length of 12 in. This reconnaissance will produce approximately 480,000 frames per day. The relative manpower requirements to determine the changes in the scenes during a 24-hr period each day are shown in Figure 7 for the side-by-side and the difference change detection techniques. Approximately 250 men would be required for the present side-by-side technique and still 33 percent of the changes would go undetected. If the difference detection technique were used, only 54 men would be required and only 3.2 percent of the targets would go undetected. The number of errors could be reduced further by use of a flicker technique in conjunction with the overlay method.

The experiments performed to date have been somewhat limited since they were made in the noise-free condition. The difference between the conventional side-by-side and either the difference or flicker techniques is sufficiently large to indicate that the latter methods would greatly improve operator performance.



NOTE
TARGET DISPLAY SCALE = 4 MINUTE UNITS

Figure 5 - Commission Errors for Various Methods of Change Detection

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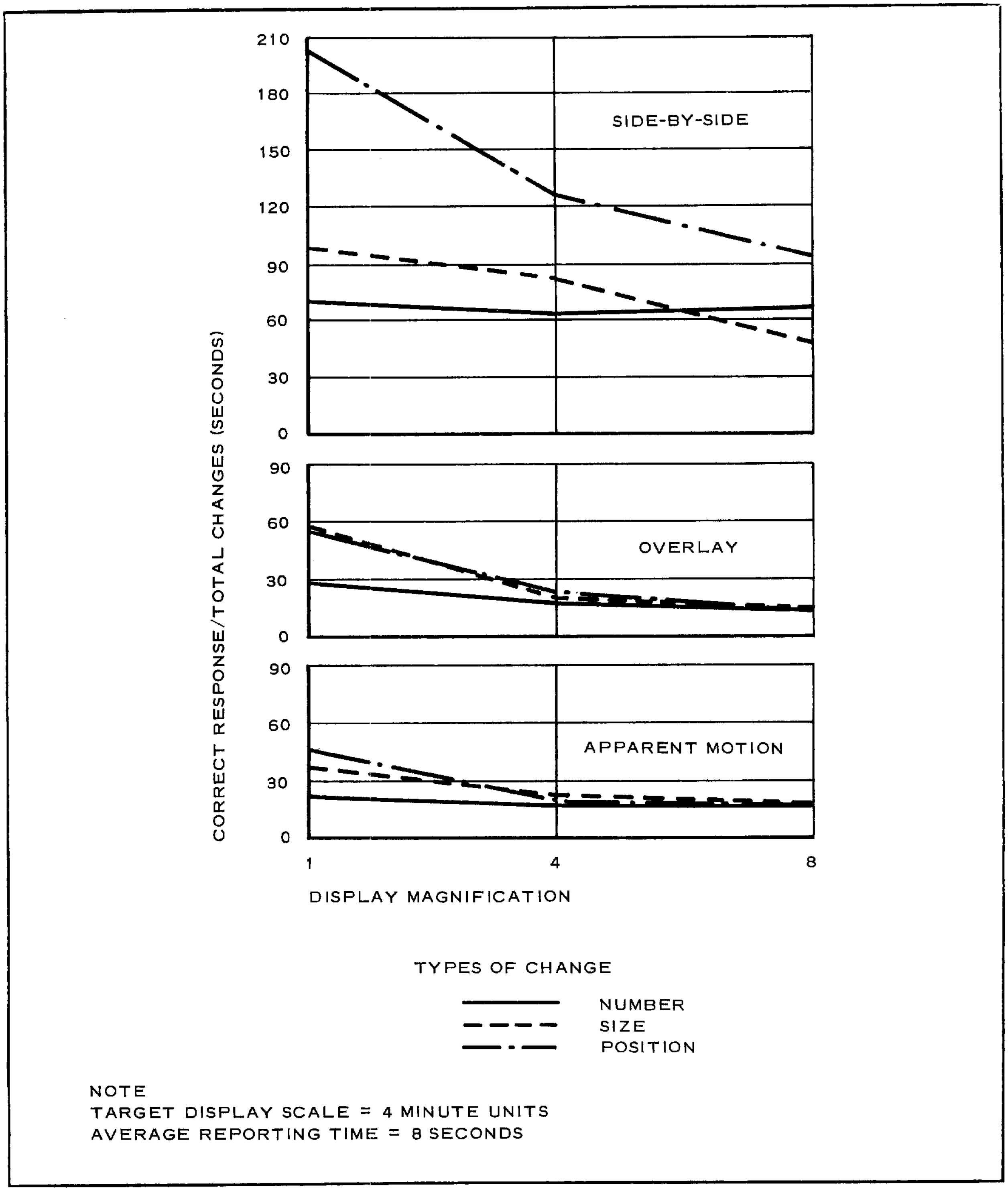

Figure 6 - Efficiency of Various Methods of Change Detection

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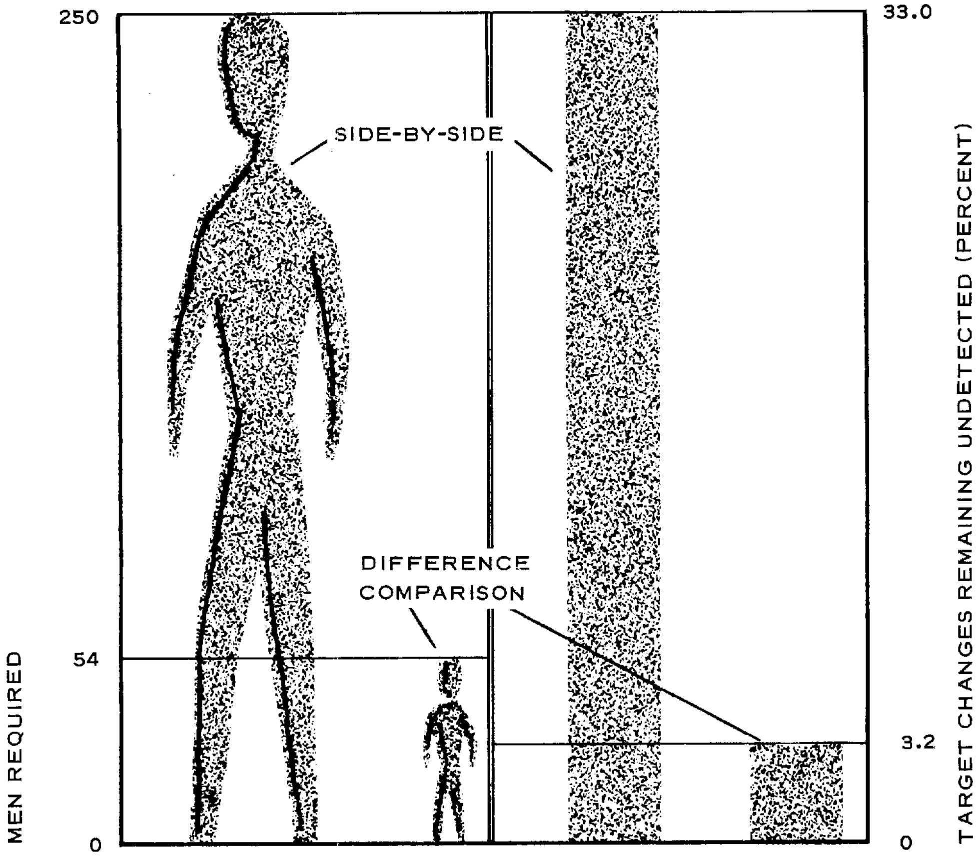

Figure 7 - Manpower Requirements for Side-by-Side and Difference Methods

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SECTION III - RECOMMENDED SYSTEM

1. SYSTEM CONSIDERATIONS

The proposed system is essentially a difference or overlay type change detector. Since the registration of the two images is also required for the flicker method, this equipment will have the optional capability of providing such a display to the viewer. The electrical mixing of scene data was chosen because of recent studies (see item 5, this section). Equipment is proposed that will automatically register and compare two images and then read-out and display the differences between them. Figure 8 shows a simplified functional block diagram of the change detector. The first operation in the change detection process is the selection of two images (referred to as the comparison scene and the reference scene) of the same general area in which changes are to be detected. The two selected images are inserted in the change detector and scene information is brought into registration by means of an automatic cross-correlation technique. Registration normally requires four degrees of freedom namely x, y, θ, and magnification. Translational displacement (x and y) of one scene relative to the other is necessary, since it is very unlikely that the centers of the two scenes will have the same geographic location. The rotation of one scene relative to the other is necessary to compensate for any differences in the azimuth alignment of the images. The magnification of one scene must be adjusted to compensate for differences in the image scale-factors that result if camera focal lengths differ or if the pictures were obtained from different altitudes.

After the two scenes have been properly registered, they are subjected to a comparison process whereby each scene is examined in detail and a comparison is made resulting in a display signal proportional to the difference between the two scenes.

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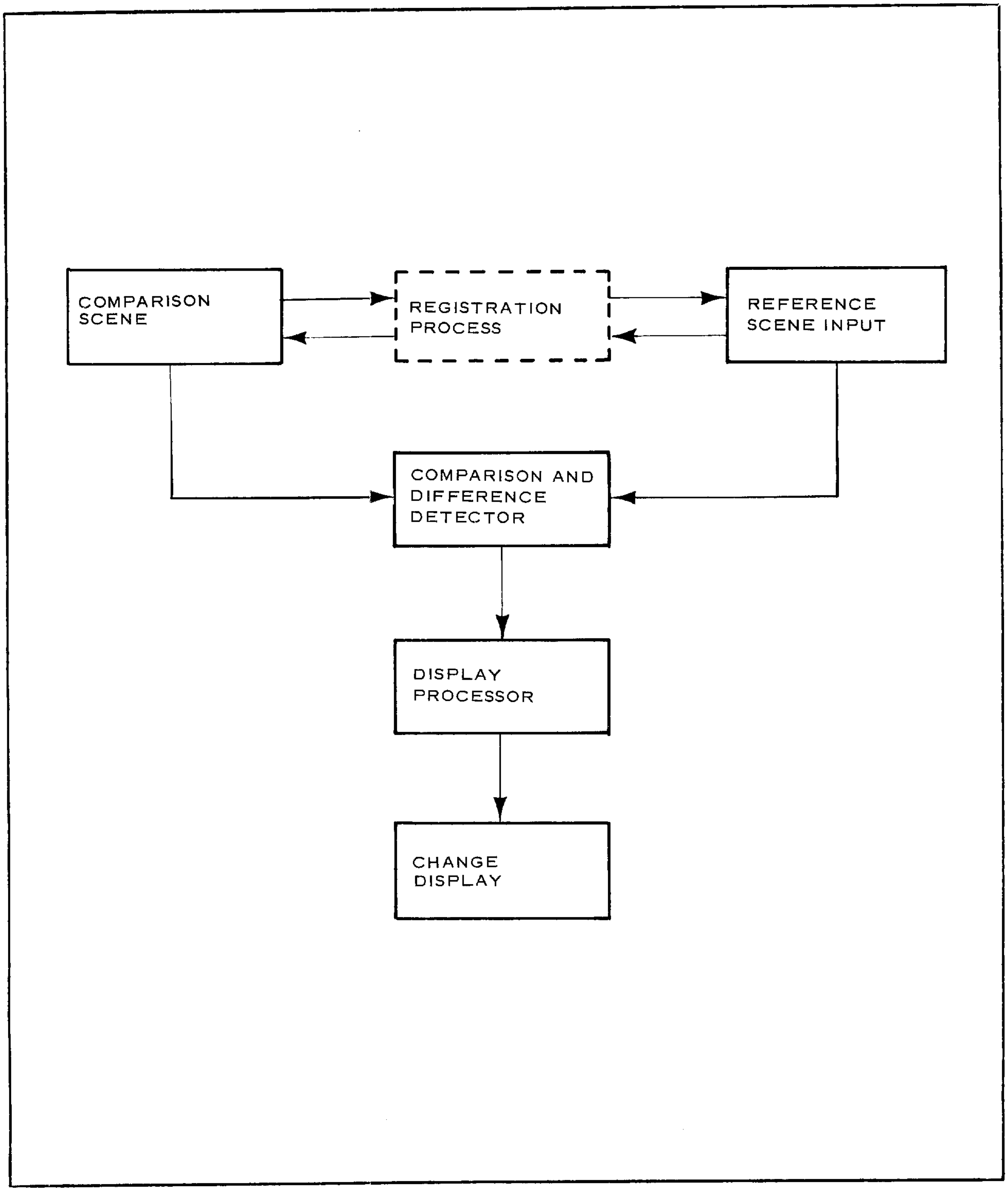

Figure 8 - Simplified Block Diagram of Change Detector

A signal is displayed that is proportional to all the differences between the input and reference scenes. While this display permits quick identification of those locations where changes have occurred between scenes, it is not limited to changes that may have military significance. Examples of undesired changes are (1) the existence and orientation of shadows, (2) cloud cover, and (3) system noise. It is therefore desirable to reject (filter) these differences, which have for the most part little military significance (see item 4, this section). Figure 9 shows a typical display with various changes noted. The coordinates of the displayed changes with respect to the reference scene can be obtained by inclusion of a reference coordinate system that can be superimposed on the monitor at the time of readout.

