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EKIT REPORT NO.6

NIGHT DETECTION PHOTOGRAPHY

(EKIT FLIGHT TESTS NO.4&5)

28 FEBRUARY 1967

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Itek

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1. SUMMARY

This is the sixth report in the EKIT series and contains the evaluation of three photographic materials used at night in the 112B system. The film of prime interest was type SO-340 which is an improved Tri-X emulsion coated on an Estar base. The second film under test was type SO-180 which is a color emulsion designed to be used ordinarily in detecting camouflaged objects by their infrared reflection characteristics. The third film was type SO-121 which is a high resolution color material specifically designed for daytime aerial reconnaissance. The prime objective of the test was to evaluate what can be seen of a missile launch complex at night.

It was an attempt to evaluate the system as a detector of activity, not to obtain images illuminated by moonlight. Activity would be represented by areas illuminated by artificial means.

1.1 SCOPE OF THE TEST

Since the prime objective was to detect missile launch activity at night, the main target area chosen was Vandenburg Air Force Base, California. Although three separate night tests were run, the main one was conducted on 13 January 1967. This was the evening before a KH-4 launch (mission 1038) and it was suspected that there would be activity on the pad at night in preparation for the launch on 14 January 1967.

In order to use the available flight time to the maximum, several other areas were covered. The photographic portion of the flight line included the Los Angeles area, Vandenburg, and the San Francisco-Vallejo areas. The photography was obtained with the 112B camera system at a nominal altitude of 65,000 feet. Three night missions were required to complete the effort. Two day-coverage missions that were flown over the same flight lines as their night counterparts were used as a control. The first mission obtained good imagery in the Los Angeles and San Francisco areas, but not at Vandenburg, due to bad weather. A second night mission was immediately rescheduled and flown that same week. A partially cloudy condition was present during this mission, though the extent was not known until after the film was processed several weeks later. Both flights had good imagery in most areas except the prime target, Vandenburg. The third mission was flown 13 January 1967, and successfully covered Vandenburg. The first two flights used a camera in which the entire slit mechanism could be removed, thus providing an effective exposure time of 1/50 second. For the third mission, a different 112B unit, from which the slit bar could not be removed was used; therefore, an exposure time of approximately 1/120 second had to be used.

The analysis performed on the material consisted of an examination of the information available as judged by photointerpreters, a sensitometric analysis, and a small scale imagery analysis. The problems of static and fog are also discussed. The conclusions drawn at the end of the photointerpreters' evaluation and sensitometric analysis apply to the EKIT test itself and therefore to the 112B system. The final conclusions, Section 6, are those drawn from the entire analysis that are applicable to the J-3 (improved KH-4) system.

1.2 CONCLUSIONS

The following is a brief summary of the conclusions from the night detection tests.

1. High speed black and white photography at night has a potential as a nighttime activity indicator from satellite altitudes.

2. Comparable day coverage is desirable for specific target identification.

3. Viewing by stereo (day combined with night) or overlaying the two images is an interesting technique for interpreting the images.

4. Panoramic distortion makes precise location of targets difficult, particularly over distances of more than 5 to 10 inches on the film.

5. The very large dynamic range present suggests that other processing (i.e., low gamma) or a dual speed emulsion would be useful for recording more information.

6. The overriding characteristic of an emulsion used in night photography as an indicator of activity is its speed. Resolution and/or color are of secondary importance.

7. The principal target area, Vandenburg Air Force Base, was located. At satellite altitudes, it will also be possible to detect and identify parts of the illuminated missile complex.

8. Static, fog, and corona discharge may be a problem with the higher speed emulsions.

2. TEST PLAN

EKIT test no. 4/5 consisted of a total of six flights. The 112B camera system, the details of which are discussed in Section 2.1, was used in a high flying aircraft. Modifications to the unit are discussed in Section 2.2 and specific details of the camera settings for each flight in Section 2.3.

2.1 112B CAMERA SYSTEM

Though discussed in previous EKIT reports, the description of this camera system will be again presented to familiarize the new reader with the system employed in this test series. The camera is a pan scanning type that has been designed around the diffraction-limited Petzval type lens of 24-inch focal length, with an f/3.5 aperture that covers a 6-degree field angle. To obtain stereo, a pair of these cameras is tilted from the nadir at 13 degrees each, and set face to face so that each camera scans in opposing directions. The lens is continuously rotated about its operational nodal point scanning across the line of flight, and is translated against the flight direction for image motion compensation.

During approximately 70 degrees of the lens rotation, a capping shutter is open to permit the aerial image to expose the 70-millimeter film through a slit. This slit controls the exposure time, e.g., at a 20-inch-per-second scan rate, a 0.40-inch slit produces an effective exposure time of 1/500 second. At the completion of the photographic scan, the capping shutter is closed.

The film is continuously being transported in from the supply spool and out to the takeup spool. A frame-metering roller controls the frame length (the correct amount of film placed in the format area) and clamps at each end of the format hold the film stable in the approximate focus position. The excess film is accounted for by a shuttle assembly that gives or takes according to demand.

The focal position is determined by a scan head assembly mounted on a precise arm from the nodal point to the focus. This scan head gently lifts the film from the rails to the image plane during exposure and returns it to the rails after exposure. The rails are required only to hold the film at the approximate focus and to guide the film during transport.

Recorded on the film edge outside of the format area on each frame are the frame number, binary time, and timing pips of 125 cycles per second. These timing pips are scanned on the film across the 70-degree format length with one pip blanked out to indicate when the binary time data block is printed. Three scanning rates are built in to match the V/h requirements while maintaining approximately 10 percent overlap at the format center. Increased overlap is acquired on both sides of nadir as the off-vertical scan angle increases.

2.2 CAMERA MODIFICATION

One of the considerations for all of the EKIT tests is that no modification be made to the 112B camera system that would be incompatible with the J-3 system. For this test the slit bar was removed for two (flight tests 5 and 5A) of the night flights. The normal widest slit available on the 112B is 0.150 inch (approximately 1/120 second). By removing the slit bar completely, a slit width of 0.375 inch (approximately 1/50 second) which approximates the 0.340-inch slit width available on J-3 was obtained. On the third night test (flight 5B) the slit bar could not be removed. This meant that a faster shutter time was employed.

2.3 FLIGHT TEST PLAN DETAIL

A total of six flights were made in order to satisfactorily complete this test. The original plan called for only two flights, though bad weather conditions interfered with the test and further flights were required. Tables 2-1, 2-2, and 2-3 are summaries of specific data pertaining to the camera for each flight.

The initial tests (first two flights) covered Los Angeles, Vandenburg, and the San Francisco-Vallejo area. The flight line did not go directly over the prime target (Vandenburg) area but was intended to obtain imagery at the edge of the format. This alleviated the problems involved in getting the flight clearances for a direct overflight. There is, therefore, a question of whether or not the partially cloudy weather over Vandenburg or the skirting flight line caused the lack of imagery. For the third night flight, permission was obtained for a direct overflight and the weather at that time was clear.

Note also that type SO-180 was replaced with type SO-121 for the last night flight for the following reasons:

1. The flight was made in conjunction with another EKIT flight that required all of the available type SO-180.
2. Preliminary analysis of the first flights of type SO-180 provided enough information concerning its performance at night.
3. The use of type SO-340 in both cameras was thought to be an unnecessary duplication.
4. Extra type SO-121 was available and it was decided to test its usefulness at night.

Table 2-1 — Summary of Six Flights

EKIT Flight Test No.	Test
4	Initial day coverage for first night flight, partially cloudy
5	First night flight, partially cloudy over Vandenburg
4A	Second day flight, partially cloudy over Vandenburg
5A	Second night flight, also cloudy over Vandenburg
4B	Third day coverage, clear weather, color film in one camera
5B	Third night flight, successfully covered Vandenburg though at higher shutter speed than previous night mission

Table 2-2 — Specific Details for the Three-Day Flights

EKIT Flight No.	4	4A	4B
GT No.	349-66	306-66	0047A
Date	1 Sept. 1966	6 Sept. 1966	13 Jan. 1967
Time	09:20 to 16:20	11:00 to 15:00	11:00 to 18:00
Master Unit			
Aft-Looking Camera	I5	I5	I3
Film	3404	3404	SO-121
Slit width	0.049 inch	0.049 inch	0.009 inch
Exposure time	1/385 second	1/385 second	1/2400 second
Haze filter	Wratten no. 21	Wratten no. 21	Wratten no. 2-E
Color correction filter	None	None	30cc B
Scan mode	II	II	III
Slave Unit			
Forward-Looking Camera	I6	I6	I4
Film	3404*	3404	3404
Slit width	0.049 inch	0.049 inch	0.075 inch
Exposure time	1/385 second	1/385 second	1/300 second
Haze filter	Wratten no. 21	Wratten no. 21	Wratten no. 21
Color correction filter	None	None	None
Scan mode	II	II	III

*Camera malfunctioned, no exposures made.

Table 2-3 — Specific Details for the Three-Night Flights

EKIT Flight No.	5	5A	5B
GT No.	304-66	307-66	0057A
Date	2 Sept. 1966	6-7 Sept. 1966	13 Jan. 1967
Time	01:00 to 05:00	20:00 to 12:00 (approximately midnight photography)	20:00 to 23:15
Master Unit			
Aft-Looking Camera	I5	I5	I3
Film	SO-180	SO-180	SO-121
Slit width	0.375 inch	0.375 inch	0.150 inch*
Exposure time	1/50 second	1/50 second	1/120 second
Haze filter	None	None	None
Color correction filter	None	None	None
Scan mode	I	I	I
Slave Unit			
Forward-Looking Camera	I6	I6	I4
Film	SO-340	SO-340	SO-340
Slit width	0.375 inch	0.375 inch	0.150 inch*
Exposure time	1/50 second	1/50 second	1/120 second
Haze filter	None	None	None
Color correction filter	None	None	None
Scan mode	I	I	I

*NOTE: Shutter speed faster than on previous night flight.

3. PHOTOINTERPRETER'S COMMENTS

The following are the photointerpreter's comments relative to the day and night photography. Night photography (or rather, its use) is relatively new to most photointerpreters. These comments are in some ways related to the learning process that took place while the imagery was viewed. Several different approaches were taken in studying the imagery. For example, viewing a day and night image in stereo was used as a technique for finding areas on the day coverage that looked interesting on the night imagery. This technique was then found to be very useful in locating other target areas as the study continued.

Another convenient method for viewing the imagery was overlaying the negatives of the night coverage on the positives of the day coverage. Since the majority of the night negatives are only at a density level of base plus fog, this procedure does not interfere with the examination of the day imagery. The grain structure of the night photography was somewhat bothersome, though this technique was used only for location of targets. When superimposed in this manner, pinpoint location of details on the night photography is very rapid. Several attempts were made to illustrate this effect, principally by sandwiching the night and day negatives and printing them onto one piece of paper. These attempts failed at showing what can be seen on a light table with the original material. It might, therefore, be concluded that this type of viewing would have to be done by hand on the light table for the most effective method of obtaining the desired information.

It was generally found to be easier to find something on the night coverage and then locate it on the day coverage, rather than the other way around. Something that was lit up during the night could almost always be found on the day coverage. But, several interesting targets (i.e., a Nike launch complex) were found on the day coverage but not on the night. It could have been cloudy or possibly no lights were on. Most likely there were no lights on since some other obviously clouded images were recorded a few miles from the launch site.

The images discussed in the appendix were made from all three night flights. All original material for the night prints were taken at an exposure of 1/50 second at f/3.5. This represents the same exposure that will be available on the J-3 in its normally operated maximum exposure slit position. The essential difference in these images and those of the J-3 is the scale difference ($7\frac{1}{2}$:1).

The images in Figs. 3-1 and 3-2 were the prime objective of the entire test. They were made during the third night flight and were at an exposure of 1/120 second at f/3.5.

3.1 SUBJECTIVE EVALUATION: GENERAL IMPRESSIONS

The evaluation of high altitude night photography presents a completely new aspect to aerial photointerpretation. Image and illuminant relationships long established in the mind of the viewer are drastically changed and a reorientation is required before one can feel at ease or have confidence in any but the most obvious evaluations.

However, most interpreters should have little trouble in adapting to the medium, especially those with experience in radar, infrared, ultraviolet, and related nonconventional image recording systems.

One of the first conditions apparent is the relative lack of imagery on the film. This is particularly true with lower speed emulsions, especially color, where the exposure threshold of the film is above that of most of the ground luminances. Illuminants such as street lights, signs, and displays show up quite well, though, due to the direct nature of the imagery. Buildings with configurations similar to gas stations, with large glass areas and strong inside illumination, tend to be silhouetted by the light "spilled" on the ground adjacent to them.

For the tests to be described, three emulsions were used at night. Control coverage during daylight hours was flown using 3404 film with a Wratten no. 21 filter. This flight provided the basis for orientation and location of specific light patterns.

Night coverage was flown with SO-340 for black and white and SO-180 for color and infrared records. The flight lines duplicated those of the day coverage, thereby facilitating identification. One later night flight substituted type SO-121 for the SO-180.

Distracting electrical discharge marks on the black and white film are quite apparent, particularly during the first cycles of each run. Though some imagery is superimposed on these marks, the imagery in general was not obscured. The extreme contrast presented by the clear background and the minute images make the use of the negative material difficult. A positive print, on the other hand, renders the background dark and the light patterns are much more apparent and considerably easier to work with.

Prints and film positives made at various exposure levels broaden the scope of presentation of available information in any one black and white negative. Lower density level printing produced positives with information in the less illuminated areas of the target but show blocked-up areas where the high intensity illumination was present. Conversely, higher exposure levels on the prints cleared the blocked areas at the expense of the dimly illuminated areas. For general use, an intermediate exposure might prove most usable, but in special cases, individually controlled exposure for making duplicates will be required.

Evaluation techniques may vary from interpreter to interpreter depending on training and personal preference, so no firm judgment as to what is the "best" method will be made. Instead, several approaches are presented along with comments.

Black and white coverage as mentioned above is more useful in the positive print conditions for most cases. Utilizing the night negative as an overlay on the day coverage (preferably in a positive print form) allows a direct superimposition of lights upon their sources. The usefulness of this technique will be demonstrated for specific cases in comparisons that follow. In this manner, superfluous information can be weeded out and areas pertinent to the evaluation can be delineated.

Image superimposition is also practical with color transparency materials, however, the high overall density of night photography makes orienting two images somewhat more difficult.

Use of a color emulsion incorporating an infrared sensitive layer, as in SO-180, extends the sensitivity of night color photography into a region where considerable extra radiation from incandescent sources is detectable. It is conceivable that determination of the nature of illuminating sources is practical if control exposures of known sources are available for comparison.

