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# *Feasibility Research on a System to Provide High Resolution Photography Over Denied Areas*

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# Feasibility Research on a System to Provide High Resolution Photography Over Denied Areas

A Research Study

By

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APPROVED:

[redacted]

Chief, Operations Technology Division, ORD

April 1978

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# APPENDIX A TABLES

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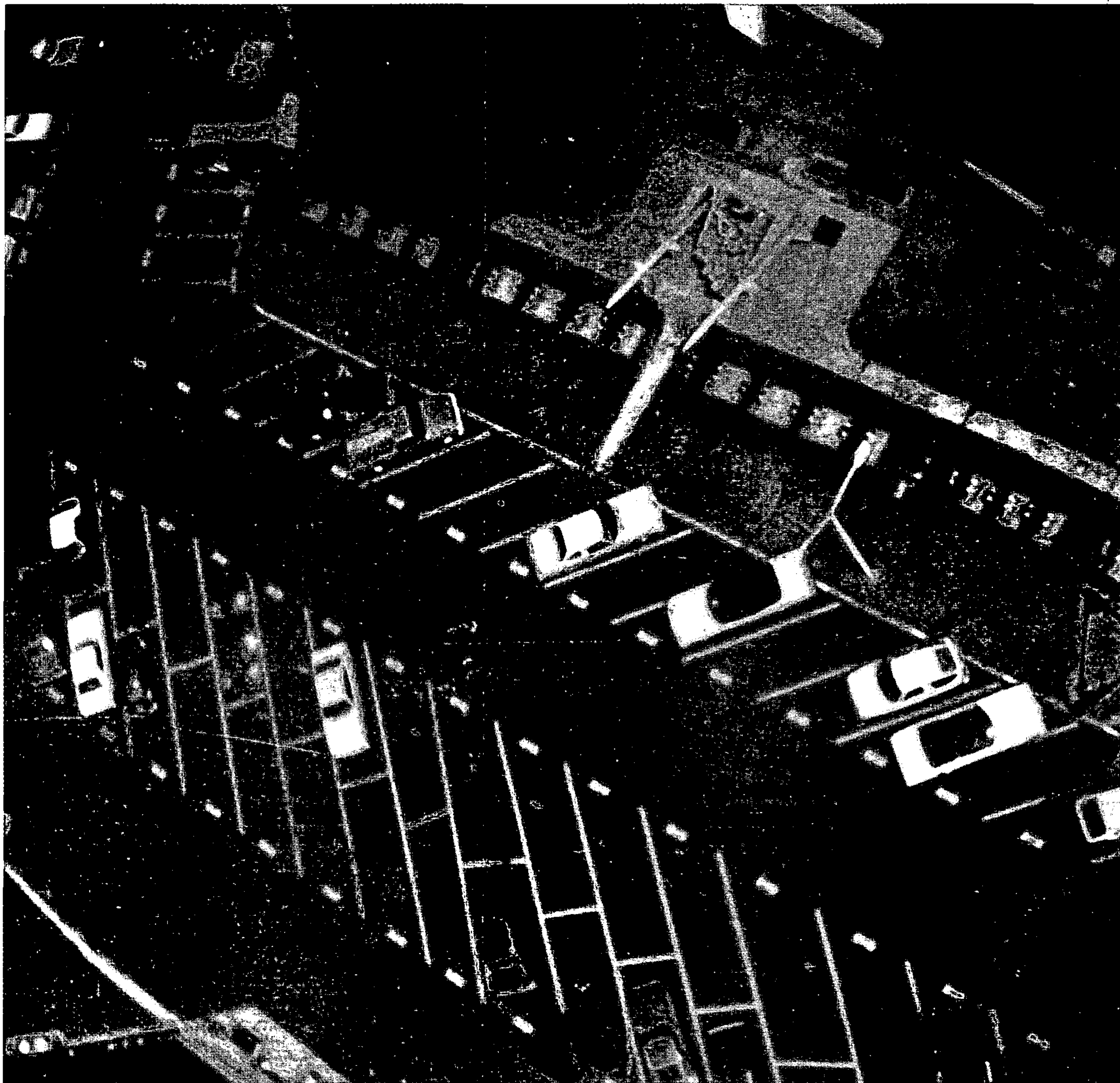

2445 Color of Museum Park

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# FEASIBILITY RESEARCH ON A SYSTEM TO PROVIDE HIGH RESOLUTION PHOTOGRAPHY OVER DENIED AREAS

## ABSTRACT

(TS) Research was conducted on a system (Tacana) which may provide high-resolution photography over denied areas by the use of homing pigeons. The pigeons receive no specialized training; they fly from the release point across the target to the home loft (e.g., [redacted] etc.). An adjustable timer in the camera starts the photographic coverage over the target and lasts for about four minutes (150-220 pictures). Each picture covers an area on the ground about 90 feet square. The research was directed toward photographic coverage of denied areas where direct overflight is possible. Coverage of the Soviet Nuclear A-class submarine work at the shipyards in Leningrad was considered as an example high-priority target. Two simulated targets (Andrews AFB and the Washington Navy Yard) were chosen to provide data on system performance, including in-flight photography. The photographic analysis was performed by NPIC and compared with overhead satellite photography and the specific intelligence requirement in the Leningrad area. It is concluded that there is a good probability that homing pigeons can be used to satisfy the high-resolution photographic requirement in the Leningrad area. A 16mm silent film is available showing various aspects of this program. High resolution prints of the Avian Photography are available under separate cover as a supplement to this report.

## ACKNOWLEDGMENTS

(C) The National Photographic Interpretation Center (NPIC) provided all photographic development and analysis. This was coordinated through [redacted] (ISB/ APSD/TSG) who also directed the photographic experiments and recommended the type film and film development best suited for this particular system.

(TS) Acknowledgment is also extended to the Deputy Director for Intelligence (DDI), whose offices (OIA and OWI) provided data associated with the Agency's high-resolution photographic require-

ment in the Leningrad area. The DDI was also instrumental in arranging the temporary reassignment of [redacted] (an avid homing pigeon enthusiast) from the Office of Strategic Research to the Office of Research and Development. [redacted] was responsible for the selection of loft keepers in Oregon, Alaska, and Virginia and directed the relocation experiments. He was also responsible for collecting the photographic data over the two simulated targets (Andrews AFB and the Washington Navy Yard) which included all aspects of operation, maintenance, and field repair of the avian cameras.

# PART 1
# INTRODUCTION

(TS) The idea of using birds for emplacement and photographic coverage has been explored by the Agency for several years. These studies invariably required some form of specialized training which required the birds to respond in a desired, predictable way to a specific recognized object. The purpose of this research is to investigate the collection of high-resolution photography by the use of homing pigeons which receive no special training other than learning to carry a small avian camera. The pigeons fly from the release point across the target to the home loft [redacted] An adjustable timer in the camera starts the photographic coverage over the target and lasts for about four minutes (150-220 pictures). Each picture covers an area of about 90 feet square from an altitude of 100 feet and has a resolution on the order of one inch (see Appendix A: Evaluation of Photographic Coverage).

(TS) Though this research applies to any target where direct overflight is possible, photographic coverage of the Soviet Nuclear A-class submarine work at the shipyards in Leningrad is considered as an illustrative example. Part 2 of this report discusses the high-resolution photographic requirement in the Leningrad area and shows the possible launch points, target sites, and loft locations [redacted]

(S) With the exception of the camera development, this research was conducted in the time frame between September 1976 and July 1977. The program was designed to answer critical questions associated with the relocation of homing pigeons, their ability to collect photography over example targets, and the behavior and statistics of their performance. Part 3 discusses the camera development, and Part 4 describes two example targets in the Washington, D.C. area (Andrews AFB and the Washington Navy Yard) used to provide statistical data and in-flight photography. Part 5 addresses bird behavior and statistics for the relocation and example target phases of the program. An example Scenario and Mission associated problems are discussed in Part 6. Part 7 presents the Summary and Conclusions and discusses certain areas in which further research may be needed.

(TS) The analysis of the photography collected over the example targets was performed by NPIC and compared with overhead satellite photography and the specific intelligence requirement in the Leningrad area. This analysis is presented in Appendix A. It is felt that the overall results to date firmly establish the feasibility of using homing pigeons to collect the desired high-resolution photography in the Leningrad area. The total contractual cost for this research was $78,000.

# PART 2

# TARGET DESCRIPTION

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# PART 3
# CAMERA DEVELOPMENT

### *Background*

(S) Significant camera development started subsequent to the [redacted] tests conducted in the fall of 1975. During these tests, pigeons flew with an MCW-22 camera which used 9mm film, a Minox "Bull's Eye" lense, and weighed about 55 grams. The shutter speed at this time was 1/200 to 1/400 of a second, and a very high percentage of the pictures were excessively blurred. It was determined that the blurring was due to angular rates produced by the six hertz flapping frequency of the bird. Calculations conducted in late 1975 predicted a required shutter speed of 1/1200 to 1/2500 of a second in order to obtain resolutions on the order of one inch per 100 feet of altitude. However, with the f/3.5 Minox lense, exposure constraints precluded rates faster than 1/1400 of a second. Therefore, two approaches were taken: first, research was initiated on a [redacted] f/2.7 lens to permit subsequent design of a very high speed camera; and, second, a 1/1400-second system was designed and constructed using the existing Minox lense and a 16mm film format. This camera, called the MCW-24, weighed only 35 grams and was first test flown in January 1976. Furthermore, this camera contained two timing circuits (the MCW-22 used only one) which not only turned the camera on at the predicted time-over-target, but also turned the camera off at the end of the roll. This second timer prevented excessive camera wear and increased the system reliability to a great extent. The design of this camera also included a linear motion compensation feature; the film velocity during the taking of pictures exactly compensates for a forward ground velocity of about 36 mph at 100 feet altitude. This feature was verified by photographing bar charts fixed to the side of an automobile driven at various speeds.

(S) The MCW-24 was test-flown through the spring and summer of 1976 for a total of about 30 flights. About 20 to 30 percent of the pictures taken during these tests showed a resolution of one inch (or better) per hundred feet of altitude (100 feet is a typical altitude), whereas about 30 percent also showed resolutions of 1½ to 2 inches, and about 40 to 50 percent were excessively blurred due to flapping and high roll rates of the bird in turns. This was close to the expected result and verified the prediction that the high-speed [redacted] camera would be required to obtain high resolution a large percentage of the time. Table 4 lists some data for the MCW-24 camera. Here, resolution is defined by the measurements from "bar charts" which were photographed from the birds during in-flight experiments. Figure 9 shows the MCW-24 camera with harness.

### *Current Effort*

(S) The current effort was begun in early October of 1976. The [redacted] six-element lens system (f/2.7) had been assembled and tested, and work was initiated to develop a complete [redacted] Camera" with a shutter speed of about 1/2400 of a second. At this time tests were initiated, using the MCW-24 Camera to investigate a variety of film types and several film processing techniques under a variety of sun angle/lighting conditions. These tests, directed by NPIC, were conducted by use of a helium-filled balloon which hoisted the camera aloft to take pictures of bar-chart and miscellaneous targets. Figure 10 is a print using 3400 film processed in D-76 for five minutes. The sun angle is 68 degrees and the ground resolved distance (GRD) is 0.56 inches at 50 feet. Tests were also made with color using Aero Color negative 2445 and MS Ectachrome positive. Special AHU film and a high-resolution 3414 film were tested, as well as equivalent types with ultra thin base. The 3400 (or 3410) is essentially a "pan X" film and was selected over the higher resolution films because of its greater speed and the fact that GRD, or blurring, was due more to the avian platform motion than the "graininess" of the film. The MCW-24 camera was test flown on birds a total of 49 times, which includes 12 flights over Andrews Air Force Base and seven flights over the Washington Navy Yard. There were a total of three MCW-24 camera failures, one due to film jamming and two due to damaged E-cells in the

**TABLE 4**

**MCW-24 Characteristics**

| | |
|---|---|
| Camera Plus Film | 28.0 grams |
| Timer and Batteries | 7.0 grams |
| Harness | 4.5 grams |
| TOTAL | 39.5 grams |

| | |
|---|---|
| Lense: | f/3.5, 15 mm focal length |
| Film: | 16 mm format 90′ wide by 45′ in track at 100′ |
| | 140 to 200 pictures per roll |
| | 14 acres area coverage per roll |
| | 1.5- to 2-inch resolution at 100′ |
| Dimensions: | 0.8 x 0.8 x 1.8 inches |

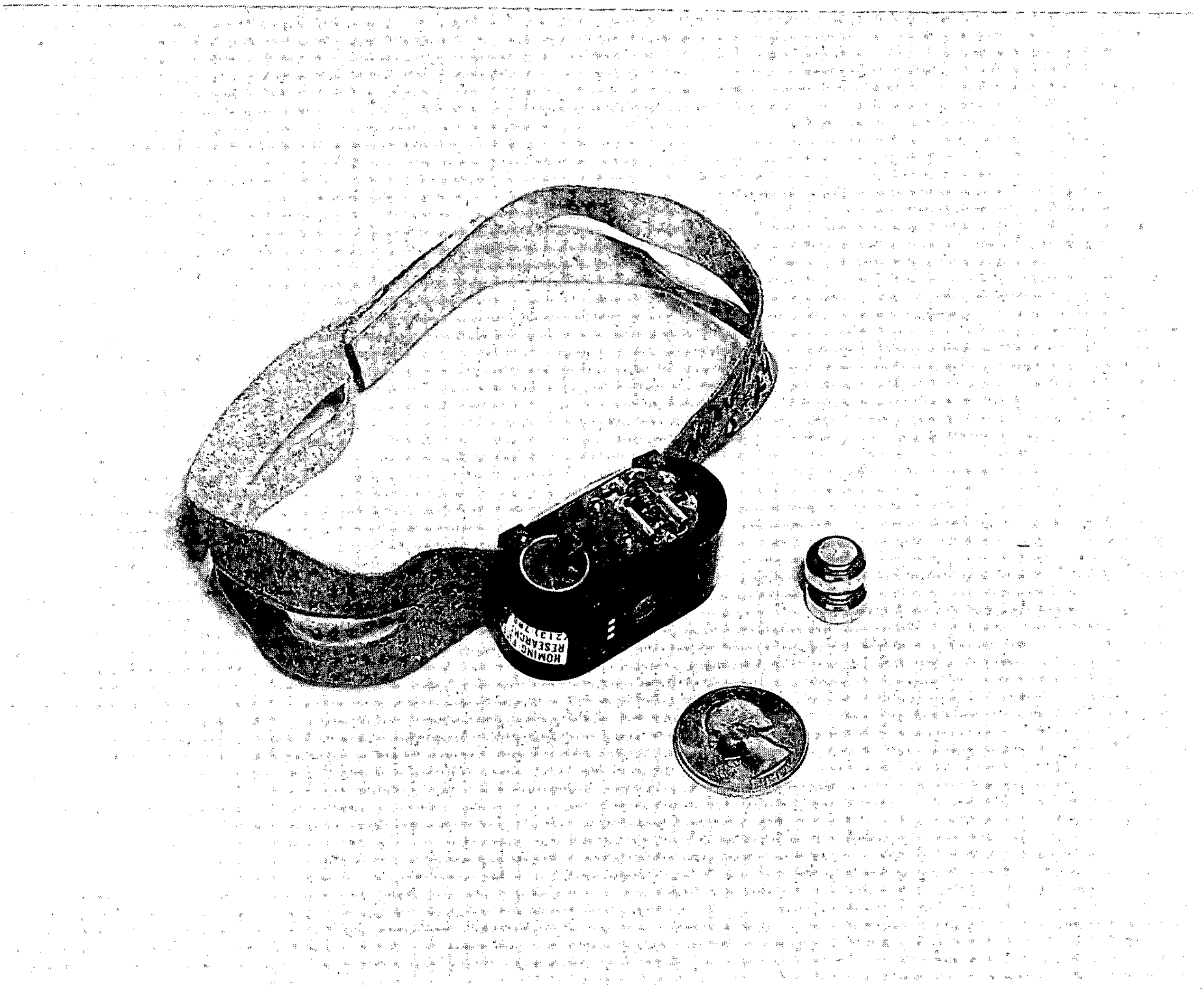

FIGURE 9. MCW-24 Camera

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timer circuit. The faulty E-cells were traced to an improper timing procedure which allowed transient current spikes to damage the E-cells. Also, analysis of the flight films over Andrews Air Force Base showed that the pictures taken with the MCW-24 camera had considerably more blurring than those taken during the spring and summer of 1976. This was traced to a fatiguing of the shutter spring which caused a reduction in shutter speed from 1/1400 of a second to 1/1000 of a second. Since delivery of the new [redacted] camera was imminent at the time this problem was diagnosed, no attempt was made to redesign the MCW-24 shutter spring. Other detailed data on temperature tests, current drain, and battery performance are contained in Appendix B.

(S) The [redacted] camera with f/2.7 lens was first test flown on 21 January 1977. This system provides a square format on 16mm film which covers an area of 90 feet by 90 feet on the ground from

FIGURE 10. Balloon Picture Using 3400 Film SECRET

an altitude of 100 feet. The film capacity is 220 frames (using UTB film) which corresponds to about 41 acres of area coverage per roll from 100 feet altitude. The first [redacted] camera, labeled C-10, had a shutter speed measured at 1/2200 to 1/2400 of a second. On the second flight over the Washington Navy Yard, this camera and bird were lost; the bird returned two weeks later without the camera. However, almost all pictures from the first flight over the Yard were extremely sharp and showed little blurring due to platform motion.

(S) [redacted] cameras C-11 and C-12 were received from the contractor and test flown through early July of 1977. However, these cameras experienced several shutter failures which were eventually traced to too deep an anodizing process which was structurally weakening the shutter material. This problem was corrected and the cameras were also modified so that new shutter assemblies could be installed in the field should failures continue to occur. No further camera failures occurred, but it was noticed that the pictures from C-11 and C-12 were not as consistently sharp as those from the one roll of C-10. The problem was finally traced to a malfunction in the timing equipment used to measure the shutter speeds of C-11 and C-12. The result was that all pictures taken by C-11 and C-12 prior to July 1977 were made with shutter speeds of only 1/1600 of a second instead of the desired 1/2400 of a second. This problem was corrected and four additional flights were made with camera C-11 and six with C-12. Table 5 gives some general data for the [redacted] camera, and Figure 11 shows the [redacted] camera with harness and avian transmitter. Figure 12 shows the bird

**TABLE 5**

**[redacted] CAMERA DATA**

| | |
|---|---|
| LENS | |
| Wide angle 48.5° Circular Field (90 ft. at 100 ft.) | |
| Less than one inch resolution at 100 ft. | |
| f/2.7 with 15mm focal length | |
| FILM | |
| 16mm format with 220 frames/roll | |
| Motor driven continuous 1.2 sec/frame | |
| 3 or 4 rolls per set of batteries | |
| 41 acres area coverage/roll at 100 ft. | |
| WEIGHT | |
| Camera, film, batteries, fasteners | 43 g. |
| Harness | 4.5 g. |
| TOTAL | 47.5 g. |
| Dimensions—7/8 x 1 x 2.2 inches | |
| Shutter speed—1/2200 to 1/2400 of a second. | |

with camera and harness. Other detail data are contained in Appendix B.

~~(S)~~ At this time it is felt that the [redacted] camera contains all the features required to obtain the desired high-resolution photography from a bird platform, and that sufficient research has been conducted to adequately demonstrate feasibility.

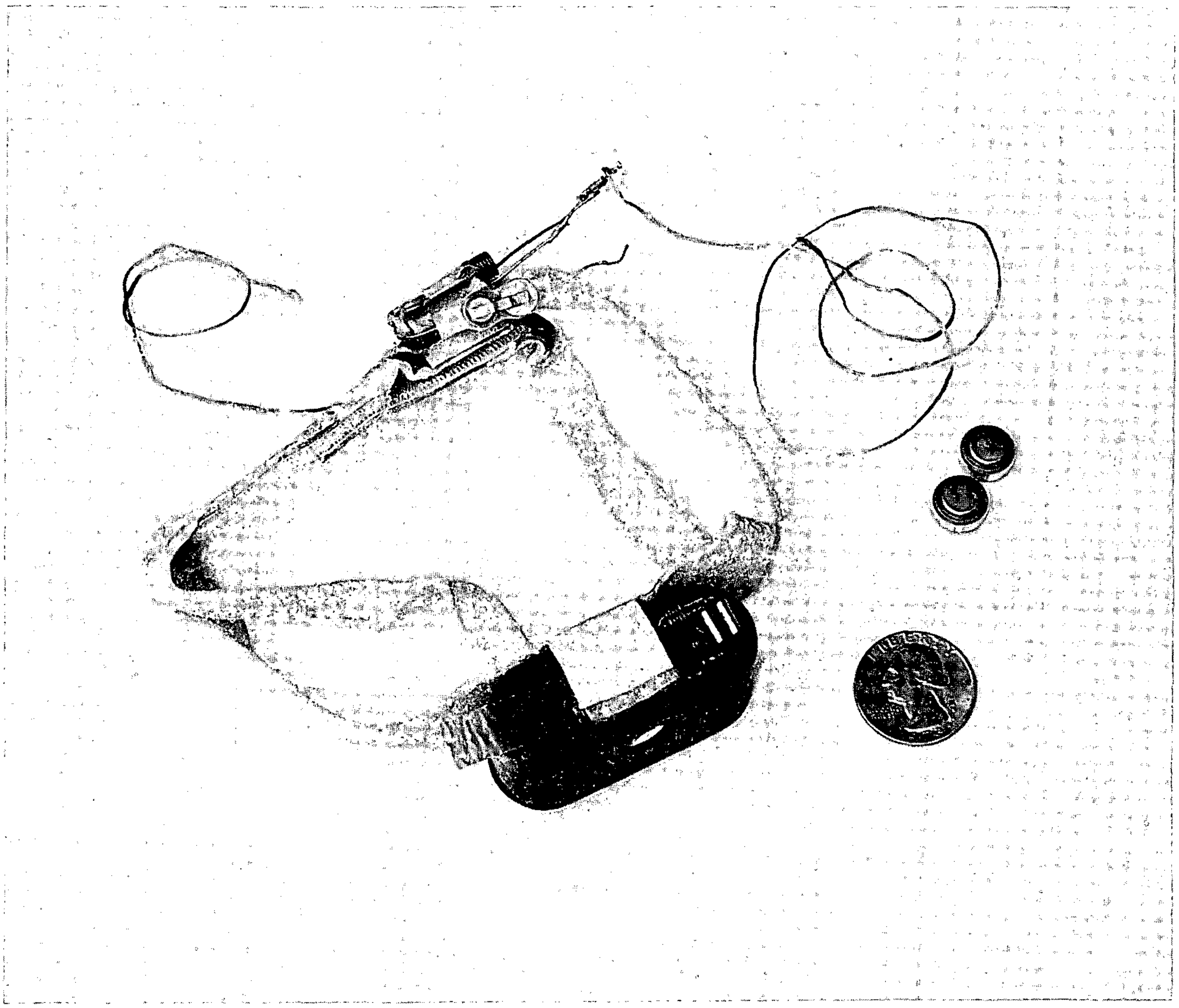

FIGURE 11. [redacted] Camera

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FIGURE 12. Bird With Camera

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# PART 4

# TWO EXAMPLE TARGETS IN THE WASHINGTON, D.C. AREA

### *Andrews Air Force Base*

(S) One of the first actions in the program was to obtain a group (kit) of birds which could be used to collect data against local targets. Such a group, called kit 1F, was purchased [redacted] located at [redacted], Virginia. These birds (nine in all) had previously been trained only to the west (75 miles) of [redacted] The first training flight on this program was conducted on 4 October 1976, one mile to the southeast, toward Andrews Air Force Base. There were two training flights at three miles and one each at six and 12 miles. The sixth flight, on 15 October, was from Andrews Air Force Base, 18 miles from the home loft at [redacted] On the next day, four birds were selected to carry harnesses and weights the 18 miles home. The birds were then given one day rest and, on 18 October, bird number 1F4 carried camera number C-7 over Andrews Air Force Base; camera numbers C-9 and less are MCW-24 models described in the previous section.

(S) It had been very difficult to determine vanishing bearings (final directions of departure) from the launch site due to the high density of trees to the east of the Base. The film from camera C-7 was compared against satellite photos to determine the bird's trajectory during the several minutes of photography. Figure 13 shows this first trajectory (labeled no. 1) was to the north of the direct line home. Figure 14 is an example of the photography (about 140 pictures) taken on this flight. For the next flight, the launch point (no. 2 in Figure 13) was moved to the southwest and the trajectory, though still north of the line home, was closer to the runway and hangers. Figure 15 shows several military trucks parked on the base. For the third trajectory, the launch point was moved still further to the southwest, and the bird flew right up to the runway before turning north. Figure 16 shows an incinerator plant located in the southeast portion of the base.

(S) At this point it was suspected that the birds might be avoiding the runway because of the noise and aircraft traffic. One particular bird, number 1F2, had been flying the 18 miles in about 33 minutes with a dummy weight and a 12 mph headwind. On 27

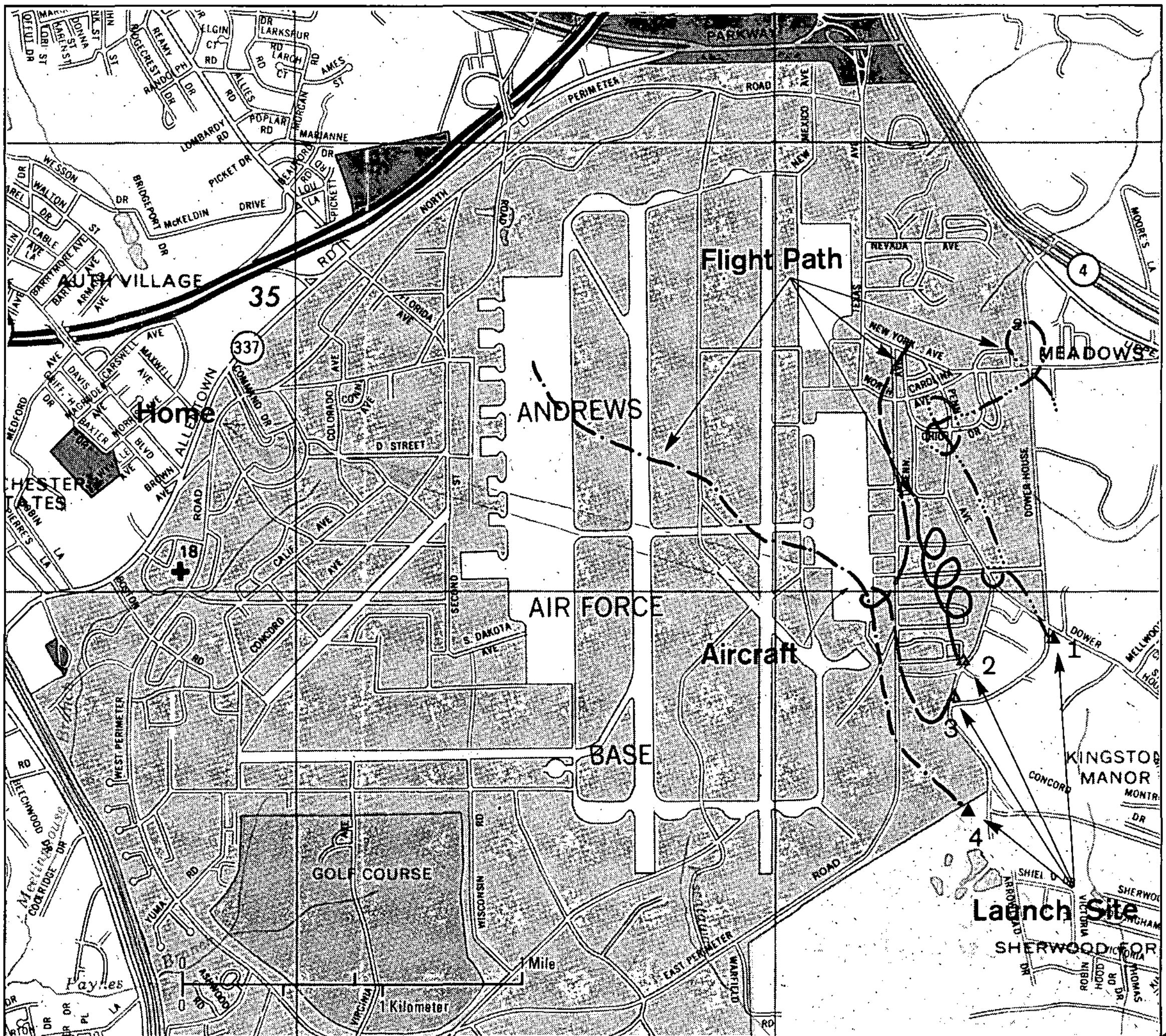


FIGURE 13. Four Flight Paths over Andrews Air Force Base

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November, this bird carried camera C-5, returning home in 34 minutes. The flight path is shown as trajectory no. 4 in Figure 13. This flight was directly across both runways, resulting in the photo of the aircraft shown in Figure 17.