2. IMAGE REGISTRATION

To accomplish registration, one of the images is moved to align its scene objects with the corresponding objects on the other image. The two images must be brought into register accurately before the changes can be detected. For example, if the movements of vehicles or construction of small buildings must be detected, the registration error must be less than the dimensions of these objects (i.e., five feet or less). This process is performed automatically through a correlation technique.

Although various methods are available to correlate image data, the theory of operation is essentially the same for each method. Consider, for example, that the comparison scene consists of a positive transparency that is back-lighted as shown in Figure 10. This scene is imaged on the reference scene, which is also a positive transparency. The light transmitted through the reference transparency and focused on a photo-sensitive element is a measure of the crosscorrelation between the two images.

When the two scenes are correlated, light from the information in the

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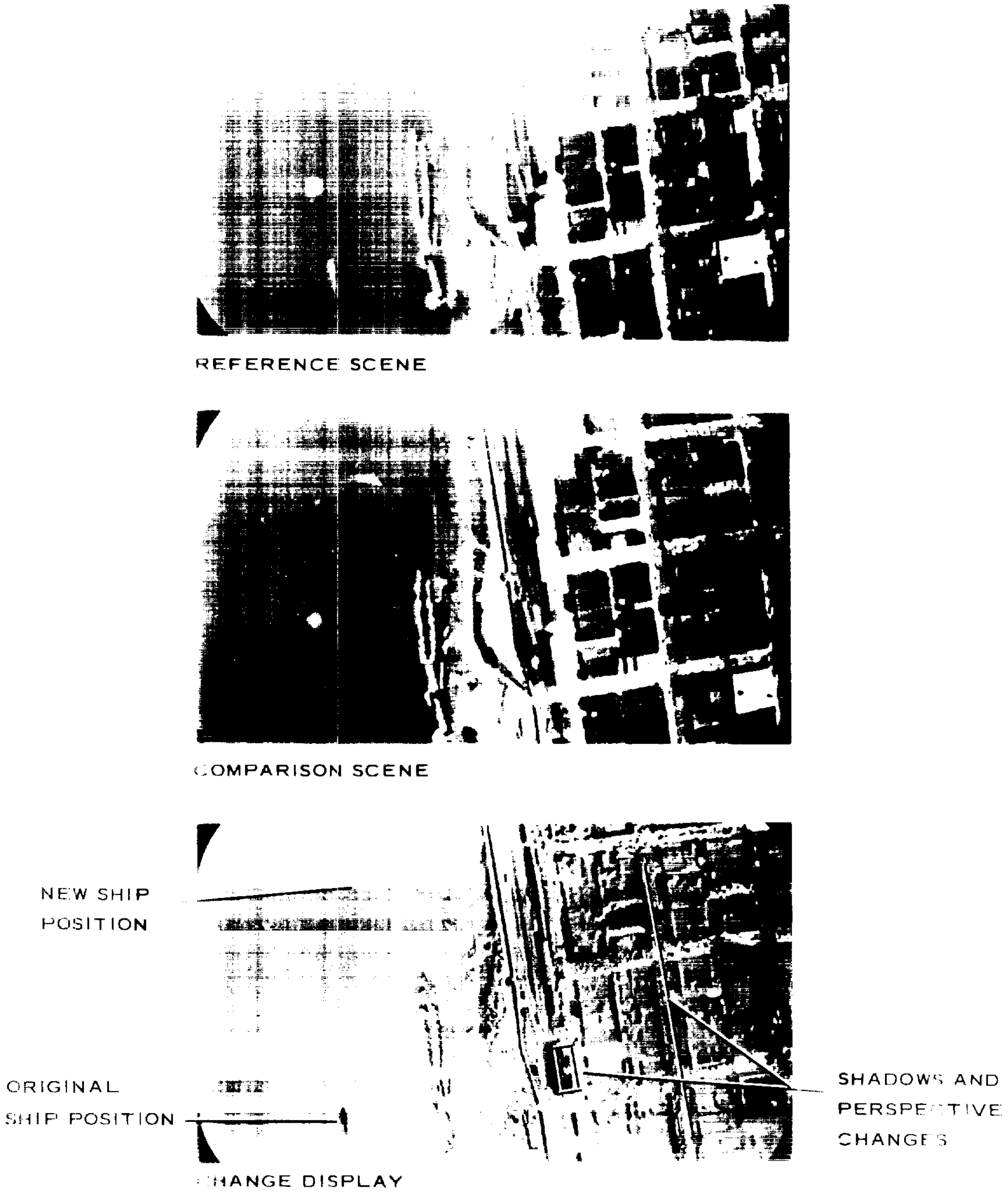

Figure 9 - Typical Display with Various Changes

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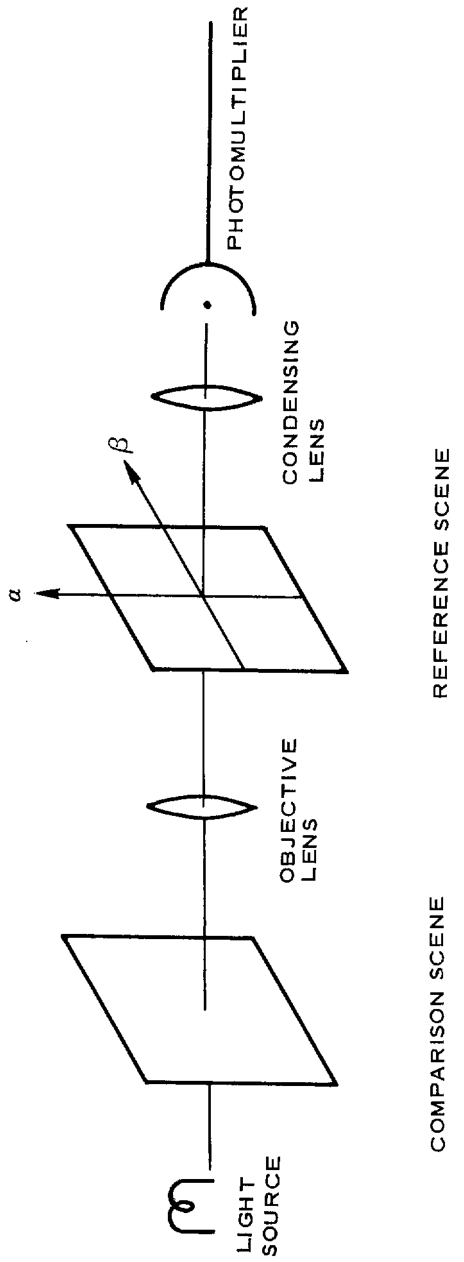

Figure 10 - Correlation of Two Scenes

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input scene is directed on corresponding information in the reference scene, which results in a maximum of transmitted light.

The light transmitted through the reference transparency is proportional to the product of the transparency functions of the input and reference scenes. Mathematically, the process can be defined as

$$L = \int_A \left[\phi_c(x, y)\right]\left[\phi_r(x + \alpha, y + \beta)\right] dA \quad ,$$

where

ϕ_c = transparency function of the comparison scene,

ϕ_r = transparency function of the reference scene,

x and y = ground coordinates of each target in the scenes,

α and β = relative displacements between the two scenes,

and

A = area of the comparison scene.

Figure 11 is a three-dimensional representation of the light detected at the phototube after it passes through the reference transparency as the reference is moved in directions α and β relative to the comparison scene. An error signal is generated that is used to drive the reference scene in the α and β directions so that the detected light flux is maximized. The process is essentially the same as that described mathematically by the correlation function.

If one of the scenes is a positive transparency and the other a negative transparency, the point of maximum correlation is represented by a minimum of transmitted light.

Figure 12 shows a two-dimensional correlation curve for a positive and negative transparency that results when the reference and comparison scenes are displaced in one direction only. This curve is normally