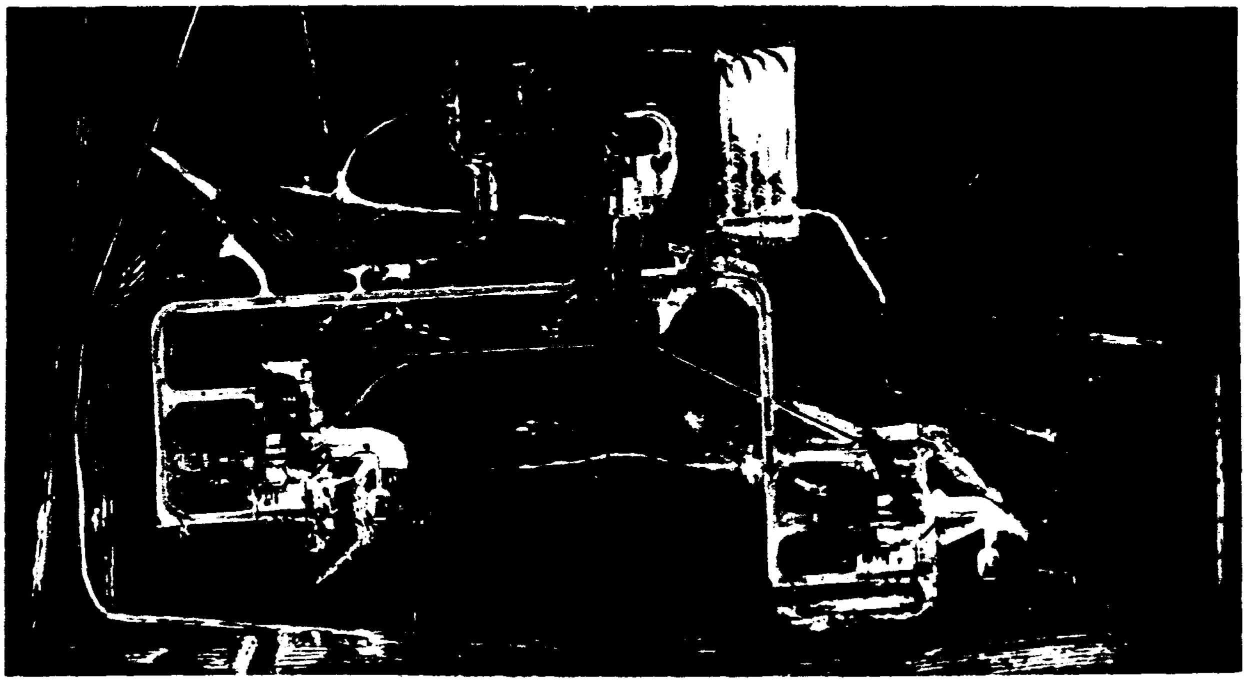

Fig. 3-1(a) — Vandenburg AFB—launch facility; day, 3404 film, 6× enlargement

Fig. 3-1(b) — Vandenburg AFB—launch facility; night, SO-340 film, 6× enlargement

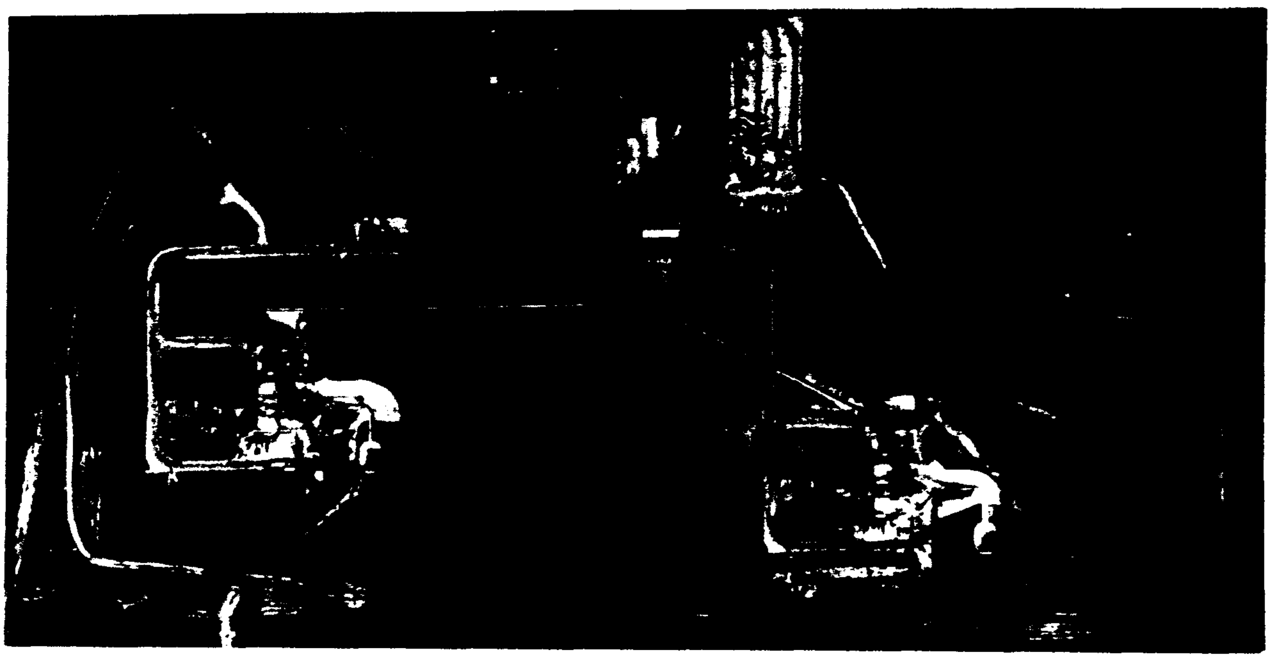

Fig. 3-1(c) — Vandenburg AFB—launch facility; day, SO-121 film, 6× enlargement

Fig. 3-2(a) — Vandenburg AFB—Minuteman launch facility day, 3404 film, 6× enlargement

Fig. 3-2(b) — Vandenburg AFB—Minuteman launch facility; day, SO-121 film, 6× enlargement

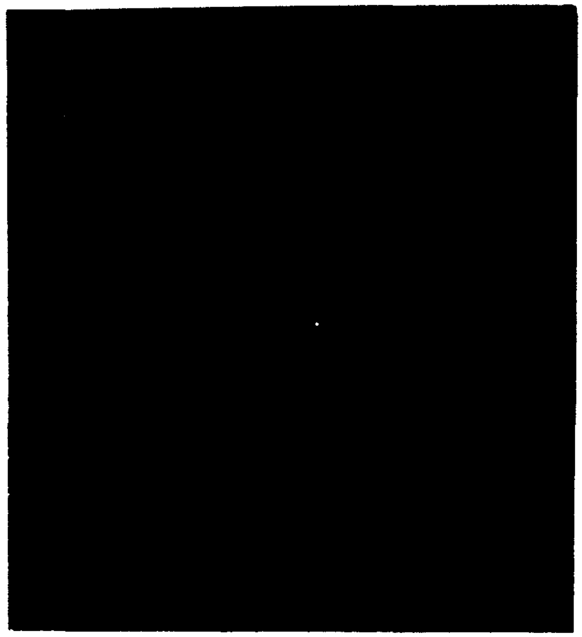

Fig. 3-2(c) — Vandenburg AFB—Minuteman launch facility; night, SO-121 film, 6× enlargement

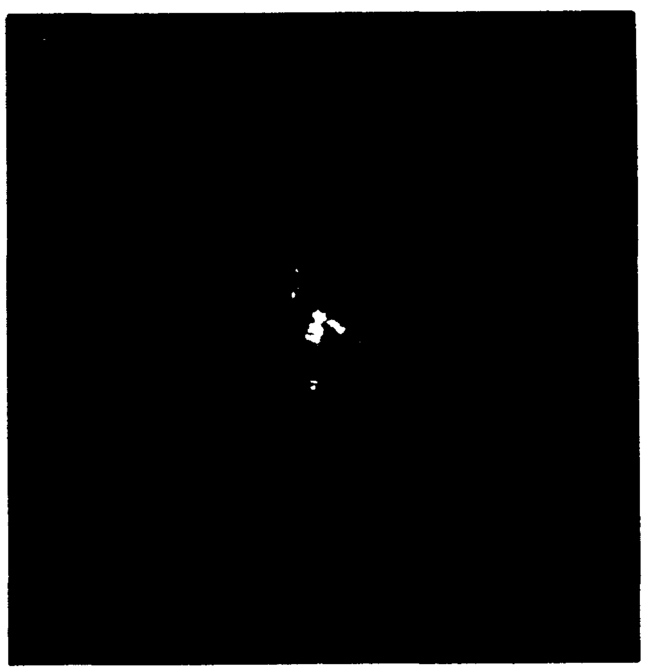

Fig. 3-2(d) — Vandenburg AFB—Minuteman launch facility; night, SO-340 film, 6× enlargement

Specific cases for comparison follow, and undoubtedly each individual viewing them will have his own opinions concerning their usability and/or interpretability. Some samples are for illustration of a single facet such as sensitivity and illuminant differences, but other samples show very specific areas of application in intelligence collection of night photography.

3.2 SUBJECTIVE EVALUATION: SPECIFIC GOAL OF NIGHT TEST

Since the prime target area was the Vandenburg AFB missile launch complex, it will be discussed first. The successful photographic mission took place on the night of 13 January 1967. The launch complex SLC3 was to have a KH-4 missile (1038) launched on the next day, Saturday the 14th, and therefore had activity proceeding on the night of the 13th. The photointerpreter knew that this missile launch complex would be illuminated and his task was to find it. He had the advantage of knowing the general shape because he knew what the day coverage of this area looked like. What he did not know, though, was that there was nighttime activity taking place at a Minuteman complex (MM/LF-00-08) in the northern part of the base. He found this area with no foreknowledge of its presence because it stood out very distinctly against the minimum density background. The specific identification was obtained from locating the same area on the day coverage by the overlaying and stereo technique described in the previous section. The following is his discussion of the two complexes.

Both elements of the launch facility, SLC3, that were illuminated are shown in Fig. 3-1 and present an outstanding target area. Most illumination is on the deck area, the gantries essentially being dark though several small lights are seen at their tops. Structural details and limits are clearly defined but the most important fact is that night activity is detectable. This image was obtained from the final night test and was shot with a stop less exposure than all of the previous images.

Night color coverage for this flight used type SO-121; its relatively low speed produced no results of any importance. Small lights at the top of the gantries were observed as barely discernable points. A print was therefore not necessary. Activity was apparently not present on similar launch facilities on the base, due to the conspicuous absence of any other lights of this configuration.

The Minuteman launch facility (MM/LF-00-08) is the subject of the Fig. 3-2 series. Considerable activity is seen about the silo in Fig. 3-2(a) in the daytime control coverage. Night black and white exposure [Fig. 3-2(b)] records many details of the site and activities and locates the sources of illumination.

The appearance of corresponding imagery on the SO-121 night mission [Fig. 3-2(c)] was somewhat of a surprise. Illumination by the very presence of recordable images must be quite high.

Combining the facts of activity extending well beyond sunset and the intensity of lighting, it appears that rather important work is being performed. Superimposition of the night coverage upon the daytime imagery fixes the location and identity of the night record with a high level of confidence. This area was not known to be active and represents a real "find" as far as night activity detection is concerned. It was learned after the analysis had been performed that a Minuteman missile had been launched two days before this night flight. The activity was the refurbishing of the silo.

3.3 SUBJECTIVE EVALUATION: OTHER INTERESTING TARGETS

Many areas other than the prime target area of Vandenburg were covered in these night missions. The following contains an evaluation of the more interesting observations.

The appendix contains all prints made for this discussion. Figs. A-1(a) and A-1(b) are examples of comparative day and night black and white coverage. This is a sporting field of some sort, probably soccer. The field is well illuminated at night and the high contrast afforded by the white lines on the grass makes a striking appearance. Illumination is quite even over the playing field but of relatively low intensity with respect to the color material, Fig. A-1(c). The response of the color film to this scene is very poor. The red-hued grass is seen as a predictable characteristic with only the vaguest hint of yardage lines. Only the high intensity lamp at the "Cerritos" end of the field shows prominently.

Figs. A-2(a), A-2(b), and A-2(c) are very similar to the previous series. A sporting event, probably a football game, is shown. Though yardage lines are not present, the high reflectance uniforms of the players are in sharp contrast to the field and present the same result. Some of the degradation of the day coverage is due to a thin layer of clouds, as can be partially seen in the lower right corner of Fig. A-2(a). There may also be a thin layer of clouds in the night photography but it is difficult to tell. Clouds could be covering the lights, or there may not be any lights on at all.

The series represented by Figs. A-3(a), A-3(b), A-3(c), and A-3(d) are related to the athletic fields shown in Figs. A-1(a) and A-2(a) in that they represent a nighttime sporting contrast under lights. The target is the Dodger home field, Chavez Ravine. Illumination of the field is much greater, resulting in a blocking up of the subject by high density in the black and white film and by a very impressive red image on the color film.

Selective use of exposure in printing the black and white scene is illustrated in Figs. A-3(b) and A-3(c). A shorter printing time results in a print as shown by Fig. A-3(b). The playing field is blocked up but much detail is seen in the parking lot and silhouetting of two buildings by internal light spilling out on the surrounding ground. Fig. A-3(c) was printed with a longer exposure time to bring out the playing field and stand detail at the expense of the other information.

The color recording in Fig. A-3(d) is very good. The level of illumination is high enough in this case to be used effectively by the film. Though no details surrounding the field are discernible, worn spots in the grass of the outfield made by the players can be seen. Note that the worn spots can be directly correlated to similar spots on the black and white print, Figs. A-3(a) and A-3(c). Fig. A-3(e) is a daytime color record on a normal aerial color emulsion for comparison with Fig. A-3(d). It was obtained by chance from another EKIT flight crossing these flight lines at Chavez Ravine and has been included as a comparison with the SO-180 at night. It is interesting to note that the worn spots in the field are not as evident on the normal color record. Camouflage detection film works under the principle that the three colors (blue, green, and red) in the image are formed in the same manner as in regular color films. However, the energy that forms these colors is green, red, and infrared. Therefore objects of high infrared reflection look red on the final image. The chlorophyl in green grass reflects more infrared than it does green. The green (highly reflective in infrared) grass illuminated by the tungsten lamps (with high infrared emission) combined to form a tremendous amount of infrared to the film, thus the vivid red ball field.

An urban area containing a number of parking lots and auto sales lots with various illumination levels and sources is shown in the Fig. A-4 series. Multiple printing levels are again illustrated as well as silhouetting in the black and white records. The color film in this instance exhibits the ability to discriminate between different illuminant sources. This is particularly noticeable in the lot at the center of the format. Though the lighting appears uniform in the black and white record, very distinct blue and yellow areas are apparent in the color.

Because of the color differences, one can deduce something about the sources of light in these areas. With the false color film, blue images were from green objects. Therefore, the chances are high that those blue parking lot lights are mercury vapor lights which have strong emissions in the green region. The yellow images were probably from reddish or infrared emitting sources, i.e.. tungsten lamps.

The Fig. A-5 series shows another urban area, very well illuminated. The main business district is readily apparent, particularly in black and white [Fig. A-5(b)] where individual vehicles can be seen as well as traffic lines and detail in store fronts. Halation can be detected about some of the brighter lights. Color film [Fig. A-5(c)] has several bright individual points of light that are not visible on the black and white record. These are probably different lamp types that have a high emission in the region to which the black and white film is not sensitive. Or, even though the black and white and color night pictures were taken at almost the same time, the difference in look angle could have caused a difference. Some lights might have been hidden behind billboards or buildings in one record and not in the other. Extremely bright lights could have affected all three emulsion layers of the color film, producing bright white spots.

Detection of aircraft was attempted and two samples are presented here. San Francisco Airport (Fig. A-6 series) contained a number of aircraft under various conditions of illumination. Side illumination by spilled light from low loading terminals makes aircraft detectable but only shows one side. Several planes outside a large hangar show much more of their configuration, due to a combination of overhead lighting and ground spilled light from the hangar interior. The color record [Fig. A-6(c)] shows no aircraft and is identified as an airport only by its light pattern showing resemblance to the black and white night and day cover. This series shows that in some cases neon type signs can be seen. Though not as clear on the color print [Fig. A-6(c)] as on the original material, the UNITED AIR LINES sign was identified by an individual who did not know what he was looking at. This is a United Airlines facility and the letters are located on a brilliant red sign. This is not apparent on the day coverage or the night because of the gross overexposure.

In the Fig. A-7 series, an individual commercial passenger plane was detected at the Douglas Aircraft plant in Torrance. This craft was being fitted and remained stationary for several days. By chance, the initial photography was taken during the airline strike of the fall of 1966 and many aircraft were stationary from day to night. The high illumination apparent in black and white night coverage [Fig. A-7(b)] indicates that late shift work is being performed. Basic structural members are apparent. The color record [Fig. A-7(c)] is helped considerably by the bright lighting, though not that much detail can be discerned other than that it is an aircraft, but the fact that work is in progress at night could be significant.

Of strategic interest is the Mare Island Naval Shipyard depicted in the Fig. A-8 series. Two submarines are being built in drydocks, the larger a polaris type and the smaller possibly a nuclear attack type. Night black and white coverage [Fig. A-8(b)] shows a great deal of activity on board the large vessel indicating continuous construction activity. Work on the smaller sub, by comparison, appears to have ceased for the night. However, superimposition of the negative of the night flight over the corresponding day imagery shows activity that could easily go unnoticed. The temporary structure aft of the conning tower shows illumination indicating that work on the vessel, probably in the propulsion areas, has continued. Dock structures, building silhouettes, and work areas are illuminated and gangways are discernible. Fig. A-8(c), the color print, shows only very bright lights, though activity is apparent on the polaris type vessel. The pattern of blue lights around the drydock is a key factor in location and orientation.

Perhaps one could infer that the completion of the Polaris sub was of more importance than that of the smaller craft. With knowledge of the amount of work being done at night, better estimates of schedules, rate of production, etc., could be made. These estimates would be subject to serious error if it was not known that night work was continuing.

The figures in the A-9 series are contact prints of a single area that had a lot of activity over a large area. Three printing levels are shown from the black and white and infrared color films to show the types of detail that can be seen at each printing level. The intermediate level [Figs. A-9(c) and A-9(f)] of each night image is the best of the three, although there is additional detail in the print on each side of the middle one. This area also has within it two scenes that were enlarged and discussed previously, Chavez Ravine (Fig. A-3) and the parking lot (Fig. A-4). Note that the streets that can be seen on the night imagery are secondary roads in the city. The freeways are conspicuously absent in the night imagery. Apparently the illumination contributed by store vendors and signs contributes significantly to the lighting of the streets.

3.4 IMAGE DEGRADATION

Image degradation manifests itself in several ways. Aircraft motion during exposure produces smearing of the imagery if the rate of change is excessive in relation to shutter speed. In one case there was a "stroboscopic" effect. This appeared to be caused by a chance combination of vehicle roll rate and slit scan direction and velocity. Static discharges, as mentioned previously, were a continuous factor in the black and white coverage at night. In instances where detection of night imagery is critical, the images might well be lost in the midst of a lot of static. Since the image area is such a small percentage of the total area, the changes of static interference with something important are relatively small.

SO-180 was not as susceptible to the electrical discharges, probably because of the slower speed. Occasional marking manifested itself in the form of a red mark across the frame, and the margin of the film adjacent to the pulse marks showed very frequent marking.

Similar markings across the frame were observed on the SO-121, but colored green. The marginal markings were less frequent but still in evidence. Emulsion damage is apparent in the form of small spots that look like pinholes, but under high magnification exhibit rough edges. A comet-like mark shows frequently, having a clear center, magenta corona, and tails that are all oriented in one direction. This could possibly occur in processing. At first it was thought that these were hot emissions from a smoke stack but this proved not to be the case. One of these spots was precisely pinpointed (via stereo with day coverage) and found to be in the middle of a super highway. It could not have been an exhaust from a truck because the tail was perpendicular to the direction of travel. All other spots like this were in the same direction, alluding to the trailing effect in the processing machine.

3.5 PHOTOINTERPRETER'S CONCLUSIONS

Nighttime aerial photography by artificial illumination has shown itself to have a distinct advantage for some kinds of intelligence evaluation. It appears that color photography is very seriously limited by speed, though SO-180 may be of some use as a spectral analysis medium.

High speed night black and white coverage has a potential for broadening the scope of photographic interpretation into an around-the-clock activity observation method.