(S) By the end of October, three of the birds were lost (one returned three weeks later) and eight more birds were added to kit 1F. Flights continued through December with a total of 11 camera flights and 19 flights with dummy weights. As mentioned in the previous section, analysis of the film showed that there was a higher percentage of blurred photos (see Figure 17) than during the previous summer tests due to a decrease in shutter speed from 1/1400 to 1/1000 of a second. Since the [redacted] camera was to be delivered shortly, these MCW-24 cameras were not modified. While waiting for delivery of the [redacted] camera, the birds were worked to the east of [redacted] toward the Washington Navy Yard.

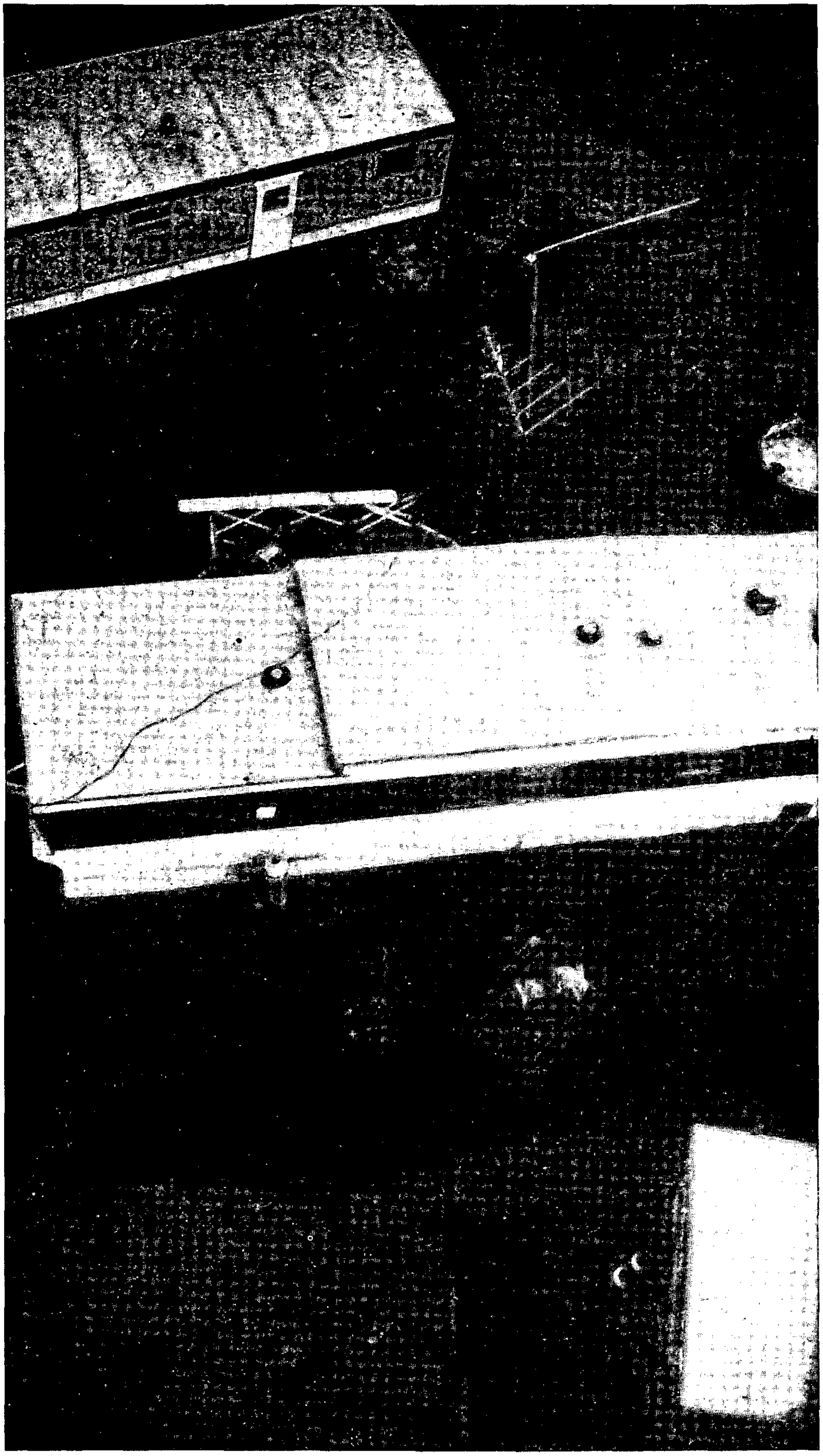

FIGURE 14. Mobile Home Complex on Andrews Air Force Base

FIGURE 16. Incinerator Plant on Andrews Air Force Base

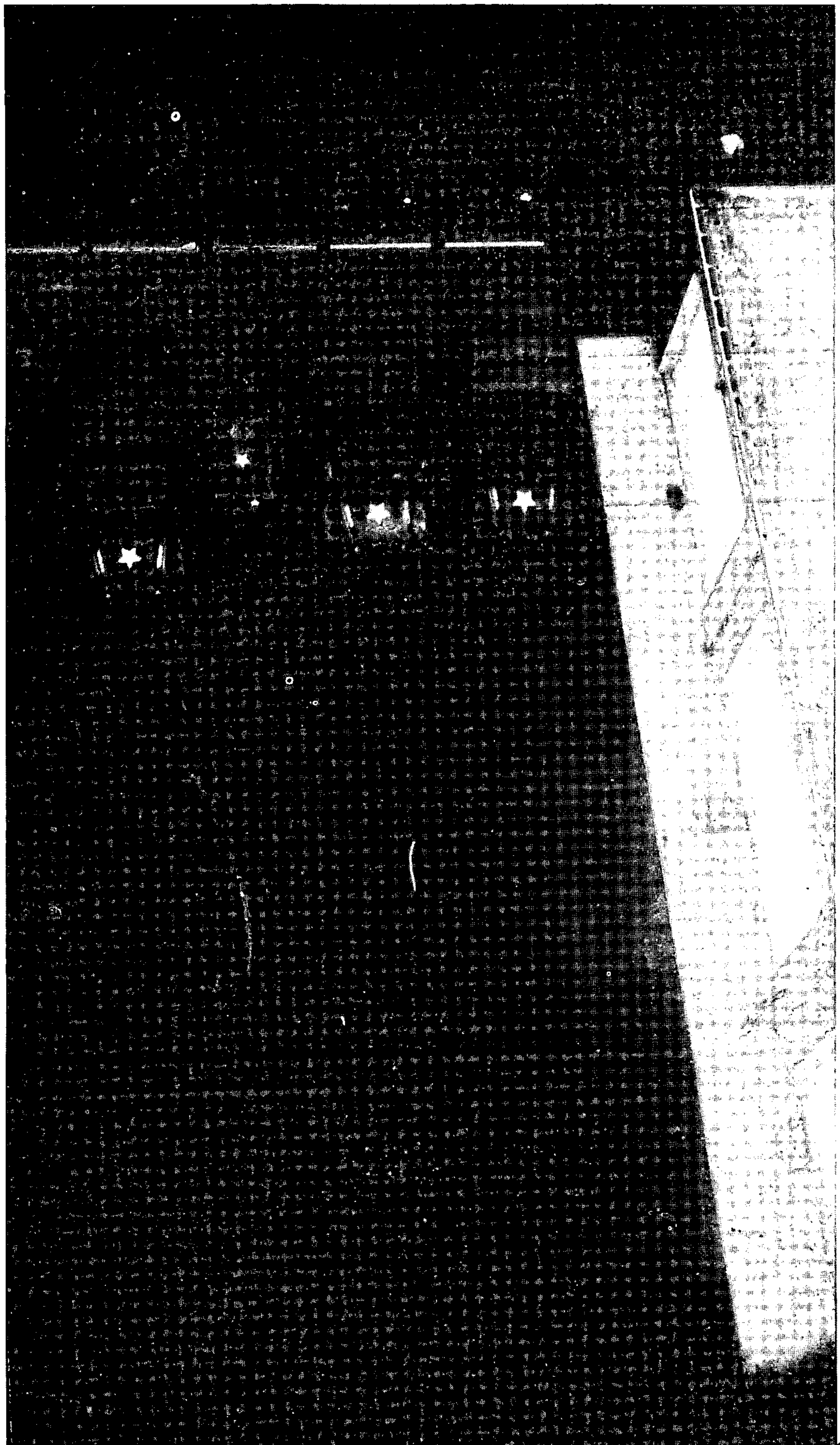

FIGURE 15. Military Trucks on Andrews Air Force Base SECRET

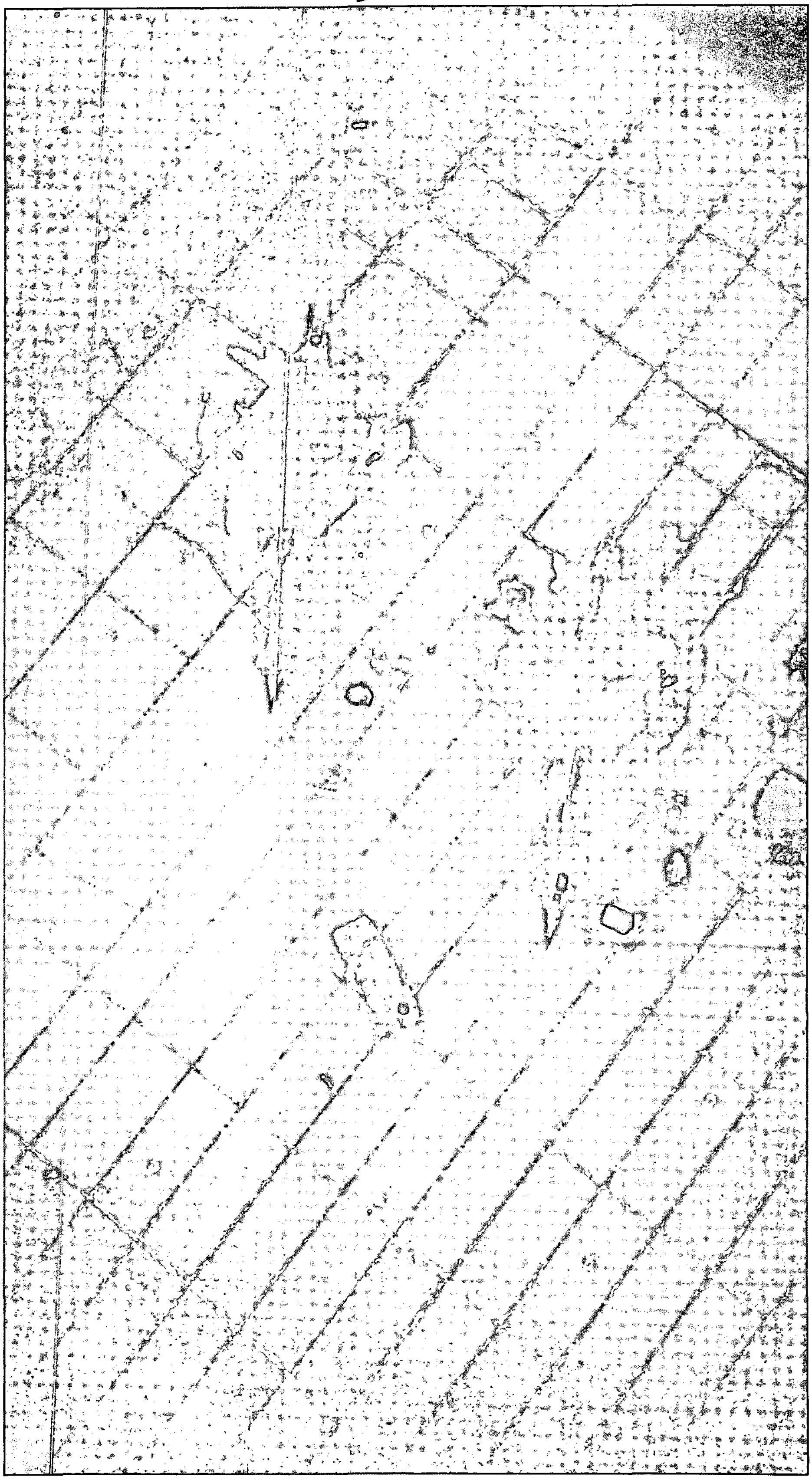

FIGURE 17. Military Aircraft on Andrews Air Force Base

(S) On 21 January, bird 1F2 was released at Andrews with a [redacted] camera and a small avian DF transmitter (see Appendix B) which totaled about 50 grams in weight. Just after release, the bird was attacked by a hawk and managed to escape to the east. By use of the DF equipment, the bird was located one mile distant on top of a church, apparently unharmed. On the following morning, the bird had not returned. With the temperature in the low teens, the bird and camera were found in a packing crate behind a shopping center some three miles northeast of the church. Though this bird continued to fly well, it would never again perform properly with either camera or weight.

(S) Over Andrews Air Force Base, there were a total of 12 flights with the MCW-24 camera, 19 flights with dummy weights and one attempted flight with [redacted] camera number C-10. Many of these flights were conducted during one of the coldest winters on record in this area. There were no camera failures due to low temperature. It is important to note that the body temperature of a pigeon is 107°F. Generally, pigeons perform well in cold weather and poor in extremely hot weather.

(S) The 12 camera flights recorded most of the Andrews complex with exception of the active runways. It is felt that the birds avoided these because of the noise and aircraft traffic. The primary difficulty in launch site selection was the inability to observe the vanishing bearing among the numerous tall trees. This required tedious work and time consuming delays in comparing the flight film with satellite photos in order to determine how best to adjust the launch point. Figure 18 is a satellite photo of Andrews showing the surrounding terrain.

### *The Washington Navy Yard*

(S) A group of young birds (Kit 2F) was purchased in late December and trained to home during January 1977. By 17 February, these birds and Kit 1F were flying with weights from the Washington Navy Yard to [redacted] directly west of the Yard. At this time, four relocated birds were also flying the [redacted] with weights. During the remainder of February and early March, these birds were "single-tossed" (launched one at a time) to collect data on individual performance. The goal was to overfly the small museum park located between the Navy Yard museum and the river. The park and four of the trial launch sites are shown in Figure 19. The single-toss experiments did not work well. Almost every bird circled for three to five minutes waiting for other birds with which they could fly home. On 9 March, double-toss (launched in pairs) experiments began with immediate improvement in results.

In pairs, the birds immediately took up a heading in the direction of home. The "Homing of Single Pigeons" is discussed in Reference 3, and their performance does improve with training. However, this increases the training manhours by an order of magnitude. On 7 March, flights began with the [redacted] camera C-10, resulting in excellent pictures over the Navy Yard. The trajectory is shown in Figure 19. Figures 20 through 23 show the quality of pictures obtained on this flight; about 80 percent of the pictures were of this quality. On 8 April, camera C-10 was damaged and sent back for repair. Launch experiments continued from the 11th Street Bridge site, and on 21 April, camera C-10 was flown again and lost. A DF transmitter was carried with the camera, but no signal could be found during an extensive search. The bird returned three weeks later without the harness or camera.

(S) [redacted] camera C-11 was received and flown on 29 April, and camera C-12 was first flown on 6 May. By mid-May several shutter failures had occurred which were eventually traced to too deep an anodizing process which caused a structural weakening of the shutter material. This problem was corrected and the cameras were also modified so that new shutter assemblies could be installed in the field should failures continue to occur. No further camera failures occurred and tests continued through 22 June. Example photography is shown in Figure 24 (an oblique of the museum park), Figure 25 (the main gate), and Figure 26 (the old Naval Gun Factory building). Analysis of this photography showed that a higher percentage of the pictures (i.e., Figures 24 and 25) were blurred from C-11 and C-12 than from C-10. At first it was thought that the increased percentage of blurring was due to the high winds or nervous birds. However, it was finally determined that the equipment used to measure the shutter speed had malfunctioned, resulting in an actual shutter speed of only 1/1600 of a second instead of the expected 1/2400 of a second. This problem was corrected, and between 6 and 15 July, four additonal flights were made with camera C-11 and six with camera C-12. These tests focused on testing several "special films" supplied by NPIC. These were:

1. Aero color negative 2445
2. FE 6526, a high-speed fine grain film
3. 1414, a high-resolution UTB film
4. SO-131, an infrared film
5. H&W Type 77 panchromatic

Figure 27 shows a color shot of one corner of the museum park. A detailed analysis and evaluation of film and photography is contained in Appendix A.

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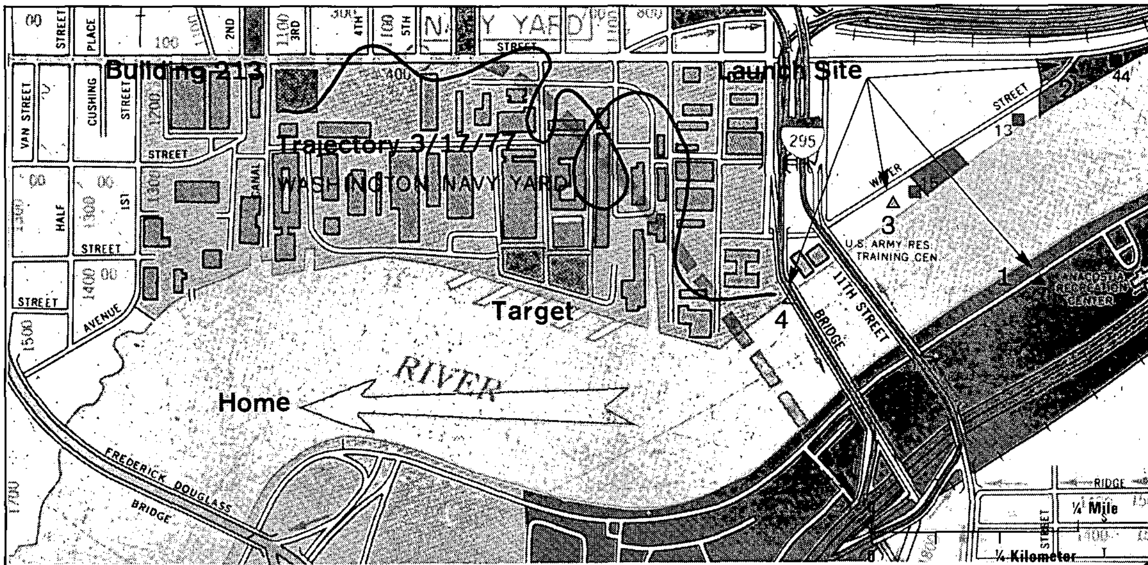


FIGURE 19. Map of the Washington Navy Yard

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(TS) Of these last ten flights, four were recorded as "hitting the target." It should be pointed out that the included angle of the museum park, measured from the 11th Street Bridge launch site, is 10 degrees in azimuth. In Figure 4 the included angle of the Sudomekh Yard, as measured from the release point near the [redacted] is about 80 degrees in azimuth. An acceptance angle of 80 degrees is equivalent to trying to hit any part of the Washington Navy Yard from a release site on the 11th Street Bridge. Of 84 paired flights from the 11th Street Bridge, fewer than six missed the Navy Yard completely. However, this was after the behavior of the birds was established and the release site adjusted for maximum probability.

(S) On one flight, the camera was tilted to the side to obtain a high percentage of oblique shots. If a pair of birds were flown with cameras titled to the right and left, a large area to either side of the flight path would be recorded. Figure 28 is an example of this kind of oblique photography.

(S) There were a total of 219 flights over the Navy Yard with either cameras or weights. Seven flights were with the MCW-24 camera and 31 were with the new [redacted] Camera. The remaining 181 flights were with weights; 64 were with relocated birds. During a series of 84 paired flights from the 11th Street Bridge, 25 percent were visually recorded as hitting the target (the museum park), and 54 percent missed the target by less than 75 yards. These statistics are discussed in more detail in the next section. Figure 29 shows a satellite photo of the Navy Yard and surrounding area.

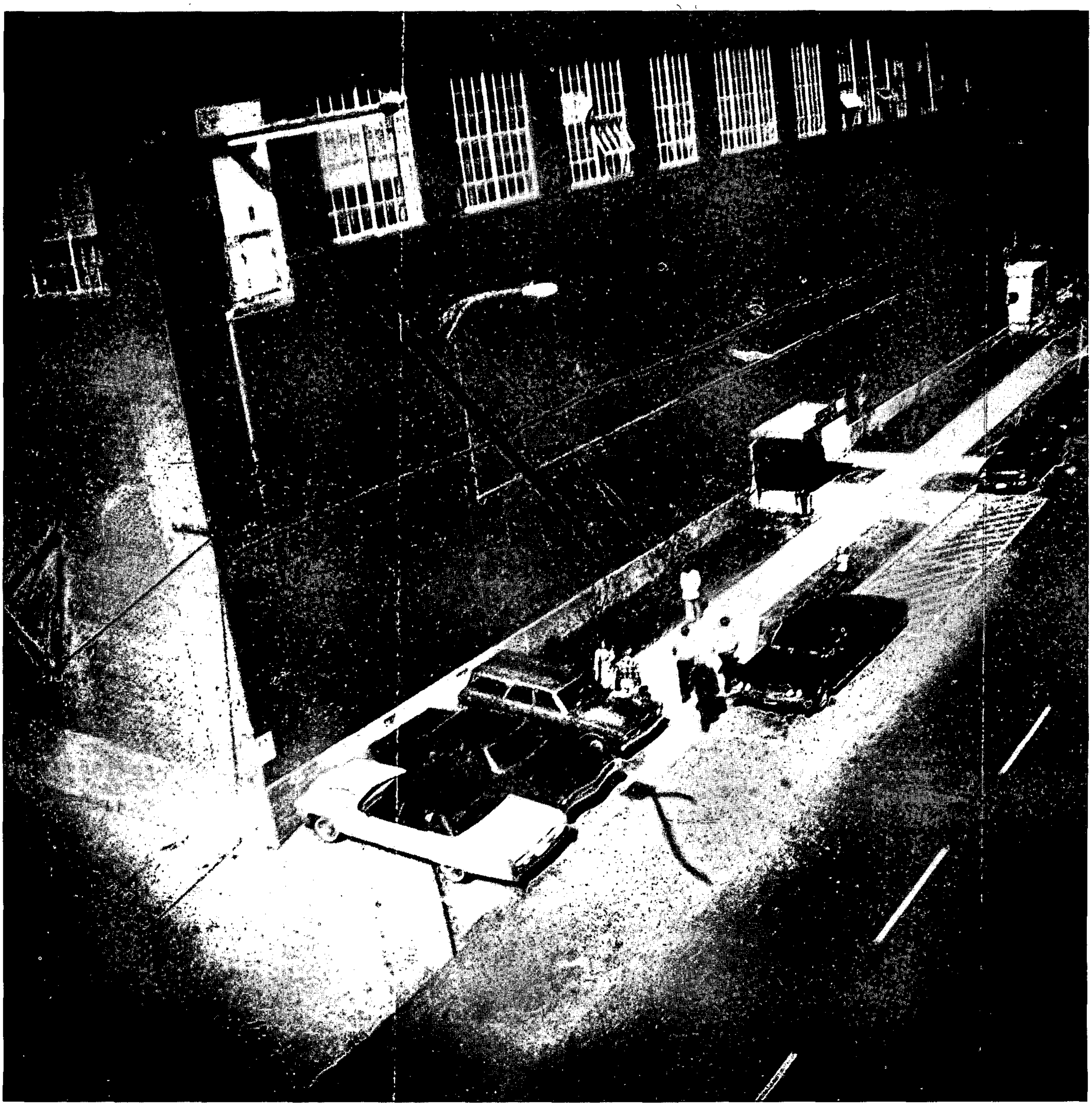

FIGURE 20. Corner with People Walking to Work

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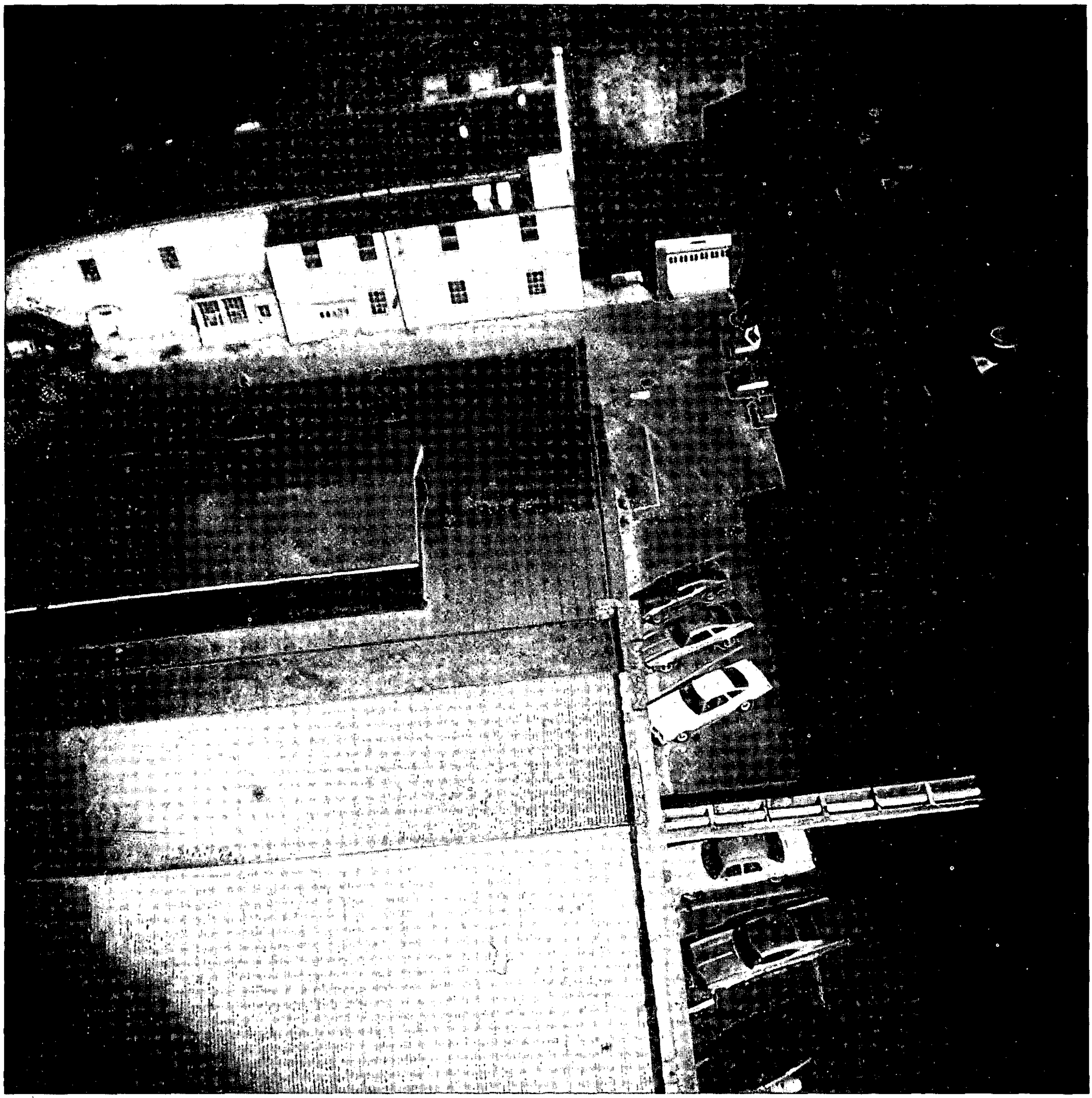