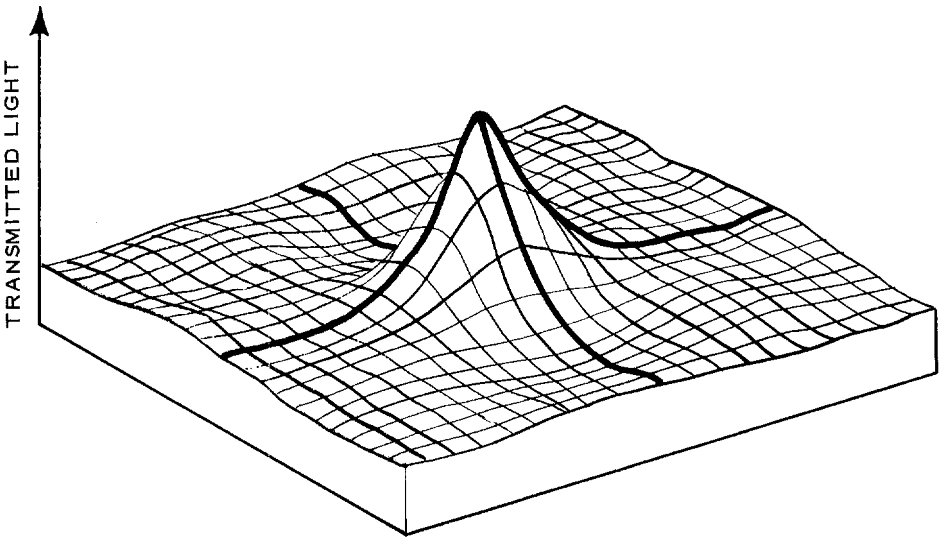

Figure 11 - Three-Dimensional Correlation Surface

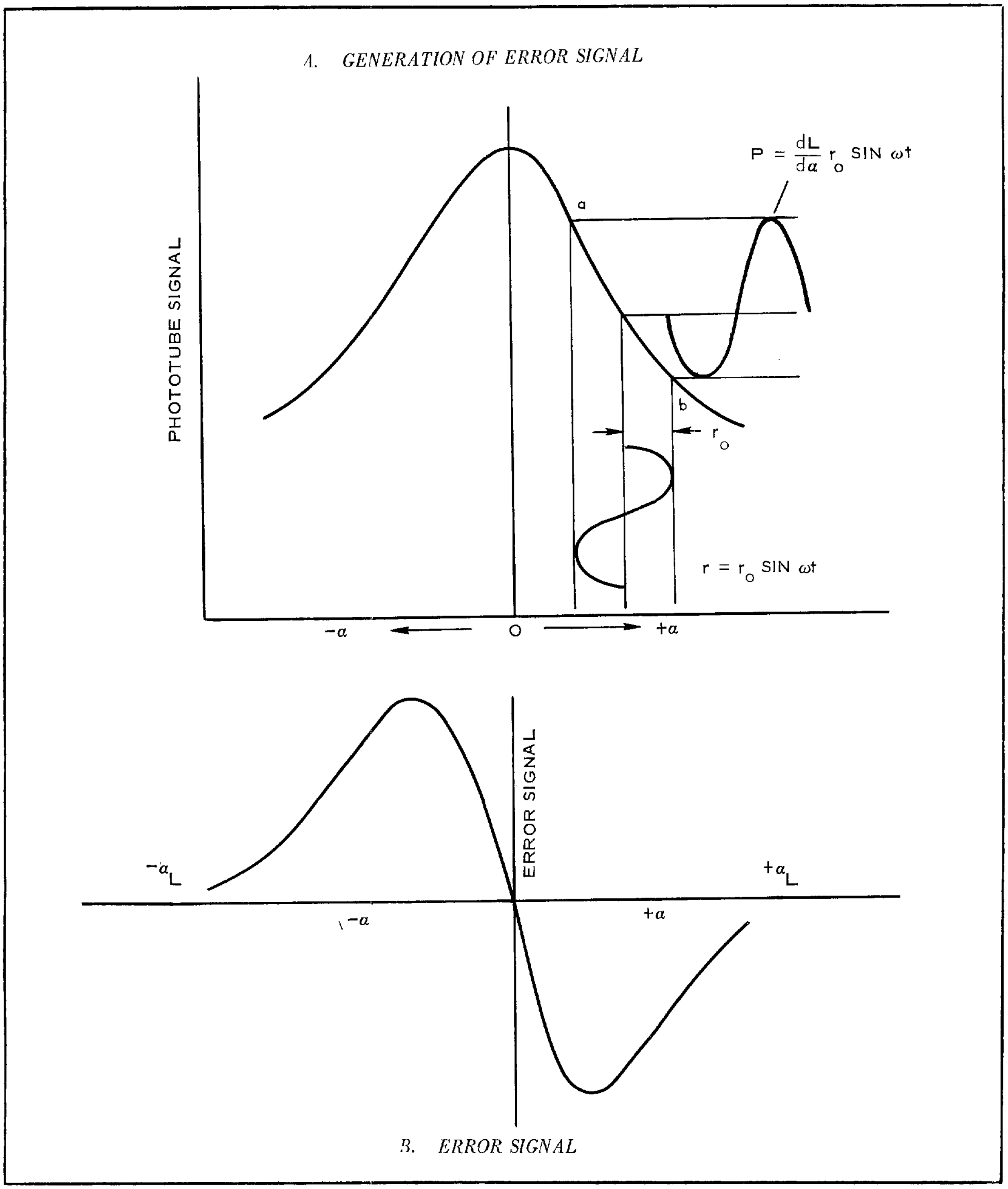

Figure 12 - Generation of Error Signals

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referred to as the static match curve. A direction-sensitive error signal can be generated from the correlation signal curve by nutation of the reference scene relative to the comparison scene. In Figure 12, the nutation is a sinusoidal displacement in the α direction and produces a change in transmitted light that, in turn, produces a varying phototube output. The phototube output together with a nutation reference signal is fed into a phase discriminator, which generates a signal proportional to slope of the correlation curve.

If the selected nutation radius, r_o, is small enough, the portion of the curve from a to b can be considered a straight line. Then the output of the phototube will be

$$P = \frac{dL}{d\alpha} r_o \sin \omega t \quad ,$$

and the output of the phase discriminator will be proportional to dL/dx. This signal can then be used to determine the direction of the mismatch and to drive the transparencies to the point of best correlation (match point). A plot of this error signal as a function of mismatch, α, is shown in Figure 12. Figure 13 shows an aerial photograph and the resulting two-dimensional correlation curve obtained when the photograph is correlated with itself.

Figure 12 shows that an error signal can be obtained with scene displacements between $-\alpha_L$ and α_L. This value of displacement is called the lockon range of the correlator. If the initial displacement between the two scenes exceeds this range, a search operation must be implemented to move one scene relative to the second scene in such a pattern that, at some time during the search, the film will pass within the lock-on range, thus generating an error signal. The output of the phototube is monitored by a "matchpoint" detector that determines by the establishment of a signal threshold, when the two scenes are near the match point. When this occurs, the search operation is stopped and the system is driven into exact registration by means of the error signal. An alternate implementation consists of a search through the complete pattern

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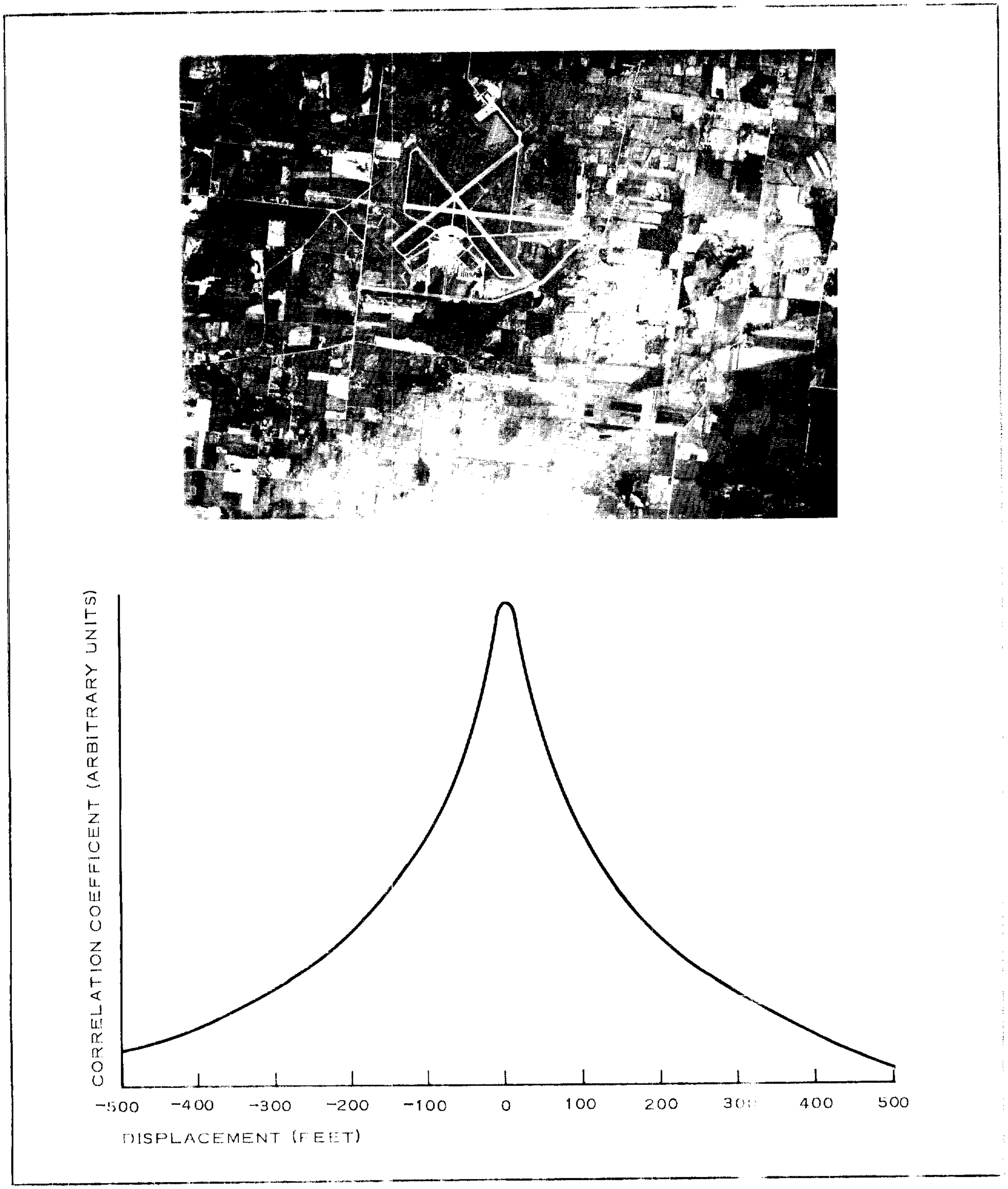

Figure 13 - Correlation Curve

and storage of those coordinates that result in the greatest correlation signal. The error signal is then used to return the displaced scene to the stored coordinates for exact registration. This alternate approach will be used since it does not require the establishment of a signal threshold and is therefore relatively insensitive to changes in film base densities and contrast. A typical example of a detector signal obtained as a function of displacement in a search operation is shown in Figure 14. The upper trace is a record of the search position versus time in one direction of an Archimedes spiral search pattern while the lower trace is the input signal to the match-point detector.

Correlation in the azimuth direction can be performed in a manner similar to that just described for the x-y direction. If one scene is rotated relative to the other, a two-dimensional correlation curve similar to the one shown in Figure 12 will be generated. Application of azimuthal nutation and phase-discrimination results in the generation of an error signal similar to the one shown in Figure 12.

If the scale-factors of the two scenes are not the same, the correlation between the two scenes can be described by

$$L = \int_A \left[\phi_r(x, y) \right] \left[\phi_c(\mu x' + \alpha, \ \mu y' + \beta) \right] dA \quad ,$$

where

ϕ_r = reference scene,

ϕ_c = comparison scene,

x and y = coordinates of reference scene,

x' and y' = coordinates of comparison scene,

α and β = relative displacement between the two scenes,

and

μ = scale factor.

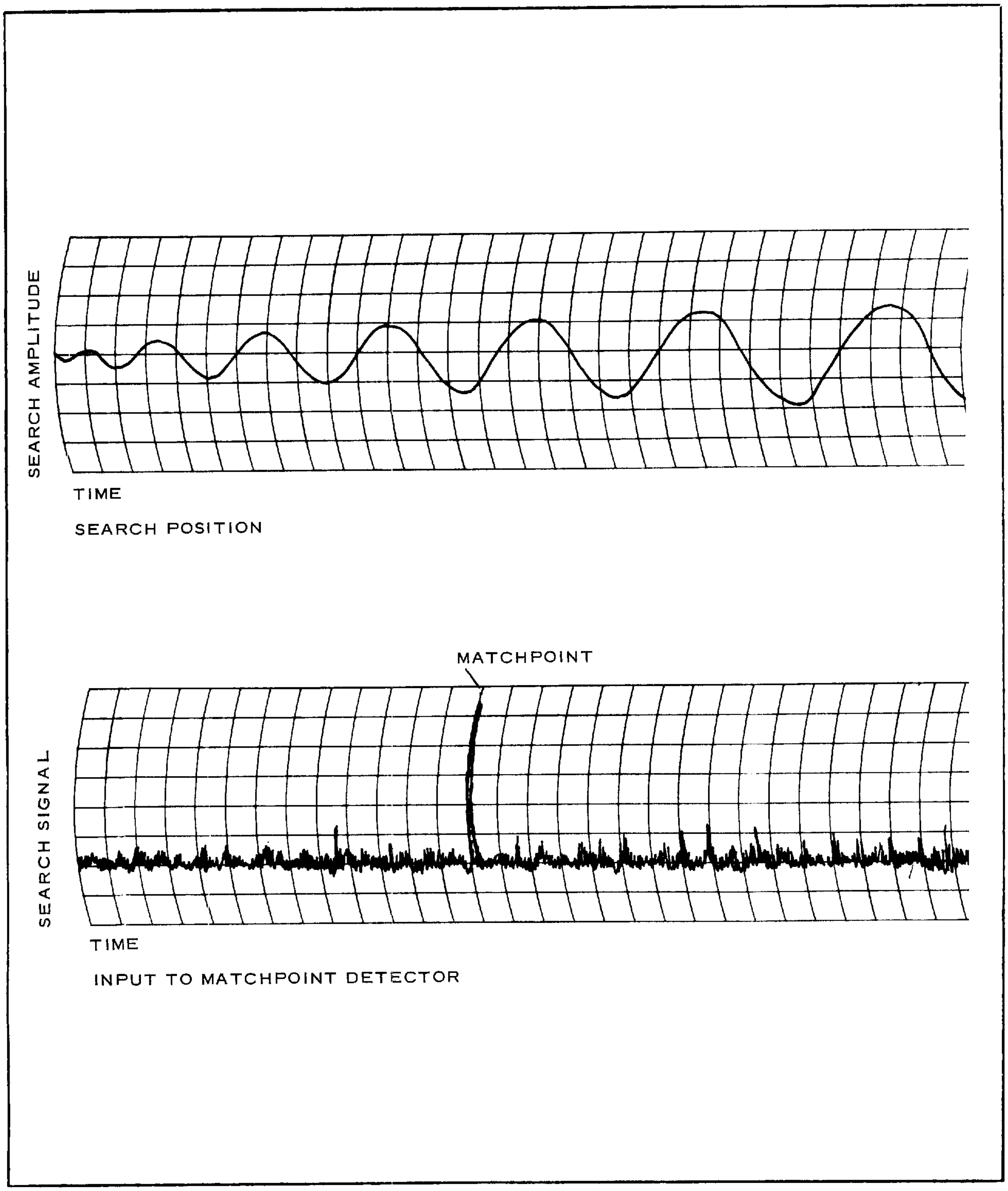

Figure 14 - Detector Signal during Search Operation

If α and β are constant, this function can be represented by a static match curve as a function of μ. Nutation can also be applied to the magnification matching process and an error signal generated in the same way as described for the case where the scenes are displaced in x and y. A scale-factor nutation amplitude of one percent of the normal value of scale factor is normally adequate for correlation. Nutation in x, y, and μ can be performed simultaneously if the nutation frequencies chosen are sufficiently different to permit their separation by filtering with a minimum of cross talk.