Sufficient resolution and acuity are present even in the coarse-grained emulsions required to get sufficient sensitivity in the lower illuminative regions. Contrast is quite high but selective printing has shown that a wide range of exposure levels can be accommodated on the original negative.

Comparable day coverage was an absolute necessity for locating targets on this imagery. If, with the J-3 system, precise locations were known by the predicted orbits, then the day coverage may not be needed for target location. But it will still be needed for accurate interpretation of the night patterns. Viewing techniques such as superimposition of night and day photography or viewing the two in stereo greatly aid in identification of target details.

Probably the most important facet learned from the numerous samples evaluated is that observation of strategically important targets (shipyards, missile launch sites, and hardened silos), can be carried out day or night to obtain information on loading, maintenance, state of readiness, and activity.

4. SENSITOMETRIC ANALYSIS

One of the most important characteristics that must be considered in a photographic material used for night detection is its sensitometric properties: speed and contrast. These two properties have been found to be more important than color or image quality for detection of activity. There must be enough speed to record the image. The contrast factor enters in with speed because it is related to the dynamic range on the ground that can be recorded and which can be seen in the image. Obviously, very low resolution will lower the detection capability of the film, but with the level of image quality encountered, emulsion speed is of prime concern. It should also be noted that high speed does, under some circumstances, degrade the imagery because well illuminated targets are too bright.

In night aerial photography the total information which can be recorded is related to the level of illumination at ground level. This illumination is provided by the incandescent sources in the target area. The sources range from the very high intensities of flood lamps to the much lower intensities provided by low level street lights. Illumination at target areas results in two different types of information. General, overall illumination (usually from above the target) gives detailed information, shows variation of patterns in the target, and usually describes the target. Illumination close to ground level, such as used to illuminate facades, etc., only delineate the target; it is therefore only an outline of the target area with little or no detail.

The amount of information that can be detected is primarily dependent upon the type of illumination, upon the reflectivity of the target, and upon the intensity of the source present in the target.

4.1 DENSITOMETRIC ANALYSIS

This analysis was designed to determine the effective exposure that several different types of targets presented to the film. The method used was photographic photometry. The densities of the targets were measured with a microdensitometer and these densities in turn related to exposure through the D-log E curve. The characteristic curve for type SO-340 is plotted in Figs. 4-1 and 4-2. The densities of selected targets in two images are indicated on each of the curves. Fig. 4-1 is for a parking lot in Los Angeles (see Fig. A-4 in the appendix). The subjects measured are indicated on the characteristic curves. Fig. 4-2 is a similar plot for the prime target area, the missile launch complex SLC3. Table 4-1 summarizes the densities, exposures, and calculated energy at the object site. The equation representing the estimated energy reflected from the ground objects is represented by:

$$\text{ground luminance in foot-lamberts} = \left(\frac{\text{exposure}}{\text{time}}\right)(4)\ \ (f/no.)^2/(T_a) \cdot (T_\ell) \cdot (10.76)$$

where f/no. = 3.5
exposure = exposure in mcs
time = 1/50 second (or 1/120 second)
T_a (assumed night atmospheric transmittance) = 0.8
T_ℓ (approximate lens transmittance) = 0.9

Some of these data were used in the system analysis of Section 5.

The points scattered all over the curve in Fig. 4-1 illustrate the range of tones that are recorded. There were not very many points that were brighter than the neon sign of this figure. Neon signs are far below the resolution limit and therefore subject to errors in photographic photometry due to the nature of the emulsion spread function. Larger areas do not suffer as much from this phenomenon. Therefore, there probably are not many large target areas of interest that

Table 4-1 — Density, Exposure, and Target Luminance for Figs. 4-1 and 4-2

Objects from Fig. 4-1	Density	Log Exposure, mcs	Approximate Ground Luminance, foot-lamberts	
Neon lights	2.15	$\bar{2}.45$	9.0	
Cars in well illuminated parking lot	2.10	$\bar{2}.40$	8.0	
Cars in smaller parking lot	1.90	$\bar{2}.20$	5.1	
Cars in another parking lot	1.65	$\bar{2}.05$	3.6	
Pavement in parking lot	1.03	$\bar{3}.70$	1.6	
Center of main road	0.67	$\bar{3}.47$	0.96	
Crosswalk at intersection	0.37	$\bar{3}.20$	0.50	
Objects from Fig. 4-2				
Base of launch complex (A)	1.77	$\bar{2}.10$	9.6	Also indicated on Fig. 5-2
Reservoir adjacent to service area (B)	1.22	$\bar{3}.79$	4.8	
Lights on gantry (C)	0.36	$\bar{3}.20$	1.2	
Deck area (D)	0.29	$\bar{4}.90$	0.61	

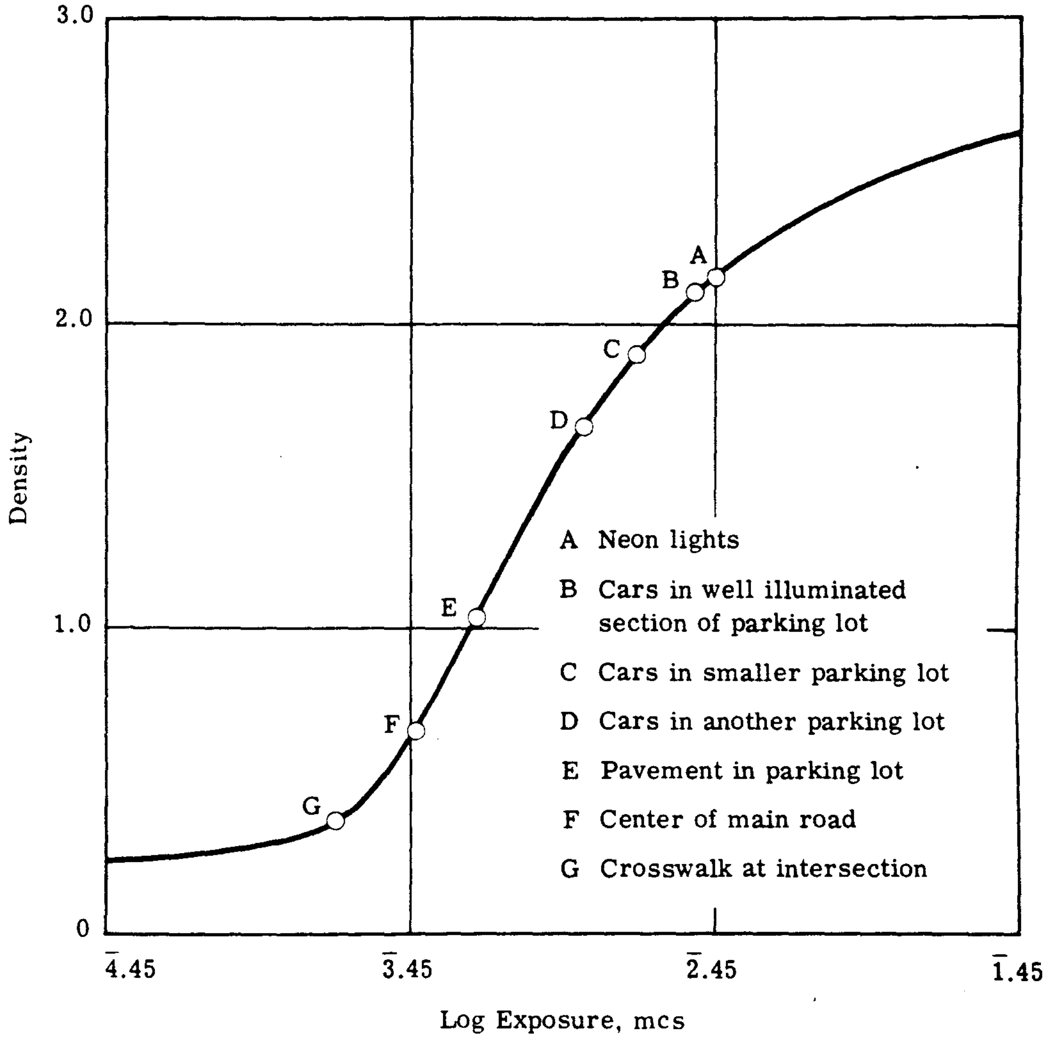

Fig. 4-1 — Characteristic curve for SO-340; density readings are from parking lot exposed at 1/50 second

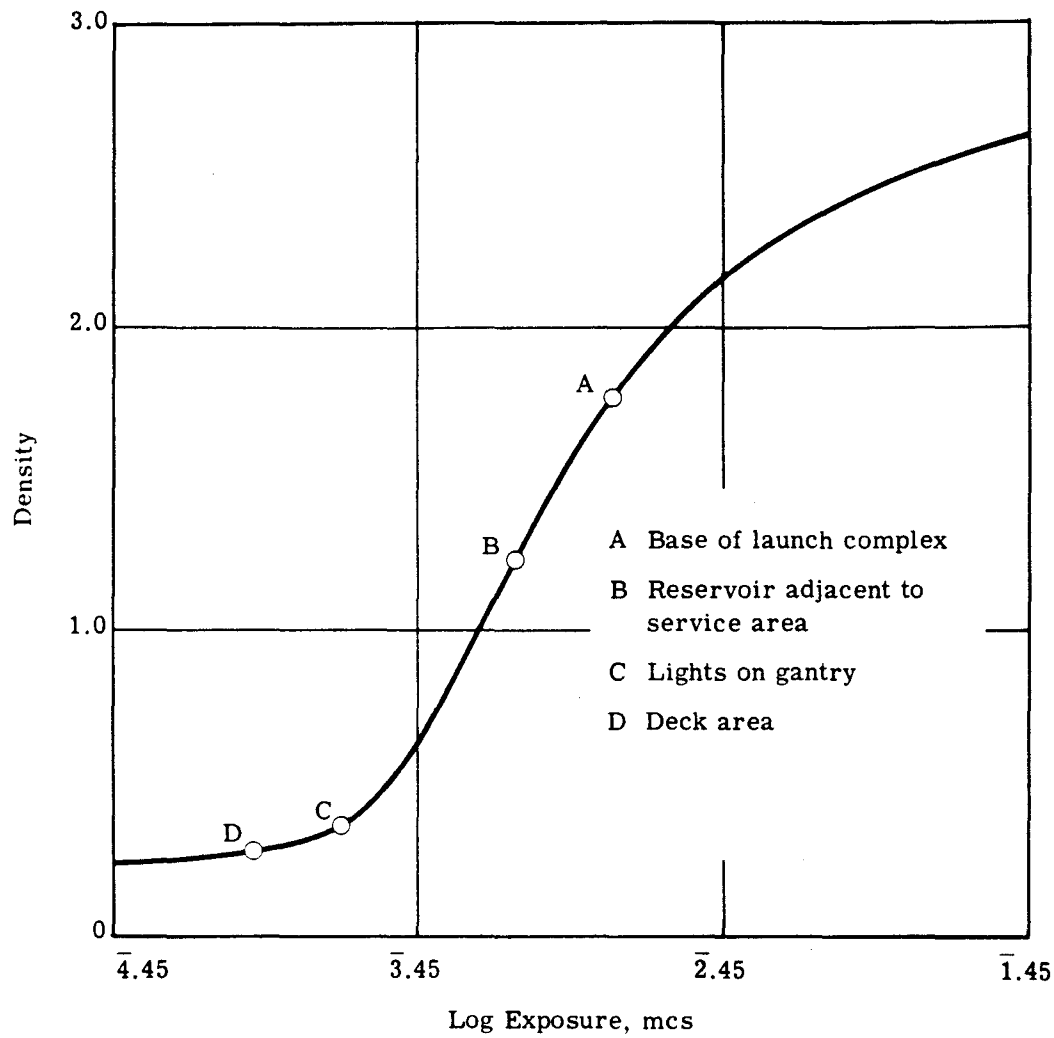

Fig. 4-2 — Characteristic curve for SO-340; density readings are from Vandenburg missile launch complex SLC3 exposed at 1/120 second are much brighter than the neon lights. The type SO-340 was slow enough to record the bright large surface areas. The question remains as to how much useful information in the underexposed region was not recorded. This, though, is impossible to tell from this analysis. A second question is, then, how can the information that is there be used more effectively. The density range of the images on type SO-340 is greater than 2.0. The normal duplicating stock (type 8430) can only accept a log exposure range of slightly more than 1.0. This automatically means that at least two duplicates are necessary in order to record all of the information that is available.

The most logical solution is to process the original negative to a low gamma. Since type SO-340 is a new emulsion, no work has been done to date with low gamma processing of this material. Work has been done in these laboratories with low gamma processing of lower speed emulsion (i.e., type 3404). This was successfully accomplished with no loss in emulsion speed. Since it is more difficult to do this with fine grain emulsion, no problem is anticipated in doing the same with an emulsion-like type SO-340. Coarse grain emulsions inherently lend themselves to low gamma processing. Fig. 4-3 represents the two stage duplication process necessary to record all of the information on the negative. What would be desirable would be to have the brightest and darkest points recorded in one duplication instead of two as is shown in this figure. Fig. 4-4 is these two points on one duplication material and shows what negative gamma (i.e., about -3) would be required to properly record the subject information.

4.2 MATERIALS AVAILABLE FOR NIGHT PHOTOGRAPHY

Type SO-340 is an improved version of the Tri-X emulsion coated on a thin base. Though it has a lower toe speed than Royal-X emulsions it has considerably higher contrast. With this higher contrast, the improved Tri-X type emulsion is actually faster in the higher density regions than the Royal-X type emulsion. In view of the contrast of the scenes photographed at night, this is perhaps a disadvantage. Higher high density region speeds are not very useful in night photography for the information discrimination capability since large density differences are not necessary. As long as a significant density difference exists, the information will be there.

Royal-X type emulsions could be useful in night photography. According to the manufacturer though, they would be very difficult, if not impossible, to coat on the required thin base due to the thickness of the emulsion.

A new emulsion, type SO-166, has recently been issued by Eastman Kodak. It is a very new film and exact comparisons between it and type SO-340 are not presently available. However, the film does appear to be roughly five times faster than type SO-340. With this emulsion, more information would be available in the toe region of the characteristic curve (at the expense of highlight detail). If this film were to be used, serious consideration should be given to lower gamma processing to extend the useful log exposure range. In addition, any static or fogging present would effectively be increased.

Another area to look into is that of double coating an emulsion such as has been done with the EG&G extender range film. This emulsion has three separate films, each of a different speed, coated on one base. Each emulsion layer produces a different colored record. The various speed regions can therefore be seen by selective printing techniques. This type of material is intended only as an intermediate since it in itself is very difficult to interpret.

4.3 SENSITOMETRIC ANALYSIS CONCLUSIONS

1. The dynamic range of night scenes is very large due to (a) the nature of the illumination, and (b) the absence of haze light that ordinarily reduces contrast.

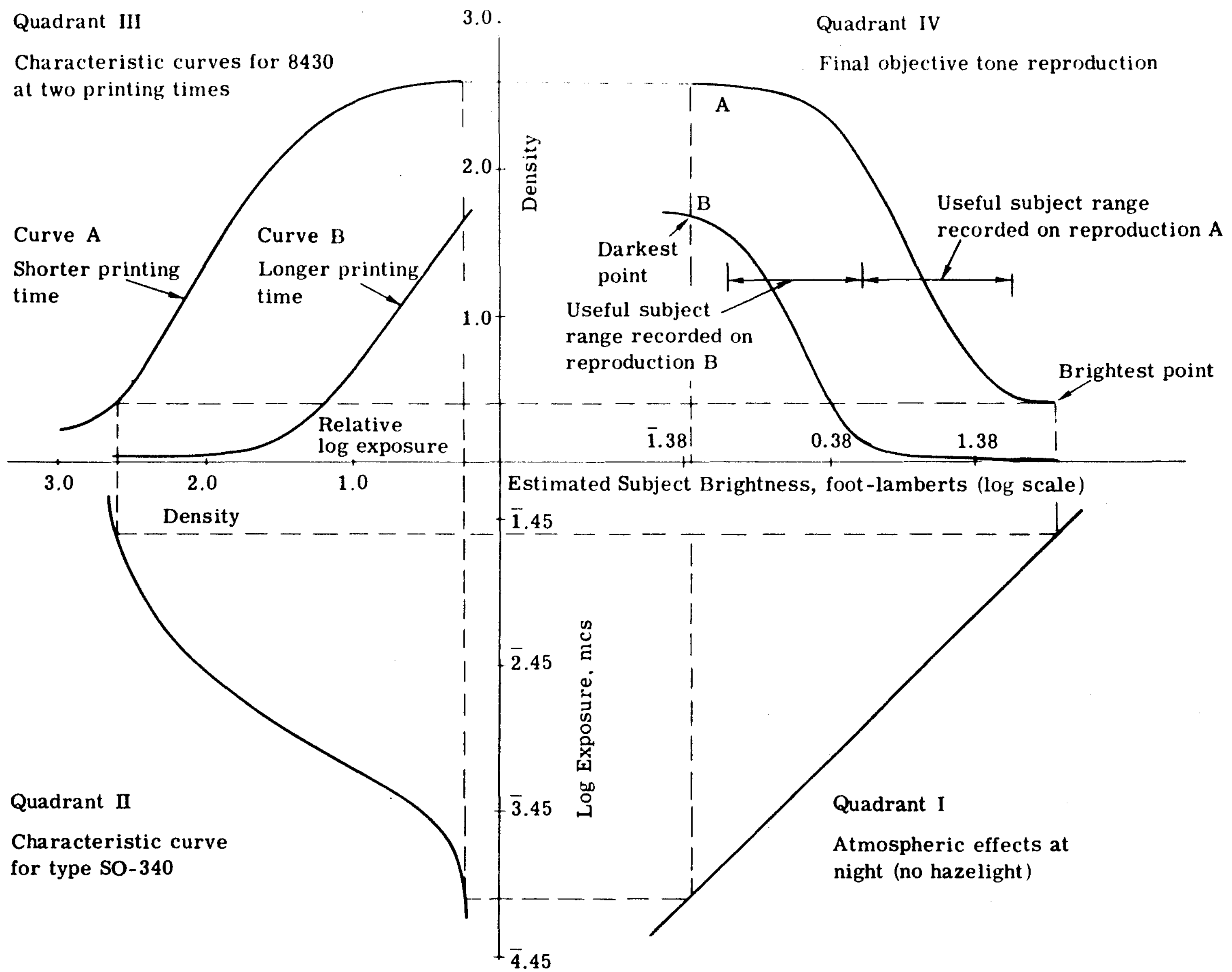

Fig. 4-3 — Two stage duplication necessary to use all available information recorded on the original negative