FIGURE 21. Alley Way

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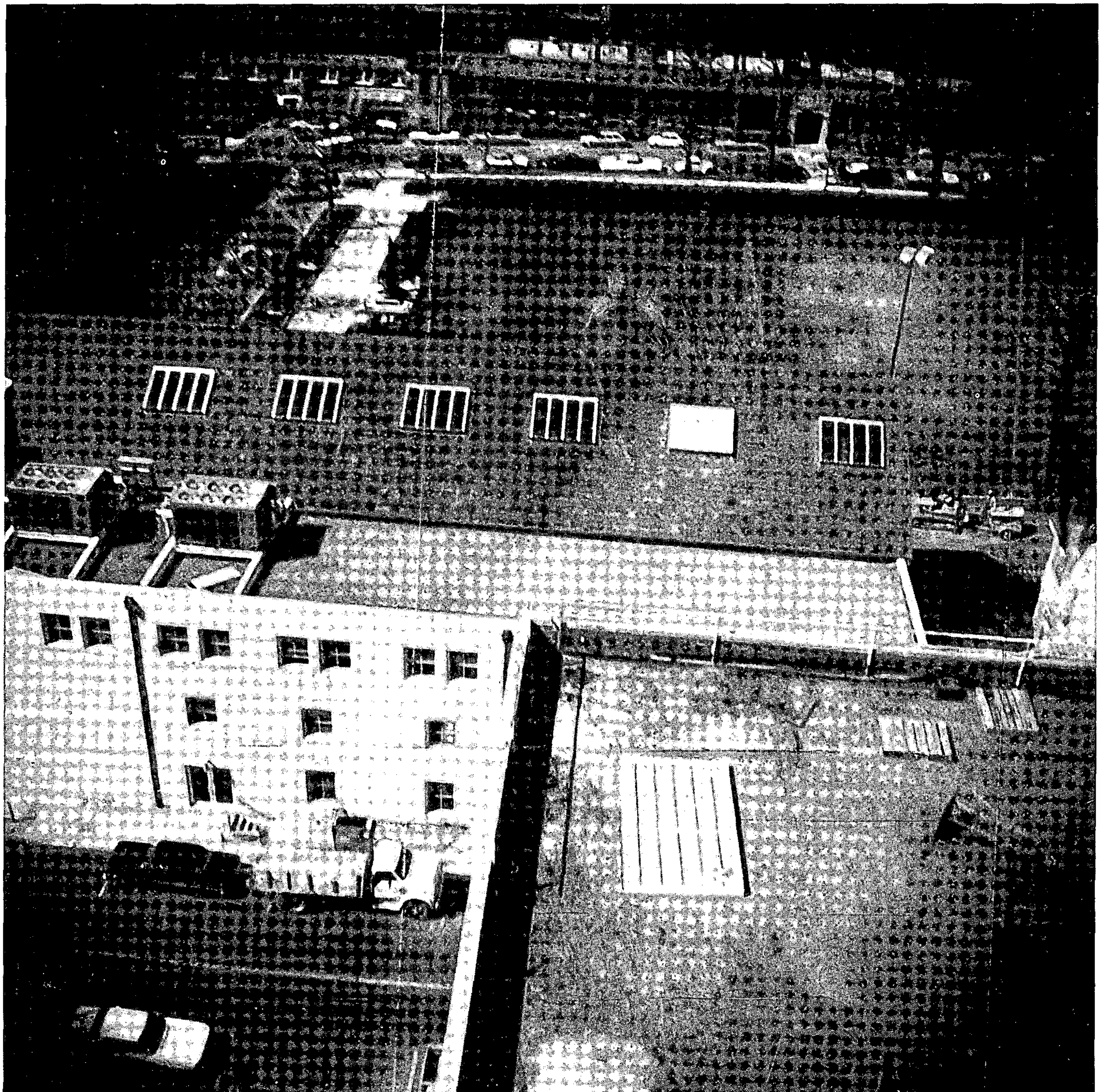

FIGURE 22. Roof Top with Air-Conditioner

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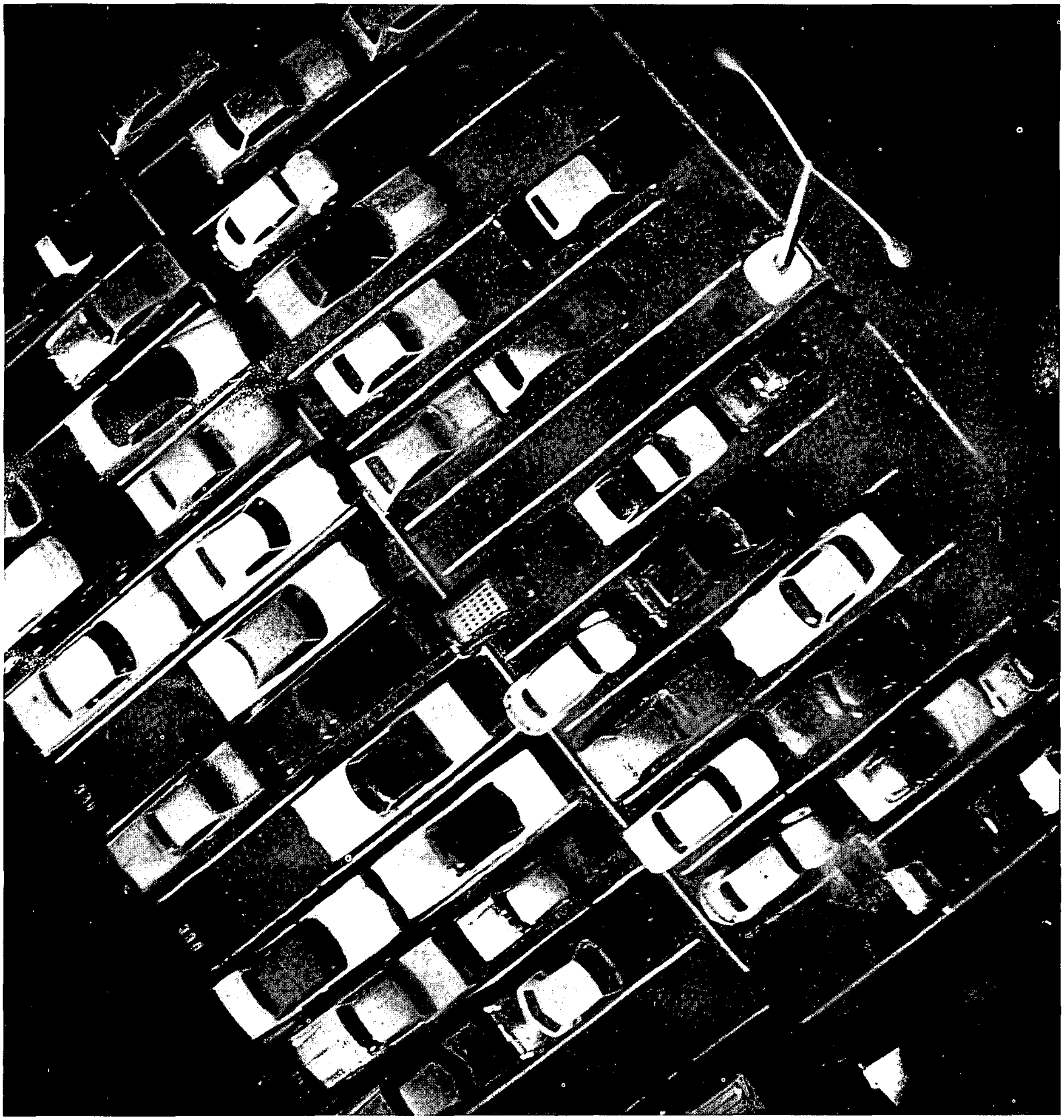

FIGURE 23. Parking Lot

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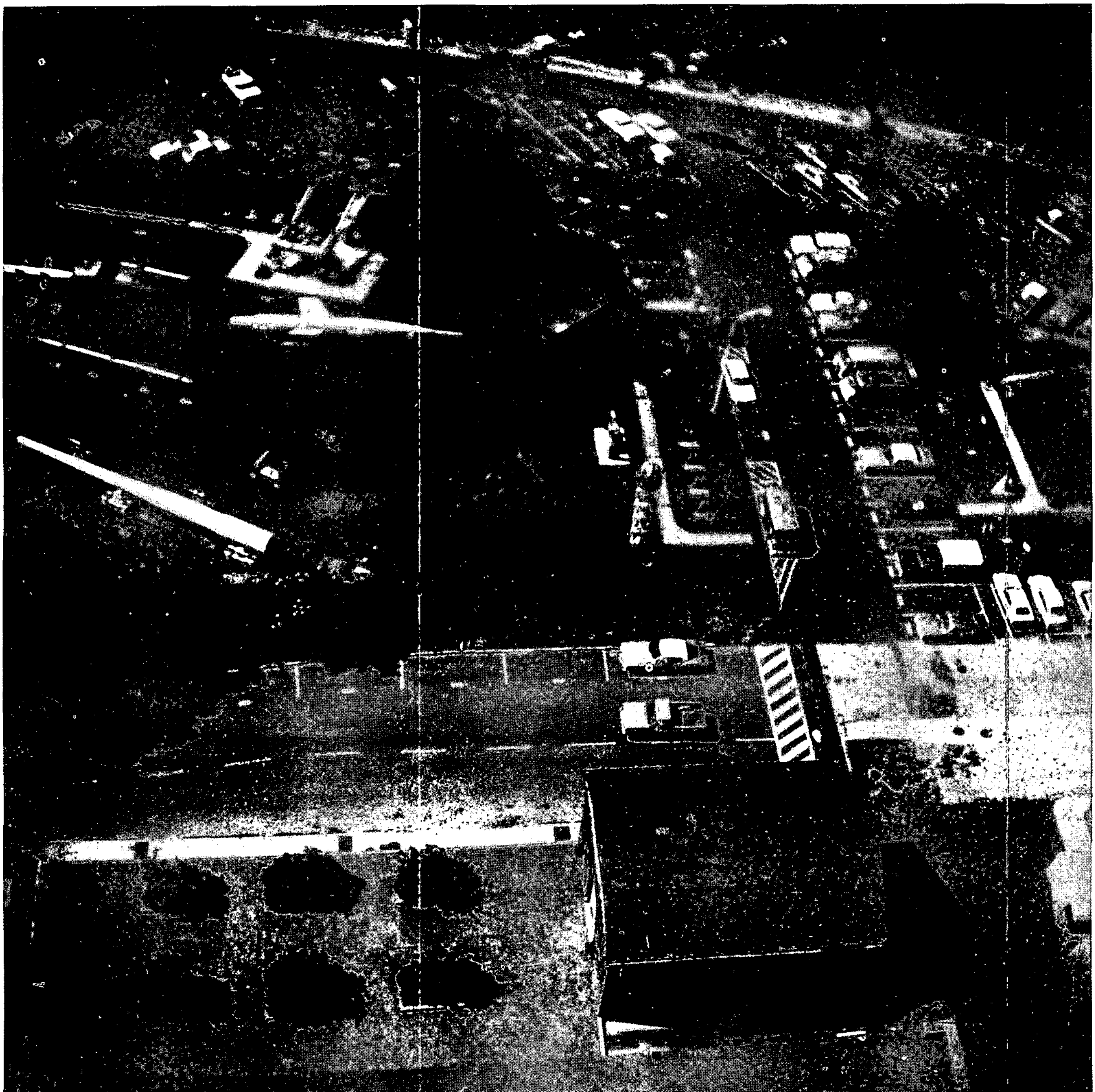

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FIGURE 24. Oblique Shot of Museum Park

FIGURE 25. Navy Yard Main Gate

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FIGURE 26. Old Naval Gun Factory

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FIGURE 27. 2445 Color of Museum Park

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FIGURE 28. Oblique Photograph Over the Navy Yard

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# PART 5
# BIRD BEHAVIOR AND STATISTICS

(S) It is not enough to show that the camera can take acceptable pictures over the target. Certainly of equal importance is the capability of the bird to fly over the target and the frequency, or expectation, of its performance. Data on performance were collected almost entirely from local birds which were flown over two example targets in the Washington, D.C. area.

(S) Another very important problem is that of providing birds of proven performance in the target area. This might be done in several ways. One way is to test birds locally over example targets and select those of good performance for relocation to the target area. A second possibility is to take young birds to the target area so that this is their primary home. These birds could then be relocated in the Washington area and tested over example targets. Those of acceptable performance could then be taken back to the target area with a high degree of confidence that they would perform well at their primary home. In either case, the issue of relocating birds from their primary home to a distant secondary home is of great importance. During this research, experiments were conducted with 132 homing pigeons which were relocated to lofts in Oregon, Alaska, Missouri, and Virginia.

### *Performance Over Example Targets*

(S) In early October 1976, the first group (Kit) of nine birds was obtained [redacted] located at [redacted] Virginia. This Kit, called 1F, was increased to 17 in number by the end of October. These were all veteran flyers; three had won diplomas in 300-mile races, and the rest had been trained to at least 75 miles to the west of [redacted] The first training flight was conducted on 4 October 1976; and the sixth flight, on 15 October, was from the far side of Andrews AFB, 18 miles to the southeast of [redacted] On the next day, four of the nine birds were selected to carry weights (the same shape and weight as the camera) the 18 miles home. It was found very difficult for observers to obtain vanishing bearings from the launch site due to the high density of tall trees to the southeast of the base. On 18 October bird number 1F4 was launched with a camera, resulting in trajectory number one shown in Figures 13 and 18 by a comparison of avian and satellite photography. It is apparent that this trajectory is considerably north of the direct line home to [redacted] It is speculated, as discussed in Reference 3, that this behavior might be due to the effects of the previous training direction, which required the birds to fly east, instead of northwest, to get home. In order to compensate for this factor, the launch point was moved several times to the southwest, finally resulting in trajectory number four which crossed both active runways and photographed the military aircraft shown in Figure 17. It is also speculated that the birds may have avoided the runways due to the noise and aircraft traffic. For this reason, and the difficulty in observing vanishing bearings, attention was turned toward the Washington Navy Yard as a second example target.

(S) In late December 1973, a group of young birds (Kit 2F), 14 in all, was obtained and trained to fly during January 1977. Unlike Kit 1F, these birds had never flown before. By 17 February both kits were flying with weights from the Washington Navy Yard, located [redacted] directly east of [redacted] Virginia. These tests continued through mid-July 1977.

(S) Of the 17 birds in Kit 1F, seven survived through July 1977, two were lost at the loft for unknown reasons, and eight were lost in flight training. These eight were lost before the end of November 1976. This implies that about half of the old birds could not adapt to the regimen of being trained to carry weights and "dropped out" early in the program. Table 6 shows the "Loss" data for Kit 1F. Of the seven surviving birds, four showed exceptional performance, and three were marginal. Table 7 shows the flight performance of Kit 1F in terms of the number of times a weight or camera was carried by each bird. These data include flights with weights at short training distances which provided a gradual buildup in carrying ability.

**TABLE 6**

**LOSS DATA FOR KIT 1F**

| BIRD NO. | DATE LOST | DISTANCE MILES | NUMBER FLIGHTS |
|---|---|---|---|
| 3 | 1/19/77 | 0 | * |
| 7 | 10/05/76 | 3 | 2 |
| 9 | 10/29/76 | 18 | 9† |
| 10 | 11/27/76 | 18 | 13 |
| 11 | 11/06/76 | 3 | 1 |
| 12 | 11/16/76 | 3 | 1 |
| 13 | 4/07/77 | 0 | * |
| 15 | 11/27/76 | 18 | 13 |
| 16 | 11/27/76 | 18 | 13 |
| 17 | 11/17/76 | 1 | 2 |

*Lost at loft, reason unknown.
†Four times to 18 miles, two with weights.

TABLE 7

FLIGHT PERFORMANCE FOR KIT 1F

| BIRD NO. | TOTAL FLIGHTS WEIGHTS | ANDREWS AFB | | NAVY YARD | |
|---|---|---|---|---|---|
| | | WEIGHTS | CAMERAS | WEIGHTS | CAMERAS |
| 1 | 10 | 1 | 0 | 2 | 0 |
| 2 | 22 | 3 | 5 | 9 | 1 |
| 3† | 10 | 2 | 3 | 0 | 0 |
| 4 | 29 | 2 | 4 | 13 | 3 |
| 5* | 21 | 4 | 1 | 4 | 0 |
| 6 | 25 | 2 | 0 | 12 | 3 |
| 8 | 30 | 2 | 0 | 20 | 15 |
| 9** | 2 | 2 | 0 | 0 | 0 |
| 13† | 20 | 1 | 0 | 9 | 0 |
| 14* | 8 | 0 | 0 | 3 | 0 |

*Placed on widowhood 3/3/77.
†Lost at loft, reason unknown.
**Lost fourth time from Andrews.

TABLE 8

FLIGHT PERFORMANCE FOR KIT 2F

| BIRD NO. | TOTAL FLIGHTS WEIGHTS | NAVY YARD | |
|---|---|---|---|
| | | WEIGHTS | CAMERAS |
| 2 | 15 | 11 | 0 |
| 10* | 21 | 15 | 0 |
| 12 | 17 | 13 | 9 |
| 13 | 26 | 29 | 6 |
| 14 | 14 | 10 | 0 |

*Placed on Widowhood 3/3/77.

(S) Of the 14 young birds in Kit 2F, four were selected for experiments associated with relocation; of the ten remaining, five were lost on the very first release at the home loft. This is an unusually high rate of loss and is most probably due to the late start in their training. These birds were about 60- to 80-days old at the time of their first release; typically, young birds are first released at about 30 to 40 days of age, before they become too "wing strong" and while they are less likely to fly off before learning where home is. Normally, only a 10- to 20-percent loss is expected. Of these five remaining birds, all survived. Table 8 shows the flight performance of Kit 2F in terms of number of times a weight or camera was carried, including several short training flights. As seen in the Table, two of these five young birds performed exceptionally well and carried a camera many times over the Navy Yard. Bird 2F10 was placed on "Widowhood," which is explained later.

(S) The experiments at the Navy Yard were directed toward finding a launch site from which the birds would fly over, or as close as possible to, the small museum park located between the Navy Museum building and the river. This park contains many naval artifacts, such as missiles, torpedos, small submarines, etc. Ground truth data was measured on several of these items for use in evaluating the avian photography. This park runs for about 250 yards west along the river and is about 70 yards wide. As mentioned above, all birds were flying from the Yard with weights by 17 February 1977. The first experiments were from across the river in Anacostia Park (launch site one in Figure 19). At this site the birds were "single-tossed" (launched one at a time) in an attempt to collect individual data on vanishing bearings. However, with few exceptions, the birds circled in the area for two to five minutes and departed in various directions. The launch site was moved across the river (launch site two in Figure 19) and then to just east of the 11th Street Bridge (launch site three in Figure 19) with only slight improvement in results. At this time it was decided that the reason the birds were circling for several minutes was because they were waiting for other birds with which they could fly home. Therefore, on 9 March double-toss experiments (launched in pairs) began at launch site three with a significant improvement in results. Most pairs of birds took up an immediate heading in the direction of home. This experiment was repeated on 10, 11, and 15 March with comparable results. Figure 30 shows a single-toss experiment from launch site two.

FIGURE 30. Single-Toss Experiment

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(S) On 17 March, a detailed series of experiments began from the 11th Street Bridge (launch site four) during which 84 paired flights were launched. Visual landmarks were located with respect to the museum park so that miss distance data could be recorded for each pair of birds. The actual launch site was adjusted along the bridge in order to maximize the likelihood of overflying the park. Of the 84 flights from this site, 21 were recorded as hits (a miss of less than 35 yards from the center of the park). Figure 31 is a histogram of this data in terms of miss distance from the center of the park. Since the bridge site is about 400 yards from the park, the angular miss can be determined as the arc tangent of the miss distance divided by 400. Twice the angular miss (measured from the target center) can be considered as the total subtended angle of a hypothetical target. In this way one can sum the data in Figure 32 to compute the cumulative distribution as a function of the subtended angle of a particular target as measured from a chosen launch site. Figure 32 shows the chance of overflight by one pair of birds as a function of the subtended angle of the target. For example, if the target in question subtends an angle of 25 degrees, there is about a 50-percent chance of overflight. However, this applies only when the launch site has been adjusted to locate the most probable direction home through the center of the target.

(TS) For most of the launch sites in Figure 4, the Sudomekh Yard subtends an angle of 10 to 70 degrees. This would indicate a

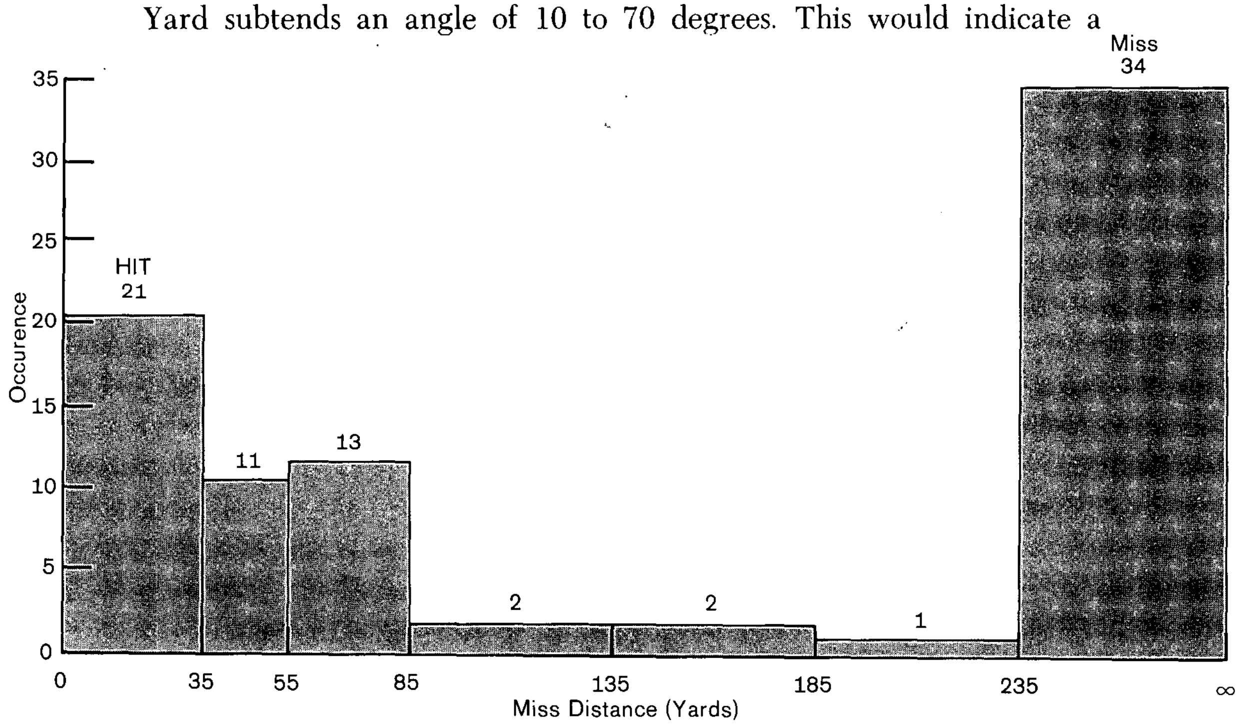


FIGURE 31. Histogram of 84 Paired Flights

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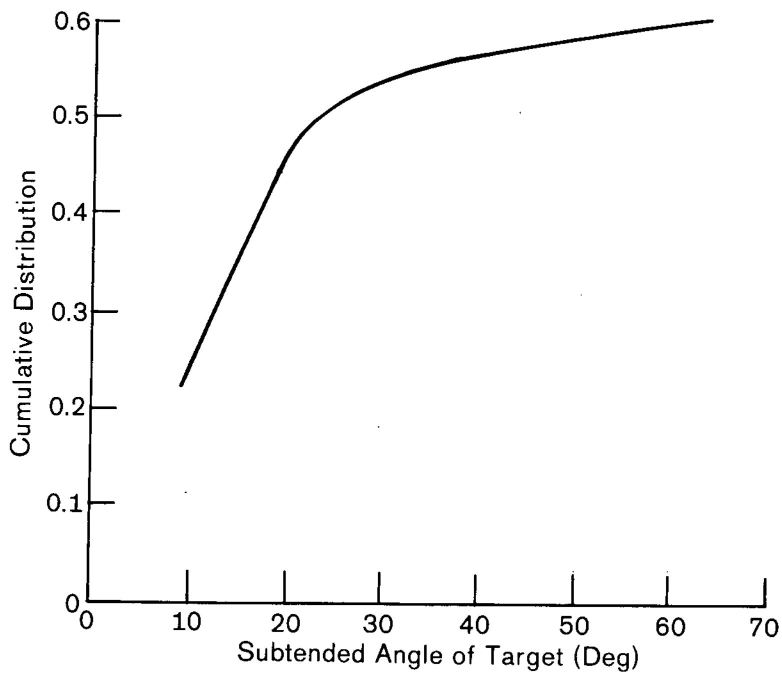


FIGURE 32. Chance of Overflight vs. Subtended Target Angle

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25- to 60-percent chance of overflight once a preferred site (or flight line) has been determined. If there is good visibility, the direction of the preferred flight line can be established without risk of flying the avian camera. Otherwise, as was the case with Andrews AFB, the avian and satellite photography must be compared to determine the new trial launch site.

(S) The 84 paired flights were conducted with eight birds, four from Kit 1F and four from Kit 2F (the young birds). During the last ten flights, four pairs were recorded as hitting the target. Figure 33 shows a bird with camera returning from a flight over the Navy Yard.

(S) NPIC analyzed 36 rolls of avian film. Of these, six rolls contained 23 frames of the museum park.

### *Relocation Experiments*

(TS) One of the first problems on this project was to find competent loft managers who could provide and receive birds for relocation experiments. It was felt important that these lofts should be as widely separated as possible and that one should be in Alaska which has the same latitude and magnetic dip angle as Leningrad. Three highly competent people were found in [redacted] Oregon; Anchorage, Alaska; and [redacted] Virginia. A fourth loft was constructed in [redacted] Missouri, on the farm of [redacted]

FIGURE 33. Bird With Camera Returning From the Navy Yard

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[redacted] This fourth loft provided relocation data by an "informed novice" as well as a ready supply of birds for flight testing the avian camera prior to shipment.

(S) Three kits of birds (1L, 2L, 1W) were obtained from the [redacted] area. One of these kits, 1W, had been relocated several times before on the previous project. A fourth kit, 1D, was obtained from [redacted] as young birds which had never flown. All other birds were obtained from Oregon, Alaska, and Missouri, and distributed to the four selected lofts. Table 9 shows the disposition of the 118 birds used in this experiment, including the date each kit was received and the date of the first release at the new home loft. Table 10 shows the results for each of the 118 birds, including the number of days each bird was held captive before the first release. As expected, the birds which had never flown before, kit 1D, had the highest percentage of survival (55%). This, however, is low for young birds and most probably due to the fact that they were too old and "wing strong" causing them to fly off before learning the surrounding area. This is essentially the same percentage, and probable cause, described previously for kit 2F. In Table 10, loss data is shown by number of release at the loft (1R, 2R, etc.) and also with respect to the number of training flights from a remote launch site (1F, 2F, etc.). All birds that survived were trained from sites at least five miles from the loft.