The correlation curve (static match curve) for various scale-factors obtained from an aerial photograph is shown in Figure 15. The error signal generated by nutation and subsequent discrimination is shown in Figure 16. This signal is used to close a magnification (scale factor) loop, thus adjusting the scale of one scene to correspond to the scale of the other scene. Figure 17 is a detail block diagram which shows the various functions required to provide registration in x and y, azimuth, and magnification.

3. DATA COMPARISON

When the comparison and reference images are registered the scene data are compared to determine whether or not any differences or changes exist between the two images. This is accomplished by a video-difference detector, where the information from each scene is first converted to video signals by synchronous scanning and then subtracted, leaving only the differences for display. For two video signals, each obtained from scanning of the same geographic area and each containing a target that does not appear in the corresponding scene (as shown in Figure 18), the video-difference signal (A-B) detects not only the existence of the changes but also their polarity. A target in video A that does not appear in video B results in a positive-difference signal. (For this illustration, a target is defined as a clear area in the

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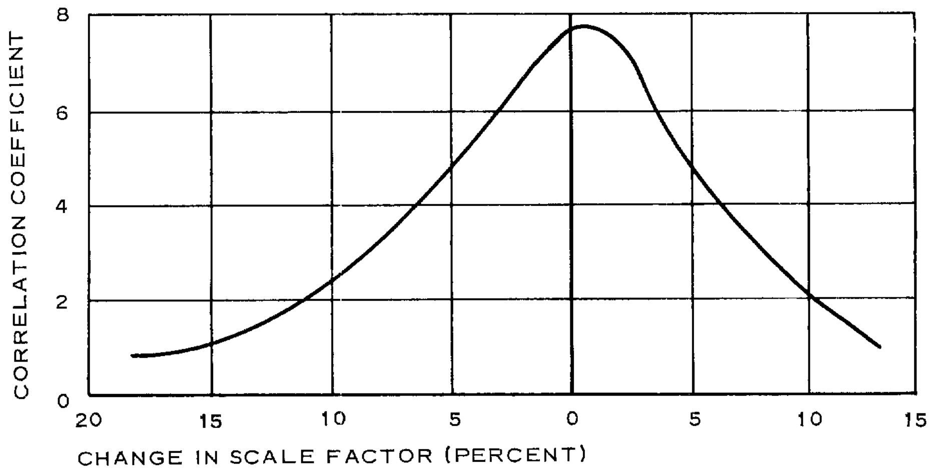

Figure 15 - Static Match Curve for Magnification

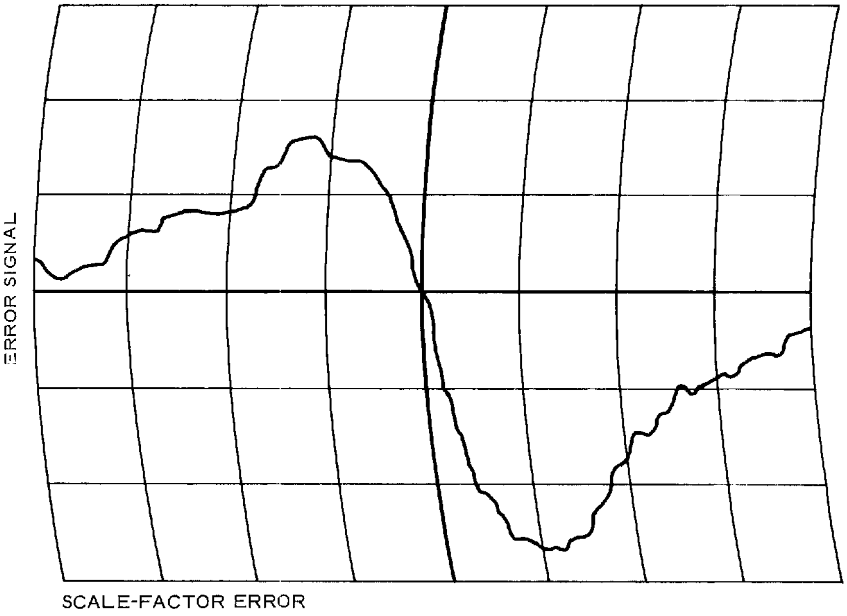

Figure 16 - Error Signal for Magnification

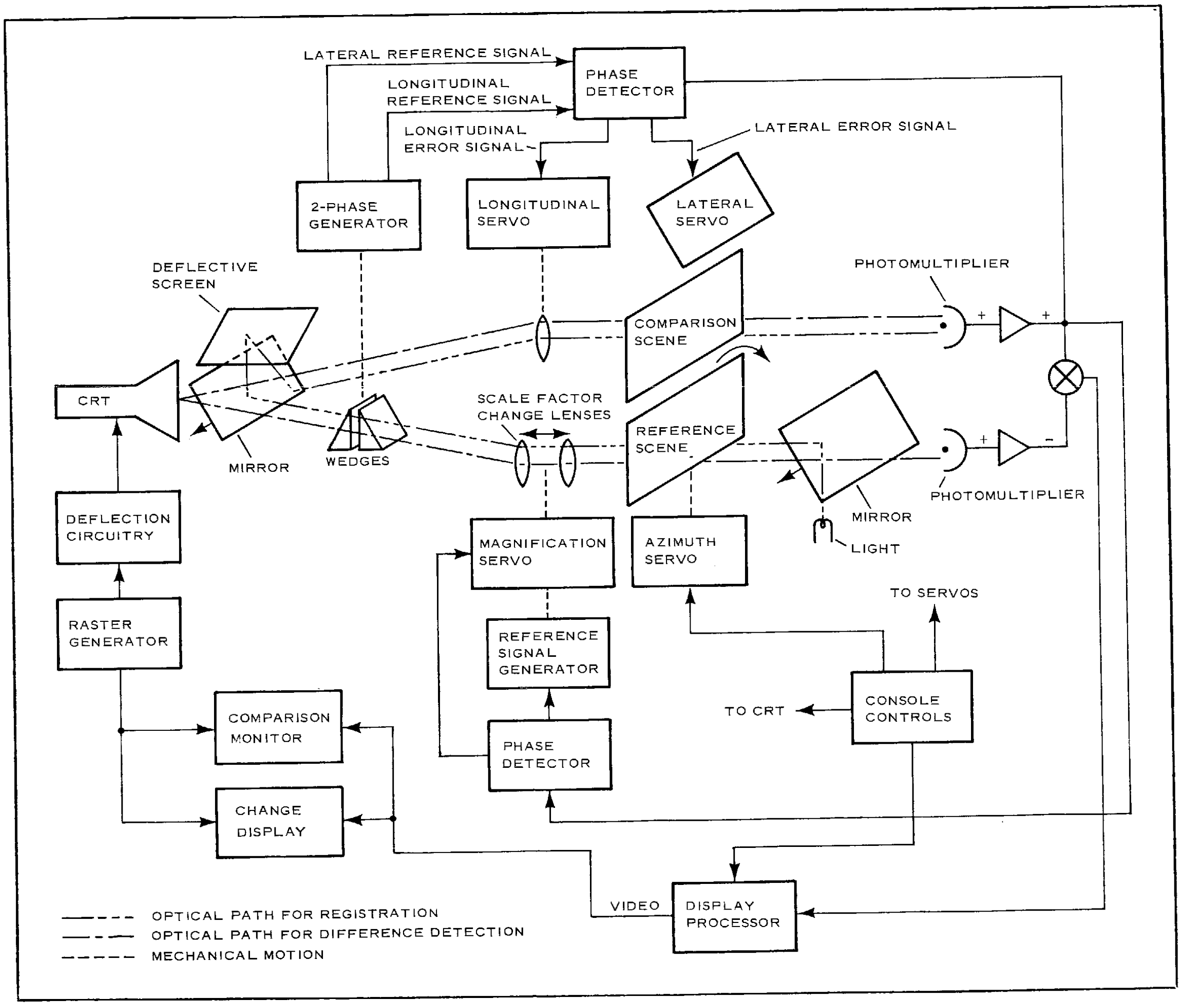

Figure 17 - Block Diagram of Proposed Change Detector

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transparency). A target in video B with none in video A results in a negative-difference signal.

A block diagram of a simple video-difference detector is shown in Figure 19. In this implementation the two scenes in the form of transparencies are scanned with a flying-spot scanner (fss) and a split-optical system. The video signals obtained from the two phototubes are amplified and subtracted and used to modulate the intensity of a monitor crt. The deflection of the monitor crt is synchronous with the deflection of the flying-spot scanner so that the scene geometry is maintained. The gain of the video channels is controlled so that a "no-difference" condition results in a gray level. A change in either scene will appear as a very light or very dark area depending on the type of change and the scene in which it occurs.

4. REJECTION OF UNWANTED DATA

As described previously the difference detection technique cannot discriminate between changes that have occurred in the terrain and changes caused by such things as the movement of shadows and clouds as well as seasonal variations, which would make variations in growth appear as changes on the read-out display.

Several methods are available to reject (filter) certain unwanted changes from the display. One characteristic of shadows that can be used in a shadow rejection technique is their normal appearance as a very high density on a positive transparency, particularly under bright sunlight conditions when shadows are the greatest problem. Figure 20 shows an aerial photograph and a trace of the transmissivity across the line as shown. The shadowed areas have the lowest transmissivity and are quite apparent on the densitometer traces. It is possible to insert a clipper into the video circuits to prevent the video signal obtained from each scene from going below a predetermined level.

[redacted]