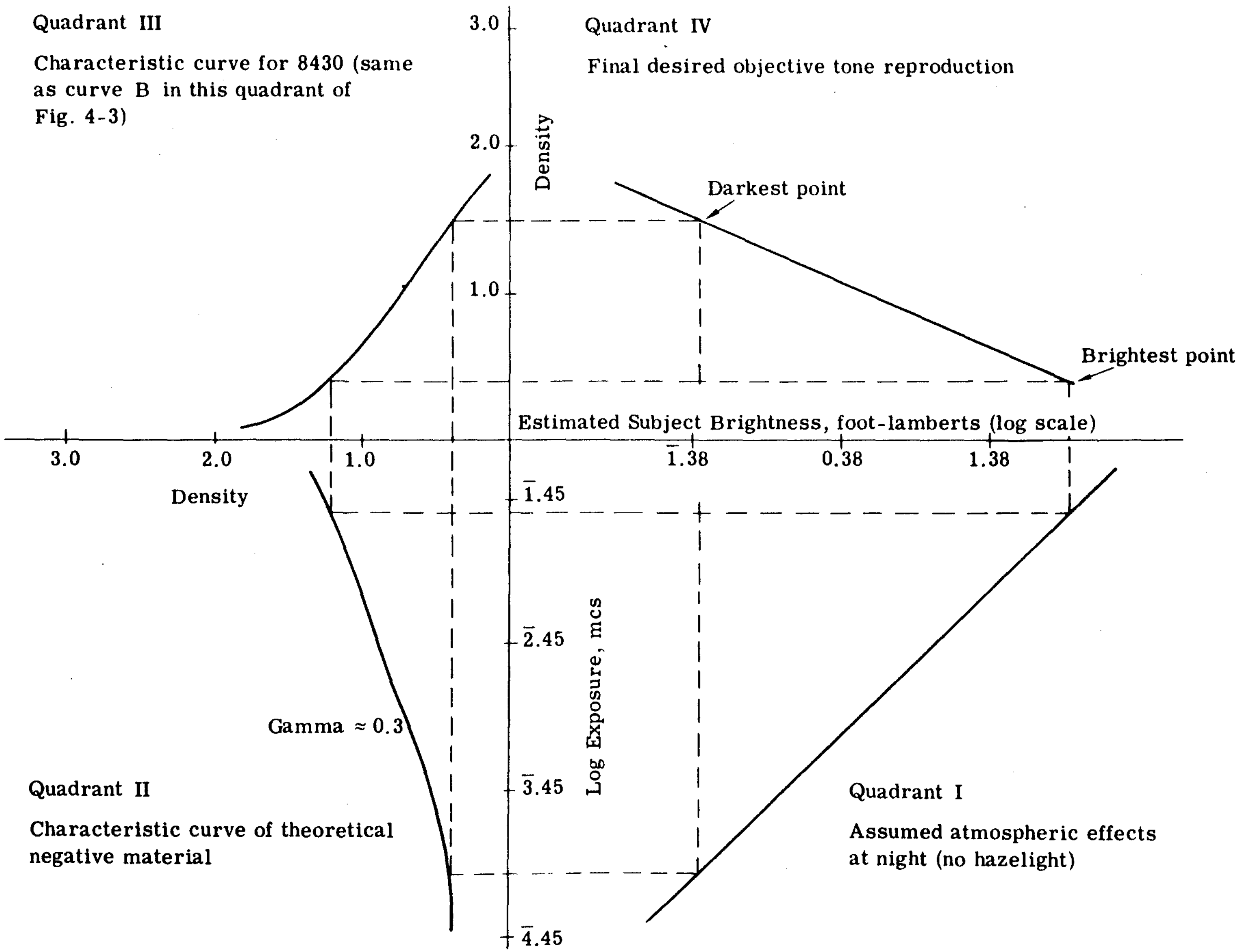

Fig. 4-4 — Theoretical negative required to record the subject range from the brightest to the darkest point with one printing level on 8430

2. The present photographic materials can record a significant amount of information, however, selective printing is required to fully utilize this information.
3. It is suggested that laboratory work be undertaken for lower contrast processing in order to improve the useful log exposure range and resulting density range of the materials.
4. If night photography is to be thoroughly studied, it is also suggested that the possibility of the manufacture of a dual speed emulsion be investigated.

5. J-3 SYSTEM CONSIDERATIONS

The purpose of the EKIT test series is to answer a specific question concerning a particular photographic technique that is used in the 112B camera system and then extrapolate to determine the probable effect on the operational J-3 system. The prime difference between these systems is the factor of $7\frac{1}{2}$:1 scale. In most of the EKIT tests, this scale difference is not a major factor to consider. For example, the relative performance of two films, such as in EKIT Report No. 5, is not going to change significantly at higher altitudes. However, in this EKIT test, the factor of $7\frac{1}{2}\times$ smaller images must be considered.

A second consideration that must be taken into account is the effects on higher speed emulsion of prolonged orbiting times at considerably lower atmospheric pressures. Both fogging and static could be serious problems. These two considerations are discussed in the following section.

5.1 SMALL SCALE DETECTION

Since the 24-inch Petzval lens is used in both the 112B and J-3 systems, this EKIT test must consider the differences in image scales from the two altitudes. Conclusions have been drawn as to the detection capability from the photointerpreter's discussion of the 112B system in Section 3. Consideration will be given here, not to the image detail that can be seen, but merely to the fact that some kind of activity is going on as evidenced by a spot of light recorded on the film. The following analysis was performed to determine how big and how bright ground objects must be in order to be detected on the film.

Selwyn's constant is defined as:

$$\mathbf{G} = \sigma_D \sqrt{A}$$

or

$$\mathbf{G} = 0.88\ \sigma_D \cdot d$$

where **G** = Selwyn's constant

σ_D = rms fluctuations in density where a microdensitometer scans uniformity density

A = area of the scanning spot

d = diameter of the scanning spot

It has been found that this constant, **G**, remains constant for black and white emulsions over a range in microdensitometer apertures of 6 to 30 microns. At the scales of the J-3 system this is approximately $7\frac{1}{2}$ to 375 feet.

Though the σ_D varies as the size of the scanning aperture changes, obviously the material being scanned does not change. The constant **G**, therefore, is a better number to characterize an emulsion. since implied within it is the scanning aperture diameter, and the value of **G** remains constant as the scanning aperture is changed.

If an image were to be exposed on a film within a uniform background density, its average density, $\overline{D}_2$, would be greater than that of the average background density, $\overline{D}_1$. If, however, the random fluctuations, σ_D, due to the grain pattern were the same as this difference, $\overline{D}_2 - \overline{D}_1$, would the image be detected? By the normal statistical variations in the scan, 16 percent of the background measurements would, by chance, be as great as the average image density. In this case, where $\overline{D}_2 = \overline{D}_1 + \sigma_D$, the signal-to-noise ratio is unity. The signal could be detected easier if, (a) the signal itself were strengthened, or (b) the noise were reduced.

Assuming the signal cannot be strengthened, the next best approach is to reduce the noise. Since Selwyn's law states that the σ_D varies as the square root of the area of the aperture, or directly as a function of the aperture diameter, the noise can be reduced by simply enlarging this aperture. In order to do this, though, the image area must also be appropriately enlarged. This fact now enables a relation to be made between the size of the target area to be detected and the granularity of the film. Since the σ_D is only a density difference, it can be related to an exposure difference through the sensitometric curve of the film when plotted as D versus E instead of the ordinary method of D versus log E. Therefore, the size of target areas can in turn be related to the illumination necessary to detect them with a microdensitometer. However, the problem of detection of these signals is a visual process, not an instrumented one. Tests at Eastman Kodak have shown that the threshold of detection of a signal density level on a grainy background occurs at a point where the signal-to-noise ratio is about 8:1. Thus, with this data, the visual detection of targets of various sizes can then be related to the illumination on them.

Rearranging the equation,

$$\mathbf{G} = (\sqrt{A})(\sigma_D) = \sqrt{\frac{\pi}{4} d^2}\,(\sigma_D)$$

$$\sigma_D = \mathbf{G}/0.88d$$

$$\Delta D_V = 8\sigma_D$$

$$\Delta D_V = 8\mathbf{G}/0.88d = \frac{9\mathbf{G}}{d}$$

where ΔD_V is the density difference necessary for visual detection.

Since the granularity of the film varies as a function of density level, the value of **G** had to be recomputed for the three density levels that were used in this analysis (see Table 5-1).

The following is a sample calculation for a single point, including the assumptions that were made to determine this point, in Fig. 5-2.

A spot diameter of 8 microns covers an image area (scale of 240,000:1) of 10 feet on the ground. From Table 5-1, 9**G** is 7.5 at the base and fog density level.

$$\Delta D_V = 9\mathbf{G}/d = 7.5/8 = 0.94$$

Adding this density range to the fog level

$$0.94 + 0.24 = 1.1$$

Table 5-1 — Initial Granularity Data at Three Density Levels

Background Density	σ_D	G	9G
0.24	0.04	0.84	7.5
0.50	0.07	1.48	13.3
1.00	0.12	2.54	24.0

Interpolating from the characteristic curve, Fig. 5-1, this density is produced by an exposure of 0.007 meter-candle-second. Since this image was made at 1/50-second exposure time, there was $(0.007) \cdot (50) = 0.35$ meter-candle incident upon the film. This light came from a ground object whose illumination was reduced by the factor $T/4(f/no.)^2$ when photographed.

With a nominal lens transmittance, T, of 0.90 and an f/no. of f/3.5, this ground illumination was reduced by a factor of 55×. Therefore, the ground illumination was $(0.35 \text{ mc}) \cdot (55) =$ 19.2 meter-candles, or dividing by 10.76, 1.8 foot-lamberts. Since the photography was made at night, it is assumed that there was no additional haze light, but there were losses from the transmittance of the atmosphere. Assuming the atmosphere transmitted 80 percent, then the ground illumination must have been greater than 1.8 foot-lamberts by the reciprocal of 80 percent, or 2.4 foot-lamberts.

Thus, a 10-foot diameter area on the ground could be visually detected above the background fog level if it acted as a luminous source emitting 2.4 foot-lamberts. This procedure was carried out for other aperture sizes and at a background density level of 0.5 and 1.0. The sizes that could be calculated ranged from 7½ to 375 feet, since this is the equivalent ground size over which Selwyn's law holds. The graph of Fig. 5-2 illustrates the detectable curves for these three background sizes.

Detection means, in this context, the ability to see something. It does not mean that ground detail can be seen and accurately interpreted. It does, however, indicate the amount of light necessary to detect large areas (in comparison to pinpoints of light). These large areas would in all probability be related to an area of activity such as a baseball field or the concrete around a missile launch pad. Objects below the threshold of resolution will still be visible, though only as spots of light about the same size as the spread function for the system.

In order to obtain an estimate of the resolution of the system, the system MTF was determined by scanning an edge and computing the Fourier transform of the spread function of exposure within the emulsion. By dividing the system MTF by the MTF of the film, and crossing this curve with the AIM curves, a resolution of 27 lines per millimeter was obtained. This is only an approximate value since the MTF and AIM curves used were for an older version of the Tri-X emulsion. Fig. 5-3 shows the MTF's and the predicted resolution.

At these scales, this converts into a ground resolution of 46 feet in the J-3 system. Since resolution is measured as a bar and a space, a bar of approximately 23 feet could be resolved. Although this is only a rough approximation to real objects, it does put a region on the detectability graph of objects that cannot be resolved. The object detection curve, though, indicates that smaller detail can be seen. This is not a contradiction since there is a distinct difference between the objects that can be detected (i.e., as small as the spread function of the system) and objects that can be seen and identified by the size or the detail within them.

As far as the application of Fig. 5-2 to future J-3 flights, two factors must be known about the target areas: (1) how big they are, and (2) how bright they are.

From the sensitometric analysis of Section 4, the brightness of several areas at the main missile launch complex were determined. Since the illumination is at different levels for various portions of the target, several measurements were made and are shown summarized in Table 5-2.

The two larger areas (A and B) would be both bright enough and large enough to be visually detected against the background fog level. They are also larger than the ground resolution limit and therefore not only will they be detectable, but they will be large enough so that some detail

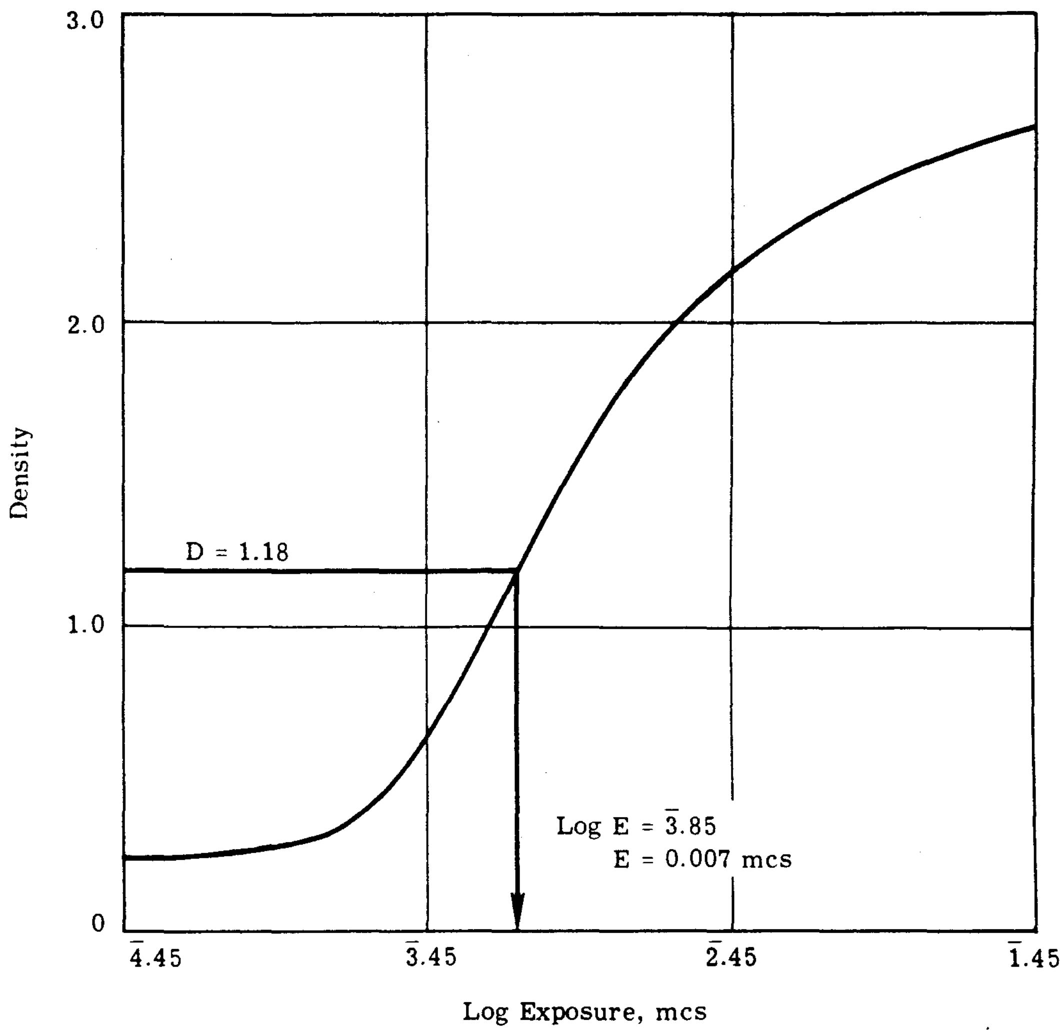

Fig. 5-1 — Characteristic curve for processing condition of SO-340 used at night

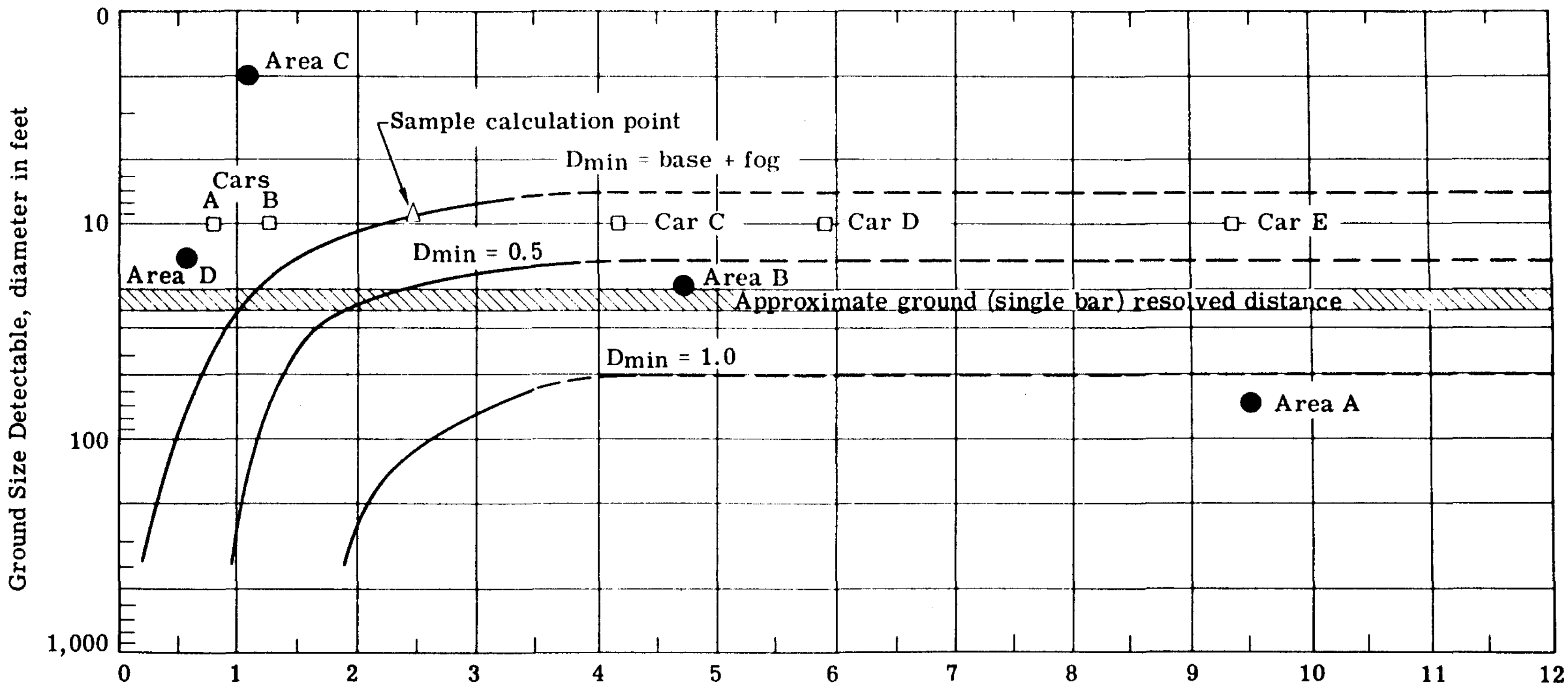

Fig. 5-2 — Ground object size versus illumination necessary at three background detection levels