## TABLE 9

## DISPOSITION OF 118 BIRDS

| KIT | NUMBER BIRDS | ORIGIN | DESTINATION | DATES RECEIVED | DATES RELEASED | NUMBER DAYS CAPTIVE |
|---|---|---|---|---|---|---|
| 1W* | 6 | California | Oregon | 10/25/76 | 12/26/76 | 62 |
| 1L | 13 | California | Oregon | 10/25/76 | 12/02/76 | 38 |
| 2L | 12 | California | Oregon | 10/25/76 | 12/05/76 | 40 |
| 1D** | 11 | California | Oregon | 11/30/76 | 12/26/76 | 26 |
| 1B | 12 | Oregon | Missouri | 11/05/76 | 11/27/76 | 22 |
| 2B | 12 | Oregon | Alaska | 11/06/76 | 12/08/76 | 32 |
| 3B | 6 | Oregon | Virginia | 11/05/76 | 12/23/76 | 48 |
| 1S | 12 | Alaska | Oregon | 11/09/76 | 12/26/76 | 47 |
| 2S | 12 | Alaska | Missouri | 11/09/76 | 11/28/76 | 17 |
| 1H | 12 | Missouri | Alaska | 10/30/76 | 12/07/76 | 37 |
| 2H | 10 | Missouri | Virginia | 10/29/76 | 12/17/76 | 48 |

*Had been relocated several times previously.
**Young birds which had never flown.

## TABLE 10

## RELOCATION EXPERIMENTS WITH 118 BIRDS

| | BIRD NUMBERS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1W | 1R | 1R | * | 1R | * | * | | | | | | | |
| 1L | D | 1R | * | 1F | D | 1F | 1F | 3R | * | 1R | 1F | 1R | 1R |
| 2L | 1R | 1R | H | * | * | D | 1R | 1R | * | * | * | * | |
| 1D | 1R | 1R | * | * | * | * | * | 1F | 1R | * | D | | |
| 1B | 3F | 1R | 2R | * | 2R | 2R | 1R | 2F | 2R | * | * | * | |
| 2B | 4R | 4R | * | 4R | * | 4R | 4R | 4R | 4R | 4F | D | 4R | |
| 3B | 1R | 17F | 2R | 1R | 1F | * | | | | | | | |
| 1S | 1R | I | H | S | * | 2R | * | I | * | * | * | 2R | |
| 2S | 2R | * | * | 2F | 3R | 3R | 2R | * | 3R | 3R | 3R | 2R | |
| 1H | 4F | * | 4F | 4F | 5R | * | 5R | 5R | 9R | 5R | 5R | 4F | |
| 2H | 1R | * | D | * | E | I | D | * | D | 15F | | | |

D=died, I=injured, S=sick, H=hawk, E=escaped.
1R, 2R, etc.=lost on 1st, 2nd, etc., release at loft.
1F, 2F, etc.=lost on 1st, 2nd, etc., flight from remote site.
*=survived and homed in (31% of 118 birds).
NOTE: Kits 1W and 1D were not 1st relocation birds.

(S) Of the 101 birds (discounting kits 1W and 1D) being relocated for the first time, Table 11 shows survival statistics relating to the origin of kits, and Table 12 shows statistics relating to their destination or new home loft. The low origin statistics for Missouri and Oregon (23%) are primarily due to the low destination statistics for Alaska (only 17%). In order to investigate this anomaly, which could impact severely on the proposed Leningrad targets, an additional kit (3B) of 25 birds was obtained from Oregon and sent to Anchorage on 1 January 1977. One of these birds died. Of the remaining 24 birds, 12 were flown many times from 30 miles, and

TABLE 11

ORIGIN STATISTICS ON 101 BIRDS

| ORIGIN | KIT | FRACTION | ORIGIN FRACTION | ORIGIN % SURVIVAL |
|---|---|---|---|---|
| California | 1L | 2/12 | 8/25 | 32 |
| | 2L | 6/12 | | |
| Oregon | 1B | 4/12 | 7/30 | 23 |
| | 2B | 2/12 | | |
| | 3B | 1/6 | | |
| Missouri | 1H | 2/12 | 5/22 | 23 |
| | 2H | 3/10 | | |
| Alaska | 1S | 5/12 | 8/24 | 33 |
| | 2S | 3/12 | | |

TABLE 12

DESTINATION STATISTICS ON 101 BIRDS

| DESTINATION | KIT | FRACTION | DESTINATION FRACTION | DESTINATION % SURVIVAL |
|---|---|---|---|---|
| Alaska | 2B | 2/12 | 4/24 | 17 |
| | 1H | 2/12 | | |
| Oregon | 1L | 2/13 | 13/37 | 35 |
| | 2L | 6/12 | | |
| | 1S | 5/12 | | |
| Missouri | 2S | 3/12 | 7/24 | 29 |
| | 1B | 4/12 | | |
| Virginia | 2H | 3/10 | 4/16 | 25 |
| | 3B | 1/6 | | |

two of these have been to 120 miles. These 12 surviving birds have been worked steadily (at least once a week) from 30 miles since their release in February. At this writing, all 12 are still flying at the Anchorage loft and have been worked harder than any other kit.

~~(S)~~ Table 13 shows overall relocation statistics for the 101 birds with a 28-percent survival from losses of all kinds. Note there were not always losses on the very first release. However, of the 44 birds lost during release at the loft, 31 were lost the first time losses occurred, and the remaining 13 were lost the second time that losses occurred for each kit. This implies that losses do not always occur at the first opportunity, but they do appear to occur in large groups. It was noticed that the "first loss" occurrence did tend to happen on bright sunny days with low wind and few clouds. The same statements can be made with regard to the 15 losses during flight training from remote launch sites; 13 birds left the first time losses occurred, and the remaining two left the second time losses occurred. It is interesting to note that of the 59 birds lost during release and flight training, only 25 percent were lost in flight training whereas over half of the losses happened the first time losses occurred.

~~(S)~~ A small project loft (see Figure 34) was constructed adjacent to the [redacted] loft at [redacted] Virginia, which was used to train kit 2F to fly, and also for the relocation of kits 2H and 3B. Table 12 shows that four of the 16 birds survived relocation. However, Table 10 shows that two of these birds (2H10 and 3B2) had made 15 to 17 flights (4 or 5 with weights) before they were lost. Table 14 shows the flight performance for these two relocated kits in terms of the number of times they carried weights of the same shape and weight as the avian camera. Bird 2H8 was eventually lost in April 1977, after numerous flights from the Navy Yard, and was not counted as a relocation loss. Two of these birds were moved to the widowhood experiment to be discussed later.

### *Additional Relocation Experiments*

~~(S)~~ Including kits 1W and 1D, there were 33 birds surviving the relocation experiments in Oregon, Alaska, and Missouri. Most

**FIGURE 13**

**FIRST RELOCATION STATISTICS**

| | NUMBBR OF BIRDS | | | LOST IN RELEASE AT LOFT | | | | | | LOST IN FLIGHT TRAINING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIT | Start | Finish | Died, etc. | 1R | 2R | 3R | 4R | 5R | >5R | 1F | 2F | 3F | 4F | 5F | >5F |
| 1L | 13 | 2 | 2 | 4 | 0 | 1 | | | | 4 | | | | | |
| 2L | 12 | 6 | 2 | 4 | | | | | | | | | | | |
| 1B | 12 | 4 | | 2 | 4 | | | | | 0 | 1 | 1 | | | |
| 2B | 12 | 2 | 1 | 0 | 0 | 0 | 8 | | | 0 | 0 | 0 | 1 | | |
| 3B | 6 | 1 | | 2 | 1 | | | | | 1 | 0 | 0 | 0 | 0 | 1 |
| 1S | 12 | 5 | 4 | 1 | 2 | | | | | | | | | | |
| 2S | 12 | 3 | | 0 | 4 | 4 | | | | 0 | 1 | | | | |
| 1H | 12 | 2 | | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 4 | | |
| 2H | 10 | 3 | 5 | 1 | | | | | | 0 | 0 | 0 | 0 | 0 | 1 |
| Subtotal | | | | 14 | 11 | 5 | 8 | 5 | 1 | 5 | 2 | 1 | 5 | 0 | 2 |
| Total | 101 | 28 | 14 | | | | 44 | | | | | | 15 | | |

**TABLE 14**

**FLIGHT PERFORMANCE FOR RELOCATION KITS 2H AND 3B**

| BIRD NUMBER | TOTAL FLIGHTS WEIGHTS | NAVY YARD WEIGHTS |
|---|---|---|
| 2H2** | 7 | 3 |
| 2H4 | 21 | 15 |
| 2H8 | 19 | 13 |
| 2H10 | 3 | 0 |
| 3B2* | 4 | 0 |
| 3B6** | 7 | 4 |

*Lost after 15 to 17 flights.
**Moved to widowhood experiment 3/3/77. 2H8 was eventually lost 4/11/77.

FIGURE 34. Exterior View of the Attic Loft
**UNCLASSIFIED**

loft managers typically train their birds to come into the loft quickly in response to audio cues, such as whistles, rattling feed cans, or door chimes. During these experiments, each loft manager was provided a magnetic tape cassette with a particular music selection that would not normally be associated with an audio cue. All birds learned quickly to respond to the musical cue. In addition, all birds learned to enter the loft through an air-conditioning shell which had a 4½-inch hole in its top face. Exit from the loft, for exercise, was provided by emplacement of a ramp leading up to the drop hole.

~~(S)~~ The surviving 33 birds were shipped to Virginia by air freight. Four were used in the widowhood experiment (to be explained later) and 29 were placed in an attic loft. Figure 34 is an exterior view of the attic loft. The top most air-conditioning unit is a shell complete with drop hole and entrance way from the attic as shown in Figure 35. In Figure 34, the view is blocked to the south and west by the apex of the roof. To the north and east the view is also blocked by tall trees. The birds were held captive about 40 days during which time a round of youngsters were raised. Also, reinforcement to the music and drop hole was provided by using a simulated air-conditioning shell located on the loft floor; this training is shown in Figure 36. The 29 birds were organized into two groups. For the first release, the first group of 12 birds was

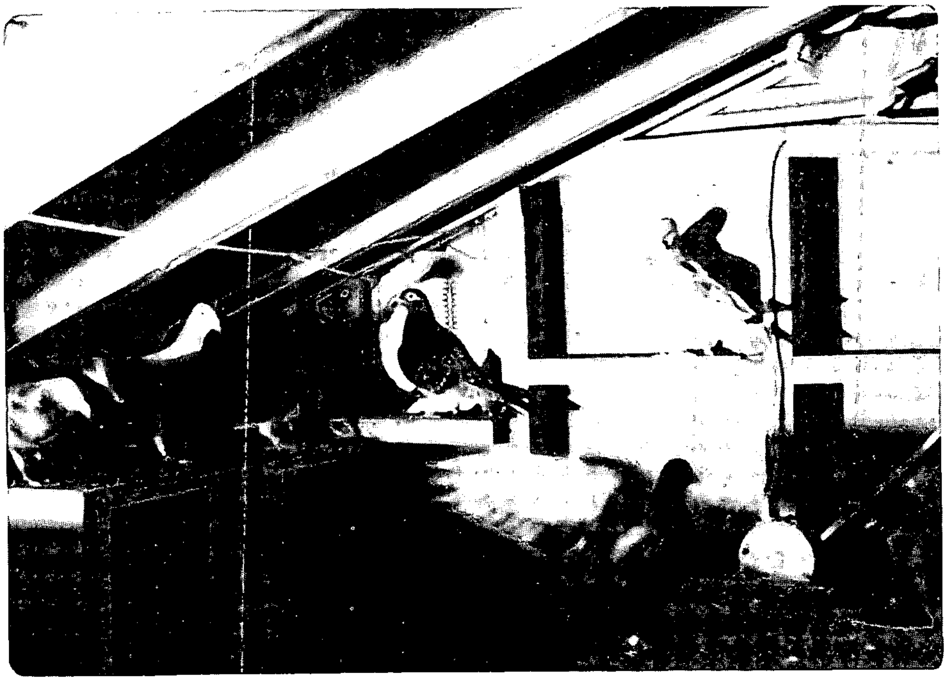

FIGURE 35. Interior View of the Attic Loft

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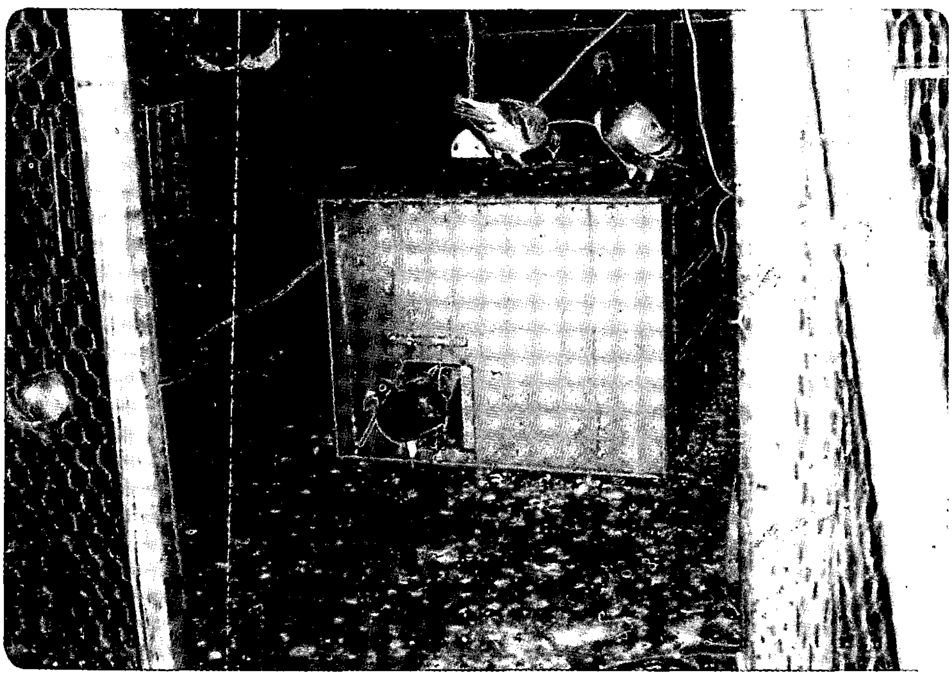

FIGURE 36. Reinforcement Training to Drop Hole

**UNCLASSIFIED**

allowed to leave the air-conditioner shell by use of a ramp similar to that shown in Figure 37. All 12 birds were lost on the first release. It was speculated that the birds could not see enough of the surrounding area through the louvers in the air-conditioning unit to prevent being lost. Therefore, the second group of 17 birds were hobbled by placing rubber bands around the last four or five primary flight feathers. This causes a gross aerodynamic imbalance and greatly suppresses the ability and desire to fly. On the first day of release, 10 of the 17 hobbled birds walked out onto the roof and spent the day. Six of these birds did not reenter the loft that evening, but all were in by the next day. After four days, all 17 birds had spent between two to four days on the roof and the wing hobbles were removed. On the first release without hobbles, 9 of the 17 birds were lost. The tenth was lost on the third release, and the eleventh was lost on the fifth release. On the seventh release, a cat was observed on the roof chasing the remaining six birds and all spent the night away from the loft; one of these did not return. By the end of the eighth release, there were five birds left, and flight training from remote sites began. By the end of the eighth flight, on 14 May 1976, all five birds were flying several miles back to the loft. A survival rate of five in 17 (29%) is typical of the previous experiments. At this time, however, unseasonally hot weather moved into the Washington area with temperatures in the mid-90's. The temperature inside the loft climbed to well over 100 degrees despite the use of overhead insulation and the installation of an attic fan in

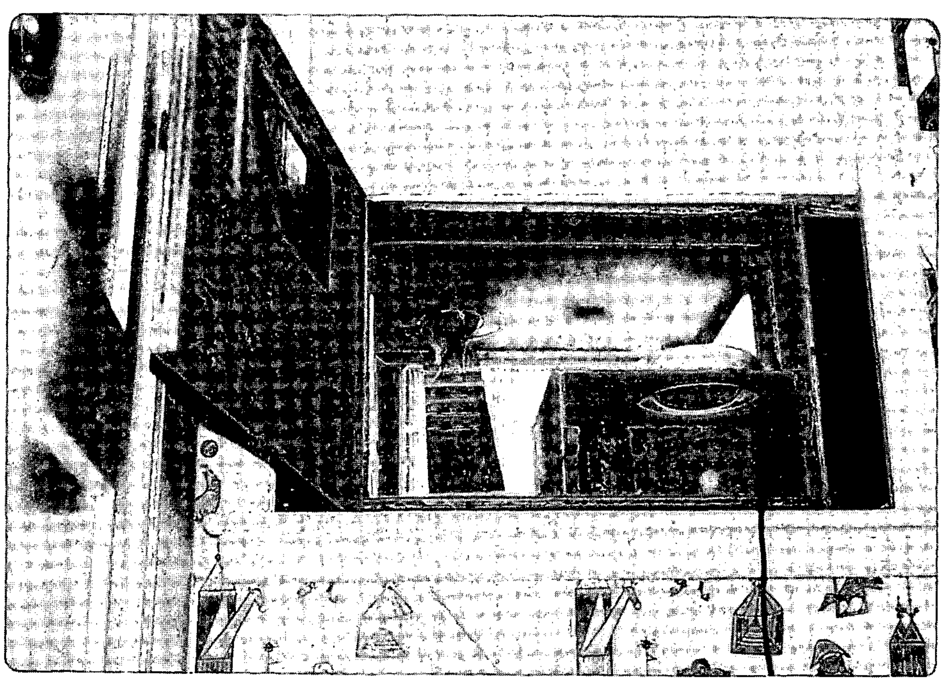

FIGURE 37. Bird Leaving Air-Conditioning Shell

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the loft area. On the ninth flight, three of the five birds did not return. The two that did were both hens that were sitting on eggs. At this point, the experiment was terminated because of the excessive temperature in the loft. It is apparent that there are a multiplicity of factors affecting relocation. Some of these are discussed in more detail in Appendix C.

### *Widowhood Experiments*

(S) The widowhood system is a complicated technique used by the more experienced pigeon handlers for the purpose of highly motivating cocks to return to the loft quickly and, thereby, win pigeon races. Some of the particulars are described in Reference 4 and in Appendix C. Briefly, cocks are taught that they may be with their hens only when they are taken to a remote site and released to come home. When a cock is working well on this system, he comes straight home and immediately enters the loft to be with his hen. Of the 33 birds transported to the Washington, D.C. area for additional experiments, four were placed on widowhood to study the effects on relocation. These birds were 2L5, 2L11, 1B11, and 1S11. Bird 2L5 was lost at the loft for unknown reasons. Bird 2L11 was relocated successfully and flown three times with weights, the last time from the Washington Navy Yard. Bird 1B11 was lost during a severe thunderstorm, and bird 1S11 was relocated but finally lost with a weight while flying back from the Navy Yard. Two of the old birds, 1F5 and 1F14, were placed on this system and did carry weights from the Navy Yard. The last, a young bird (2F10), also carried weights from the Navy Yard. Figure 38 shows the widowhood loft with air-conditioner shell for the entrance of the four relocated birds. Two birds, 2H2 and 3B6, which had survived the first relocation experiments, were tried on this system but failed to perform properly. The general consensus at this time is that the widowhood system is too complicated to be used in the field. At some future time it might be reconsidered as an advanced technique to be used by highly trained loft managers.

### *Remarks on Behavior*

(TS) It is apparent that the birds are capable of getting the camera over targets such as Andrews AFB and the small museum park in the Washington Navy Yard. By applying the results of Figure 33 to the problem of Sudomekh in Figure 4, it would appear that there is a 25 to 50 percent chance of overflight once a "preferred flight line" has been established. The fact that homing pigeons do not always have a vanishing bearing precisely in the direction of home is referred to as "launch site bias" and is

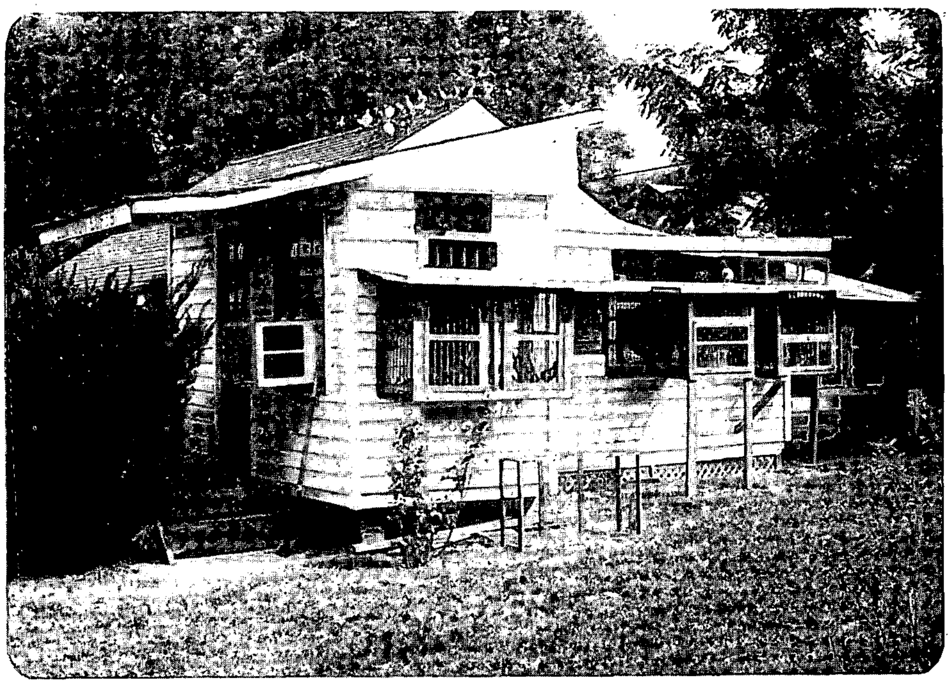

FIGURE 38. Widowhood Loft With Air-Conditioning Shell

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discussed in Reference 5. The reason for this bias is not clearly understood and must be measured for each general locality. Reference 3 also discusses visual cues wherein homing pigeons will use tall objects near their home loft to which they will visually home as a "terminal guidance" object.

(S) The relocation of homing pigeons has been a subject of study for some time. An excellent book (Reference 6) by Dr. W. E. Barker lists several essential points which are discussed in Appendix C. One of his points states that if relocated birds are placed under stress, they may well decide to leave. Certainly, this tendency was experienced on this program. On the other hand, the U.S. Army relocated many pigeons during World War II. The exploits of several decorated pigeons are described in the first chapter of Reference 7. Here, pigeons carried messages through storms and enemy gun fire, many returning with severe wounds. Certainly, these could be considered as conditions of severe stress. However, the precise techniques and methods used for relocation, and the survival statistics, have not been thoroughly researched and definitely should be, if further work is to be done on this project.

(S) Relocation experiments were conducted on a previous project during the spring and summer of 1976. Here, the entire pigeon loft (a packing crate) was transported to the new location site. In this way, the birds already knew what the outside of their new home looked like (a primary point in Barker's book). During the "attic loft" experiment, the second group of birds learned the view from outside the loft by the use of "wing hobbles," which appeared to work well. A still better way, if operationally feasible, was used by a loft manager in Japan, wherein he placed his imported birds in a small cage on the back of his Honda and drove them around the neighborhood.

(S) In conclusion, the reliability of relocated birds is still a serious question, regardless of the method used for resettling. Without further research on reliability, it is recommended that young birds be taken to the target loft so that this will become their primary home. They can then be relocated to the Washington area for training and selection. Those of acceptable performance can then be returned to the target loft with a high degree of confidence that they will perform with essentially the same statistics as that described in Figures 31 and 32. During the experiments conducted in the Washington, D.C. area, there were 51 flights with cameras and 341 with simulated weights, or 392 flights with cameras or weights. These data indicate that there is about one chance in 30 of losing a camera on each flight. However, in about half of these losses, the bird and harness returned to the loft. A better method of camera attachment would reduce losses to about one in 60.