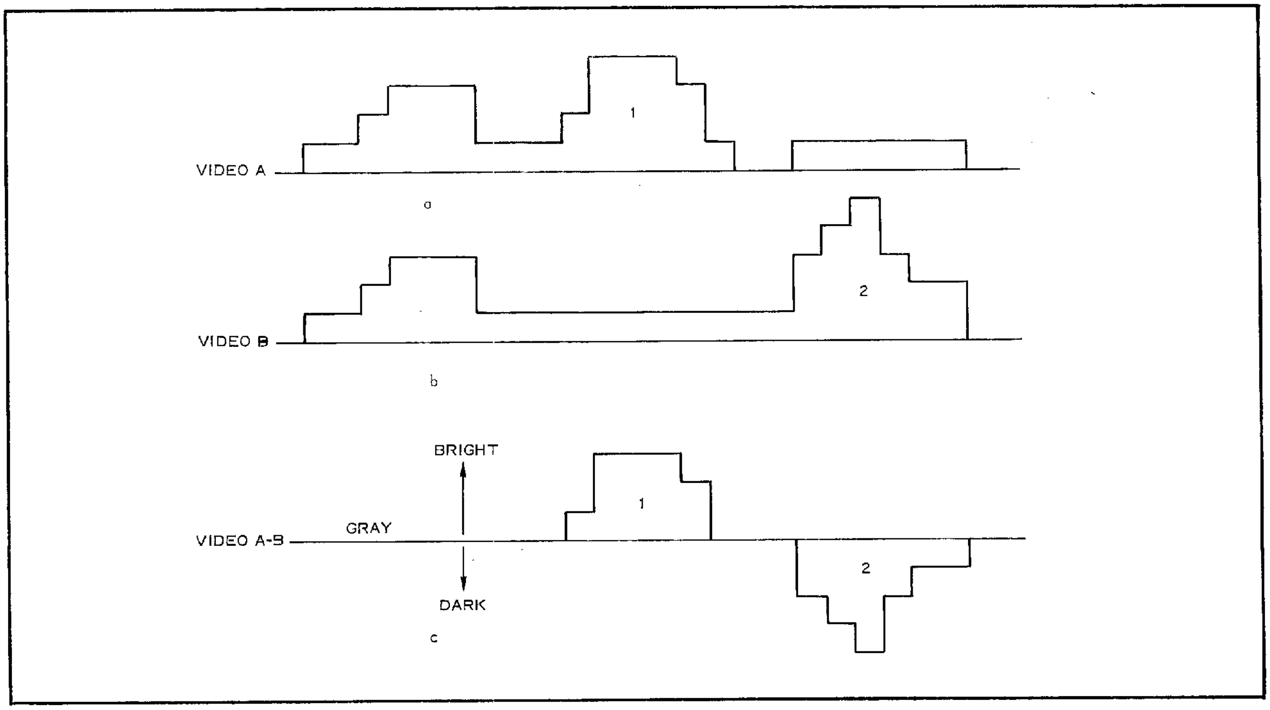

Figure 18 - Operation of Video-Difference Detector

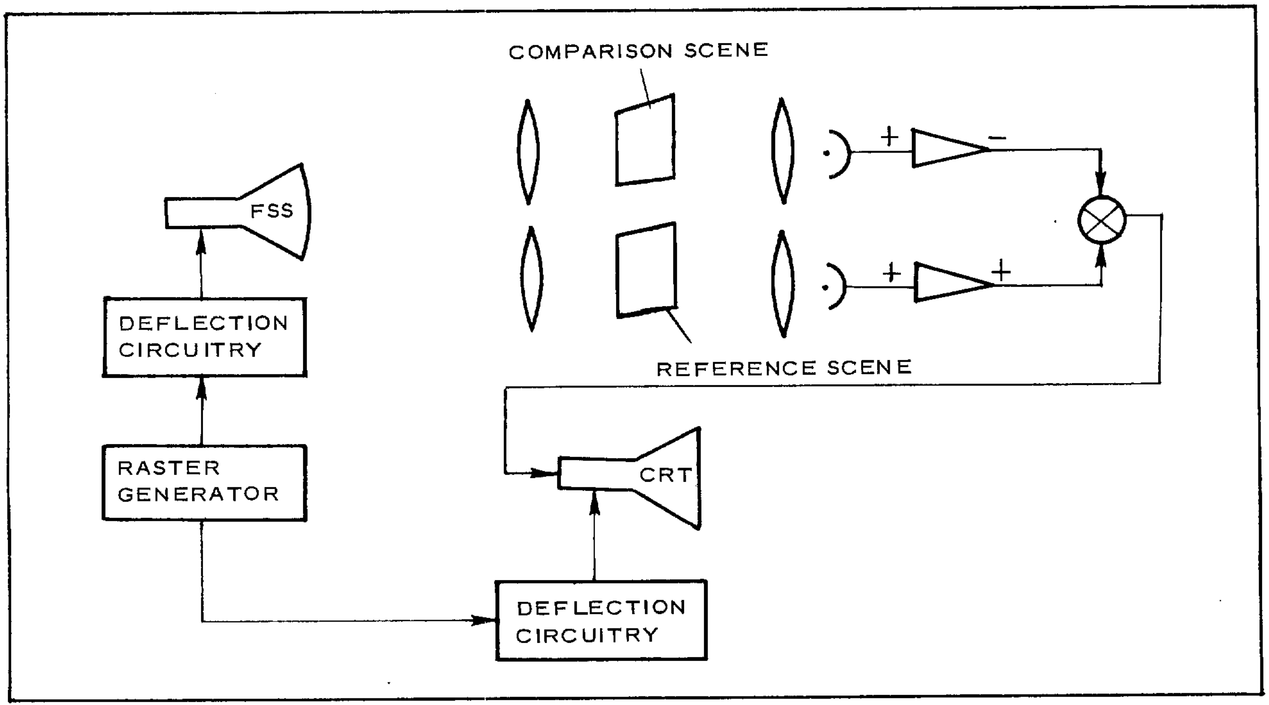

Figure 19 - Simplified Block Diagram of Video-Difference Detector

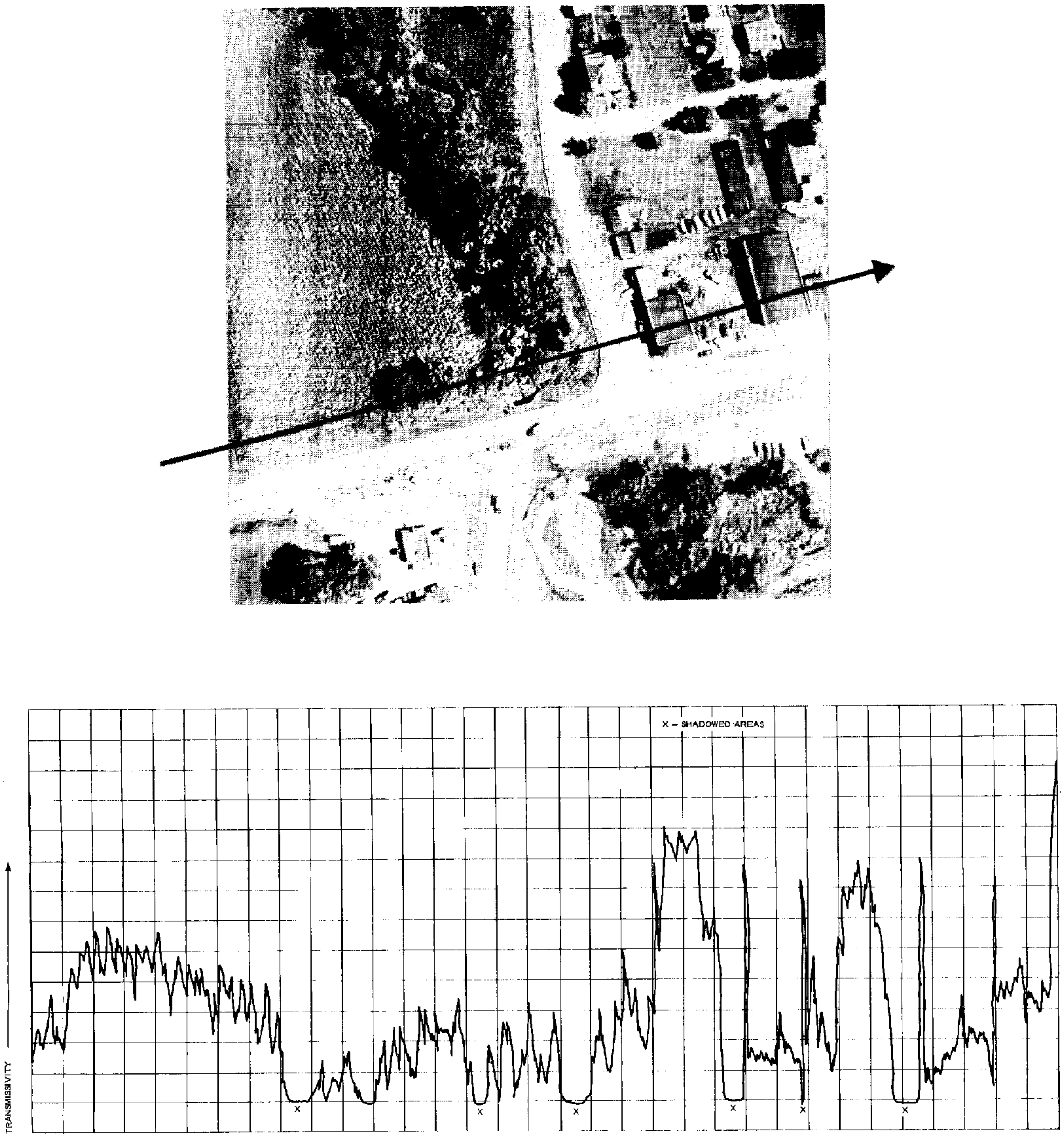

Figure 20 - Transmissivity of Shadow Areas

[redacted]

Such a level setting can be automated or it may be adjusted manually by viewing the output display and varying the clipping threshold level until the shadows disappear, or are at least lessened.

Clouds normally appear as a very low density on a positive transparency. The frequency content of data within the image of a cloud is normally very low compared to normal scene information. Rejection of scene information from clouds can be accomplished either by clipping the video signal at a predetermined level similar to the technique used for shadow rejection or by using a video filter to return the video to a gray level whenever the frequency of the scene data falls below a prescribed normal level.

Seasonal and perspective changes between scenes are the most difficult to reject automatically. There is no current method available to filter these effects from the display. Some seasonal changes such as foliage may be separated by conventional frequency filtering; however, such things as perspective changes remain difficult for machine processing.

5. RESULTS OF PRESENT STUDIES

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[redacted] Studies have been performed in three primary areas:

1. Image registration
2. Methods of image data comparison
3. Implementation studies

Registration tests were conducted to investigate the relationship between the accuracy of registration and such parameters as resolution, contrast, overlap, overlap area, azimuth, and scale-factor errors.

The studies were performed on two pieces of laboratory equipment: a static scene analyzer and a dynamic scene analyzer. The static analyzer was used to measure the correlation function and its derivatives, while the dynamic analyzer was used to perform actual registrations automatically in a manner similar to that which would be used in a change detector.

Results of the registration studies show that the accurate registration of two images can be performed with a wide variation in photographic resolution and contrast. The major effect of these two photographic parameters is a variation in equipment gain that can be compensated for with automatic gain control. The search operation is relatively independent of the scale-factor of the photographs. Results also indicate that an azimuth error of as much as 1.5 deg can be tolerated without a search of the two photographs in azimuth during the x and y registration process.

Two methods of comparing image data were investigated, namely, the video-difference and quotient-difference techniques. Both the video-difference and quotient-difference detectors employ essentially the same registration process. However, the read-out or change detection mode of each is completely different. The quotient-difference detector output is the quotient of the intensities of the two scenes being compared. The video-difference detector determines the difference of the intensities of the two scenes being compared.

These two techniques were compared to determine:

1. Whether or not one method offers a better means for the observer to detect image changes
2. The sensitivity of the two methods to the detection of image changes
3. Other characteristics of each method, such as photographic processing requirements and ease of data processing

Samples of the video-difference and quotient-difference techniques were obtained from a breadboard demonstration of each technique and are shown in Figure 21. The upper-left scene is the original. Extensions were added to the runways in the scene at the upper right. The lower-left photograph was generated by the quotient-difference method. The lower-right picture is a photograph of the video-difference scene as viewed on the monitor. The resolution of the video-difference scene is somewhat less than the quotient-difference scene, which is due mainly to the limit imposed by the 525-line raster scan used to connect the [illegible] scenes to electrical signals. This degradation of resolution can be eliminated by the addition of an electronic magnification or scene enlargement. By scanning a smaller area of the scene with the complete raster, the scene resolution on the read-out monitor is limited only by the system optics and film resolution.

Both methods accurately detect the changes. In fact, the video-difference method has detected some film-emulsion defects that appear as the small bright spots on the photograph. These defects occurred during the generation of the new scenes from the original back-lighted plates. Both methods have essentially the same sensitivity to the detection of photographic changes.

Since neither method has any obvious advantage over the other in its ability to detect changes and its sensitivity to changes, the choice of the video-difference detector was made for the following reasons.

1. The quotient-difference detector requires an extra step of photographic processing since both positive- and negative-transparency scenes are needed.
2. In the quotient-difference detector, the photographic control of scene contrast adds an additional process. If the contrast of the unchanged areas is not equal for both scenes it is extremely

[redacted]