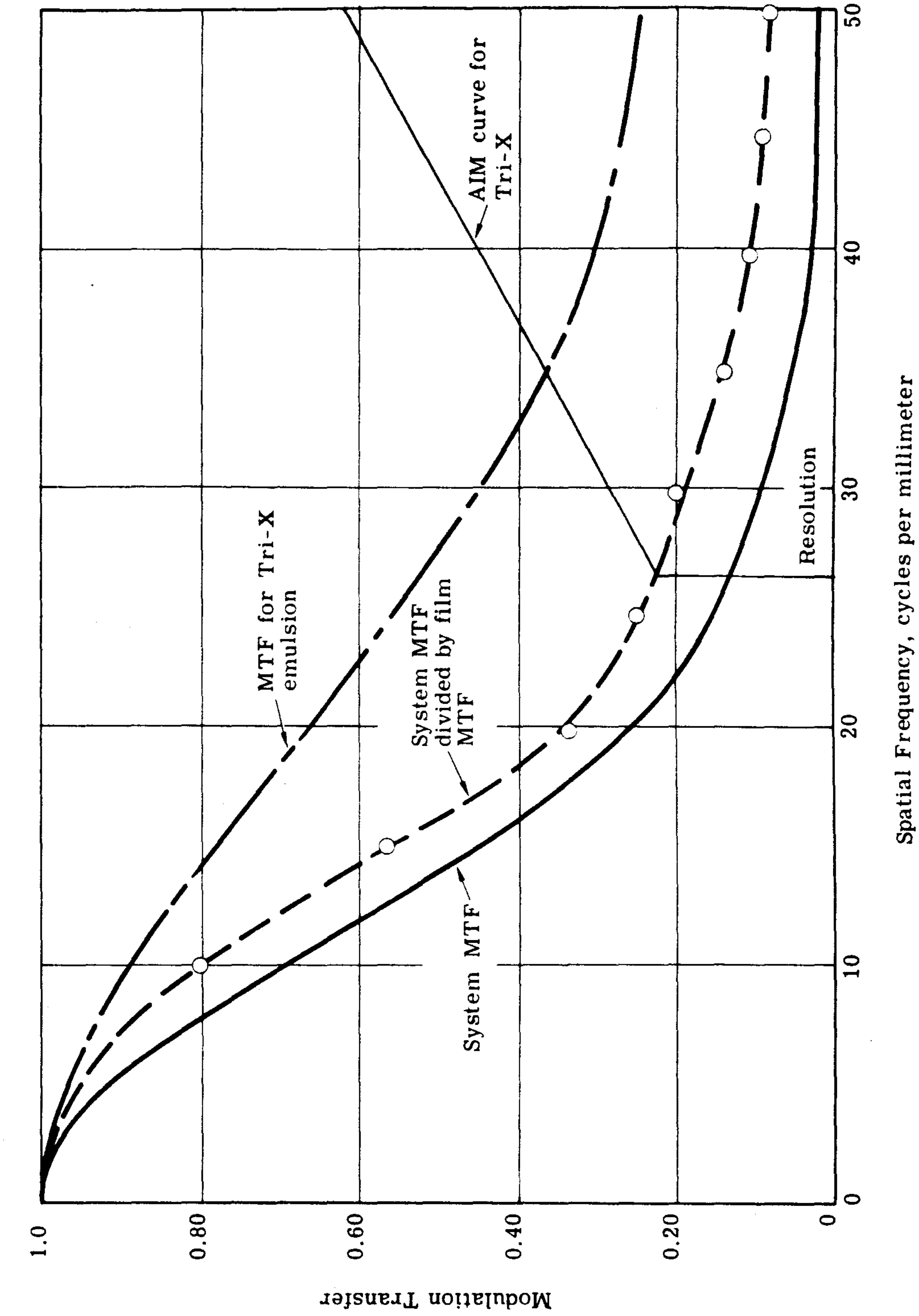

Fig. 5-3 — System MTF and predicted resolution

Table 5-2 — Summary of Approximate Size and Illumination at Main Launch Facility at Vandenburg AFB (see Fig. 3-1)

Area	Description	Approximate Size, diameter in feet	Approximate Ground Reflected Luminance, foot-lamberts
A	Well illuminated area at base of launch ramp	50	9.6
B	Reservoir and adjacent service area	20	4.8
C	Lights on the gantry	2	1.2
D	Poorly lit deck area	15	0.61

will be seen. How much detail, though, is beyond the capability of this analysis to determine. The second two areas, though, are not bright enough or big enough to be detected from the J-3 satellite system. Since area C are lights on the gantry, this would indicate that they will not be able to be used as guides as to where the gantry is. However, since the rather large concrete area is well beyond the detection threshold, perhaps the shadow will be a guide to the gantry's location.

The lower curve in Fig. 5-2 should be for detail detection against a clear base and fog background. If the background has a higher density, the upper two curves (D = 0.5 and D = 1.0) must be used. In these cases, the area must be larger and the illumination higher (or both) for visual detection. One reason for a high background density might be from fog or static marks. These will be discussed in the next section.

5.2 STATIC AND FOG

The second problem that will be present in using a high speed emulsion in the J-3 system is the excess fogging from light leaks and static marks.

The photointerpreter's analysis indicated that, although static was a bothersome problem, it did not interfere with his work. This conclusion must be viewed in a different light when applied to the J-3 system. First of all, the targets that he selected had no serious static marks, whereas in the J-3 system the targets of concern may fall in a static or fog region by chance. The analysis in Section 5 has shown that with $7\frac{1}{2}\times$ reduction in scale, larger or brighter areas must be available for detection, particularly at the higher background density levels.

The static and fog encountered on these missions occurred in a systematic pattern. The image area in the vicinity of a startup frame was almost always entirely free of static. However, there were more fog streaks across the film in this region than in imagery from continuous camera operation. There was also a burst of static at the end of the nonstatic marked areas. A constant static pattern ran through the center of most of the imagery; however, this was not present in the region of noncamera operation. The following conclusions are drawn from these findings:

1. Static and light leaks have probably always been present, but the slow speed of type 3404 did not record it.

2. The region of the film that was left in the camera (not on either film spool) had a chance to dry out during noncamera operation, thus lowering the static marks in that area that were caused by the puck arm on the takeup spool.

3. The light fog marks were also associated with this noncamera operation period in that the film remained long enough in one portion of the camera to record the light leaks.

4. The exposure static markings were formed from the film coming off of the supply spool during camera startup, which is probably more violent a motion than during normal camera continuous operation.

The implication of these findings are that some problems may occur when high speed emulsions are used in the J-3 system. Prolonged exposure from solar energy during a noncamera operating period may cause more fogging from small light leaks. The pressure in the camera bay in the aircraft was approximately 4.5 pounds per square inch, whereas it will be considerably less in the satellite system. The lower atmospheric pressure will probably cause a higher amount of static. The old problem of corona discharge may reappear again.

The sensitometric analysis indicates that a higher speed emulsion at a lower gamma would be preferable to the speed and contrast conditions that existed in the EKIT test. An atmospheric chamber test could be made with type SO-340 or any other higher speed emulsion that may be used in J-3. The puck arm on the takeup spool might also be able to be adjusted so that static from this region is reduced. These chamber tests should be designed to (1) see how serious the static and corona discharges will be, (2) to find the few remaining light leaks, and (3) to adjust the puck arm for less static.

6. CONCLUSIONS

This EKIT test allows several conclusions that are applicable to the J-3 system when used as a night detector of activity to be drawn.

1. High speed black and white coverage at night has a potential for broadening the scope of photointerpretation of strategically important targets.

2. Comparable day coverage (preferably in the same portion of the format) is desirable for locating and identifying specific targets. Even if the precise location is known by calculated methods, the day coverage is still necessary in order to interpret the minute details of the image.

3. Viewing techniques such as stereo with the day and night imagery are very useful for locating specific areas and understanding sources of illumination. Viewing the day positive with the negative night coverage superimposed on top is also a useful technique. These techniques must be used with the materials on the viewing table since multiple printing of negatives from day and night coverage is not very effective. The technique utilizing slight movements in one of the negatives on the light table is also useful for identification of sources of illumination. This cannot be done when a multiple print is made.

4. The panoramic distortions in the photography made comparisons of day and night photography difficult if the images were not in the same format position. This became less of a problem as smaller and smaller areas were studied. The main problem came from locating images in one area, while targets 5 or 10 inches away could be displaced by 1/2 inch due to the differences in distortions across the format.

5. With the lack of haze light and nature of the targets (intense lighting to black areas), the dynamic range of the SO-340 was not sufficient to record all of the information that was available. In addition, the entire density range of the negative material was used. This meant that dual exposure level prints were necessary in order to use the information on the negative. It is suggested that a film processing study be undertaken before J-3 night missions are flown in order to improve the sensitometric characteristic of the film for this application. Another suggestion is that a low gamma developer be formulated. This would alleviate the problem of the large dynamic range on the negative and to some extent lengthen the usable log E range of the negative material.

6. The overriding characteristic of an emulsion used at night is its speed. Though there must be adequate resolution, without speed there is no image. This means that the relatively slow speed types SO-180 and SO-121 have only a very limited value.

7. The principal target, an illuminated missile launch complex, was detected on the night photography. Calculation based on the signal-to-noise ratios involved indicate that it will also be detectable on the satellite photography. The identification detail within the complex itself will,

however, be quite limited. Night activity such as that at Vandenburg will be detectable. Objects as small as cars will be detected if they reflect more than 2.4 foot-lamberts. However, cars are smaller than the resolution limit and will show as points of light. Their location (i.e., in a parking lot) may indicate that they are cars, and, if they are illuminated sufficiently the photo-interpreter should be able to count them.

8. Static and fog may be a problem, particularly for long missions at the low atmospheric pressures of orbital altitudes. Some modifications on the camera (e.g., less tension on the puck arm of the takeup spool) may eliminate some of the static. Chamber tests are recommended before a night flight is made with these high speed emulsions in order to properly assess the magnitude of static, corona discharge, and fog.