# PART 6
## AN EXAMPLE MISSION SCENARIO

(~~TS~~) Several assumptions are necessary. For example, assume we wish to complete a mission in the Leningrad area before the end of the 1978 calendar year. Figures 39 and 40 show that only from the

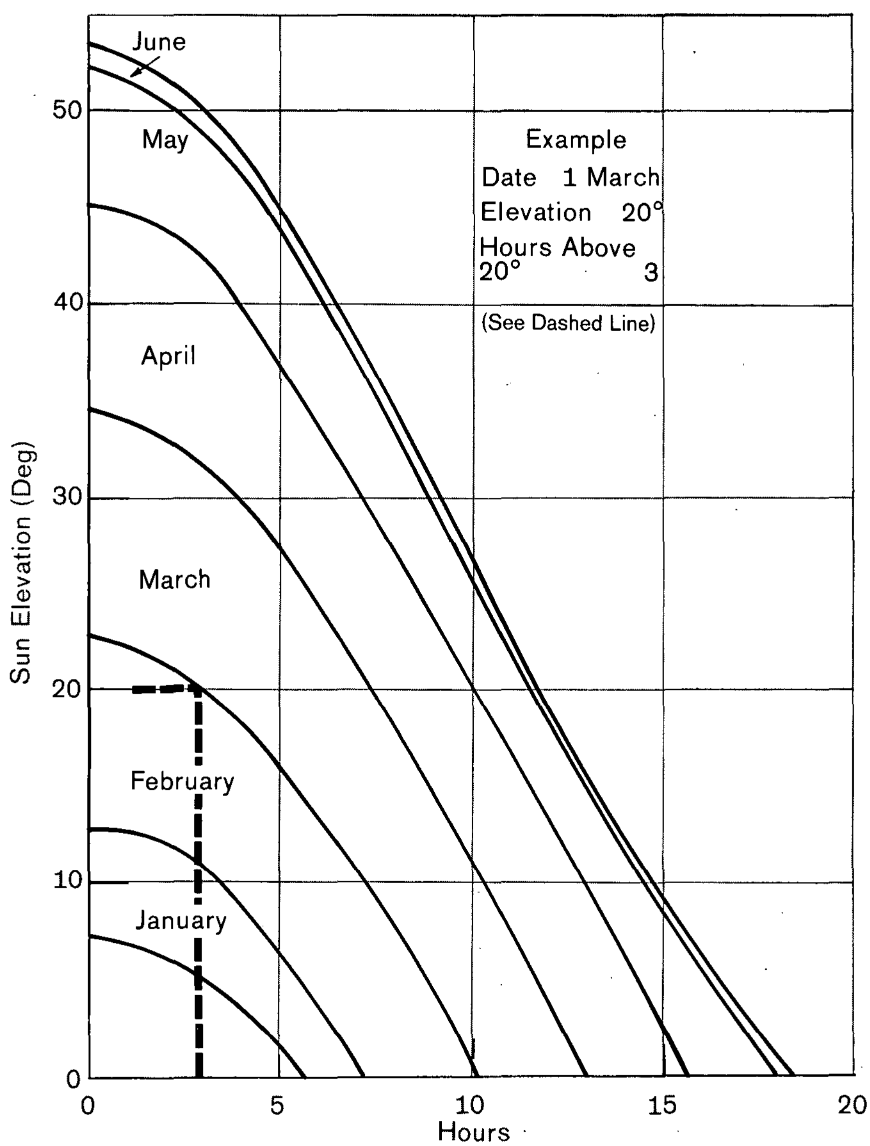


FIGURE 39. Hours the Sun is Above a Given Elevation for January - June in Leningrad

**UNCLASSIFIED**

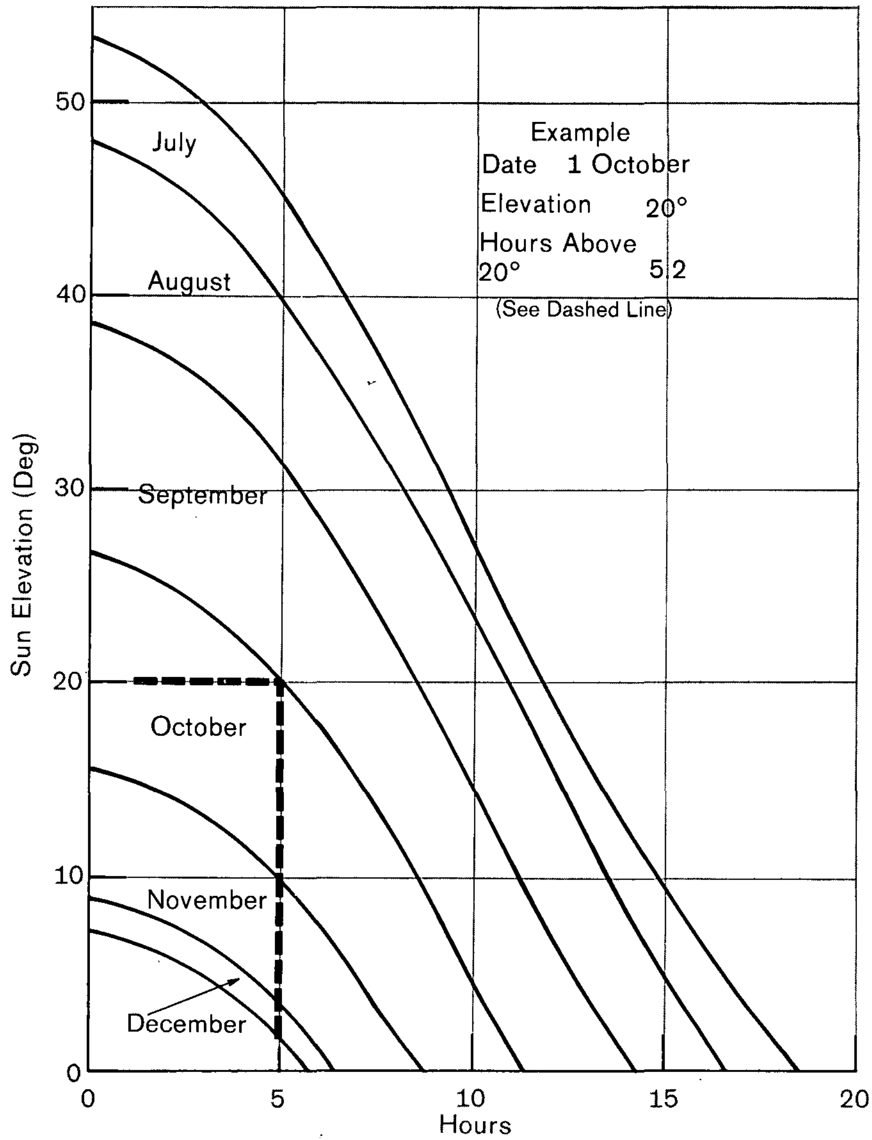


FIGURE 40. Hours the Sun is Above a Given Elevation for July - December in Leningrad

**UNCLASSIFIED**

latter part of February to the early part of October does the sun rise above 20 degrees in elevation for any appreciable period of time during the day. Results from the balloon tests in Part 3 indicate a sun elevation of at least 20 degrees is necessary for adequate contrast and exposure. It is felt that operational flights against the targets in Leningrad should begin no later than early August 1978 so that adequate coverage can be obtained by early October. Several plans are possible which trade risk against operational complexity. Two plans are discussed below which assume a start date of 1 October 1977.

### *Plan 1 (preferred)*

(TS) A local loft must be purchased or constructed by mid-October 1977. During this time, 100 pairs of exceptional breeders will be purchased at an average cost of $150 a pair. These will be placed in the local breeding loft by the third week in October so that all will be on eggs by the end of the first week in November. These eggs (about 150 to 170) will hatch by the end of November. By the end of December, about 30 days of age, all young will be out of the nest eating and drinking on their own. During these three months, a loft manager must be trained in the care, handling and flight training of young birds, and a loft must be constructed in the [redacted] About half of the young birds (70) will be handpicked for transport to [redacted] the first week in January 1978; the subject of transport will be discussed later. During January these birds will be trained into the [redacted] as their primary home. If possible, the birds should be placed just outside the roof access window, shown in Figure 6, in a wire basket for several hours a day just before their first release (about one week after arrival). Certainly, the basket should not be placed where it can be seen by any possible observation post. If the basket cannot be placed on the roof, the birds should be allowed to look out as many windows and dormers as possible prior to their first release. The birds can be released in small groups which are kept hungry so that they will come in quickly when the dinner music is played. By the end of January, or the first week in February, all birds should be flying from the loft and ranging a mile or so during exercise flights. There will probably be about 60 birds left at this time. During the remainder of February, the birds should be taken out in small groups and released in parks or wooden areas (more will be said later on clandestine release techniques) but this is not mandatory. By the end of February, about 50 young birds will consider [redacted] as their primary home.

(TS) There is certainly a temptation to select some of these 50 birds for the purpose of testing their performance with weights in the Leningrad area during the month of March and trying for a mission in April or May. However, this may involve undue risk and would require sending a new loft manager to the field who had been trained in mission-oriented techiques. A safer approach would be to bring the 50 birds back to a loft in the Washington, D.C. area [redacted]

(TS) By mid-April, these 50 birds will be ready for their first release from the local loft. Relocation techniques not available in the field can be used to increase the relocation rate of survival. It is estimated that about 20 to 25 birds will survive this relocation. By the first of May, flight training to harness and weights can begin, and the birds can be moved out toward local example targets (e.g., the Washington Navy Yard). Through the end of June, field personnel will be trained in all aspects of clandestine release, camera maintenance and repair, and techniques for determining the "preferred flight line." By the end of June 1978, 10-15 birds will be selected for transport back to the Leningrad loft.

(TS) During July, these 10-15 birds, which consider Leningrad their primary home, can be used to determine the preferred flight line and to select suitable launch points for overflight of the selected targets. By the first of August 1978, mission operations can begin with some confidence that the probabilities of overflight are essentially those of Figure 32. The disadvantages of this plan are:

1. There are only about two months before operations must be terminated due to low sun elevation.
2. The birds must be transported three times.
3. There is a great deal of "activity" in the field [redacted]
4. The time schedule is very tight with some risk of being late.

### *Plan 2*

(TS) During the first half of October an operational type loft is constructed in the Washington, D.C. area capable of housing 200 pigeons. These birds will be two to three years old and all should be of proven worth from their racing records. The cost will be in the neighborhood of $100 each. These birds will be relocated to the local loft for a first release by the early part of December 1977. Again, techniques not suitable in the field can be used to increase survival. All birds should be on eggs by the first release, and wing hobbles should be used for one week after the first release. It is estimated that there will be 70 to 100 surviving to the end of December. Starting in January 1978, these birds will be trained to harness and weights and worked out to example targets. By the end of February, loft managers will be fully trained in all aspects of the mission, and the final selection of 35 to 50 birds will be made. These birds will be shipped to Leningrad in early March and the first release, with wing hobbles, will occur during the end of April. Again, all birds should be on eggs at the time of release. At least 10 to 15 birds should survive to the end of May. The performance and, hopefully, the reliability of these birds have already been established over local example targets. By early to mid-June, launch sites should be selected and mission operations can begin. The advantages of this plan are:

1. Operations start in mid-June giving about four months to collect photographic coverage.
2. Only 35 to 50 birds are taken to the field once, and all these birds have been tested over local targets.
3. There is no need to rush into the field, as with plan 1, until all personnel (and birds) are fully trained.

The disadvantages of this plan are:

1. The care and handling of 200 pigeons through the first relocation is no easy task, not to mention the harness and weight training of 70 to 100 birds.
2. The estimate of 35 to 50 birds of acceptable performance for shipment to Leningrad is speculation. There is insufficient data from this research for a reliable prediction.
3. Assuming there are a sufficient number of birds which perform well over local targets, the probability of their holding up under additional stress at the operational target is a matter of conjecture at this time. Without further research, it must be assumed that the risk of loosing camera and bird is higher with this plan than with plan 1.

(S) Plan 1 is more complex but involves less risk in predicting performance. With additional research on the performance of birds at a secondary home, plan 2 may well be preferred; it should certainly be the goal of further research.

### *Transportation*

(S) During this project birds were shipped by airfreight from Anchorage, Alaska, to Dulles Airport on several occasions. During one shipment from Oregon, birds were lost for three or four days, finally arriving in fair condition; the primary danger is thirst and heat, not hunger. It is not uncommon for local loft keepers to ship birds to Japan or receive them from France and Belgium.

(S) The issue here is that of clandestine transport. Some research has been done in this area (Reference 8) but with species other than pigeons. However, it is felt that a pigeon in good condition is among the hardiest of bird species and should survive transport as well as any. In Reference 8, birds were transported in "hole luggage" and "carry-on luggage" for periods up to 72 hours. Some holes and air passages (quarter-inch holes in the bottom) were provided for ventilation. The birds were wrapped in cloth, or panty hose, to restrict movement, and eye coverings were used which greatly inhibited auditory noise and caused a "catatonic" like state of inactivity. A layer of San-O-Sil (trademark) impregnated with water-soluable neomiocin was placed in the bottom of the luggage in order to prevent a toxic contamination of the air by ammonia in the birds excrement.

### *Clandestine Release*

~~(S)~~ Most are familiar with the magic tricks that seem to produce large numbers of birds from nowhere. In fact, birds transport well in the outside or inside pockets of large overcoats. Consider a large inside pocket near the bottom of an overcoat. If one were kneeling, say to feed the park pigeons, it would be a simple matter to release several birds from underneath the coat.

~~(S)~~ One particular method was studied which would be convenient for the release of a number of birds over a short period of time. An access hole was provided in the floor of an automobile through which one or two pigeons could be placed onto the road or parking lot. The pigeons walked from underneath the car and immediately took flight upon reaching daylight. Figure 41 shows a pigeon with harness and weight that has just taken flight after being released by this technique. If the automobile were in a parallel parking area with adjacent parked cars, it is conceivable that several birds could be released by this method, even under close surveil-

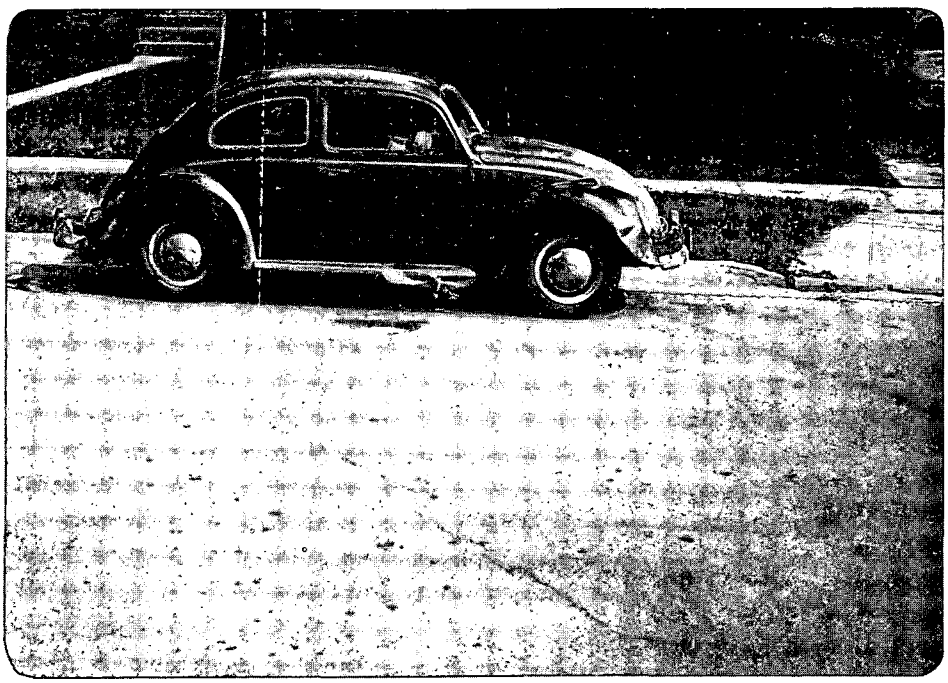

FIGURE 41. Pigeon In Flight After Clandestine Release

~~SECRET~~

lance. Various methods ranging from shopping bags to briefcases with "trick bottoms" could be tried in the local area during training exercises.

### *The* [redacted] *Loft*

(S) The loft in the target area must be completed prior to arrival of the first birds. This includes perches (a collapsible egg crate frame of ¼ in. plywood), nest boxes (if they are old birds), and an adequate supply of feed and medicine (see appendix C for the prevention and cure of disease). A grown pigeon will eat about an ounce of feed per day, and a few pounds of grit will last a month for 50 birds. The loft must be well ventilated without noticeable drafts. The colder the temperature, the better the birds thrive (the Alaskan loft has experienced temperatures of 40 degrees below zero). However, high temperatures (above 90 degrees) will precipitate disease and severely degrade performance. If loft temperatures above 90 degrees are to be expected (at the target area or locally), some combination of insulation and air-conditioning must be provided without the birds being in a direct draft. This issue cannot be taken lightly, particularly with young birds.

# PART 7
# SUMMARY AND CONCLUSIONS

(S) It is felt that the quality of photographs collected over the Washington Navy Yard is adequate for satisfying a high-resolution requirement. Furthermore, the chance of overflight, shown in Figure 33, certainly demonstrates the feasibility of getting the camera over the target. An unexpected result of this ten-month effort was a lack of data sufficient to predict the performance of relocated birds. This is due primarily to the initial allocation of priorities dictated by the constraints of manpower and funds.

### *Photographic Quality*

(S/TK) Of 36 camera flights over the Navy Yard, six collected 23 images of some portion of the target. Mensuration on 53 samples varying from 3 inches to 37.5 feet showed an average error of less than 1.6 inches. Perhaps of greater interest is the mensuration of 22 small objects (less than 2 feet) which showed an average error of about ¾ of an inch with 90 percent of all errors less than 1.8 inches. In comparison with KH-8 photography of the same target, the avian system was rated as having a higher image interpretability as well as the ability to see smaller objects. The National Imagery Interpretability Rating Scale (NIIRS) ratings were 7.8 for the avian system and [redacted] Furthermore, it is believed that the avian system, due to its extremly low altitude, has a high potential for using color photography (SCAT) for materials identification (see Table A4 in Appendix A).

### *Camera Research*

(S) It is felt that the [redacted] camera can be brought from research to operational status within the time frame of either plan discussed in Part 6. However, it is suggested that the following be considered carefully:

1. The field replaceable shutter assembly has greatly contributed to system reliability. However, a method for measuring shutter speed in the field should be developed as a check on system performance. Low shutter speeds were the primary cause of image blurring on this project.

2. A method should be developed for identifying the type, location, and degree of light leaks prior to each mission. This

problem is not difficult to solve and would provide a most important check on system performance.

3. An effort should be made to reduce the weight of the [redacted] system, particularly the method of harness attachment which is subject to periodic failure. Research in this area would improve bird performance.

4. Some barrel distortions in the [redacted] lens were observed at the edge of the field of view. Mensuration accuracy could be improved if the lens were calibrated or redesigned.

5. Appendix B contains low temperature data and suggestions for providing a low temperature system.

~~(S)~~ Some preliminary research was conducted to increase the lateral coverage by use of a miniature panoramic camera which has the same weight as the current [redacted] system. The lateral coverage is adjustable and would increase the oblique photography to the right and left of the flight path. Figure 42 is a picture of this

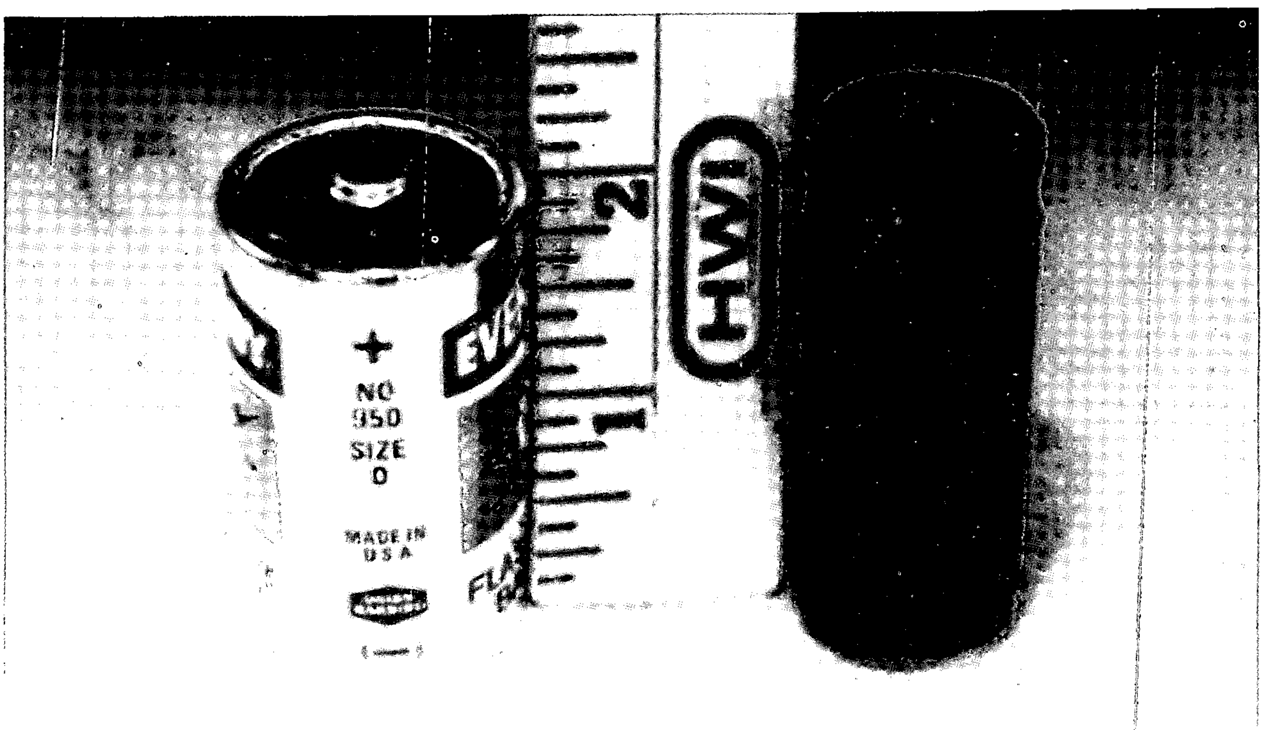


FIGURE 42. Miniature Pan Camera

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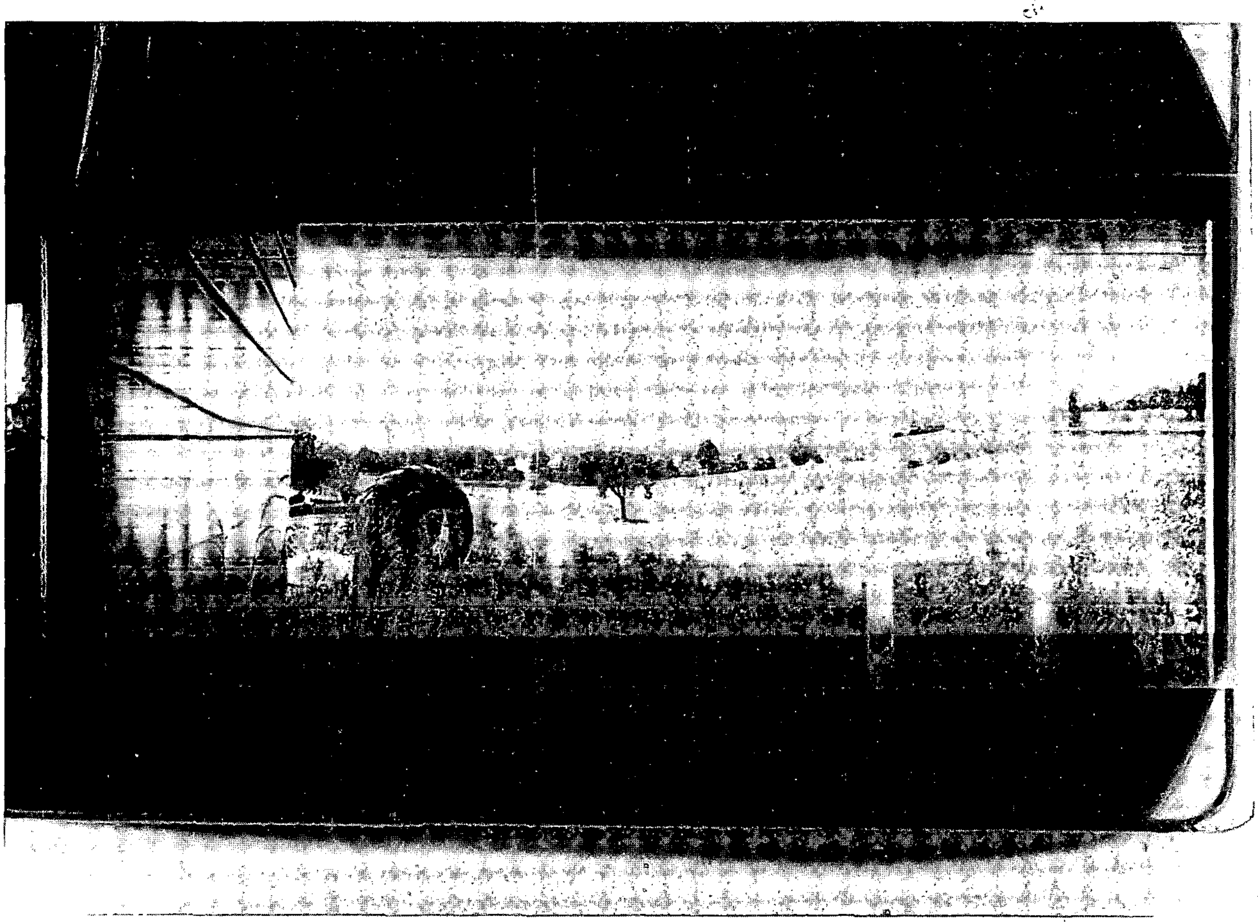

FIGURE 43. Pan Picture With 180° Field of View

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miniature pan camera. Figure 43 is a picture taken by this first research unit with a 180 degree field of view. The goal would be to achieve the same photographic quality as the current avian system. However, no further research is planned at the present time. The point here is that increased coverage would provide increased intelligence and, therefore, fewer flights and less risk.

### *Bird Performance*

(S) The ultimate goal should be to provide a hard core operational kit of birds which have been trained over local targets and selected for proven performance. These birds would be held at a local operations-type loft for rapid deployment to any target area with confidence in the expected performance and reliability. It is felt that the key ingredient in achieving this goal is the local loft and the dual involvement of research and operational field personnel. Aside from providing a training ground for personnel and a proving ground for new ideas, such a loft might act as a vehicle for fusing together the practical problems in the field with the science of research.

## *Concluding Remarks*

(S) Whether or not sufficient data has been presented to warrant the initiation of an operational plan is dependent on the importance of the intelligence need in relation to the risk and logistic complexity in the field. It is hoped that this report contains sufficient data and candor to allow those concerned with the intelligence requirement and field operations to form a proper judgment. It is suggested that an active interchange between research and the concerned parties may provide a plan with acceptable risk and logistic complexity, and clearly identify the type and degree of research required for adequate support.

# APPENDIX A
# EVALUATION OF PHOTOGRAPHIC COVERAGE
# (Prepared by NPIC)

## Section 1 Summary

### 1.1 *Introduction*

(S) During the past year (6/76-7/77) the National Photographic Interpretation Center has provided analytical and production support for a research study (Tacana) being carried on by the Office of Research and Development/Operations Technology Division to determine the feasibility of using an avian (pigeon) platform for purposes of collecting overhead reconnaissance photography. This support has included:

— The evaluation of the system imagery for exploitation purposes by the Imagery Exploitation Group (IEG) and the Technical Services Group (TSG).

— Assistance in the camera modification development, film selection, and system quality evaluation by the Technical Services Group.

— Imagery production and film processing by the Production Services Group (PSG).

(U) Following is a summary of the results of the various studies and observations which will aid in describing the quality of the exploitation product from this system.

### 1.2 *Interpretability*

(S/TK) ***The Tacana system has the capability to acquire imagery of an exploitation quality equal to, or better than existing systems, including the KH-8.***

### 1.3 *Mensuration*

(S/TK) ***The Tacana system can image measurable objects of small dimensions.*** Twenty-two measurements made of object dimensions of 3 inches to 2 feet indicate that 90% of the errors (from ground truth) are less than or equal to 0.15 feet (4.5cm). Fifty percent of the errors are less than or equal to 0.06 feet (1.82cm).

### 1.4 *Digital Image Manipulation*

(S) ***Interactive Digital Image Manipulation techniques clearly reduce the imaging effect of directional smear sometimes produced by the Tacana system.*** The beneficial effects of other IDIMS techniques (to enhance the detail of shadows and highlights, reduce grain noise and clarify fine detail) were less obvious. These techniques will usually benefit any general film imaging system (including Tacana) that has acquired threshold level detail imagery (where density and resolution information is almost present).

### 1.5 *Image Quality Analysis*

(S) ***The Tacana system has the potential to acquire imagery of less than 1 inch (2.54cm) GRD*** under optimized conditions of lighting, platform stability, camera reliability, and flying height. Most of the time the system will perform at a lower quality level due to the unpredictable nature of the platform and variable flying heights. A camera shutter speed of at least 1/2000 second is required to produce a reasonable percentage of sharp (non-smeared) images from a given flight.

### 1.6 *Film Selection*

(S) ***The Tacana is a fair weather (with sun) system and is adaptable to both black-and-white and color films*** (EK 3410, FE 6526 and Aero Color Negative 2445). Because the camera is a fixed exposure unit, clear sun (no clouds or heavy haze) acquisitions of less than 20 degrees solar elevation will require a faster film with a resultant loss in overall image quality.

### 1.7 *Other Summary Comments*

1.7.1 (S) ***An avian (pigeon) platform can be used to acquire imagery of a specified target area.*** Of 36 test flights evaluated over the Washington Navy Yard of a designated target (Willard Park, the Navy Museum display area of about 64,000 square feet), 6 flights acquired 23 images of some portion of the park.

1.7.2 (U) ***Throughout this study, image quality was compromised due to poor camera reliability*** (i.e., power failures, shutter breakdowns, light leaks producing fogged film, optical system misalignments and/or internal flare). While these "kinds" of malfunctions and effects are typical of problems associated with research and prototype fabrication, a clearer view of system performance could be obtained if they were corrected in future development efforts.

1.7.3 (U) ***The present*** [redacted] ***lens produces imagery containing a high degree of barrel distortion.*** The mensuration accuracy could probably be improved if each camera was calibrated and future lens systems (i.e., design) had reduced distortion effects.

1.7.4 (S) ***Greatest detail imagery will be obtained with this system on black-and-white film.***

1.7.5 (S) ***Using color films this system has a high potential for materials identification (using SCAT) and certain camouflage, concealment and detection applications.*** Further research should be done to determine the effectiveness of this system in these areas. The Tacana's large scale imagery and its relative freedom from high altitude atmospheric effects during acquisition are beneficial for this type of analytical analysis.