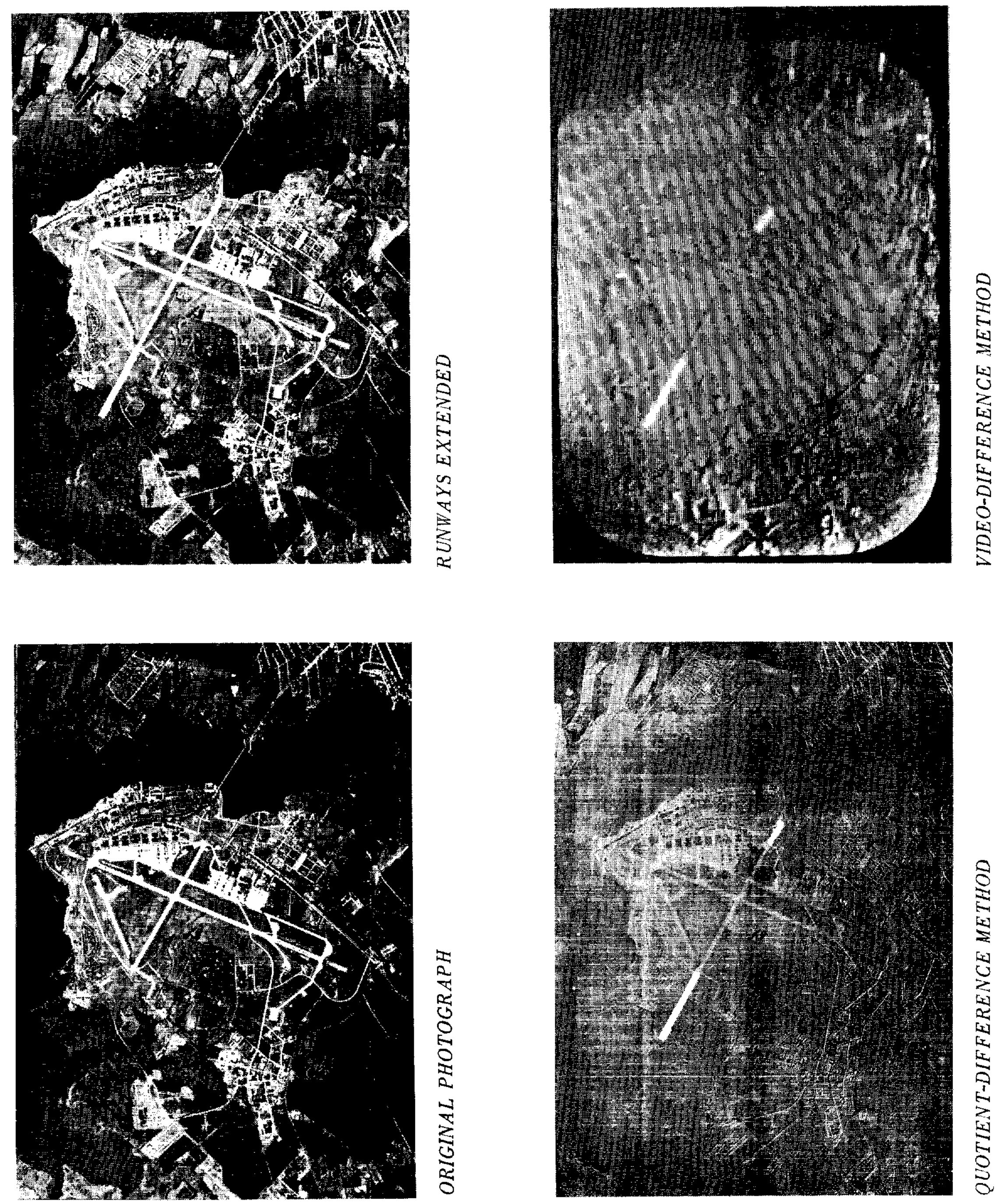

Figure 21 - Two Change-Detection Methods

difficult to make them cancel. This problem can be handled in the video-difference technique by simply changing the gain of one of the difference amplifiers following the phototubes to compensate for different contrast scenes.

3. In the video-difference detector, scanned read-outs from each scene are available for electronic data processing to perform such filtering as may be required for shadow rejection, etc.

An implementation study was directed toward an investigation into the optical requirements and a definition of the mechanical mechanism required for registration and difference detection. The optics required for the video-difference comparison paths consist of two optical paths, each of which image the same crt spot on the two photographic transparencies. The light that passes through each transparency is collected by condensing lenses and directed onto individual photomultiplier tubes (see Figure 19). This provides a means of simultaneously scanning the two scenes with a single spot. The resolution capability, flatness of illumination, and over-all transmissivity are some of the more important characteristics of the optics that must be considered. The optics must also be adjustable so that the two photographs can be registered prior to change detection. To determine the optomechanical implementation of the change detector, the following items were considered:

1. Maximum longitudinal and lateral displacement of one image relative to the other
2. Longitudinal and lateral nutation of one image relative to the other required to generate an error signal
3. Azimuth displacement of one image relative to the other

4. Magnification change of one image relative to the other
5. Magnification nutation
6. Tip and tilt adjustments of one scene relative to the other to compensate for camera stabilization differences

These studies have determined that the optics for performing the necessary registration and detection functions can be fabricated with relative freedom from shading and distortions for the 70-mm case. The use of a zoom lens for scale-factor registration demonstrated marginal results because of the light loss through it; therefore, the use of an axial-lens translating device appears to be a better solution to the problem of adjusting the scale-factor.

The resolution limit imposed by the scanning raster of the video-difference detector was eliminated by the development of an electronic magnification implementation permitting the photo-interpreter to enlarge an area and analyze it in detail.

6. GROWTH POTENTIAL

The development of a change detector establishes a fundamental building block for an improved photo-intelligence processing system. In Section II it was shown how a change detector would accelerate the first phase of photo interpretation (screening), by comparing the "take" of one photo mission with that of another and displaying and recording the changes that have taken place within common areas of the photography.

In a global satellite surveillance system in continual operation, several change detectors would play an important role in that they could be.

utilized to compare the satellite imagery on a continual basis and display the changes to a command control center. Since changes per unit area per unit time are a measure of activity, both natural and man-made, global or political unit activity could be measured on a daily basis, thus contributing to alert intelligence. Such a system could also be used by a field army commander in conjunction with battlefield surveillance.

One growth factor of a change detector is that of indexing, or plotting. Indexing, or plotting, is defined here as the process of referencing to a map base the areas covered by the photography of a particular reconnaissance mission. This function, an important one to photo interpretation, could be performed in less time by utilizing certain outputs of the change detector.

If it is assumed that the reference photography has been plotted on a map base the error signal generated in the registration phase of change detector operation can then be utilized to determine the center separation of the input scene with respect to the reference scene. Since registration occurs on a frame-by-frame basis, the separation distance is also on a frame-by-frame basis. When this information is combined with other available information such as scale-factor, orientation, and exposure numbers, the input photography can be quickly plotted with respect to the reference photography without a direct map-to-photo comparison. Although this technique is within the state-of-art at this time, it has not been considered as a part of the herein proposed change detector implementation.

Although the amount of automatic decisioning that appears practical at this time is very limited, it is possible to develop an automatic readout detector that will locate certain types of changes. Although any method that is now developed will be limited to the very obvious changes, it may be helpful for certain screening operations that are now very time consuming and hence costly when performed by humans.

[redacted]

SECTION IV - PROPOSED DEVELOPMENT PROGRAM

1. DESIGN OBJECTIVES

A program is recommended to design and fabricate a change detector with the characteristics listed in Table I.

TABLE I - CHANGE-DETECTOR DESIGN GOALS

Characteristic	Value
Film input	70-mm roll film, 100 ft maximum
Image registration	
Position (x and y)	±50 percent of full scale
Orientation (θ)	±90 deg for reference and input films
Scale factor (μ)	2 × (Minimum)
Scene magnification	
Film to display	5 ×
Area enlargement	40 ×
Output	Photo-reading of 14-in. tv display
Position read-out accuracy with respect to reference frame	
Automatic (probe) or	±5 percent of full scale
Manual (reticle)	±5 percent of full scale
Operation time	
Initial setup	2 min for first frame
Subsequent	30 sec per frame (worst case)
Scene resolution	$\overset{70}{40}$ lines per millimeter at maximum area enlargement [redacted]
Frame identification	. . . [redacted]

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It will be the primary effort of this program to develop a workable model change detector. This change detector will incorporate data processing techniques to reject certain unwanted data, which would normally appear as changes. These include such items as shadows and clouds. Specific attention will be given to the development of a console design that will give the photo-interpreter flexibility of operation with data-handling speed.

2. EQUIPMENT DESCRIPTION

a. Components

The equipment will consist basically of (1) a comparator unit and (2) a display unit (see Figure 22). The comparator unit will contain the components for performing the functions of automatically registering and comparing the image data. The display unit will provide the components for displaying the scenes being compared as well as the output comparison data and controls required to operate the console. The various subassemblies that will comprise the comparator and display units are described in Table II. A detail description of each subassembly is given under the description of Task III in Item 3, d, of this section.

b. Operational Sequence

The operation of the equipment will be centered around a console containing two tv monitors called the "comparison scene" monitor and the "change display." Figure 22 is a perspective view of the console assembly with a tentative layout of monitors and controls. The equipment will be designed to provide readout of positions of change and frame-number information to an electric typewriter or card punch. The operational sequence is listed below with corresponding scene information on each monitor:

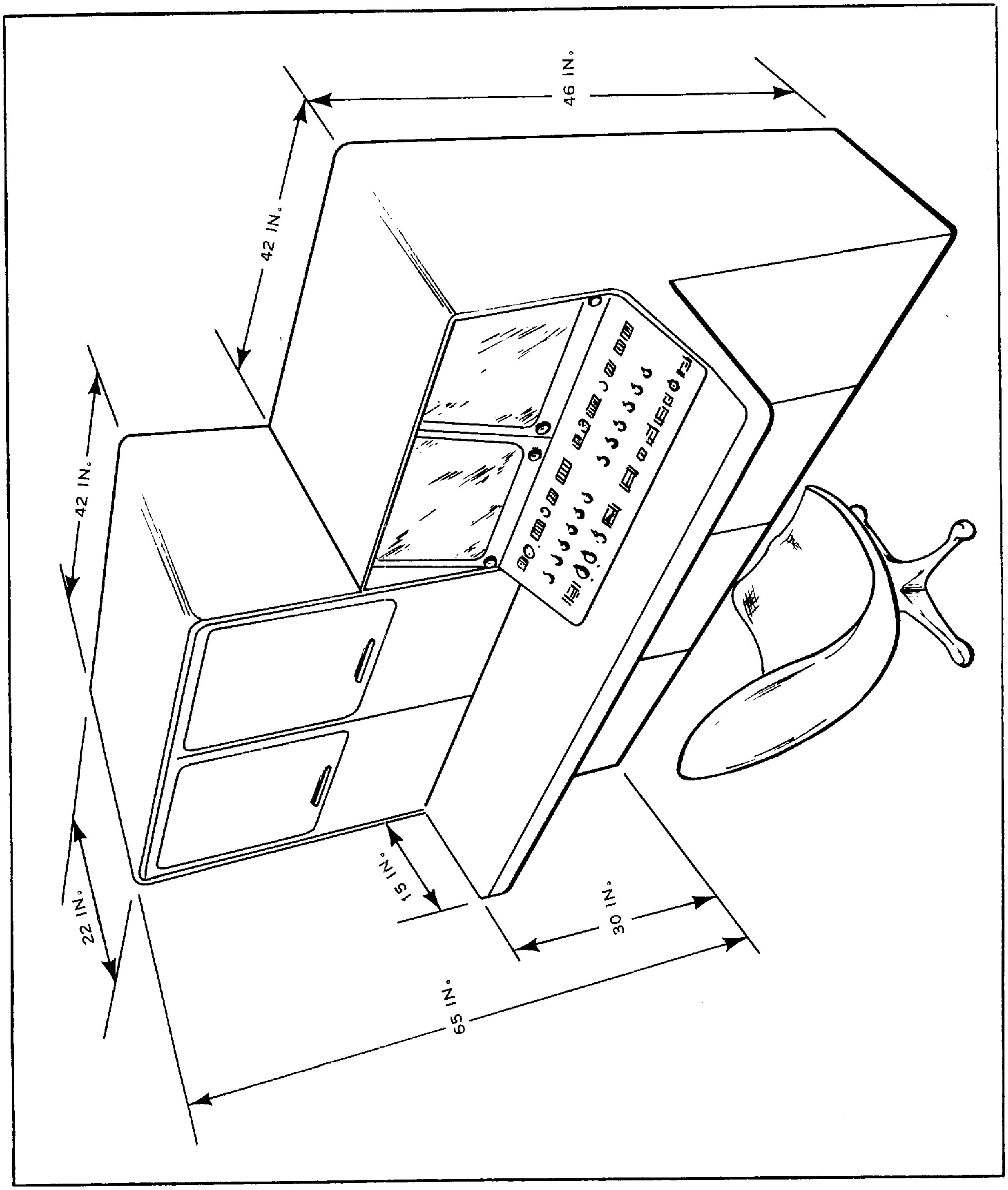

Figure 22 - Console Design

1. Insert film
2. Identification of overlapping frames
3. Initial alignment (two minutes)
    - a. Azimuth
    - b. X and Y
    - c. Scale factor
    - d. Miscellaneous (tilt, focus, etc.)
4. Automatic registration (30 sec)
    - a. X and Y search
    - b. Nutation
    - c. Azimuth trim
5. Detection of significant changes
    - a. Comparison readout
    - b. Noise rejection
    - c. Area enlargement
    - d. Selection of changes
6. Position readout (with respect to frame)
    - a. Position computation
    - b. Storage

TABLE II - COMPARATOR AND DISPLAY UNIT SUBASSEMBLY DESCRIPTION

Subassembly	Description
Comparator Unit	
Film-transport mechanism	Uses 70-mm roll film, 100-foot lengths; manual, automatic variable-speed film advance, or both; on a frame-by-frame, partial-frame basis, or both; frame identification capable of ±90 deg rotation in each channel; includes condensing optics and photomultiplier read-out sensors; tip and tilt adjustment

TABLE II - COMPARATOR AND DISPLAY UNIT SUBASSEMBLY DESCRIPTION (Continued)

Subassembly	Description
Lens displacement mechanism	Lens system capable of translation in x, y, and magnification; consists of lenses and electromechanical servos and drives in x, y, and magnification
Light source and associated optics	Backlight, lenses, and mirrors necessary to image one scene on the other; capable of automatic transition from registration to readout
Comparator electronics	Circuitry required to drive electromechanical components, i.e., servomotors in lens-displacement mechanism, match-point detectors, reference signal generators, etc.; generally, electronics required for registration; electronics required for generation of flying-spot-scanner raster; amplification of video signals for each channel; high-voltage power supplies for phototubes and crt
Display Unit	
Monitors	Comparison scene monitor, change display monitor. (Both are 14-in. tv-type monitors)
Operation controls	Frame adjust; frame advance; alignment controls in x, y directions and scale factor for each roll of film; initiating controls for automatic registration; noise rejection; area enlargement; flicker option; video gain control for contrast control (for each channel); tip and tilt control
Position read-out assembly	±5 percent maximum error design goal, measured at the film plane; contractor to explore possibility of area measurement; will provide analog outputs in x and y coordinates and will display numerical coordinates with respect to film
Display unit electronics	Noise rejection circuitry; all power supplies, except for high voltage supplies for crt

After the film is loaded, the frames on each roll can be viewed on the monitors until overlapping films are identified.