Appendix

NIGHT DETECTION PHOTOGRAPHY EXHIBITS

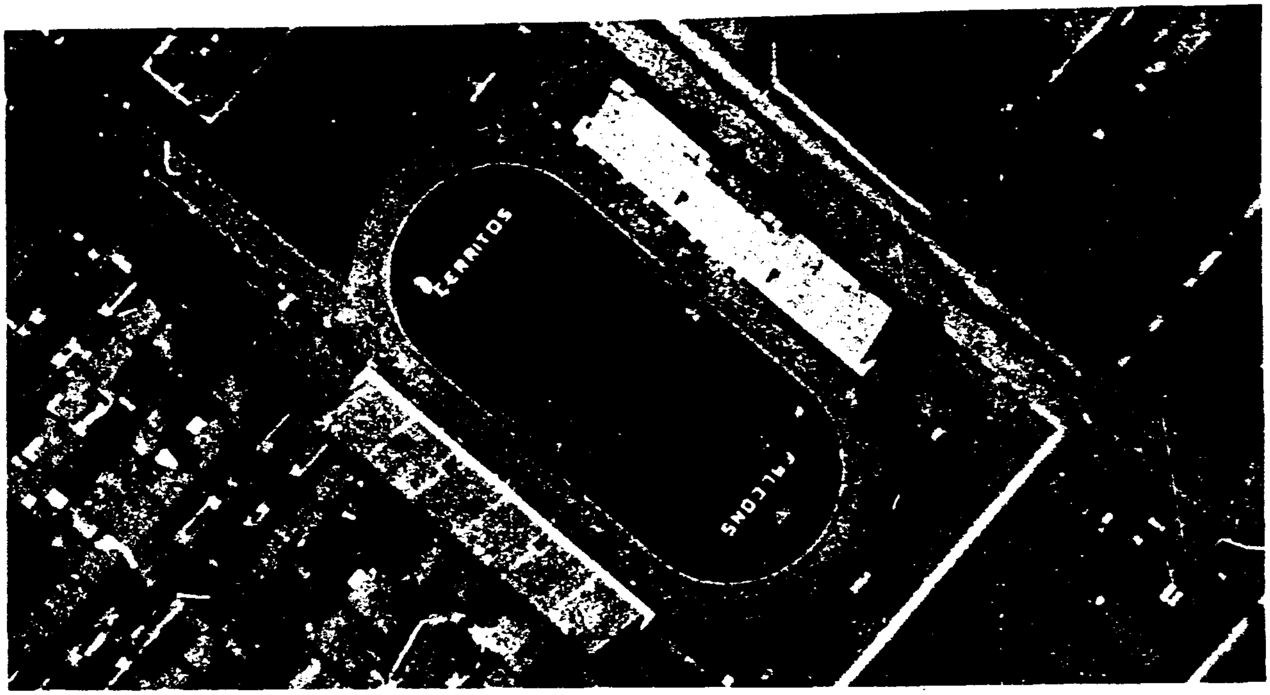

Fig. A-1(a) — Athletic field; day, 3404 film, 16× enlargement

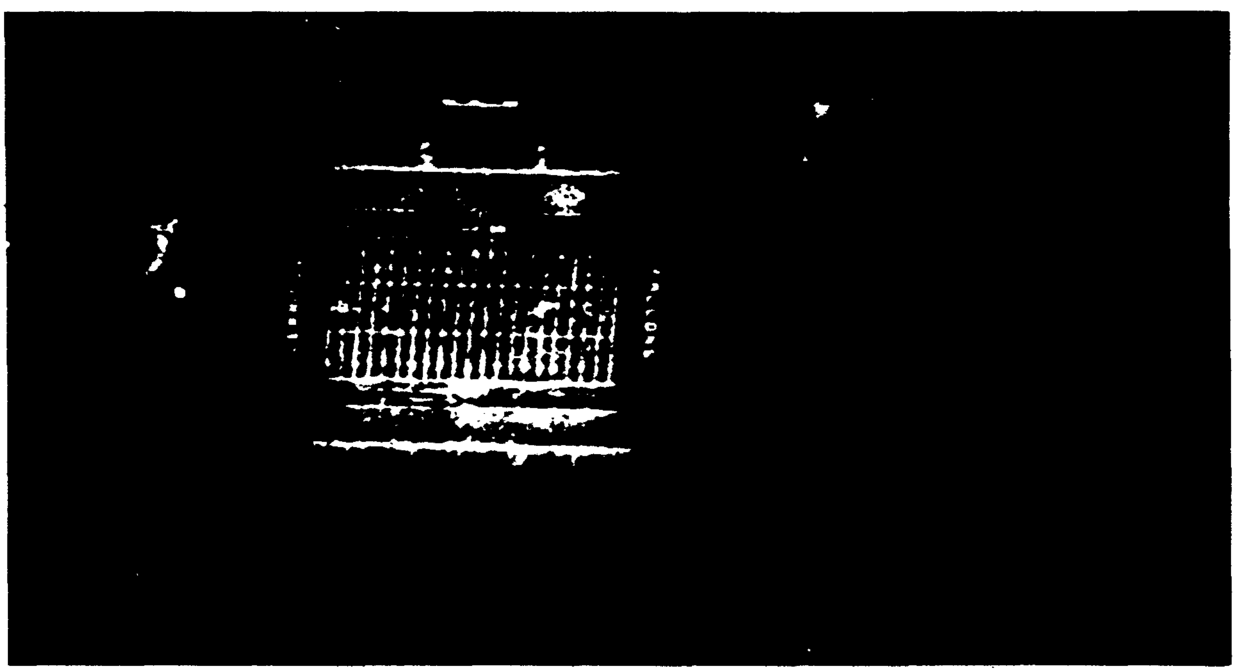

Fig. A-1(b) — Athletic field; night, SO-340 film, 16× enlargement

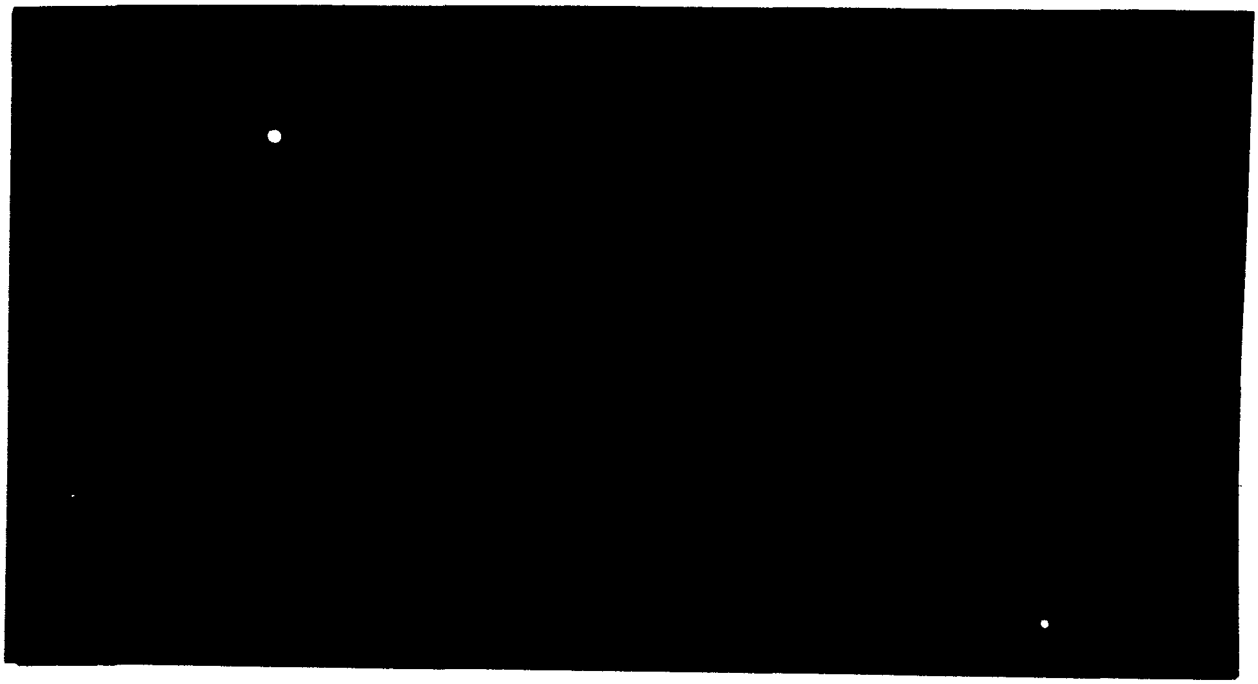

Fig. A-1(c) — Athletic field; night, SO-180 film, 16× enlargement

Fig. A-2(a) — Ball game; day, 3404 film, 14× enlargement

Fig. A-2(b) — Ball game; night, SO-340 film, 14× enlargement

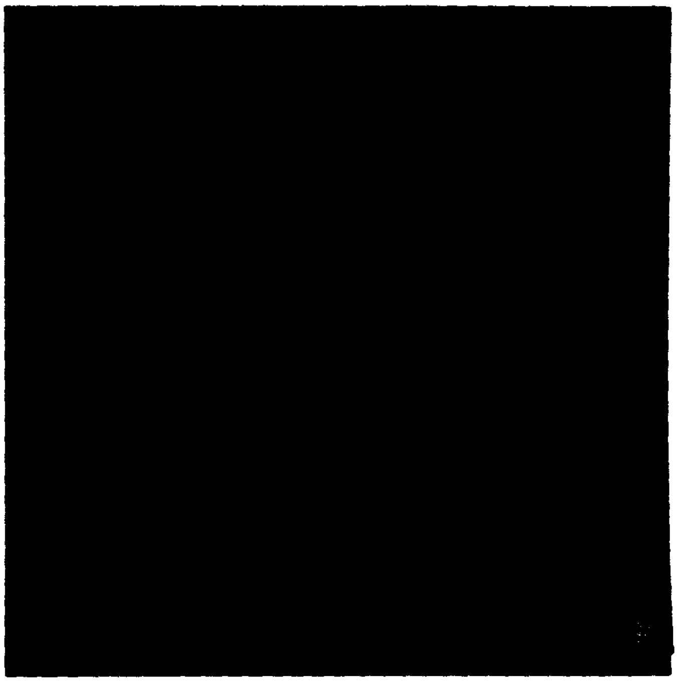

Fig. A-2(c) — Ball game; night, SO-180 film, 14× enlargement

Fig. A-3(a) — Chavez Ravine; day, 3404 film, 3.5× enlargement

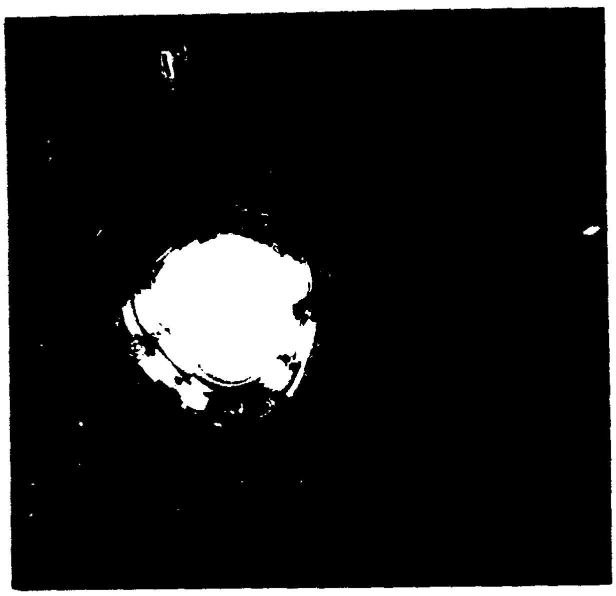

Fig. A-3(b) — Chavez Ravine; night SO-340 film, 3.5× enlargement

Fig. A-3(c) — Chavez Ravine; night, SO-340 film, 3.5× enlargement

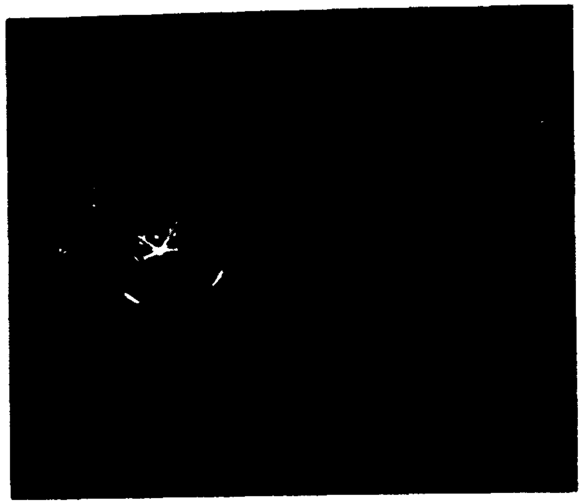

Fig. A-3(d) — Chavez Ravine; night, SO-180 film, 3.5× enlargement

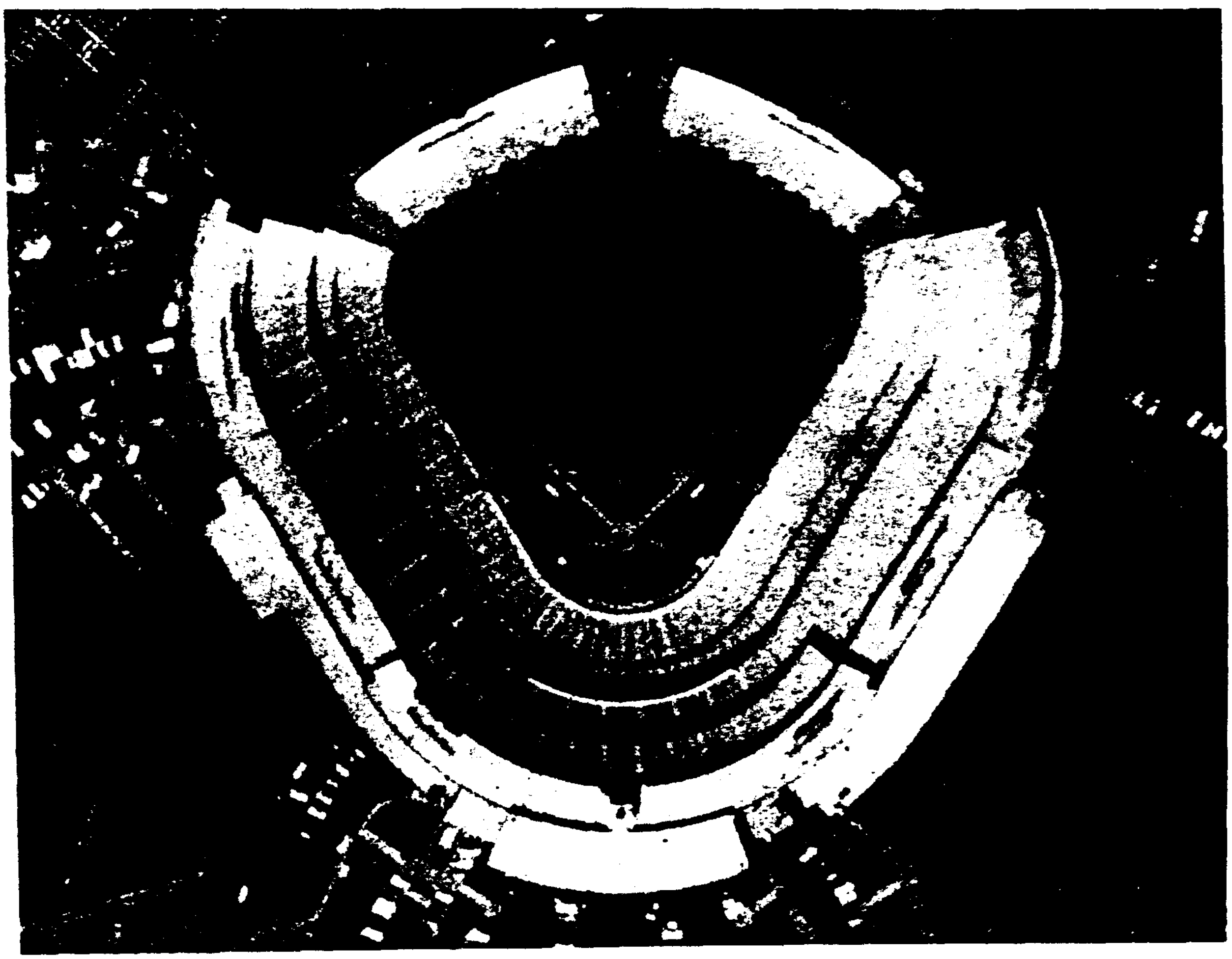

Fig. A-3(e) — Chavez Ravine; day, SO-121 film, 17× enlargement

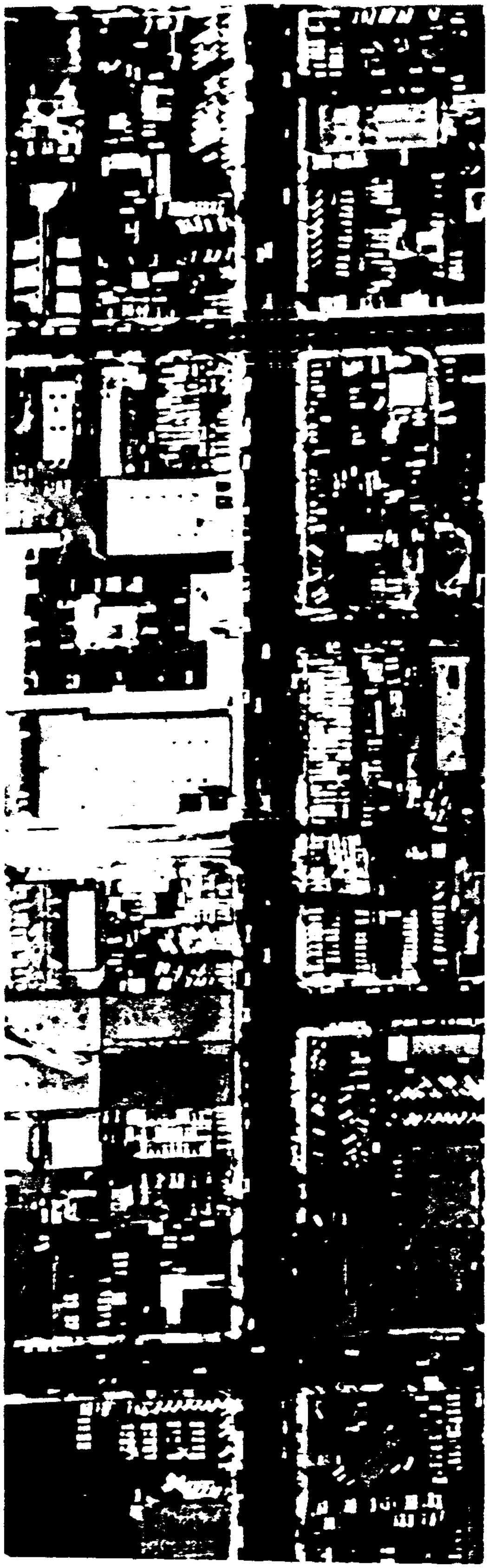

Fig. A-4(a) — Parking lots; day, 3404 film, 14× enlargement

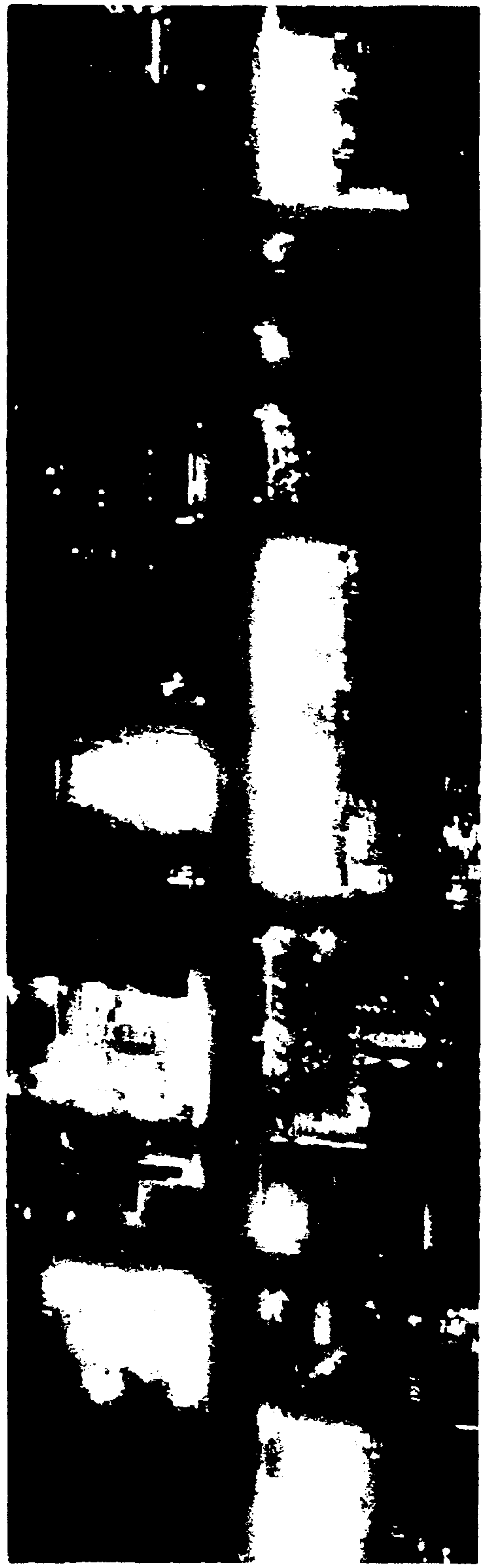

Fig. A-4(b) — Parking lots; night, SO-340 film, 14× enlargement