## Section 2 Determination of Exploitation Suitability

### 2.1 *Introduction*

(S/TK) Because the Tacana study was a research effort, it is felt a measure of performance from a user point of view would be meaningful to aptly describe the quality of the system product. Following are NPIC evaluations that describe the exploitation (interpretation, mensuration, and image manipulation) potential of the system. The nature of this study involved parallel development of the bird, camera, targeting philosophy, and films and processes; therefore, it is impossible to predict a level of system performance to be expected operationally. However, efforts were directed towards describing the exploitation suitability of the system in terms of its potential to perform when all elements appear to be functioning at their optimum, i.e., no camera malfunctions, tired and untrained birds, or wrong film/poor process combinations. Certain KH-8 data (and photography) is included in the analysis for informational purposes. For editorial convenience, a study describing the capability of the Interactive Digital Manipulation System to improve the Tacana exploitation product is placed in this section.

### 2.2 *Interpretability*

2.2.1 (TS/TK) Figure A1 shows the percentage occurrence of NPIC/IEG photointerpreter NIIRS ratings* of 85 images acquired

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*(S) NIIRS (National Imagery Interpretability Rating Scale) is a uniformly understood and systematically applied judgment by photointerpreters of the interpretability of acquired imagery, regardless of collection source. It is a graduated scale divided into 10 numbered rating categories, with 0 representing unusable imagery and nine representing imagery with the best interpretability. It is enough to know here that NIIRS is an accepted Intelligence Community measure of interpretation quality and is used to aid collection and mission planners, engineers, photoscientists and other PIs. For further information see NIIRS Documentation, Vol. II, TCS-9842/74.

by the Tacana system over the Washington Navy Yard 3/17/77. This data represents an average rating by three PIs of a complete flight operation. Operational PI NIIRS data from KH-8 Mission 4348 is also shown. The Tacana flight evaluated represents the best performance of the total system (in terms of image quality) that was obtained during the test phase of this study. This is not a measure of predicted system performance but does describe the capability of the system to produce high-quality imagery when all aspects (bird, camera, weather, etc.) are performing reliably.

2.2.2 (S) Figures A10-A17 represent Tacana vertical and oblique images from the flight that were rated by the PIs. Other types of photographs typically acquired by this system are illustrated by Figures A18 thru A20 showing observed maximum flying height (about 300 feet) and Figures A21 and A22 representing adjacent frame quality differences caused by inconsistent bird motion (a common occurrence with this system). Figures A23 thru A27 show sequential (adjoining) frames from one flight covering the Navy Yard, Willard Park Display Target Area. Of interest here is to note the target mapping effect that can be accomplished with this kind of a system. It is useful to compare these pictures with the KH-8 coverage of the target area (Figure A30). Figures A23 thru A27 also exhibit certain camera anomalies that are more completely described in Section 3.2.7.

2.2.3 (U) There are no peculiar problems associated with viewing Tacana imagery. Its small format image (12.5 x 12.5mm) and large scale (nominal 2000:1) lend themselves well to producing duplicate positives, handling, and viewing with existing (low magnification) photointerpretation equipment.

2.2.4 (S/TK) Due to the small area coverage of each frame (nominal 30 x 30 meters) and the inconsistent aiming of the platform, some type of collateral coverage should be available to the interpreter for determining his Tacana coverage in the general target area. KH-8 coverage is suitable for this mapping function.

2.2.5 (U) To simplify the duplication of this type of imagery (16mm strips, nominal 3 meter lengths per 200 exposures) a three density level exposure of each image segment will satisfy most frame-to-frame density differences caused by illumination and target brightness variations. For example, one image segment of 10-15 images would be duplicated three times (once each at three different density levels) side by side on a 20.3 x 25.4cm (8 x 10 inch) chip of duplication film. This technique allows the PI to easily select the best frame for interpretation as well as giving him the opportunity to exploit two different brightness areas (shadow and highlight) of a given scene.

## 2.3 *Mensuration Suitability*

### 2.3.1 *Introduction*

(S/TK) An exercise was performed to provide a view of the mensuration of imagery produced by the Tacana system. Supportive data and accuracy standards were provided from the KH-8 and ground truth information.

### 2.3.2 *Exercise Procedures*

(S) A target test area similar to an operational area was selected at the Washington, D.C. Navy Yard museum (Willard Park, Figure A30). Within this test area, a TALOS missile was singled out as being representative of the type of target appropriate for study (Figure A29). This missile has an assortment of different shapes and dimensions that would be both quantitatively and qualitatively important in an intelligence sense.

(U) The procedures for this exercise were to first acquire distances from the target site for use in scaling. These distances ranged from 15 to 40 feet (5 to 12 meters).

(U) Two system photographs were used for this study (Figures A25 and A28). Other coverages of the target area were not included because of severe blurring due to platform motion, lens distortion effects and/or extreme obliquity.

#### a. *Scale Determination*

(S/TK) Good satellite coverage of the Washington, D.C. Navy Yard is minimal. Two KH-8 frames were found that could be used for determining a working scale. Monoscopic measurements were made and compared with ground truth dimensions. From these values, one or more were chosen as a scale reference in deriving dimensions from system imagery. The scale dimension used had to be as close as possible to the target, generally parallel to the target and nearly in the same object plane. The last requirement could not always be done, especially in trying to get a variety of dimensions from the TALOS missile which not only rests upon a raised base, but also has a nose-up attitude. Because of this target problem, additional targets in the vicinity of the TALOS were chosen in order to demonstrate the capability of the system to "see" small dimensions.

#### b. *Focal Length and Format Edges*

(S) Although the cameras have unique design features for their size and function (moving film and an image motion compensator), the imagery can be analyzed as frame photography since the photograph is exposed simultaneously over the entire format. With that in mind, the frame format edges and focal length were looked at to find out if the imagery lended itself to analysis by either graphical or analytical means.

### 2.3.3 *Results*

(S) Preliminary results* showed that small dimensions could be measured. This exercise was to test the Tacana system for mensuration feasibility on "operational" imagery which included long dimensions (2-38 feet) and small dimensions (0.2-2.0 feet). The results also compare the image formats of the two types of cameras and their respective focal lengths. This additional information is important for future exploitation of operational imagery.

a. ***Format Edges***

(S) The format edges are important in that they are used to aid in computing the focal length. There are two types of cameras: one with a rectangular format measuring 12.5mm by 7.5mm, and the other with a square format 12.5mm by 12.5mm. The rectangular imagery acquired with the Model I (MCW-24) had fuzzy format edges when viewed on a monoscopic comparator at 5X magnification. However, the square format imagery (Model II [redacted] camera) had sharp, well-defined edges when viewed on the comparator.

b. ***Focal Length***

(S) The nominal focal length of the Tacana camera is reported as 15mm. A test was done to check this value for the rectangular format camera. Two focal lengths were computed: 14.05mm and 14.19mm.

c. ***Target Data***

(TS/TK) Mensuration data was gathered from two photographs (Figures A25 and A28). The data points were measured on the 829 Mann Comparator. There was a total of 53 dimensions measured ranging from [redacted] The scale was determined from KH-8 measurements and the scaled distances compared with ground truth. The errors, or differences from ground truth, ranged from [redacted] This data is listed in Table A1. Histograms were

*The preliminary tests were done using imagery taken from a fixed or static camera platform, i.e., a balloon. No written report was required; however, results can be reviewed.

**TABLE A1**

**MENSURATION DATA FROM NAVY YARD IMAGERY***

| GROUND TRUTH | MEASURED DISTANCE | ERROR | GROUND TRUTH | MEASURED DISTANCE | ERROR |
|---|---|---|---|---|---|
| [redacted] | | | | | |

* All dimensions given in feet

constructed for three separate data sets: overall dimensions, dimensions less than or equal to two feet, and dimensions less than or equal to one foot. See Figures A2, A4 and A6, respectively. Corresponding graphs showing cumulative percentages of errors were constructed in order to better interpret the results. See Figures A3, A5 and A7.

2.3.4 ***Conclusion***

~~(S)~~ This section will attempt to draw together those points of the study which need to be emphasized. Reviewing Figure A3 for overall dimensions [redacted] it shows (as the dotted lines indicate) cumulative percentage values of errors at both the 90 and the 50 percentile marks. Following the dotted lines over to the curve and down, it is seen that 90% of the errors are less than or equal to [redacted] and 50% of the errors are less than or equal to [redacted] ft.

~~(S)~~ Since the most interest is in small dimensions (2.0 ft. or less), Figure A5 was constructed showing the errors of those dimensions ranging from [redacted] to 2.00 ft. On this graph, 90% of the errors are less than or equal to [redacted] and 50% of the errors are less than or equal to [redacted]

(S) If only the dimensions less than or equal to one foot are graphed, the data sample becomes so small that it is difficult to make an analysis. Figure A7 of the cumulative percent of errors for these short dimensions shows that 90% of the errors are less than or equal to [redacted], and 50% of the errors are less than or equal to [redacted]

(S) In conclusion, the results show that for dimensions less than or equal to 2.00 ft., the probability of a measurement being within [redacted] of the true value is 90%, or 90 out of 100, and being within [redacted] of the true value 50%, or 50 out of 100. In a like manner, the same statement can be said for the two other data sets. It must be pointed out that the stated probabilities are applicable only for the data sample (photographs) used here.

### 2.3.5 *Summary*

(S/TK) Probably the most interesting and impacting quality of the Tacana system is its ability to "see" small dimensions that otherwise could not be seen on KH-8 imagery, and be able to measure these dimensions accurately. Limiting the test to just one target area reduced the data sample considerably. Limiting the study to two good photographs further reduced the data set. However, it must be emphasized that the exercise, being a feasibility study, was very practical. The results can be assumed to be indicative of those for an operation such as Tacana where image acquisition has not been optimized to its full potential.

## 2.4 *Interactive Digital Image Manipulation (IDIMS)*

### 2.4.1 *Introduction*

(S) Test imagery acquired by Tacana over the Washington Navy Yard was manipulated on the IDIMS to illustrate the capability of the system to improve smeared imagery for exploitation. Because Tacana has no exposure control, imagery exhibiting heavy shadows was also selected for analysis.

(U/AIUO) The IDIMS is located in Room 4N 814, Building 213, and is utilized to extract additional intelligence information from problem imagery for photointerpreters and analysts. The IDIMS consists of a Hewlett-Packard 3000 CX computer with peripherals (i.e., three magnetic tape drives, one line printer, one card reader, four analyst terminals) and two COMTAL TV display monitors. A DICOMED, Inc., image recorder is capable of producing high quality hard copy results (black/white or color) on film or Polaroid paper. Approximately 200 image manipulation processing functions ranging from simple manipulation (e.g., contrast stretching) to complex manipulation (e.g., Fourier analysis and filtering) can be applied to digital imagery. The target area on a film transparency is digitized on a PDS microdensitometer and then manipulated on the IDIMS to achieve the desired results.

(U) Upon selection of the frames for analysis, an area from each was digitized on a PDS microdensitometer using an 8 micrometer sampling and step-over interval, and an 8 micrometer scanning aperture. The digital array generated on the PDS was 512 samples x 512 lines. This array covers a square area (4.096mm x 4.096mm) on the Tacana ON film. Figure A32 (a-d) illustrates the effects of IDIMS on a smeared Tacana Navy Yard acquisition.

### 2.4.2 *IDIMS Technique*

(S) The 512 x 512 microdensitometer scan was reduced by a factor of two (i.e., making the image equivalent to a 16 micrometer scan) to speed up processing in the Fourier transform domain. No information was lost in the reduction process since this frame contains much less fine detail than the other three frames and is shown in Figure A32a. A Wiener filter/image motion correction routine was first applied to the Fourier transform of the image with little or no improvement.

(S) A second Fourier transform technique, defined as "rooting" and similar to applying a high pass filter to a Fourier transform was applied to the magnitude (i.e., amplitude) of the Fourier transform. This technique raises the magnitude to a power and is an alternate means for correcting for moderate image motion and for enhancing edge detail. Figure A32b is the result of the rooting technique and Gaussian filter only. Figure A32c represents the effect of two additional edge enhancement techniques (to A32b). The exponential value of the function was then changed to 0.5 (i.e., similar to applying a very high pass flter). The resulting image was then inverse transformed and a 5 x 5 low pass convolution filter applied to reduce the noise. This result is shown in Figure A32d. Much sharper edge definition is apparent in this result than in the original degraded image.

(U) Inverse filtering, i.e., dividing the Fourier transform by the image motion equation (sin wx/wx) to remove the image motion, was not attempted. Also, the phase portion of the Fourier transform was not corrected by direct inverse filtering.

### 2.4.3 *DICOMED Results*

(U/AIUO) The hard copy results listed above were generated on Plus-X 120 film in the DICOMED high resolution mode. This film transparency was then processed in the Versamat at a speed of ten feet/minute. The DICOMED film copy is comparable to results viewed on the IDIMS. An infinite number of results can be displayed on the IDIMS using a trackball cursor which controls the contrast/brightness upon completion of the more sophisticated IDIMS routines.

### 2.4.4 *Summary*

(S) IDIMS improved the smeared frames used in this evaluation. Some loss in "enhancement" effect is noted in the intermediate paper prints as PIs gain most benefit from the IDIMS directly from the viewing screen.

(S) Possible future Tacana experiments, if deemed feasible, should center on restoring smeared imagery using a number of existing routines with varying parameters. The maximum a' posteriori (MAP) method of restoring images should possibly be investigated. The MAP algorithm processes small sections of the image sequentially and pieces them together to create the restored picture. The Office of Research and Development/CIA is currently evaluating this technique [redacted]. Research and application of the MAP restoration technique to operational smeared photography in 1976 indicated some improvement in image quality. Tacana imagery not degraded by image motion or defocus can be manipulated with existing IDIMS functions.

## Section 3 Image Quality Analysis and Film Selection

### 3.1 *Introduction*

3.1.1 (S) Film selection for the Tacana system was based upon an examination of quality factors desired from the product which were appropriate to the exploitation objectives of this study. The quality goals were:

a. The film should have a film speed and latitude to record a wide range of target reflectances under variable light conditions.

b. The camera/film combination should have a recording potential of 5.08cm (2 in.) Ground Resolved Distance (GRD).

c. The prime film consideration will be black-and-white. Color films will also be investigated for their applicability.

d. Other factors which affect mensuration, field handling, camera/film compatibility, interpretability, etc., will be considered and maximized.

3.1.2 (U) The specific quality factors examined were:

a. Film Speed

b. Resolution

c. Exposure Range

d. Processing Flexibility

e. Base Thickness

f. Granularity

g. Field Application

h. Availability

3.1.3 (U) Final film recommendations were based upon a weighted scoring which takes into account the relative importance of each quality factor to produce an optimum image for exploitation purposes. See Section 3.2.6 for scoring methodology. Table A6 illustrates the scoring technique and weighted quality factors used for each film that was evaluated. The preceding factors and their relative significance to this system product would not necessarily be the same for other systems.

(S) For this study, there were two unusual constraints:

a. The camera is a fixed exposure type allowing no control for film speed or varying light conditions.

b. The pigeon platform is unpredictably variable in the directional nature of his motion, flight path, and velocity. The following sections will describe the techniques and results of the evaluation of each quality factor used in the film selection process.

3.1.4 ***System Parameters***

(U) Table A2 describes those characteristics of the camera, platform, target, and light conditions that were used for the analysis. Where no data was available, estimates (noted) were made for purposes of calculations.

## 3.2 *Film/Quality Factors Evaluation*

### 3.2.1 *Film Speed/Latitude*

(U) Figure A8 represents the estimated exposure range we would expect to record with this system for low altitude photography. Basic assumptions for the calculations were taken from Table A2. The exposure values were calculated from:

$$E=IT$$

where E=Exposure in meter candle seconds
I=Intensity in meter candles
T=Time in seconds

Image Illumination was calculated from:

$$IF=\frac{0.64B}{N2}$$

where IF=Image illumination
B=Surface Brightness
N=f/Number
0.64=estimated lens transmission factor

(U) The film curves shown in Figure A8 represent three significantly different effective aerial film speed (EAFS) materials. They are typical for those films and do not represent an effect of unique processing or handling.

(U) An analysis of this figure also provides the basis for an estimate of the film type which would be required to obtain a proper system exposure and dynamic range. It reflects the exposure values (Log Exposure) for shadow and non-shadow areas of a target given:

a. A fixed shutter speed (1/2200 sec) and aperture (f/2.7) camera.

**Table A2—System Parameters**

| **Camera** | **Mod. I (MCW24)** | **Mod. II (** |
|---|---|---|
| Lens type | Minox | |
| Aperture | f/3.5 | f/2.7 |
| Focal Length | 15mm | 15mm |
| Film Size | 16mm unperf. | 16mm unperf. |
| Format | 12.5 x 7.5mm | 12.5 x 12.5mm |
| Shutter Speed | .0007 sec. (1/1400) | .00045 sec. (1/2200) |
| **Platform (avian)** | | |
| Forward Velocity | variable; 40 knots* | |
| Pitch and Roll Rate | variable; 40 knots* | |
| Propulsion (wing beat) Rate | 6/Hz | |
| Flying Height | variable; 30.48M (100 ft)* | |
| **Target (Nominal, Intelligence Type)** | | |
| Contrast | 1.6:1 | |
| Reflectance | 12% | |
| **Lighting *(Sunlight,50°-60° Solar Elevation)** | | |
| Direct Illumination | 10 Foot-Candles | |
| Open Shade | 10 Foot-Candles | |

* Estimated for preliminary calculations.

b. A target of estimated 2% reflectance.

c. Various solar elevations.

(U) The range lines indicated by shadow and bright sun represent the scene exposure range. The ideal film (in terms of speed and latitude) would be represented by the straight line portion of its characteristic curve falling between the exposure range lines. By moving the left exposure range line to coincide with an appropriate solar elevation, the required log E can be estimated for various solar elevations for a clear (sunlighted) acquisition.

(S) The above analysis and subsequent testing determined that 3400 series (3410) film was the best compromise of all the considered quality factors. Eastman Kodak was also requested to determine the availability of any new films which might be compatible for the system. They indicated that a candidate film was in the R&D stage and would be available in early 1977 for testing. 3410 material was then used for all system testing until arrival of the experimental material (FE 6526) in June. It was evaluated and found to be more compatible than the 3410 (see Section 3.2.6).

### 3.2.2 *Resolution/GRD*

(S) A determination of the camera/film system resolution potential was made [redacted] Missouri. The resolution test consisted of suspending the camera from a balloon and photographing resolution targets of known contrast with color and black-and-white films. The materials used for baseline data were Eastman Kodak 3410 and 1414. They were selected because initial calculations indicated that the 3410 material had a film speed (EAFS) that would just satisfy the system exposure needs, and the 1414 would provide a high resolution base line to compare the impact of film resolution needs against exposure and camera performance. Figure A33 illustrates the test range. Objects in the scene were those readily available at the site. They were used for subjective impressions of image quality and initial mensuration estimates. The resolution targets were 100:1 contrast type (AF1959) graduated in 6th root of 2 increments.

(U) Figure A9 shows the resolution data obtained from this test. Each point represents the average of two to four resolution readings (based upon the individual coverage) from seven frames. The highest resolution readings were consistent with several prior ground/bench resolution tests. Although this test was done only for the Model I MCW-24 (Minox lens) camera, subsequent tests on the Model II [redacted] lens) camera indicated that it is representative of the camera/film performance. Also included in Figure A9 are the film resolution specifications as supplied by the manufacturer. The right axis indicates the calculated GRD at 100 ft. altitude when the resolution performance of the system is as noted on the left axis. The bottom axis indicates target contrast. For example, a 50 c/mm image taken at 100 ft. of a 2:1 contrast target could theoretically produce a GRD of 0.8 inches on 3410 film.

(S) Analysis of this balloon test data indicated that the camera was the primary resolution determinate (or the 1414 resolution would have been considerably higher). Frame-to-frame variability was high. Nonetheless, because the camera was well focused and checked out prior to the test and no malfunction occurred, it is assumed that its variability is part of the system and, at worst, its potential performance at 100 ft. altitude could provide (on the average) better than 2 inches GRD (at 1.6:1 contrast) on 3410 series film.

3.2.3 ***System Evaluation***

(TS) Subsequent to the resolution and exposure evaluation of the camera and film from the balloon platform, a test of the total system (bird, camera, film) was undertaken over Andrews AF to determine the effects of the avian platform motion dynamics on the image quality. These tests were to combine a bird location and training exercise with additional image quality and camera optimization experiments. Also it would begin to give a better estimate of the problems associated with operations over large cultured areas. Prior to this, only operational flights over basically non-cultured areas had been made and these had been difficult to evaluate from an image quality point of view. Table A3 indicates the estimated performance of the system on the Andrews tests with camera Model I (MCW-24). Photoscientists evaluated 854 images from five test flights. The quality determination was based upon a subjective estimate of GRD. A three-level scale was used for the judgments:

(1) Better than 15.2cm (6″) GRD (about NIIRS 8-9)

(2) From 15.2cm (6″) to 76.2cm (30″) GRD (about NIIRS 5-7)

(3) Worse than 76.2cm (30″) GRD (about NIIRS 1-4)

(S) Examination of the data from Table A3 indicated that the total system could perform with a potential quality (GRD) approaching study goals. This data also indicated that (1) performance

**Table A3—System Performance Over Andrews AFB**

**GRD**

| Flight No. | No. of Images | Better than 6" | 6"-30" | Worse than 30" |
|---|---|---|---|---|
| 1 | 251 | 22% | 37% | 41% |
| 2 | 235 | 15% | 41% | 44% |
| 3 | 123 | 7% | 34% | 59% |
| 4 | 117 | 5% | 65% | 29% |
| 5 | 128 | 6% | 43% | 51% |

decreased with succeeding flights, and (2) even at best (Flight #1) the probability of a system acquisition approaching the GRD goal was low (about 22%). These observations led to a camera examination which showed a shutter spring breakdown, and that a faster shutter speed was needed to increase the number of high GRD pictures. At that time the camera contractor was developing a Model II [redacted] camera unit utilizing a special design f/2.7 lens (to replace the f/3.5 Minox lens) and a larger image format. The larger lens aperture was initially proposed to allow a slower, higher resolution film to be used with the system. Based upon the preceding GRD/film performance test data and the Andrews GRD evaluations, it was felt that the unpredictable motion characteristics (altitude and velocity) of the avian platform was the greatest single contributor to degraded imagery. Therefore, the decision was made to increase the shutter speed to produce a higher percentage of sharp (non-motion degraded) images. The following formula, using known and estimated platform dynamics of roll, maximum velocity, etc., determined that in excess of 1/2000 sec. was necessary to assure more consistent, non-smeared imagery. The first Model II prototype flight incorporating the improved shutter indicated this to be so. This complete flight (85 images) was NIIRS rated by NPIC/IEG PIs for confirmation and the data is shown in Section 2.1.

$$\text{Required Shutter Speed} = \frac{\text{Platform Flying Height}}{(1000)\ (\text{Required Resolution})\ (\text{Lens Focal Length})\ (\text{Platform Velocity})}$$

### 3.2.4 *Processing and Other Film Characteristics*

3.2.4.1 (U) Numerous combinations of films and developers were tested to determine if some specialized process might optimize some specific quality factor of a film to make it more effective for this system. Developers used included: PUSH-POTA (NPIC formulation), H and W, Kodak D-76, Kodak D-19, Rodinal, and Kodak HC110. The primary process factors evaluated included film speed manipulation, contrast control, and field (operational) utilization. All films were not evaluated with all developers, but an effort was made to determine if certain high resolution films could be made of an appropriate speed and dynamic range without compromising other factors of handling and image quality. Sensitometric data was collected where possible (1414, 3410, FE6526) for evaluation.

(U) Following is a brief summary of the film/developer examinations:

a. ***PUSH-POTA (NPIC formulation)***

(U/AIUO) Effectively increased the EAFS of all films that were processed (1414, 3410, 5069) about 2 times. But 1414 (at an

EAFS of 15) was still too slow, 3410 did not need such a magnitude of speed increase, and 5069 gave almost an equivalent speed as 3410 but did not have an appropriate latitude.

Additionally, PUSH-POTA produced dichroic (chemical) fog on the 1414 and had an extremely high fog density with the 3410. Field use is possible but a 95°F processing temperature requirement and questionable storage life makes its handling difficult.

b. ***Kodak D-76***

(U) Worked well with 3410 and FE6526 films. Clean working, stable, and readily available. It produced about a 50% speed increase with a moderate loss of dynamic range.

c. ***Kodak D-19***

(U) Worked well with 1414 but produced a very limited exposure range product for this system. It is designed to add (with 1414) contrast to high altitude aerial acquisitions that are typically of low overall scene contrast (haze effects, etc.). It did not increase the 1414 EAFS enough to make it usable. Produced a high contrast image with the 3400 with some speed benefit in the highlights.

d. ***RODINAL***

(U) Produced acceptable imagery with 3410 and 410. Has potential for further evaluation, but it is difficult to handle in the field requiring very precise (syringe) application.

e. ***Kodak HC110***

(U) Good results with FE6526 film. Readily available and clean working. With a matrix of tested dilution rates and processing times, it has the capability to alter film speed and contrast relative to the camera exposure/target (scene) brightness ratio. This was used for the 6526 film the last few weeks of the study and the results obtained were sensitometrically and subjectively acceptable.

3.2.4.2 ***Base Thickness and Granularity***

(U) For this system a 2.5 mil. base thickness film is most appropriate in terms of film load (more exposures/flight) and handling. Granularity of a film has an effect on mensuration and PI exploitation. It is difficult to measure the total benefits of a finer grained material with this system's resolution capability, but it is enough to know that a lower granularity usually provides better exploitation performance.

### 3.2.5 *Color Films and Analytical Application*

3.2.5.1 (S) The system restrictions of the fixed exposure camera, variable lighting conditions, limited process manipulations available (speed pushing, etc.) and inherent lower resolution capabilities of color materials made selection limited. The films evaluated were SO-255, 2445, 2448, Vericolor II, SO-397 and SO-131 (false color infrared). All were positive types except 2445 and Vericolor II. The final selection (EK 2445, Figure A31) was made based upon its speed, resolution characteristics and wide (relatively) exposure latitude. It is well suited for duplicate positive reproduction, paper print enlargements, process manipulation and color correction.

(U/AIOU) NPIC is presently contracted with Calspan Corporation to implement SCAT onto the Interactive Digital Image Manipulation System (IDIMS). The technique is probably applicable to the Tacana system but, as yet, has not been tested against negative color materials.

*Smith, Turinetti, *RADC's Research in Color Image Interpretation,* Journal of Applied Photographic Engineering Volume 3, Number 2, 1977.

**Table A4—SCAT Materials Discrimination**

### 3.2.6 *Film Selection*

3.2.6.1(U) Table A5 summarizes the basic characteristics of the films that were considered for this system.

(U) The films selected and illustrated in this report represent materials that performed best overall as indicated by the weighted quality/performance scoring criteria (Table A6).

(U) The performance value (1 to 10) indicates how well each film performed in satisfying a given quality factor. The sum of all quality factor scores (WF X PV) was added to provide a final total value for each film. (See Table A7.)