The initial alignment is performed manually. First, one or both scenes as viewed on the monitors are oriented until the scenes are aligned within ±2 deg. The X and Y positions of the overlapping areas are then adjusted to occupy the same position on each monitor. The scale-factor of the two scenes is adjusted from the display on viewing monitor no. 2 in the difference read-out condition. Final tilt and focus are also adjusted from the difference scene on monitor no. 2. Subsequent frames can be registered automatically by initiation of the registration sequence after the frame is indexed. Registration is accomplished by first an automatic search in the X and Y directions and subsequently by nutation of the scenes to obtain final accurate registration.

To identify possible significant changes, the registered difference scene is viewed to locate all possible changes between the scenes; then changes of interest are selected after the employment of the noise-rejection or area enlargement options available to the viewer.

The positions of significant changes are referenced to a fiducial mark on the reference or input frame. Readout is accomplished automatically by the use of an electronic probe or reticle.

c. Operator Options

Various operator options will be available for selection at the control panel. These options will provide operational flexibility, thus enabling the change detector to handle films under large variations of scene illumination, contrast, resolution, etc. These options are:

1. Automatic correlation for registration
2. Manual correlation for registration
3. Automatic frame advance in both directions
4. Semiautomatic frame advance in both directions

5. Minor adjustments within frame with x-alignment control
6. Change display monitor (right side)
    - a. Reference scene
    - b. Change display (black and white changes)
        - (1) Change display minus noise
        - (2) Changes can be shown in both or either polarity (black and white)
7. Comparison display monitor (left side)
    - a. Comparison scene
    - b. Reference scene
    - c. Reference scene/comparison scene (flicker technique)
8. Flicker technique (left-side monitor; variable-speed flicker)
9. Contrast, brightness and gain adjustments (both monitors)
10. Magnification
    - a. Minimum 5X
    - b. Area enlargement 6X to 40X, continuously variable
11. Noise rejection, variable
12. Position readout (outputs to paper tape or punch cards)

3. TASK DESCRIPTIONS

a. General

The program will be divided into five major tasks, each consisting of several items of work as follows:

Task I - System Predesign
- 1. Optics
- 2. Scene registration
- 3. Breadboard modification

Task II - Display Data Processing Studies
  1. Rejection techniques
  2. Detection studies

Task III - Design and Fabrication
  1. Optical and mechanical assemblies
  2. Electronics
  3. Console and tie-in equipment

Task IV - Checkout and Evaluation
  1. Functional checkout
  2. Resolution and registration tests
  3. Performance tests

Task V - Support Engineering
  1. Project coordination
  2. Reporting
  3. Travel

b. Task I - System Predesign

Predesign studies will be performed to detail certain design specifications that will be required to meet the design objectives. These include the final choice of a lens system with adequate resolution and fidelity to permit accurate scene registration. After the lens configuration is established, tolerances on various mechanical and electrical components can be established. The length of the optical path for the assembly will be determined, thus establishing limits on a console configuration to hold the optics, electronics, and display monitor.

The method of film loading and frame advance must be chosen. Since it is desirable to locate the position changes with respect to each frame, a method of frame advance must be developed that will lend itself to the method of measuring positions within the frame to an accuracy of ±5 percent of full scale.

Requirements, if any, for various miscellaneous optics alignments, such as tilt and focus, will be determined.

The choice of an electronic probe or reticle readout will be made after investigation of the position errors that can be expected with each method.

A basic method of masking the scenes for correlation during automatic registration is required. The technique must adapt itself as the amount of overlap between frames changes.

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A manual scene registration assembly will be fabricated and added to a [redacted] breadboard change detector to evaluate the choice of the lens systems as well as to provide an experimental setup for tests of various methods of electronically filtering unwanted data (such as shadows and clouds) from the output display, see Task II).

c. Task II - Display Data Processing Studies

Several methods of electronic rejection of unwanted data from the display will be breadboarded and evaluated. Included, for example, will be an implementation of the shadow rejection scheme discussed in Section III, item 4, which rejects video amplitudes below a prescribed level. A similar method of rejecting clouds from the display will also be built and tested.

Those changes that occur presently in pictures taken at different times from different positions are seasonal and perspective changes. There is no current method available to filter these effects from the display. Some can be separated by conventional frequency filtering for such things as foliage growth. Although no solution to this problem is foreseen, studies will be initiated to seek possible solutions.

Several methods of displaying image differences will be investigated. The present method of displaying the video-differences results in both bright and dark spots for scene changes. A method of displaying all changes as bright spots on a dark background or as dark spots on a light background can be implemented by display of the square of the difference of the video signal. This method may further reduce the time required for an operator to locate changes between pictures by requiring him to search for only one polarity of signal on the difference monitor.

An investigation of nonlinear amplification of the difference signals may prove to separate further the scene changes from the background, thus making the changes more apparent to the operator.

Various display options require further study before their incorporation into the design. The option of displaying each scene alternately before and after viewing the difference image as well as the effectiveness of various amounts of contrast control and such functions as brightness, slicing, and clipping are still to be determined. The use of a nutation technique to improve the focality of the change display to the operator will be determined. This would consist of a nutation of one scene with respect to the other at a fairly rapid rate. Changes on the scene not being nutated would appear stationary while the background would move. The process must be repeated, the second scene being kept stationary and the first being nutated.

All the experiments slated for investigation under this task will be performed on the modified breadboard equipment that will be available from Task I. Since the results of this work will not appreciably affect the optical and mechanical design of the change detector model, these studies will be performed throughout the greater portion of the over-all equipment design (see schedule). Whenever the results appear promising, however, the electronics design will be modified accordingly.

d. Task III - Design and Fabrication

(1) Description

Task III will consist of the design and fabrication of a change detector with the characteristics listed in Section IV, item 1, above. The design will be essentially as shown functionally in Figure 17 and described in Section III. The final choice of a design configuration will depend upon the results of the predesign study (Task I). Task III will be broken into three major areas of activity: (1) the optical and electromechanical parts required to perform the image registration and film handling, (2) the electronics required to perform the image registration, data comparison, and display data processing, and (3) the console and tie-in equipment to integrate (1) and (2) into the final assembly.

Whenever possible, existing designs and equipment will be incorporated into this model. The display and read-out equipment will be purchased for modification at [redacted] or subcontracted to meet design specifications.

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The equipment will consist of two basic units (1) a comparator unit and (2) a monitor, control, and read-out unit (see Figure 22). The comparator unit will consist of a film-transport mechanism, lens displacement mechanism, the registration backlight, and necessary electronics. The monitor, control and read-out unit will contain the input scene and difference read-out monitors, the operational controls, and the necessary electronics to calculate the position of displayed changes. Figure 17 shows a detail functional block diagram of the proposed system. Descriptions of the various subassemblies follow.

(2) Film-Handling Mechanism

The film-handling mechanism will position a frame of 70-mm film in a film gate and index properly a strip or roll of the film frame-by-frame. The film will be used as a transparency in the system; thus, the handling mechanism must leave a clear path for the optical components. Since in the comparison read-out condition the light pattern from the crt is imaged on the film and the image of the associated transparency is imaged on the film during registration, clearances must be maintained in front of the film for these rays of light. The aperture geometry required in front of the film is established by (1) the frame size on 70-mm film, (2) scale-factor relationship between the two transparencies, (3) lateral lens displacement, (4) overlap condition, and (5) the lens aperture. Condensing optics will be installed behind the film plane to gather the light passing through the transparency and project it onto the face of a photomultiplier tube. Space is required to insert the backlight into one channel during the registration mode of operation. To accomplish this a mirror will be inserted between the condensing lenses and the photomultiplier tube. Space will be allotted within the film-handling mechanism to accommodate this backlight mechanism. The position readout requires either positioning of the principal point of the photograph at a specific point relative to the comparator reference line or measurement of the offset between the principal point and the reference line.

The film handling mechanism will be capable of accepting 100-ft rolls of film on standard spools. These spools will be mounted on either side of the photomultiplier tube with sprockets and spindles driven with geneva-type drives so that either a single sprocket hole or a single frame of information may be advanced. A differential vernier will be employed on the film drive so that the operator will have the choice of moving the film to any position relative to the aperture. This feature will be included for the handling of film from panoramic cameras.

(3) Film Mask

During automatic registration the back-lighted scene must be masked so that only the information common to both transparencies is imaged on the other transparency. The registration can be unbalanced by edge effects with an improperly masked scene. The masked scene must be smaller than the scene it is being compared with by a margin equal to the search excursion plus nutation radius. Various amounts of overlap, azimuth orientation differences, and scale-factor differences influence the manner and degree of masking required. The square format of a 70-mm frame helps define the amount of masking required for a given situation where the overlap, orientation, and scale-factor values are available. The overlap can be measured by the offsets of the lenses of the lateral and longitudinal servos, provided the frames are registered on the centerline of the comparator unit.

(4) Azimuth Orientation Control

The azimuth position control performs the function of orienting one frame with respect to the other and both frames relative to a reference on the monitor readout. Orientation will be accomplished either optically by dove prisms or mechanically by physical rotation of the film. The optical method of rotating the image will lengthen the optical path considerably due to the need for relay type optics to insert properly the dove prism. The physical size of the prism will be large since a large optical aperture will be required. Since the scale-factor adjustment will be accomplished by translation of the lens and scene (see lens displacement mechanism), centering and axial translation of the prism and prism assembly is critical. Proper corrections for the aberrations due to the effectively thick inclined-plane parallel plate presents another design problem; therefore, this method of effecting the azimuth orientation control will probably be implemented by the mechanical rotation of the film. The film rolls, film transport, photomultiplier condensing optics, photomultiplier, and backlight assembly will be part of an integral unit; therefore, if the film frame rotates, the remainder of these items must rotate with the unit. The envisioned mechanism consists of the over-all assembly of these items mounted on two torque tube type bearings so that the axis of rotation will coincide with the nadir point on the film frame. A problem area exists due to the difference in many instances between the center of rotation of the mechanism and the desired center of rotation of the area of interest, namely, the center of the overlap area. A detailed study of this problem may further require centering of the overlap area in the center of the frame aperture rather than positioning of the principal point to (1) the position computer, This requires that a lateral motion be introduced into the film position relative to the frame aperture where previously only longitudinal motion was required.

The angular positioning of the film-handling mechanism on the torque tube bearings will be accomplished by use of a servo motor in closed loop operation with a synchro transmitter and transformer for input and follow-up components. Each channel will have an individual input from a control transmitter. To orient both channels simultaneously two gaged synchro differentials will be used, each of the two being inserted between the transmitter and transformer of the individual channels.