Fig. A-4(c) — Parking lots; night, SO-340 film, 14× enlargement

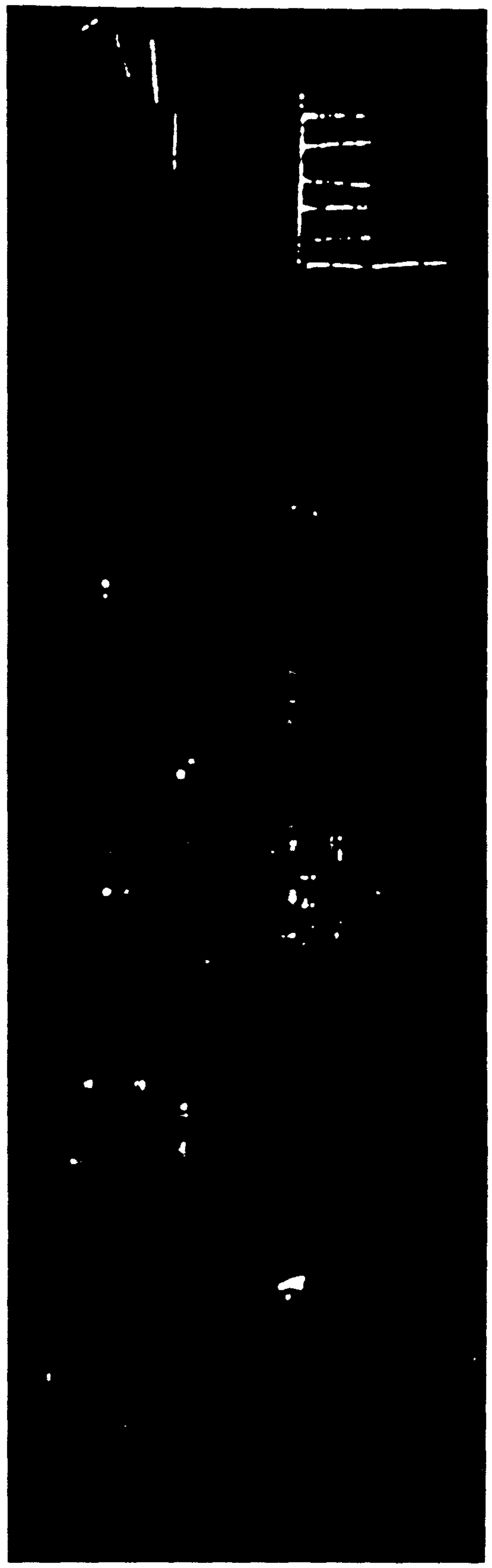

Fig. A-4(d) — Parking lots; night, SO-180 film, 14× enlargement

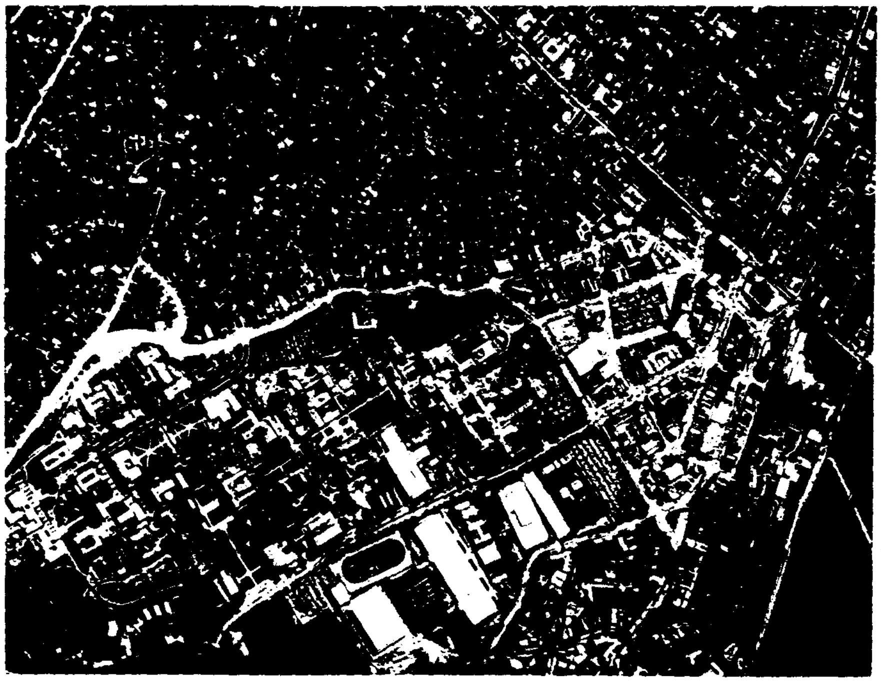

Fig. A-5(a) — Urban area; day, 3404 film, 2× enlargement

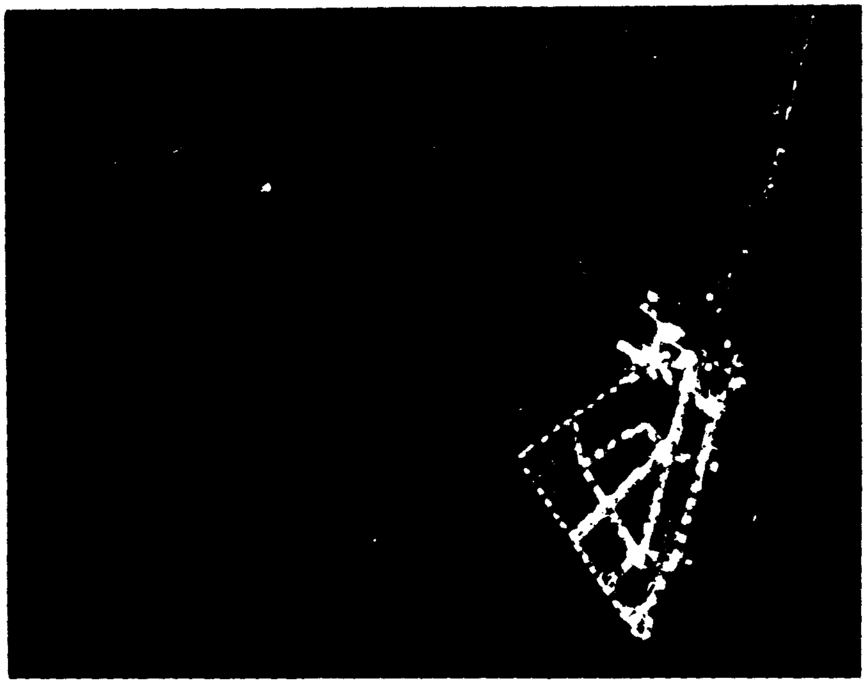

Fig. A-5(b) — Urban area; night, SO-340 film. 2× enlargement

Fig. A-5(c) — Urban area; night, SO-180 film, 2× enlargement

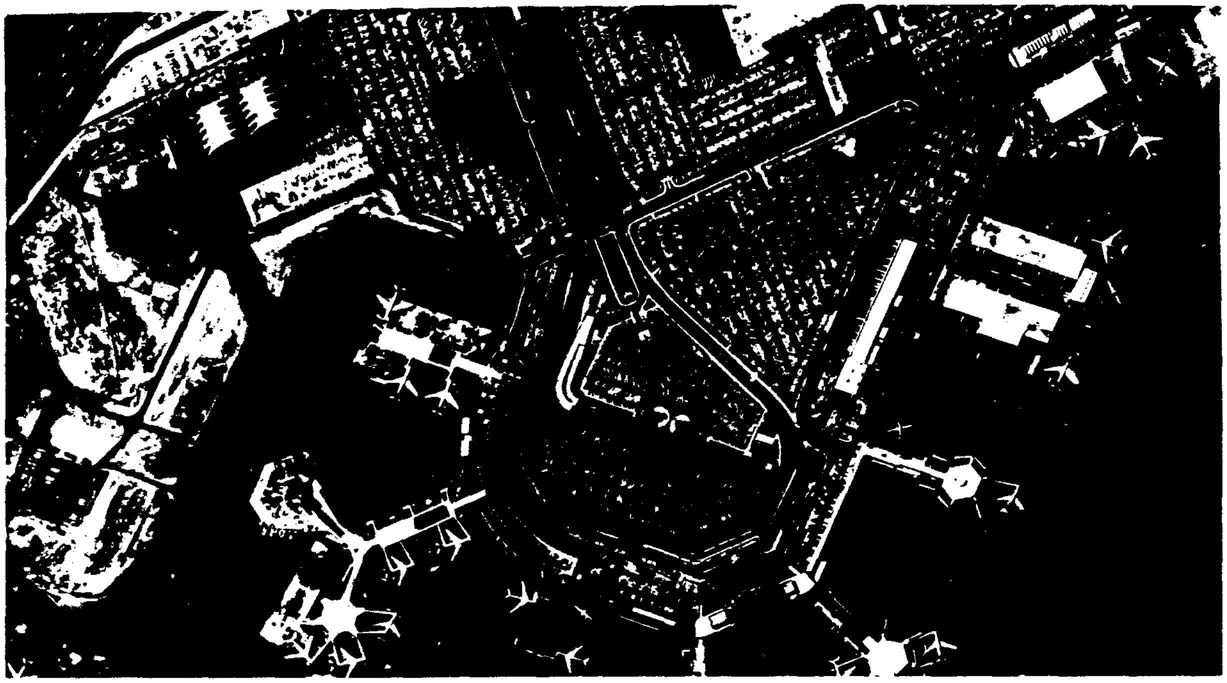

Fig. A-6(a) — San Francisco airport; day, 3404 film, 5× enlargement

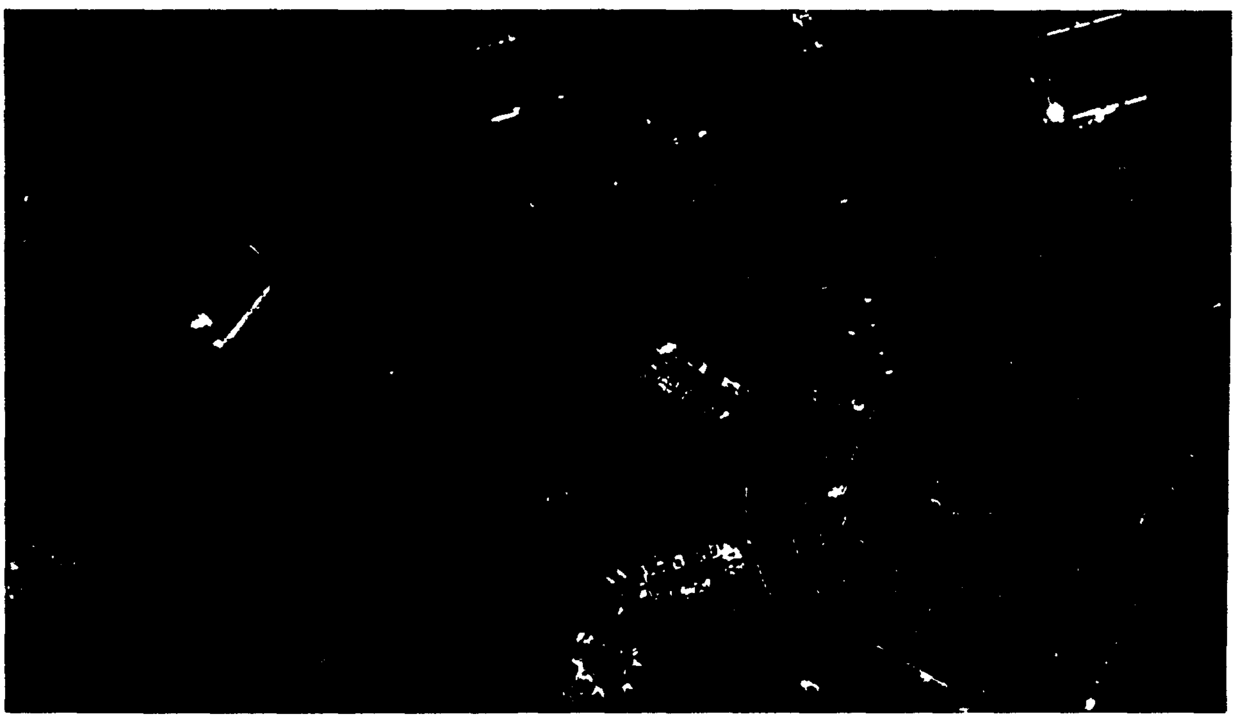

Fig. A-6(b) — San Francisco airport; night, SO-340 film, 5× enlargement

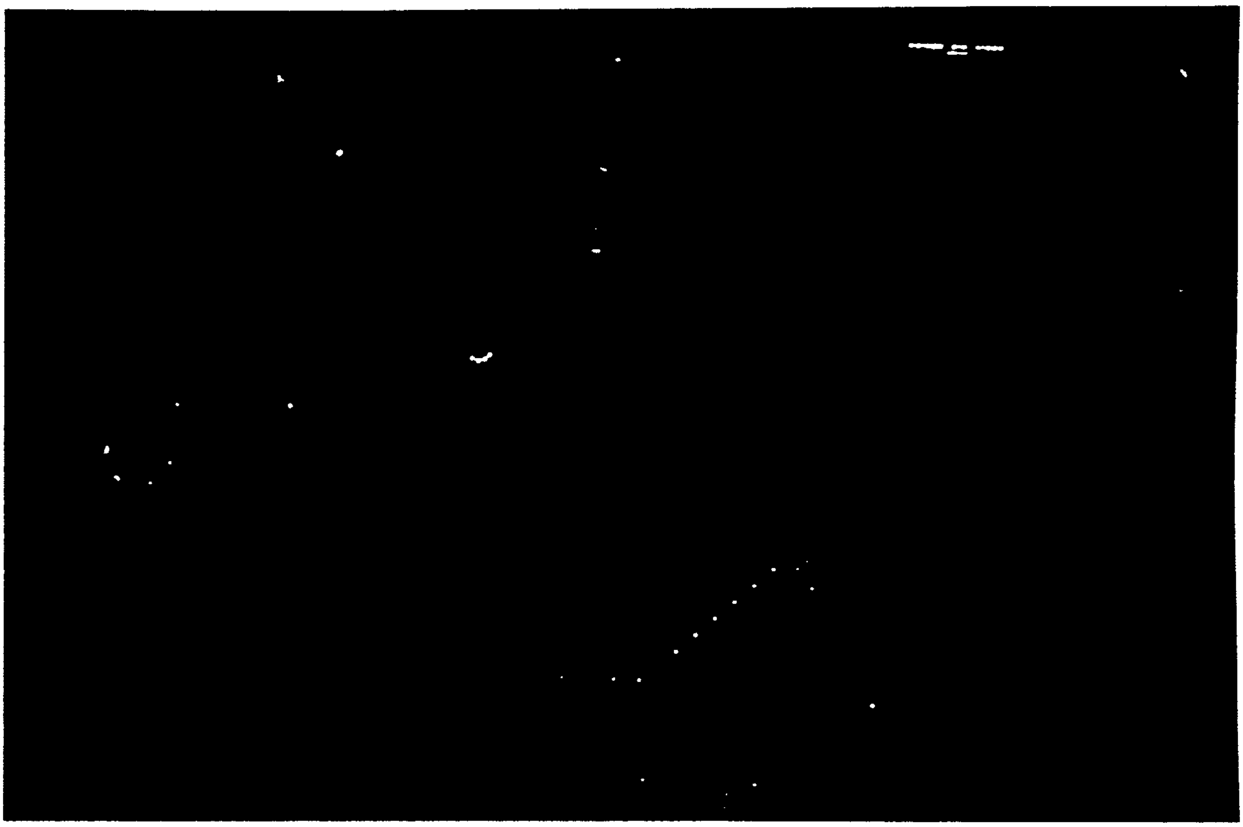

Fig. A-6(c) — San Francisco airport; night, SO-180 film, 5× enlargement

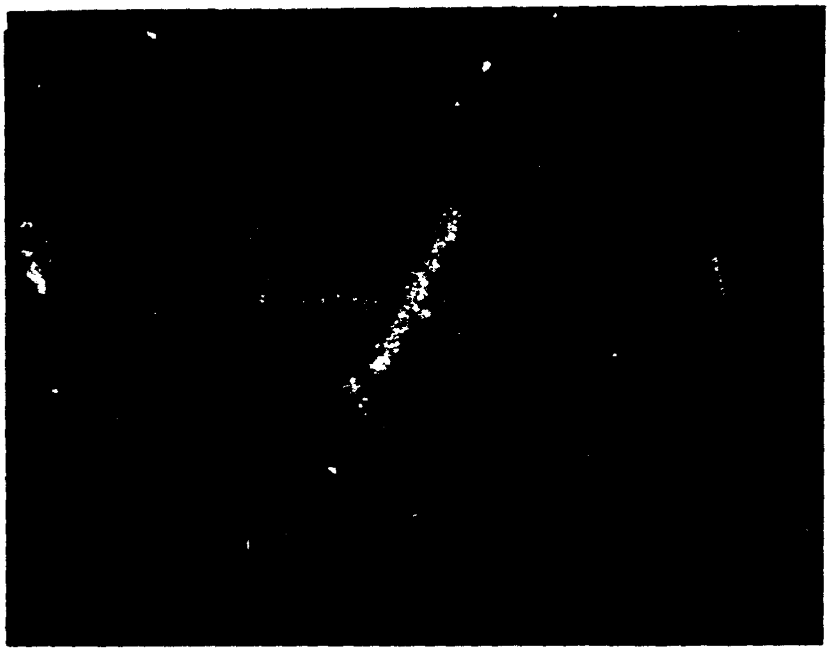

Fig. A-7(a) — Douglas aircraft; day, 3404 film, 45× enlargement

Fig. A-7(b) — Douglas aircraft; night, SO-340 film, 45× enlargement

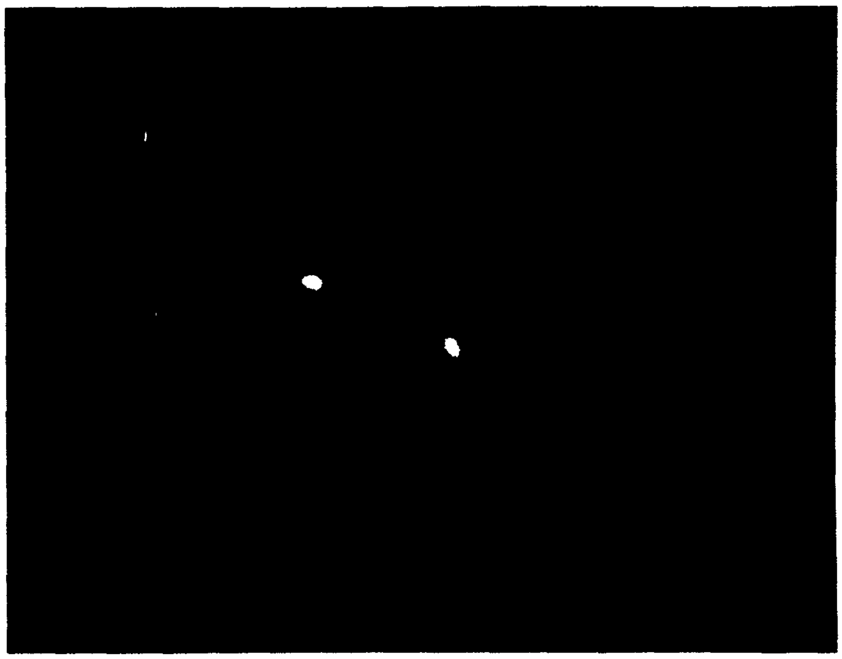

Fig. A-7(c) — Douglas aircraft; night, SO-180 film, 45× enlargement

Fig. A-8(a) — Mare Island shipyard—submarines; day, 3404 film, 7× enlargement

Fig. A-8(b) — Mare Island shipyard—submarines; night, SO-340 film, 7× enlargement