**Table A5—Film Characteristics**

**BLACK-and-WHITE**

| Film Type | Speed (EAFS) | Resolution 1000:1 | (c/mm) 1.6:1 | Granu-larity | Thickness (MILS) | |
|---|---|---|---|---|---|---|
| 3414/1414 (EK) | 9-15 | 630 | 250 | 9 | 3.2 | High Definition Aerial |
| FE6526 (EK) | 80-100 | 350 | 150 | 10 | 2.9 | Experimental, Potential to Replace 3400 Series |
| 3410 (EK) | 80-100 | 240 | 90 | 20 | 2.9 | PAN-X Aerial |
| 3401 (EK) | 200 | 95 | 35 | 32 | 3.1 | Plus-X Aerial |
| 5069 (EK) | 80-180 | 250 | 100 | — | 4.5 | High Contrast Copy |
| SO-410 (EK) | 100-200 | 250 | 100 | 6 | 4.5 | Photo Microphotochrome |
| VTE "80" (H&W) | 80-100 | 160 | 70 | — | 4.5 | Panchromatic |
| **COLOR** | | | | | | |
| SO-242/255 | 6-8 | 200 | 100 | 11 | 3.7/2.7 | High Definition Aerial (positive) |
| 2448 | 32 | 80 | 40 | 12 | 4.8 | Ektachrome MS (positive) |
| 2445 | 100 | 80 | 40 | 13 | 4.9 | Aero Color (negative) |
| Vericolor II | 100 | 70 | 30 | — | 5 | Commercial (negative) |
| SO-397 | 64 | 80 | 40 | 13 | 4.9 | Ektachrome EF (positive) |
| SO-131 | 40 | 63 | 32 | 17 | 4.8 | Aerochrome Infrared (2443 type) |

**Table A6—Film Scoring Factors**

| Film Quality Factor | Weighting Factor (WF) | Performance Value (PV) | Score (WF) X (PV) |
|---|---|---|---|
| Film Speed | 5.5 | (1-10) | |
| Resolution | 5 | | |
| Exposure Range (Latitude) | 4 | | |
| Processing Flexibility | 3 | | |
| Base Thickness | 3 | | |
| Granularity | 2.5 | | |
| Field Application | 2.5 | | |
| Availability | 1 | | |

**Table A7—Film Scores**

| Black-and-White | | Color | |
|---|---|---|---|
| Film | Score | Film | Score |
| *FE6526 | 204 | 2445 | 163 |
| 3410 | 194.5 | SO-397 | 159.5 |
| | | SO-242/255 | 148.5 |
| 5069 | 188 | 2448 | 141.5 |
| 3411 | 182 | VERICOLOR II | 138 |
| 1414 | 179.5 | SO-131 | 100 |
| VTE "80" | 177.5 | | |

* This film is presently experimental. Eastman Kodak indicates that it will replace 3400 series Aerial Reconnaissance Films in the near future.

### 3.2.6.2 *Recommended Films and Processes*

Black-and-White: Film—FE6526 (Eastman Kodak)
Developer—HC110, Dilution D
Six minutes 21°C (70°F)
Constant Agitation

Film—3410 (Eastman Kodak)
Developer—D-76, 6 1/2 minutes 21°C (70°F)
Constant Agitation

Color: Film 2445—Eastman Kodak Aerocolor Negative
Standard Color Process as recommended by the manufacturer.

### 3.2.7 *General Camera Anomalies*

(U/AIUO) The photographs in this report are used to describe The exploitation quality of the system, as such they are so referenced in preceding sections. They also show the effect of various camera problems associated with its development. Directing attention to these anomalies is only intended to indicate factual difficulties encountered in assembling system performance data and indicates the need for further reliability production efforts. It should be pointed out that the camera is a commendably engineered unit and these effects are common and expected in this type of research effort and could be corrected in the routine modification and upgrading of the camera units for field use.

Demonstrate the effect of non-uniform sharpness due to probable misalignment of the film plane with the optical axis. Decentration of an element in the optical system or an imperfect and/or improperly positioned field corrector would produce a similar effect (noted in the lower central portion of these photographs).

The off-center light area in these photographs represent an effect of internal lens flare (stray light reflected to the film by improperly baffled optical components). This fogging of the film has the effect of producing a lower contrast and resolution image. It was present in most cameras in varying degrees.

Represents the "barrel" lens distortion effect present in the [redacted] (Model II camera) lens (curved portion of waterline edge at bottom of frame). This type of distortion reduces towards the center of the image format.

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TALENT-KEYHOLE
Channels

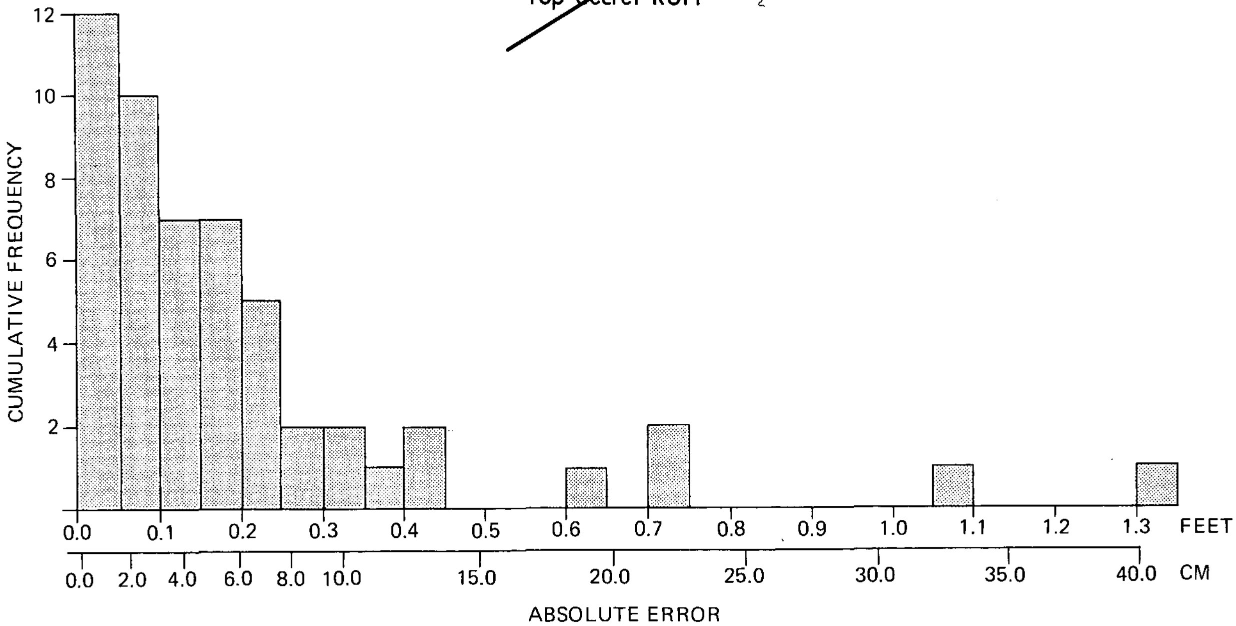


FIGURE A2. Histogram of Cumulative Frequency of Error in Measurements of 53 Dimensions (.25 Feet - 37.5 Feet)

**UNCLASSIFIED**

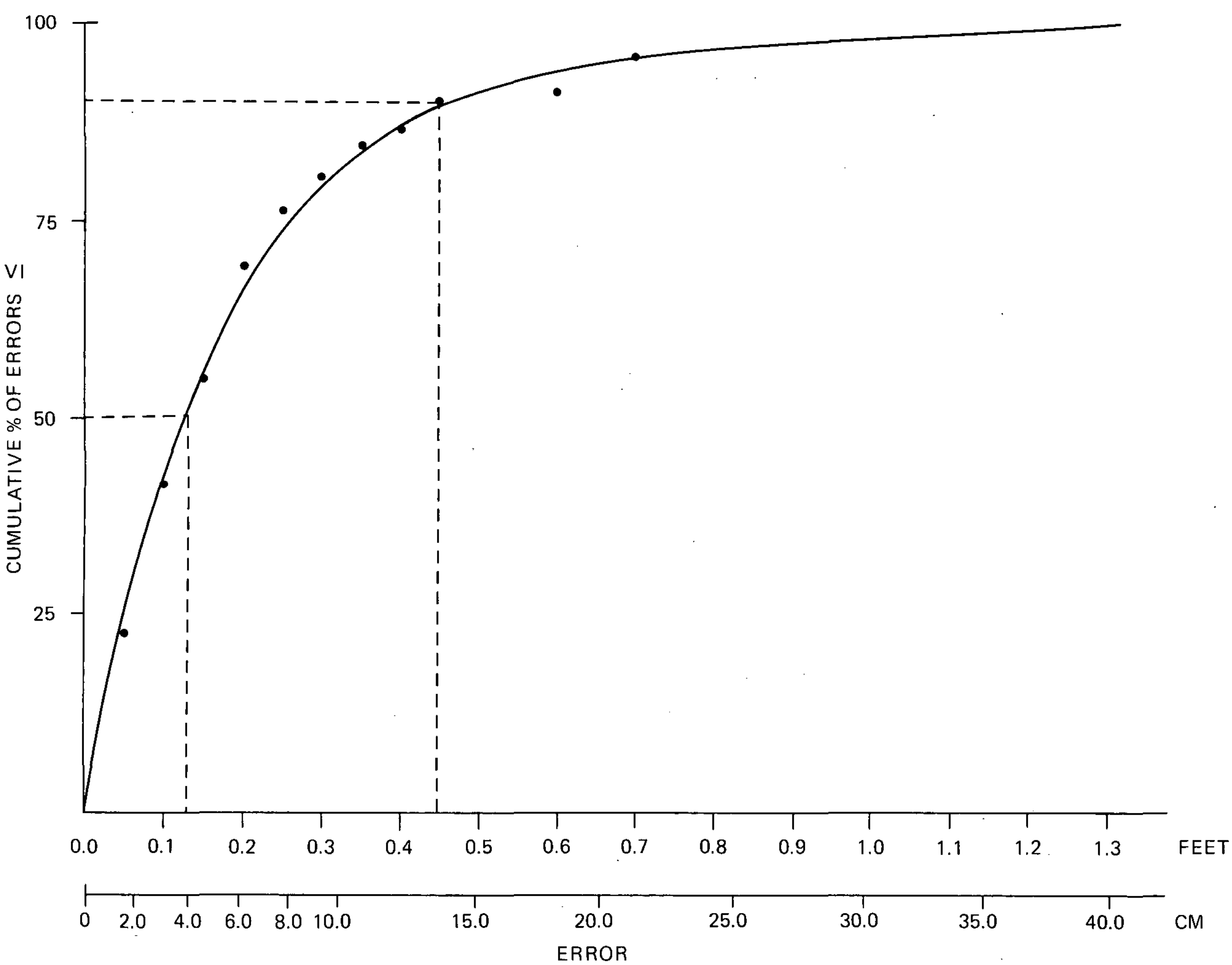


FIGURE A3. Graph of Cumulative Percentage Error for Measurements of 53 Dimensions

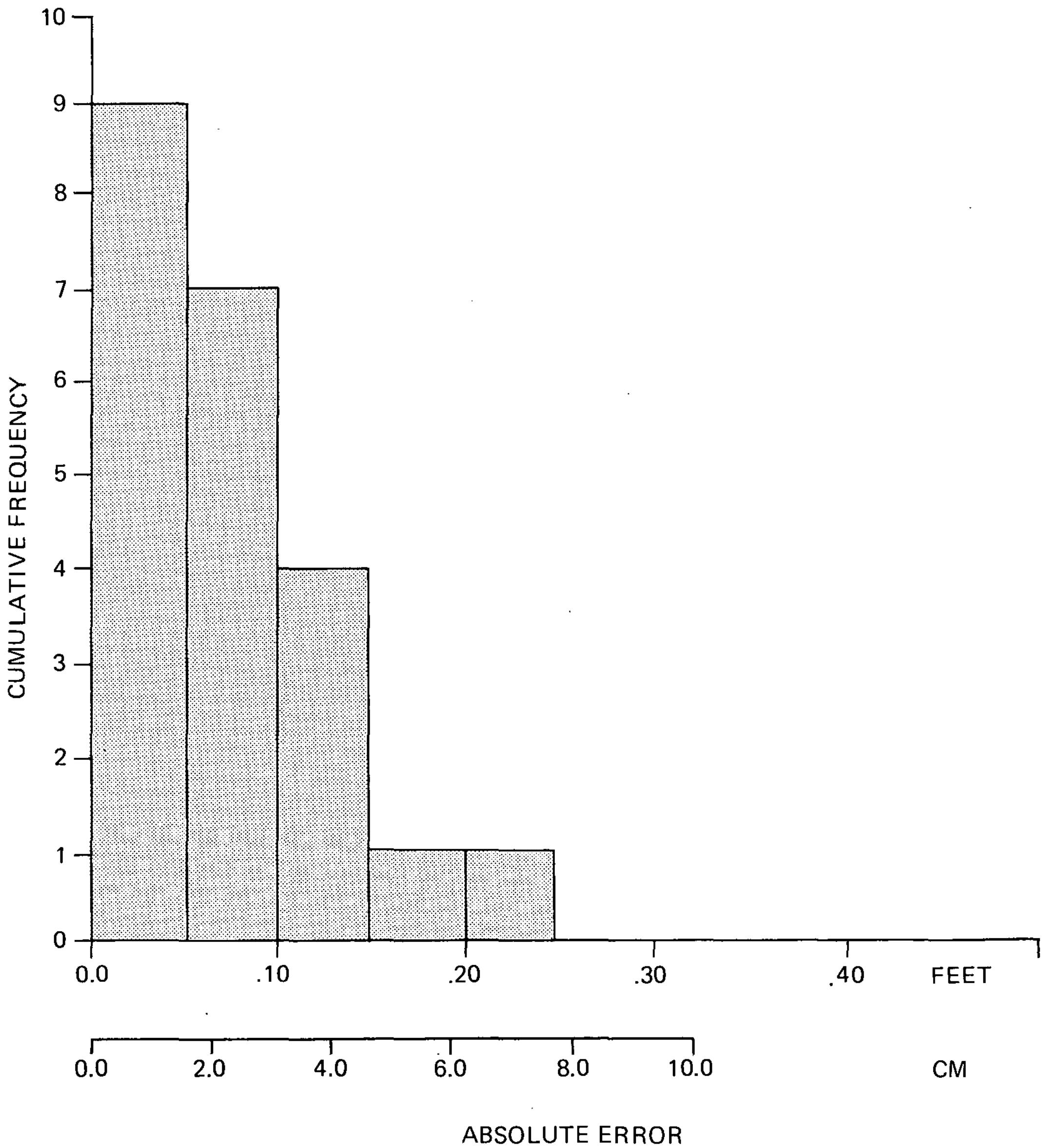


FIGURE A4. Histogram of Cumulative Frequency of Error for 22 Dimensions of 2 Feet or Less

**UNCLASSIFIED**

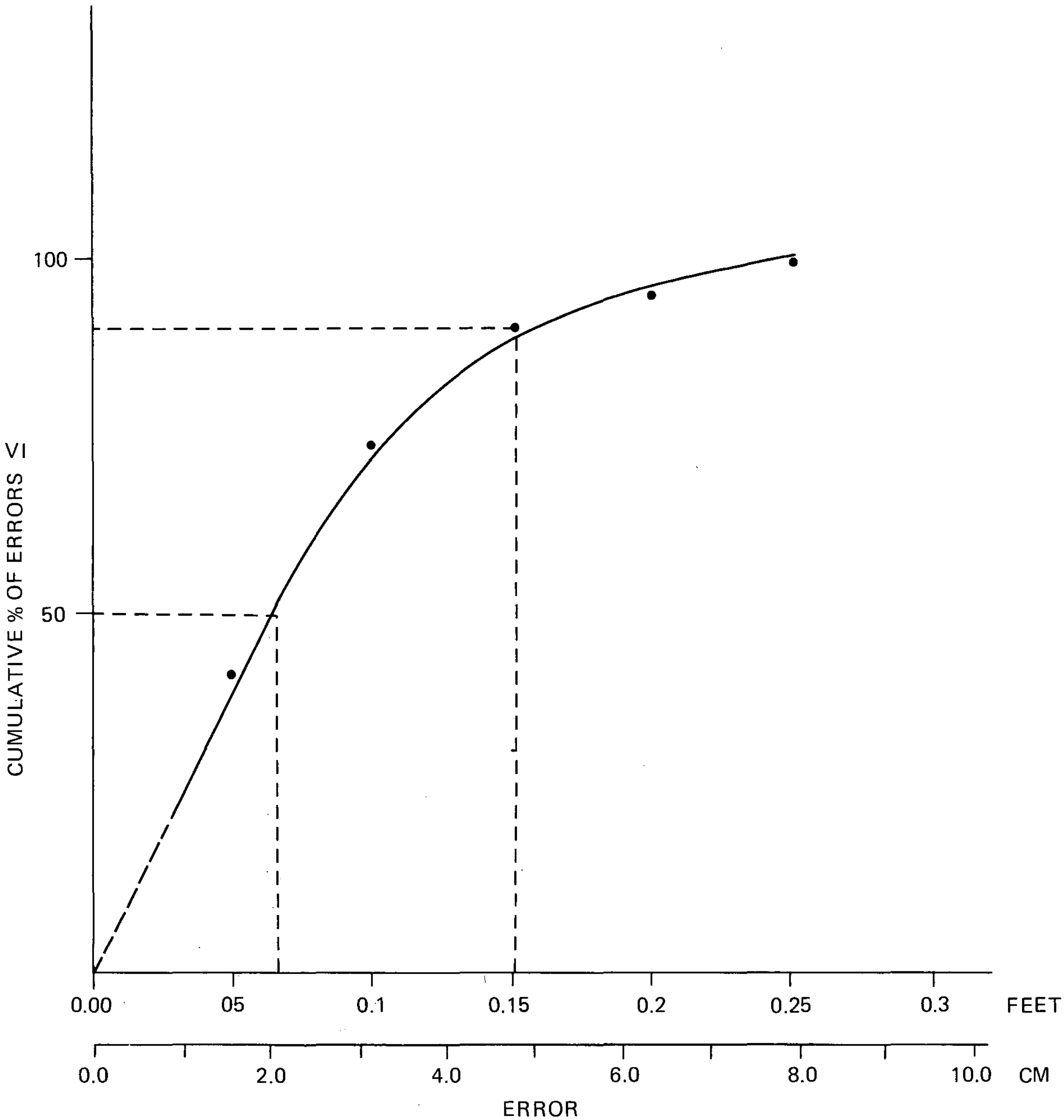


FIGURE A5. Graph of Cumulative Percentage Error for Measurements of 2 Feet or Less

**UNCLASSIFIED**

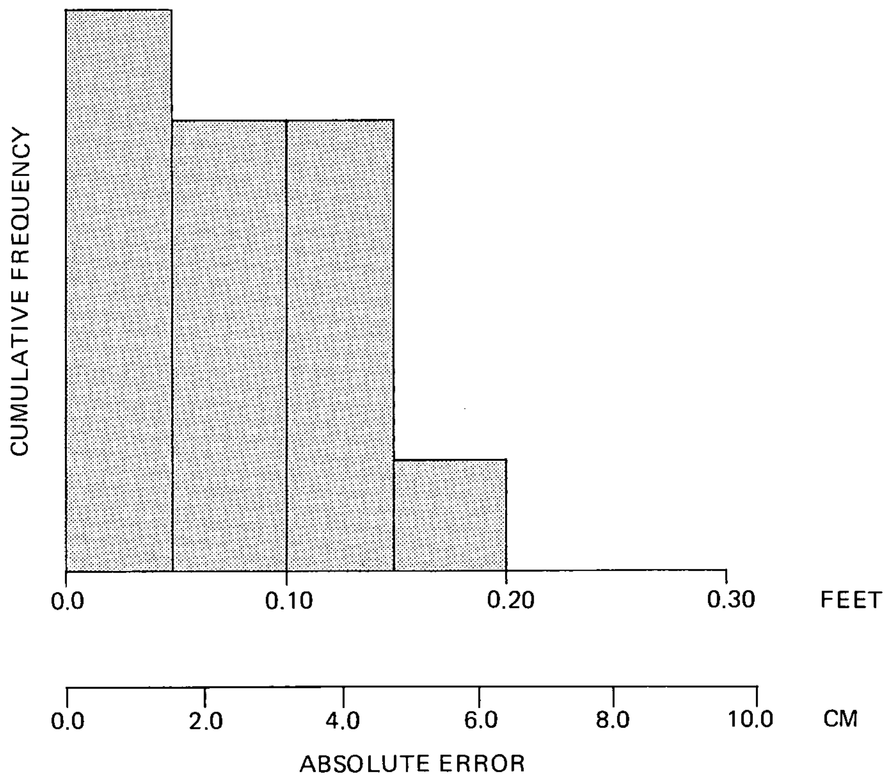


FIGURE A6. Histogram of Cumulative Frequency of Error for 14 Dimensions of 1 Foot or Less

**UNCLASSIFIED**

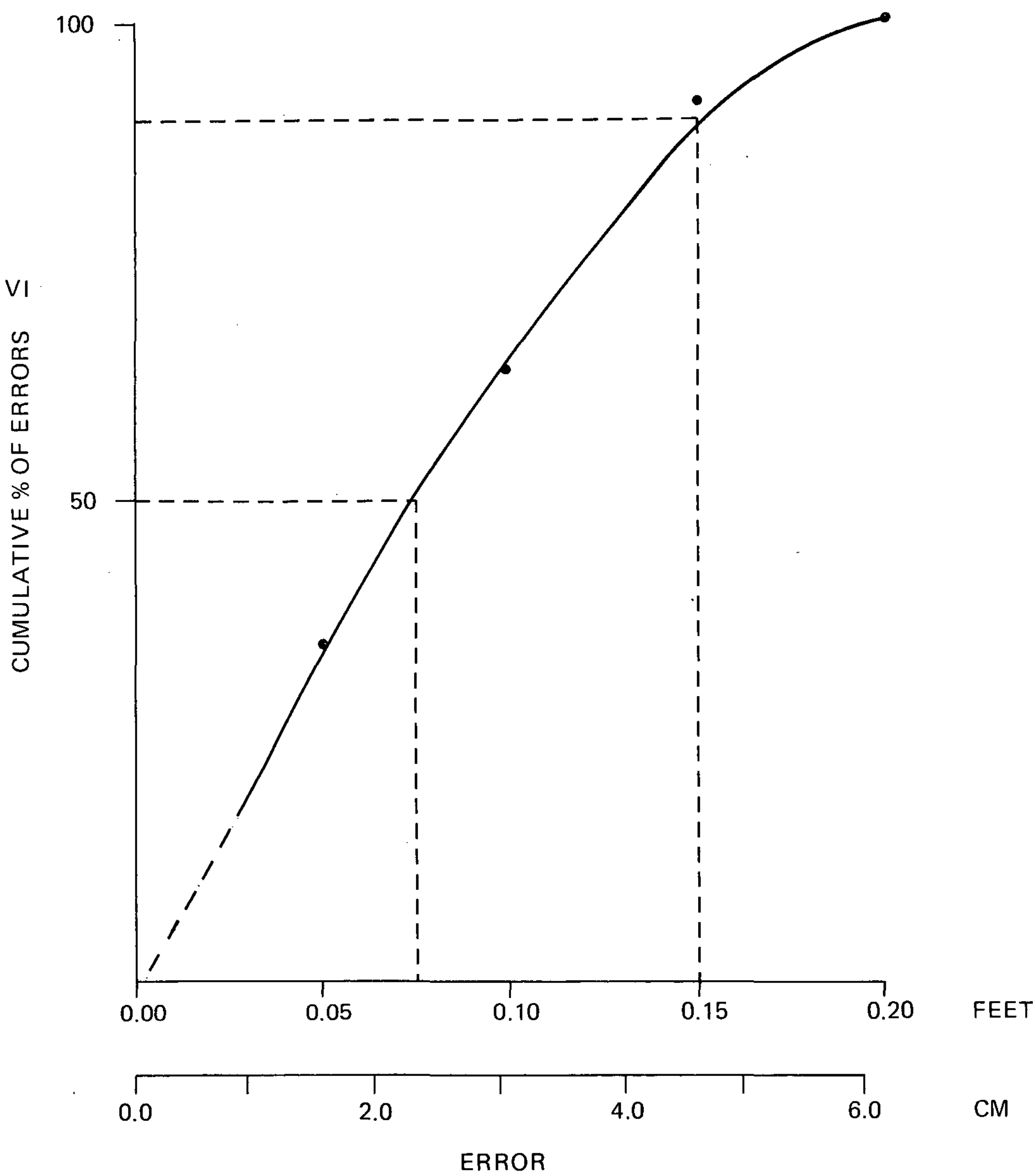


FIGURE A7. Graph of Cumulative Percentage Error for Measurements of 1 Foot or Less

**UNCLASSIFIED**

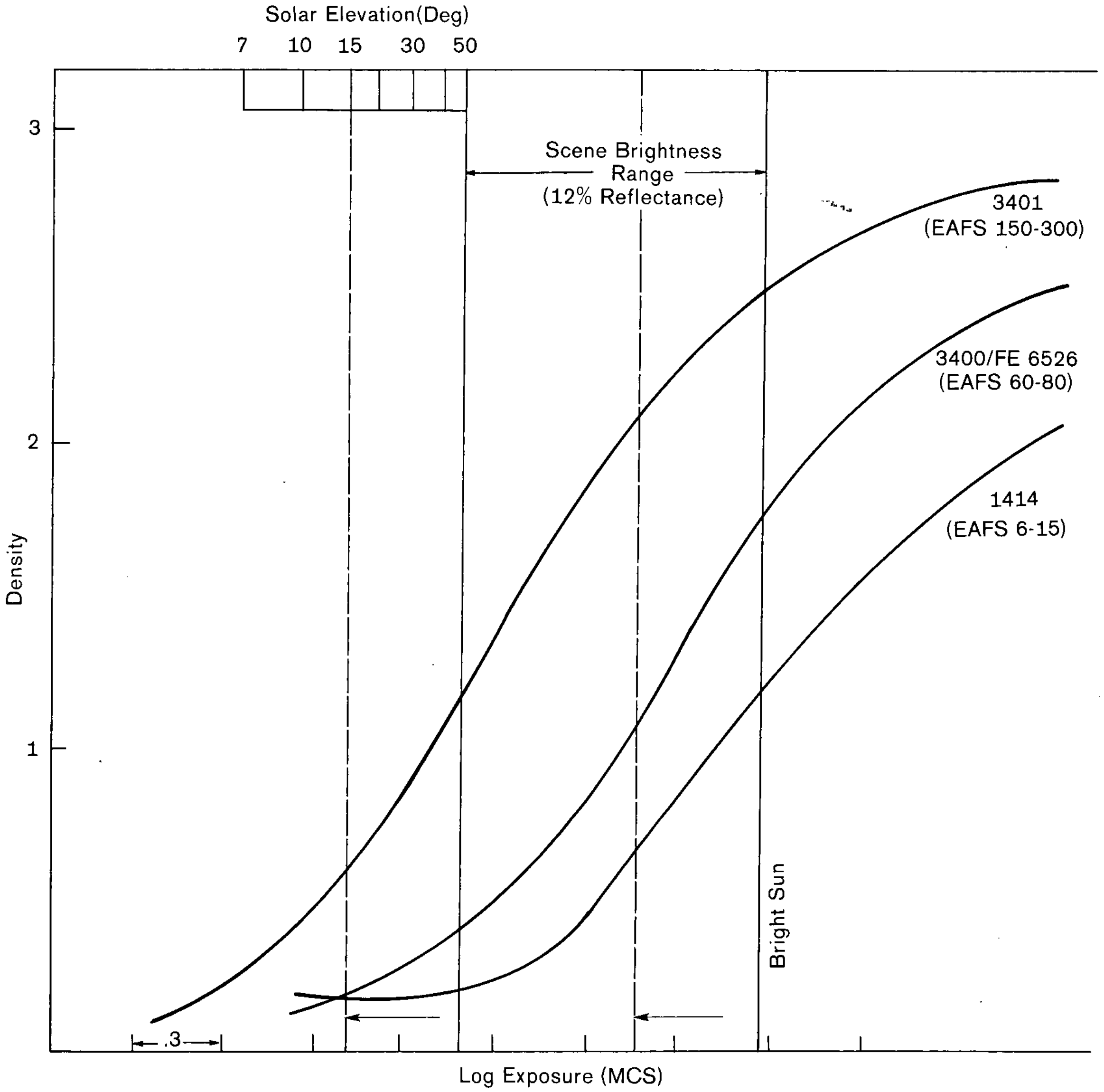


FIGURE A8. Graph of Predicted Target Brightness/Exposure Range and Film Estimates