(5) Lens Displacement Mechanism

The registration of one scene with respect to the other will be accomplished by mounting the lenses, which image the crt raster on the transparencies, so that they may be translated along two orthogonal directions for registration in an X and Y coordinate system. The translation in the X and Y directions will be accomplished with the use of servo motors so that the lens will automatically position when the loop through the correlator is closed.

Position readouts will be mounted on the mechanism in the form of potentiometers in such a manner that deflection from a center position can be electrically detected. These readouts are required to supply information of the position of the optical centerline related to the principal point to (1) the position computer, (2) the matchpoint storage unit, (3) the masking devices, and (4) the position control on the console.

The deflection of the image from the center position must be measured and the positional information is required in the masking device, the positioning control on the console, the matchpoint storage unit, the change position computer, and the FSS deflection circuitry involved in the manual and automatic image enlargement. The masking device and the automatic image enlargement are dependent upon X and Y lens position, and the mask limits must be computed so that the information will not be under-scanned nor over-masked. The processing of the X and Y lens position information may lead to the situation where it may be advantageous to use a single pickoff on each of the lens motions and follow-up servos on the computing mechanism. Since these functions require inputs from both channels and from both X and Y deflections of each channel the deciding factor will be the interaction of the servos on each other.

The difference in scale-factor requires registration of one scene relative to the other. Each channel will have a mechanism to translate the lens and transparency axially to effect a change in magnification in each channel. The initial point for translating the lens and scene in each channel will be that which allows the raster on the crt to cover fully the 2-1/4 by 2-1/4 frame of the 70-mm film. The scale-factor mechanisms will reduce the coverage of the crt on each transparency alternately.

(6) Comparator Unit Electronics

The comparator unit will contain the electronic circuitry associated with the registration process. In general this circuitry will supply the electromechanical components, such as servo motors, required to register the two scenes automatically. The items requiring design effort include: servo amplifiers, match-point detectors (X and Y search), reference signal generators, and phase detectors. In addition, the development of narrow-band amplifiers following one of the phototubes will be required to separate the X and Y and scale-factor error signals. The packaging configuration of the above items will necessarily be determined by the electromechanical components that they supply. All the electronics required to generate the raster will be incorporated with the cathode ray tube in the comparator unit. High-linearity yoke drivers will be designed to accept the horizontal and vertical scanning wave forms generated by the synchronizing generator. The yoke drivers will also be designed to accept the variable sweep amplitudes and positional bias voltages generated when the area enlargement mode is used. Much of this design will consist of repackaging of the existing breadboard circuitry.

To take the difference between the two scenes during the comparison read-out, a wide-band electronic difference amplifier will be designed. It will accept outputs from each phototube and amplify and supply difference video signals to the monitors. The option of a positive or negative polarity of either scene for use in the "flicker" comparison will also be designed into the amplifier. A video band width of 10 mc will be the design goal throughout.

Breadboards of the noise-rejection circuits and other detection methods developed during the display processing study will be repackaged and incorporated into the unit. Integration of these circuits with the electronic difference amplifier will be required.

High-voltage power supplies for the cathode ray tube and phototube will be purchased and installed in this unit.

(7) Display Unit Electronics

The display unit will contain the electronic circuitry necessary to determine the position of the change to be read-out. The type of circuitry required will depend on the choice of read-out method (probe or reticle) determined in the predesign studies. A simple analog calculator will be developed to compute the amount of lens displacement, cathode ray tube raster displacement, and film displacement for position read-out measurements. The resultant analog voltage outputs will be displayed on a digital-type of display or printed readout.

This unit will also contain the synchronizing generator necessary to generate the various wave forms and pulses required by the flying spot scanner and scene monitors. The generator will be designed to deliver the standard television rates of 15,750-cps horizontal and 60-cps vertical interlaced 2 to 1. All circuitry will be transistorized.

The low and medium voltage power supplies for the complete change detector will be located in this unit. The tentative voltages to be supplied are: ±30 v, dc, +500 v, dc, and -100 v, dc. It is anticipated that these will be purchased commercial supplies.

(8) Control Panel

A tentative layout of the control panel located below each monitor is shown in Figure 23. Frame adjust, frame advance, and alignment controls will be provided for both the input scene film and the reference film. Coarse and vernier frame position controls will be provided together with controls to index each roll of film in the forward and reverse directions manually or automatically. Alignment controls in the X and Y directions, scale-factor, and tilt will be provided for each roll of film. Initiating controls for automatic registration as well as the noise rejection, area enlargement, and "flicker" options will be provided on the control panel below the reference and difference monitor. Equipment on-off switches and a video gain control for each monitor will be located as shown in Figure 23.

(9) Monitors

Two 14-in. tv-type monitors will be provided to display (1) the new or input scene data and (2) the reference and difference readout data. The monitors will be modified to accept inputs from the comparator unit and will be programmed to display data appropriate to the various positions within the operations sequence. For example, during the frame advance and initial alignment of each film roll, input and reference scenes will be displayed. During the comparison readout the video difference image will be displayed with either the input or reference data. The left-hand monitor will be capable of displaying alternate registered pictures of the input and reference scene, thus providing a flicker-type display at the operator's option.

e. Task IV - Checkout and Evaluation

Checkout and evaluation will be performed to ensure performance conforming to normal standards for laboratory equipment. It is expected that the customer will assist [redacted] in the evaluation by contributing to the final design of performance tests and making recommendations for design modifications that may be required to meet the equipment design specifications.

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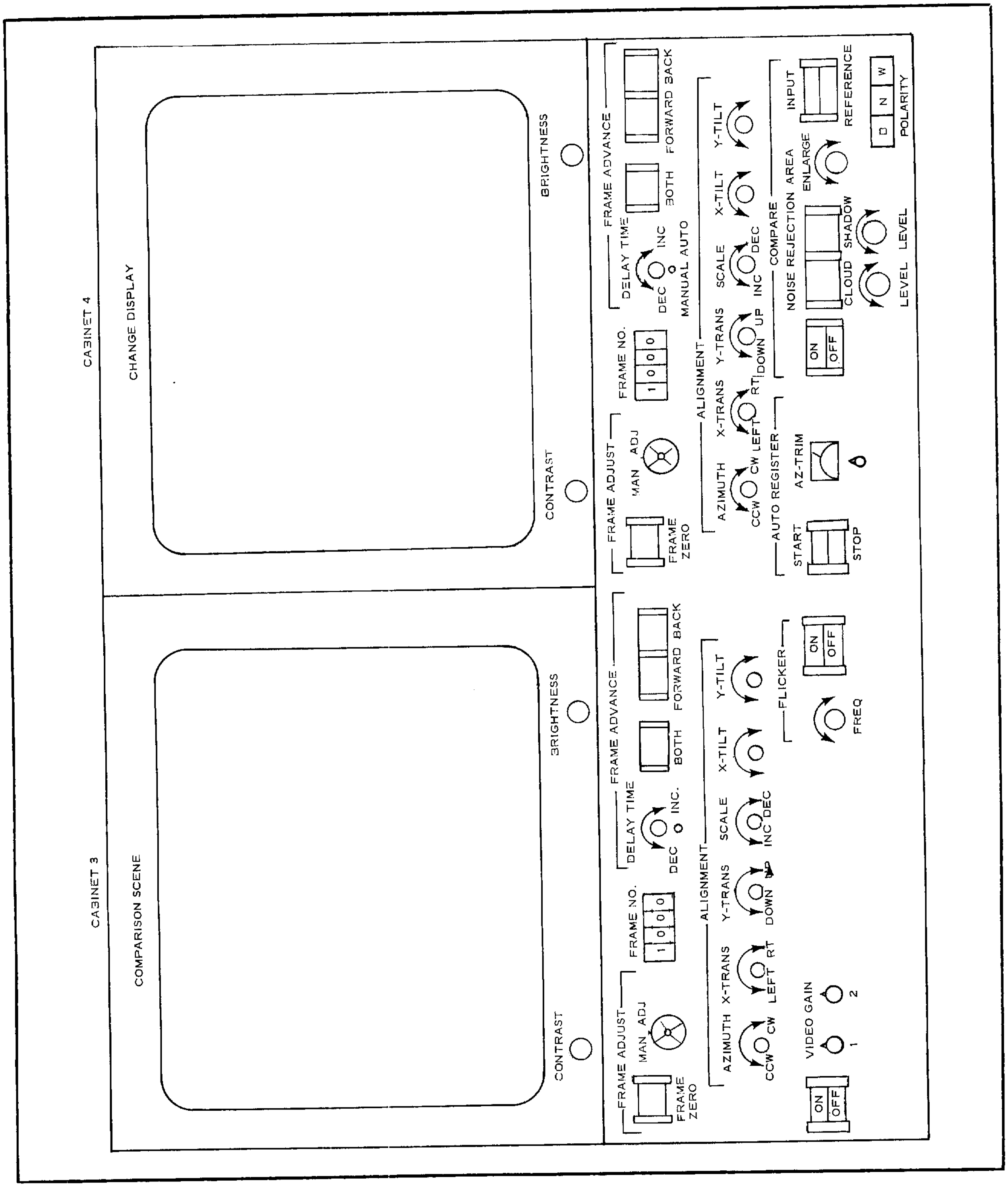

Figure 23 - Control Panel

The image resolution of the system will be measured. Registration tests will be performed with standard images so that the accuracy of registration can be determined. Representative pictures of the display readout for various types of changes will be recorded as well as the effects of various settings of display options that are finally included in the design.

Evaluation tests will be performed to establish the performance of the equipment to detect various types of changes including the number of targets, positions of targets, and the sizes of targets within the scene. Performance will be measured by the (1) time required for an operator to locate changes and (2) the errors of omission and commission for various types of changes. Standard frames with various numbers and types of changes will be made for the performance tests.

Various screening times will be determined, including (1) the time required to detect the first pertinent change within a scene, (2) the time required to detect the remaining changes, and (3) the time required to identify the type of change.

f. Task V - Support Engineering

Included in the support engineering functions are (1) program administration, (2) reporting of technical progress and program status, (3) generation of an equipment operation and service manual, and (4) delivery of the change-detector model. [redacted] will coordinate the development program in accordance with the schedule described in 4, b, this section, and will deliver the model 10 days after completion of the contract. Monthly progress letters, an interim progress report, a final technical report, and an operation and maintenance manual will be submitted as described below.

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Monthly progress letters will summarize the work accomplished, explain the derivation of technical and managerial problems encountered and actual or proposed solutions, and outline a work program for the following reporting period. A statement on the indicated sufficiency of manpower and funds for completion of the contract will be included. The first report will be delivered within 45 days following contract initiation, and subsequent reports will be delivered monthly thereafter throughout the contract. Three nonreproducible copies will be provided each period.

Fifty copies of an interim progress report will be provided on or before the 30th day after completion of the first year of the contract. The interim report will cover the work accomplished in all areas. This report will be distributed in accordance with a distribution list furnished by the customer. A copy of the distribution list will be bound into each copy.

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The final technical report will cover all work accomplished during the contract and will include schematic and wiring diagrams for all equipment or test equipment and details of techniques developed under the contract. It will be complete within itself. A preliminary draft will be submitted for review and approval prior to distribution. After receipt of approval, [redacted] will make all necessary corrections, publish the reports, and distribute them in accordance with a distribution list furnished by the customer. A copy of the distribution list will be bound into each copy of the report. A maximum of 50 copies will be provided. The preliminary draft will be submitted on or before the 30th day after conclusion of the contract work and the approved report will be distributed 20 days after receipt of approval.

The operation and service manual will cover the complete operation and maintenance of the delivered change detector and will include schematic wiring diagrams for model evaluation and a listing and description of any test equipment required for servicing the equipment. Maintenance procedures will be outlined. Two draft copies will be submitted for customer approval 45 days before delivery of the model. If the approved draft is received within 3 weeks, the 10

[redacted]

copies of the manual will be delivered concurrently with the delivery of the change detector.

4. ORGANIZATION AND SCHEDULE

a. Project Organization

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[redacted] A senior scientific staff will assist the project engineer in the monitoring and technical direction of the program. The project engineer will be responsible for the technical management of the program, including planning, schedules, review, and submittal of all technical reports and other data to the contractor. He will be assisted by a project administrator who will be responsible for such items as cost control, facilities, manpower and planning schedules, and project liaison within the company.

b. Program Schedule

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The schedule for the proposed program is given in Figure 25. The various tasks are shown with important benchmarks and phasing information noted. [redacted]

c. Personnel

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[redacted]

Next 9 Page(s) In Document Exempt

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