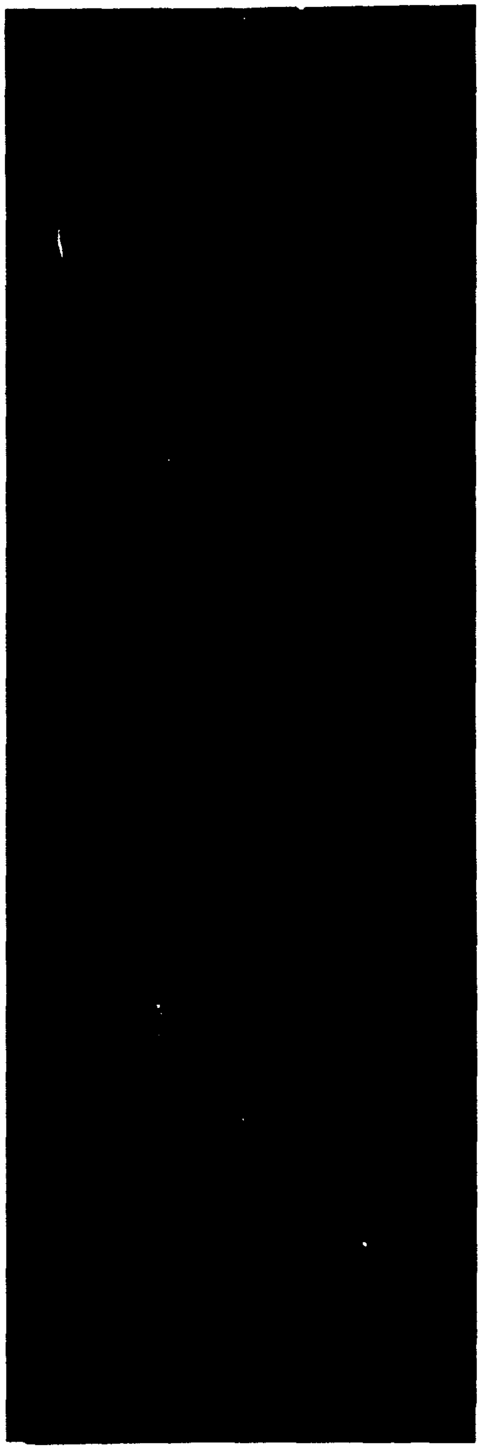

Fig. A-8(c) — Mare Island shipyard—submarines; night, SO-180 film, 7× enlargement

Fig. A-9(a) — City, day; 3404 film, contact print

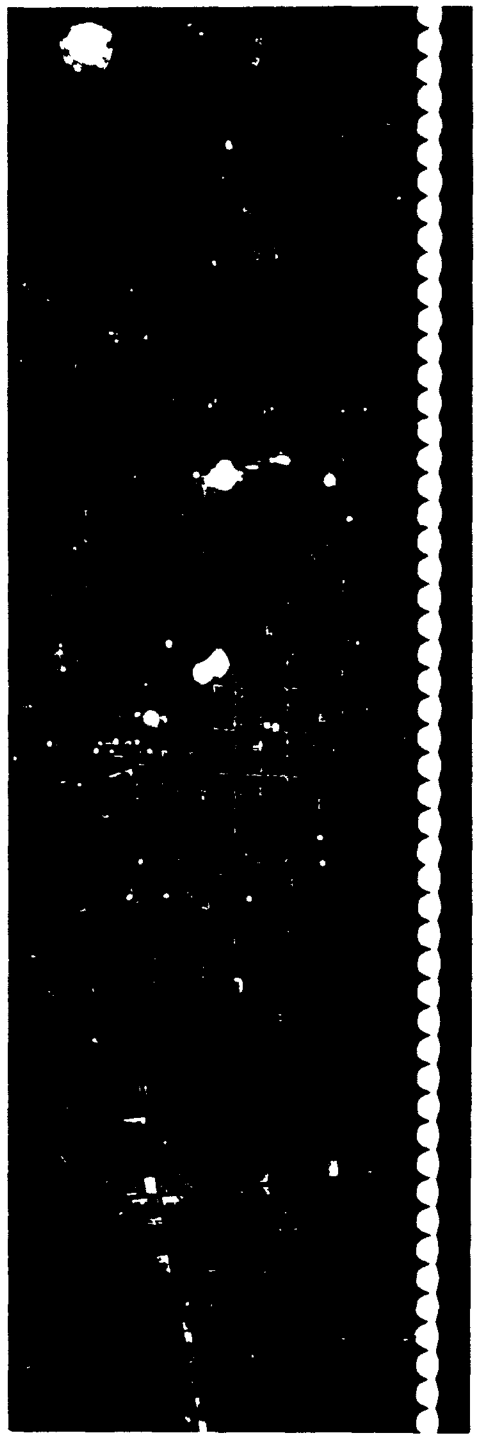

Fig. A-9(b) — City, night; SO-340 film, contact print

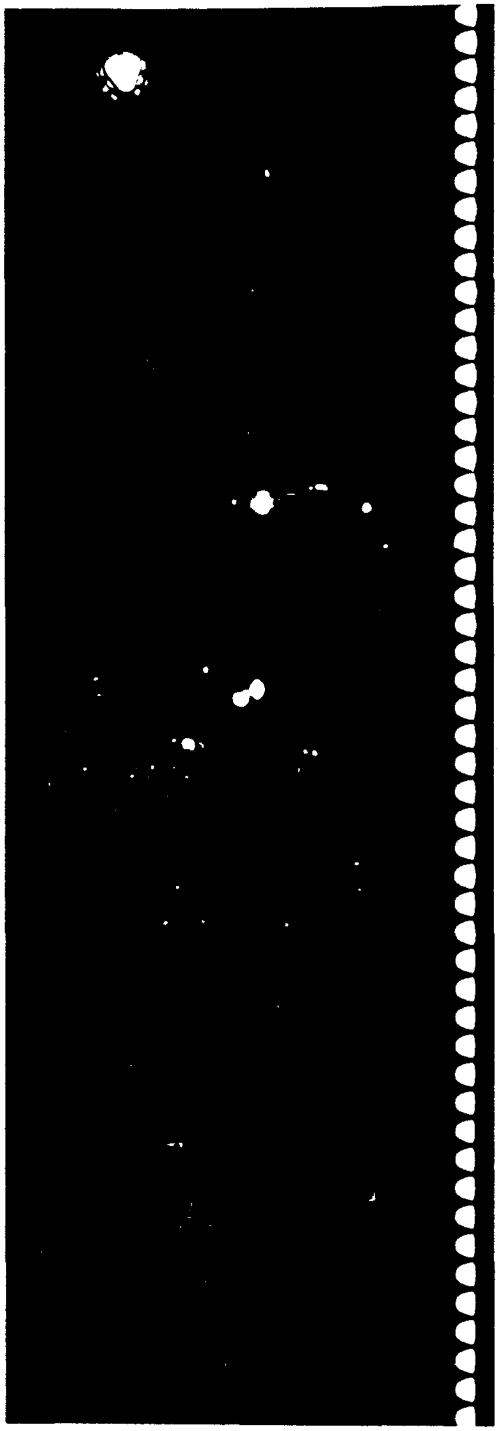

Fig. A-9(c) — City, night; SO-340 film, contact print

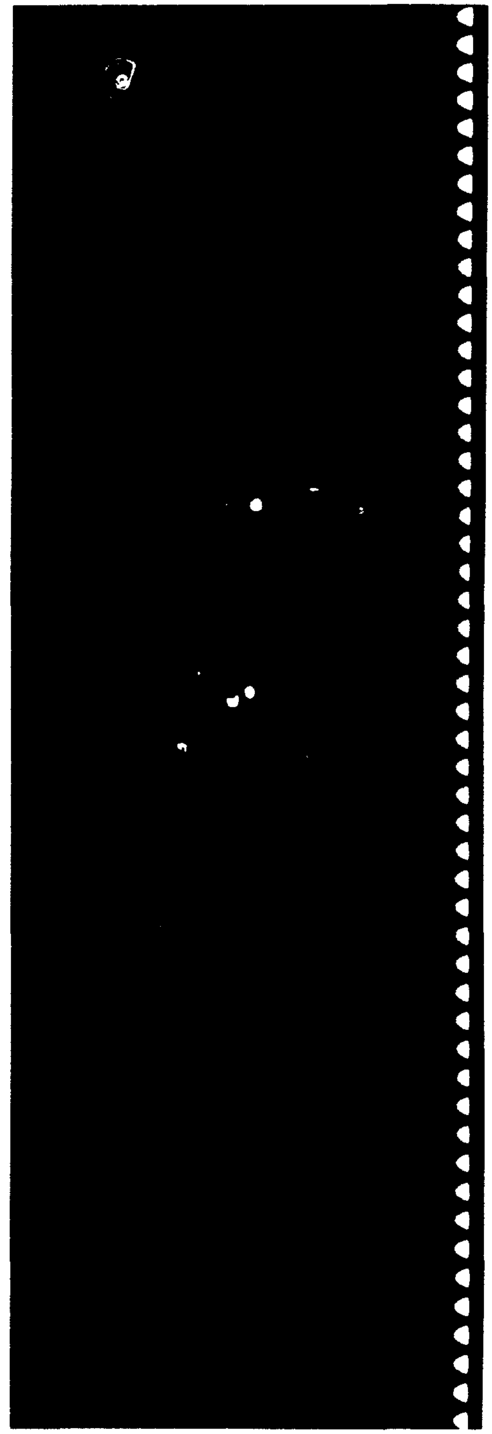

Fig. A-9(d) — City, night; SO-340 film, contact print

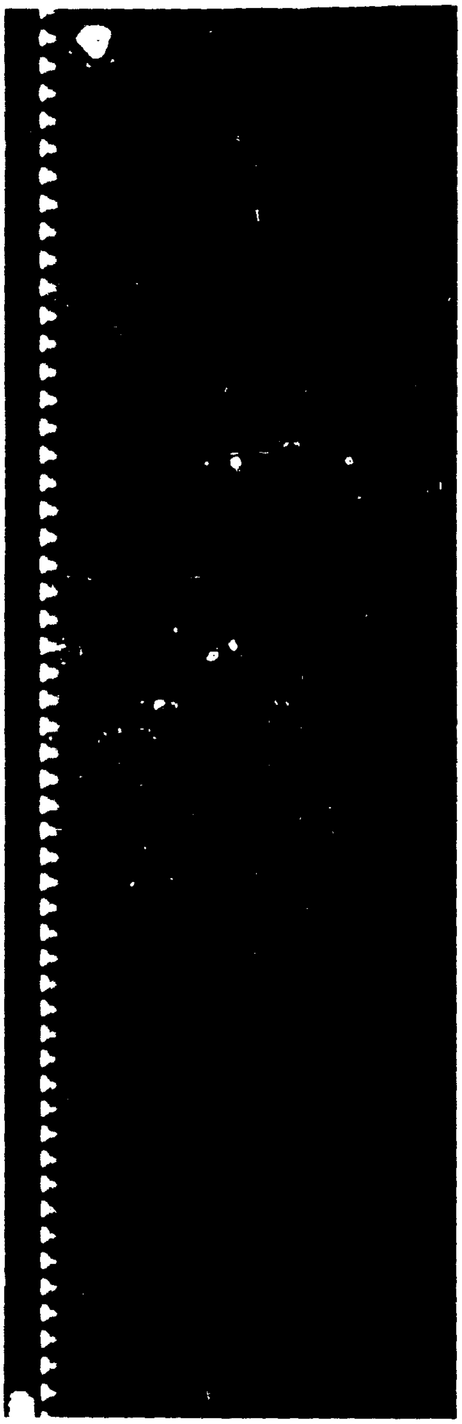

Fig. A-9(e) — City, night; SO-180 film, contact print

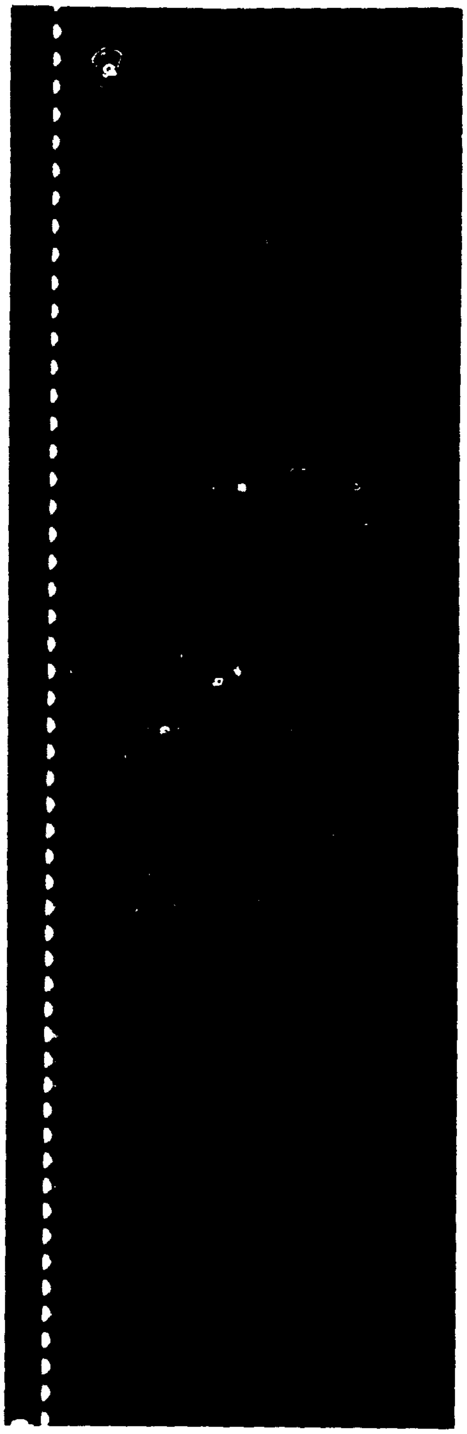

Fig. A-9(f) — City, night; SO-180 film, contact print

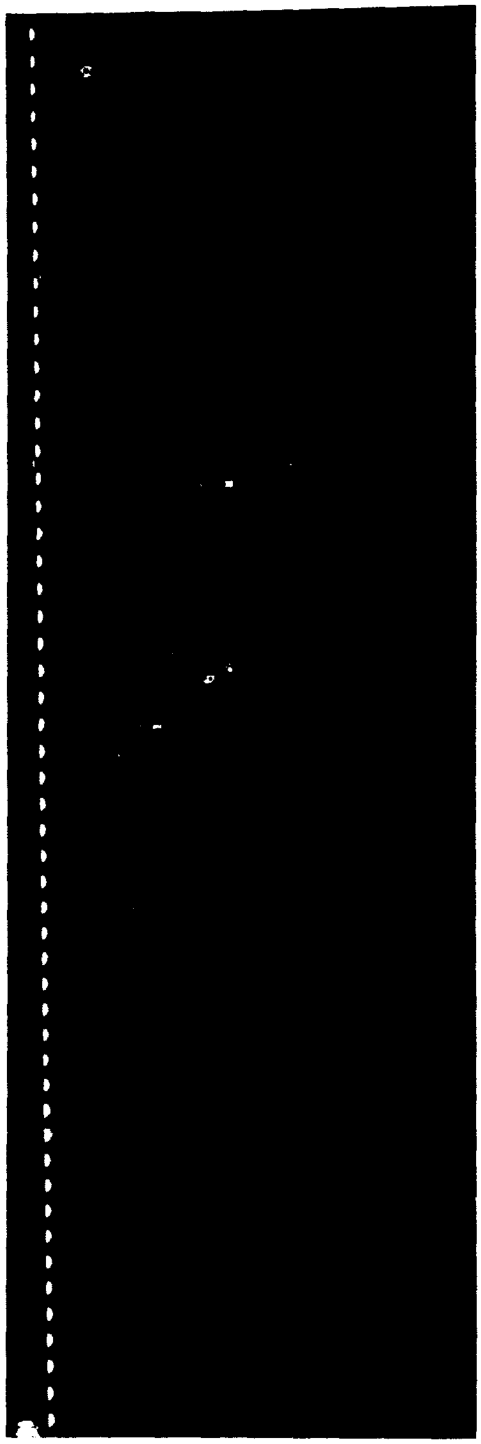

Fig. A-9(g) — City, night; SO-180 film, contact print