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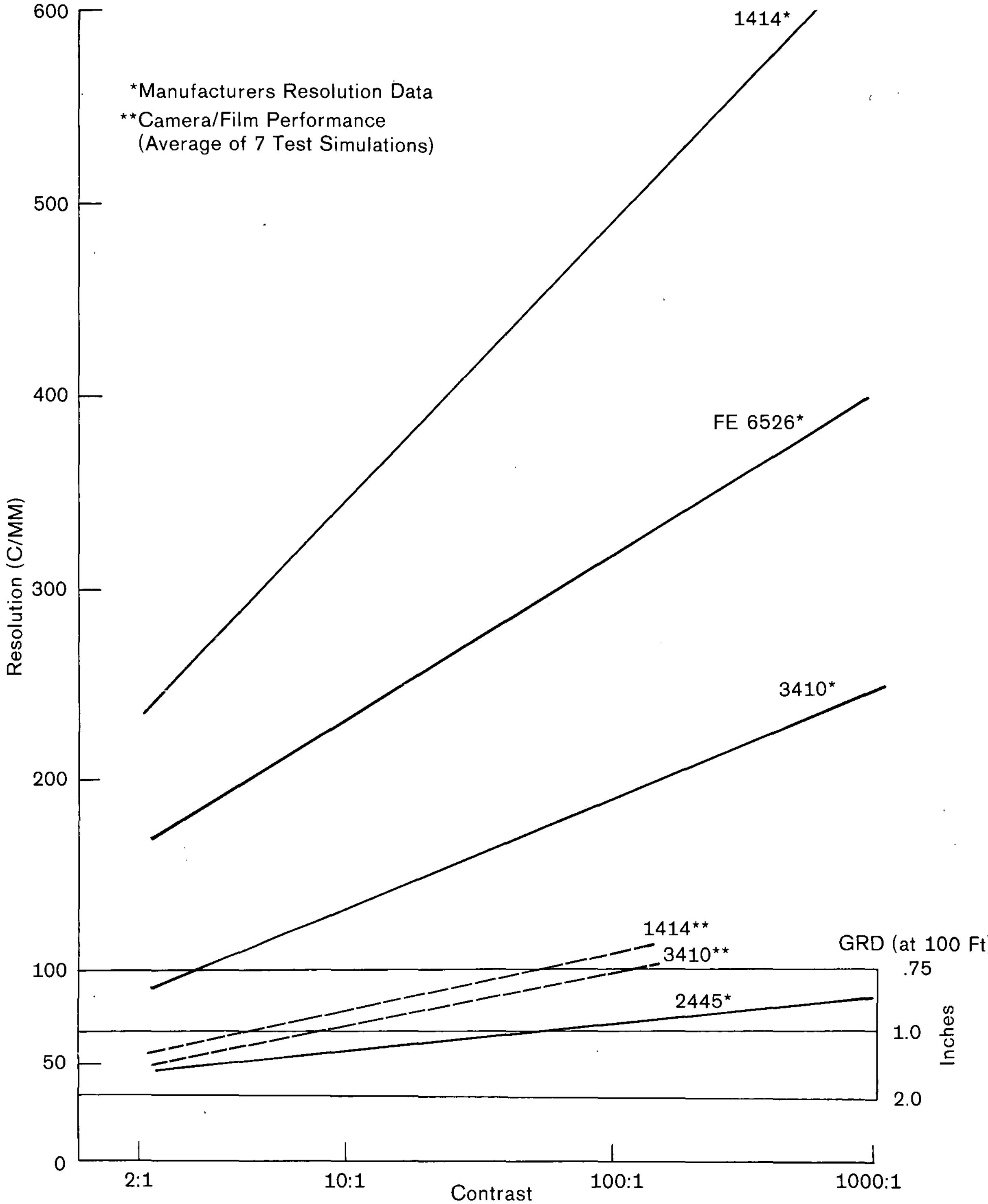


FIGURE A9. Graph of the Camera/Film Performance Evaluation and GRD Estimates

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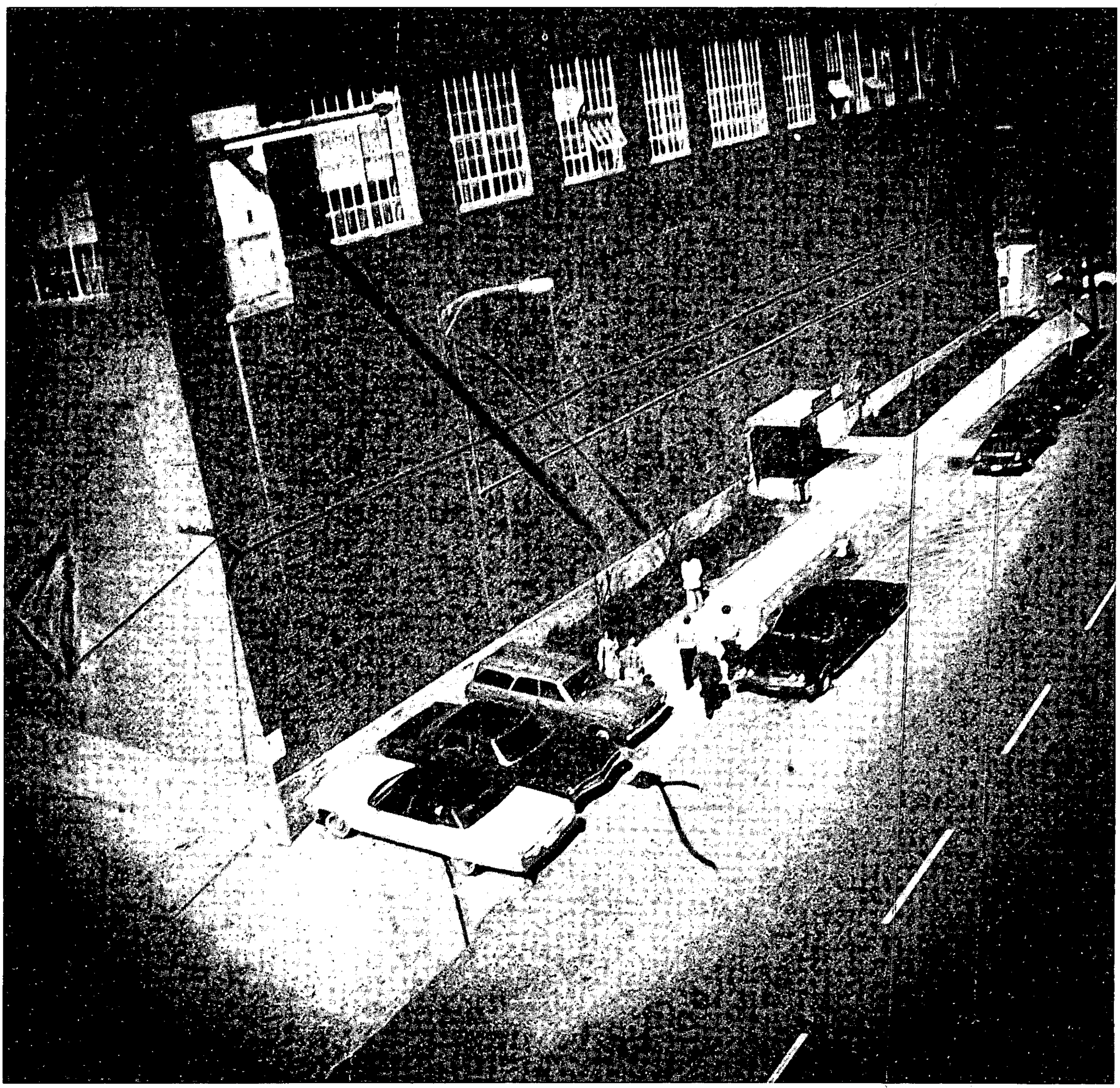

FIGURE A10. Washington Navy Yard—3/17/77
Rated NIIRS 9

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FIGURE A11. Washington Navy Yard—3/17/77
Rated NIIRS 6

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*TCS 35974-77*

FIGURE A12. Washington Navy Yard—3/17/77
Rated NIIRS 7

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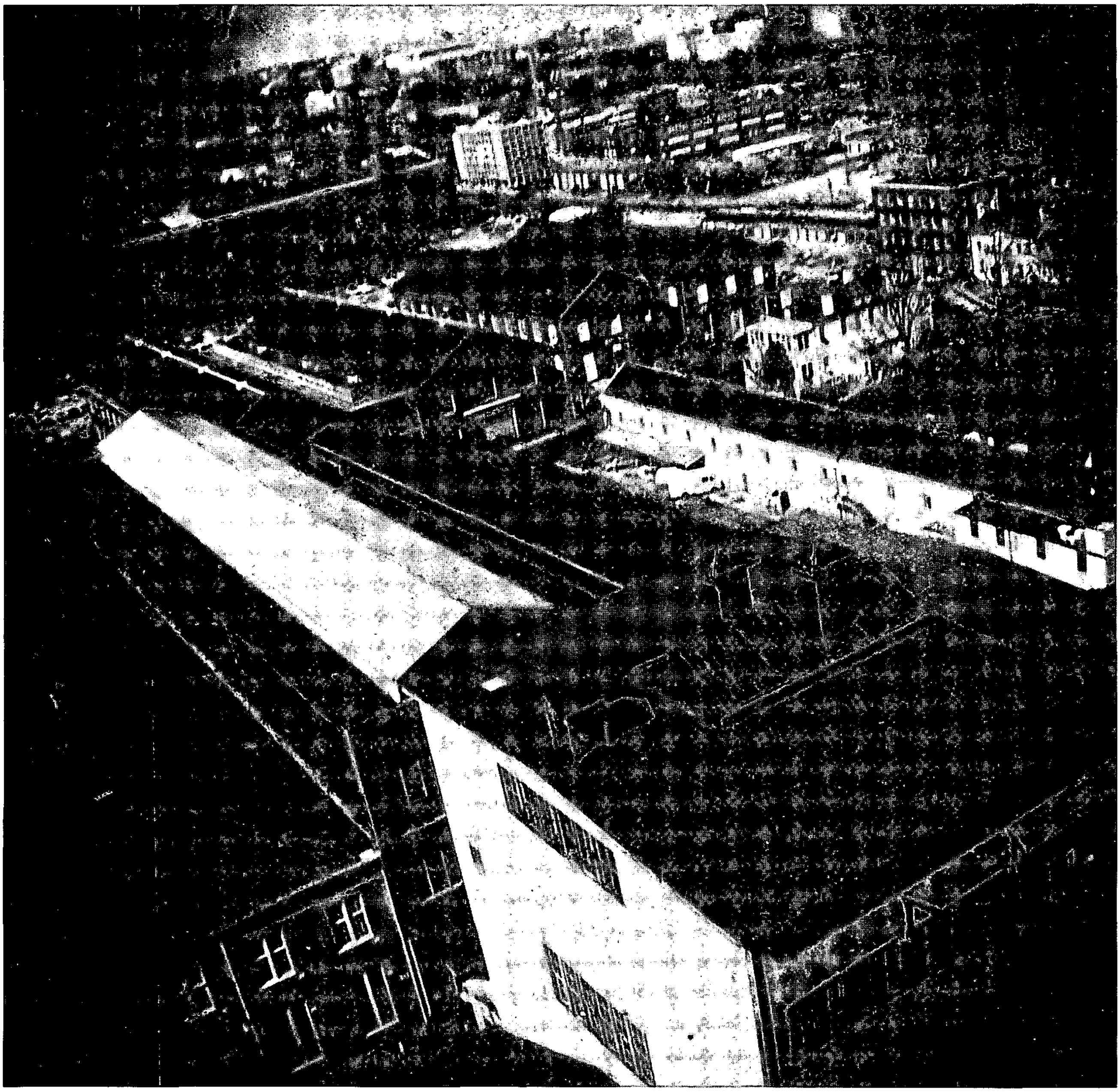

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FIGURE A13. Washington Navy Yard—3/17/77
Rated NIIRS 7

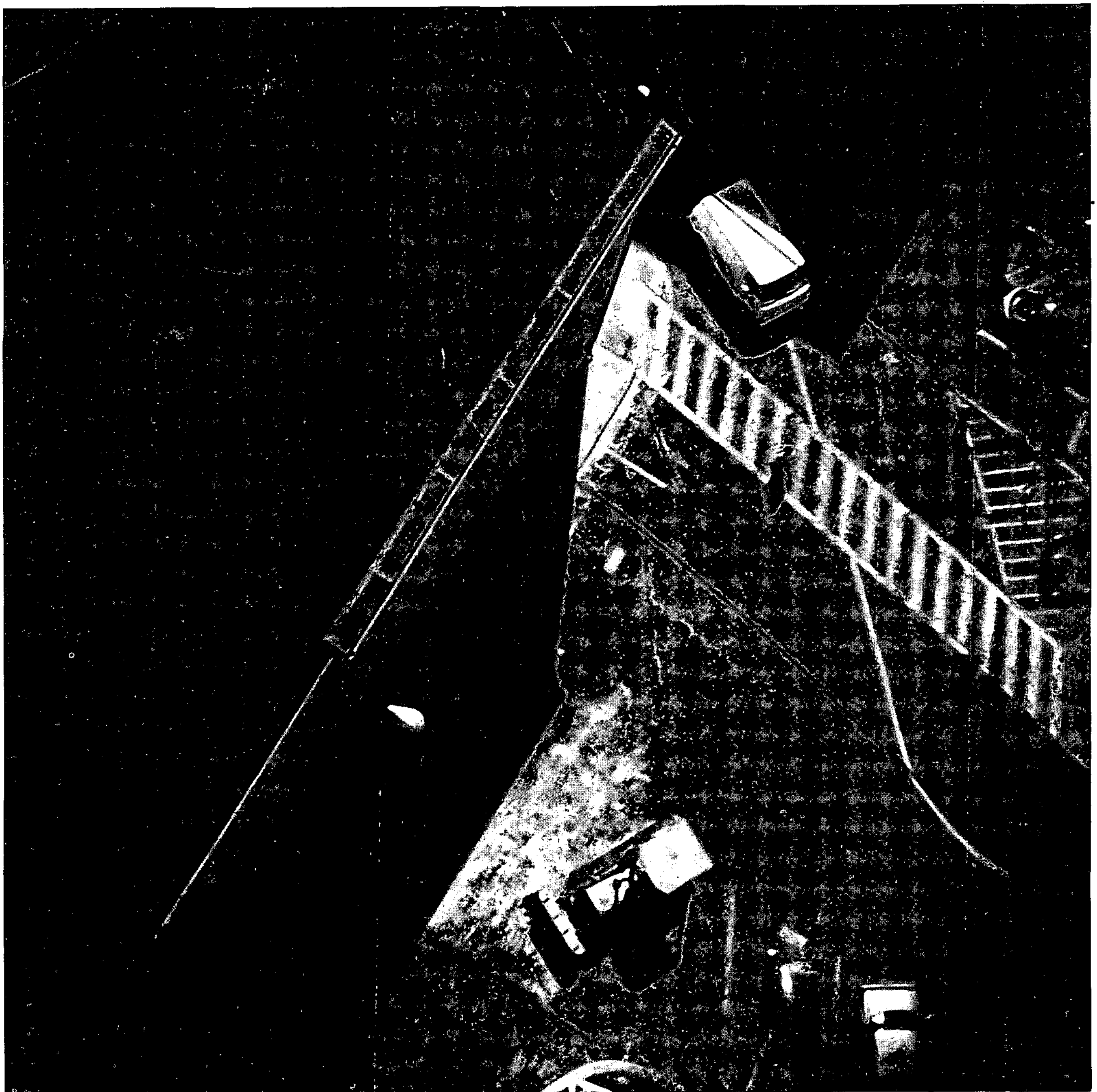

FIGURE A14. Washington Navy Yard—3/17/77
Rated NIIRS 8

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TCS 35974-77

FIGURE A15. Washington Navy Yard—3/17/77
Rated NIIRS 8

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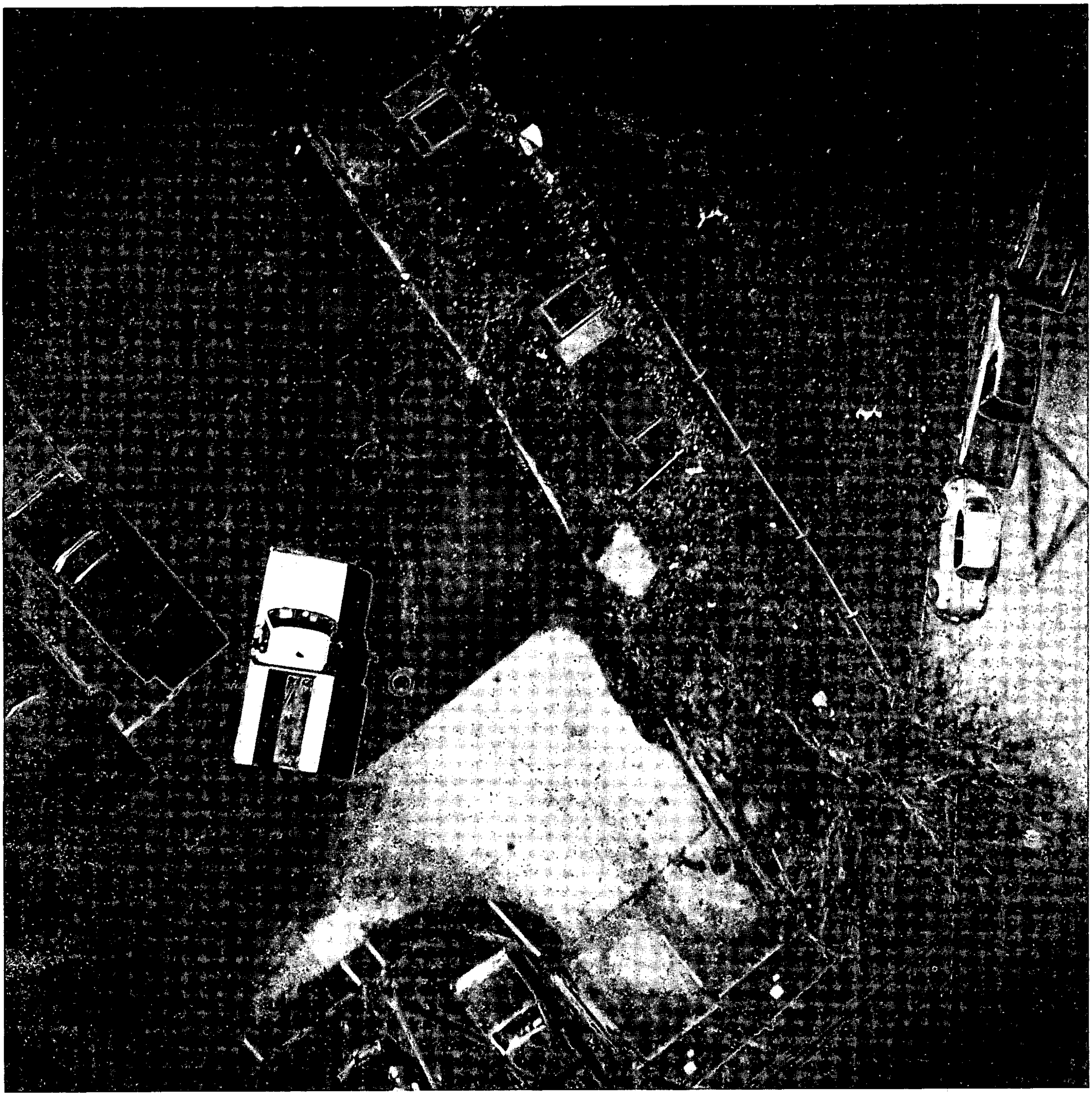

FIGURE A16. Washington Navy Yard—3/17/77
Rated NIIRS 9

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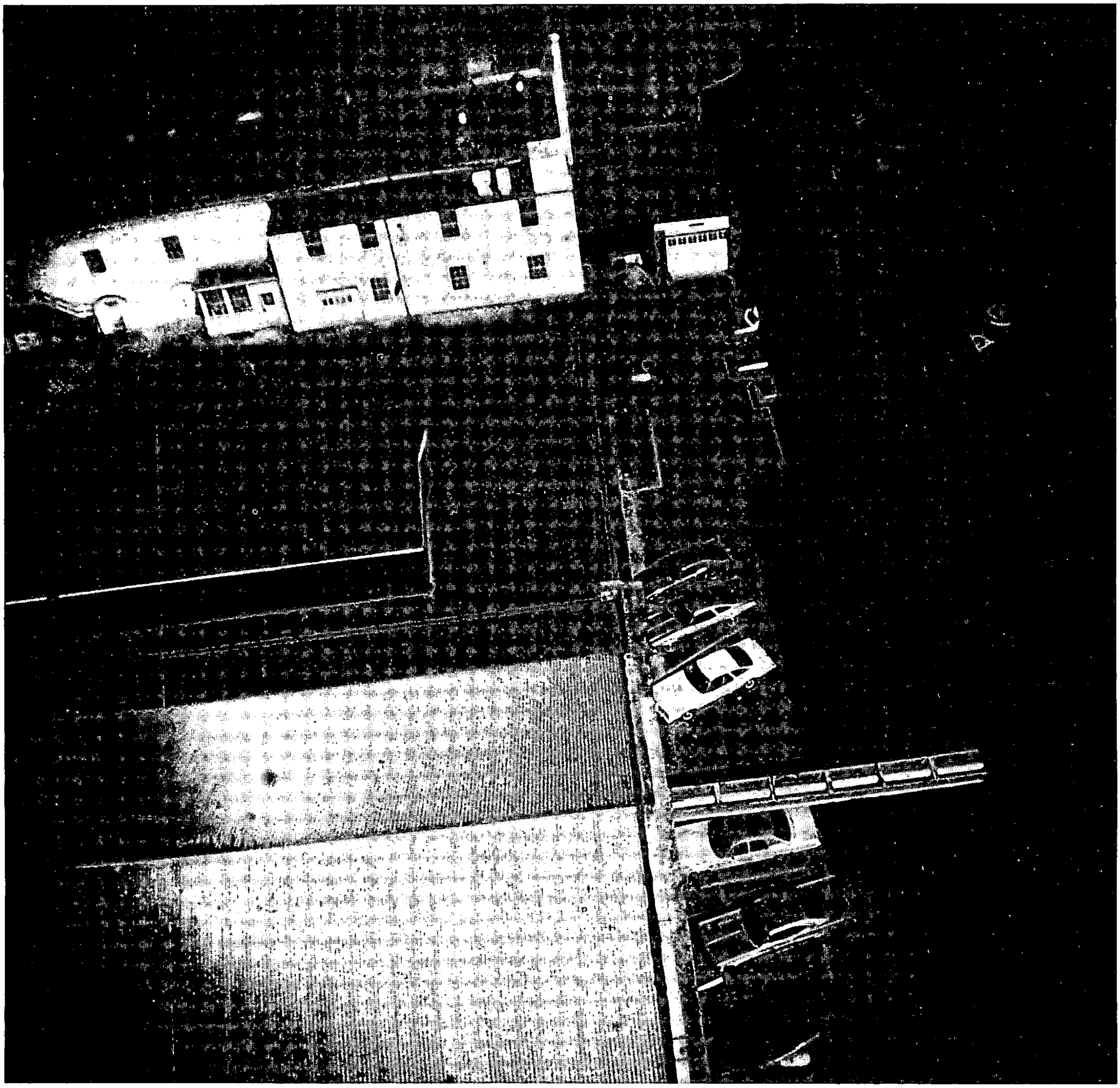

FIGURE A17. Washington Navy Yard—3/17/77
Rated NIIRS 9

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FIGURE A18. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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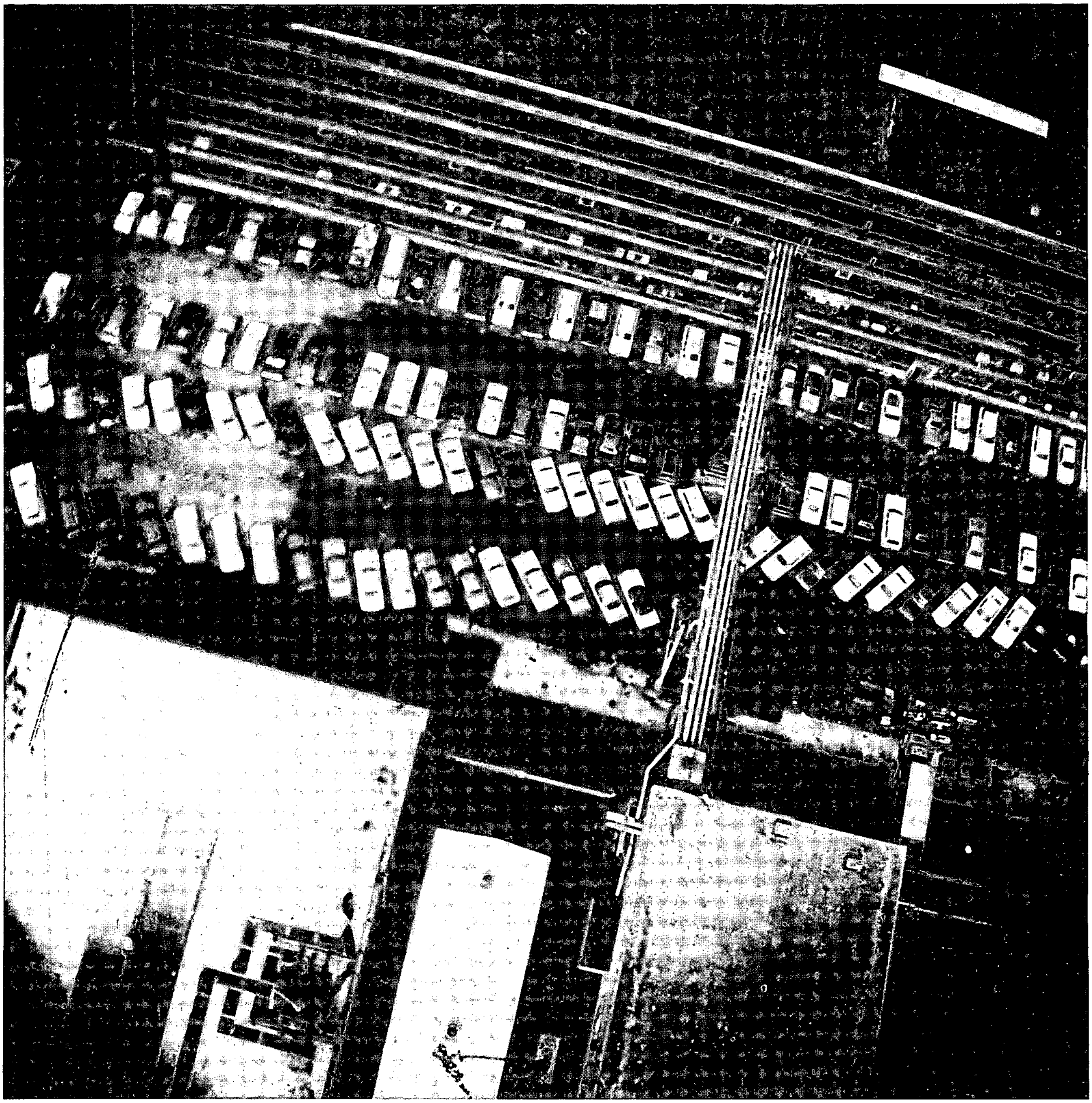

FIGURE A19. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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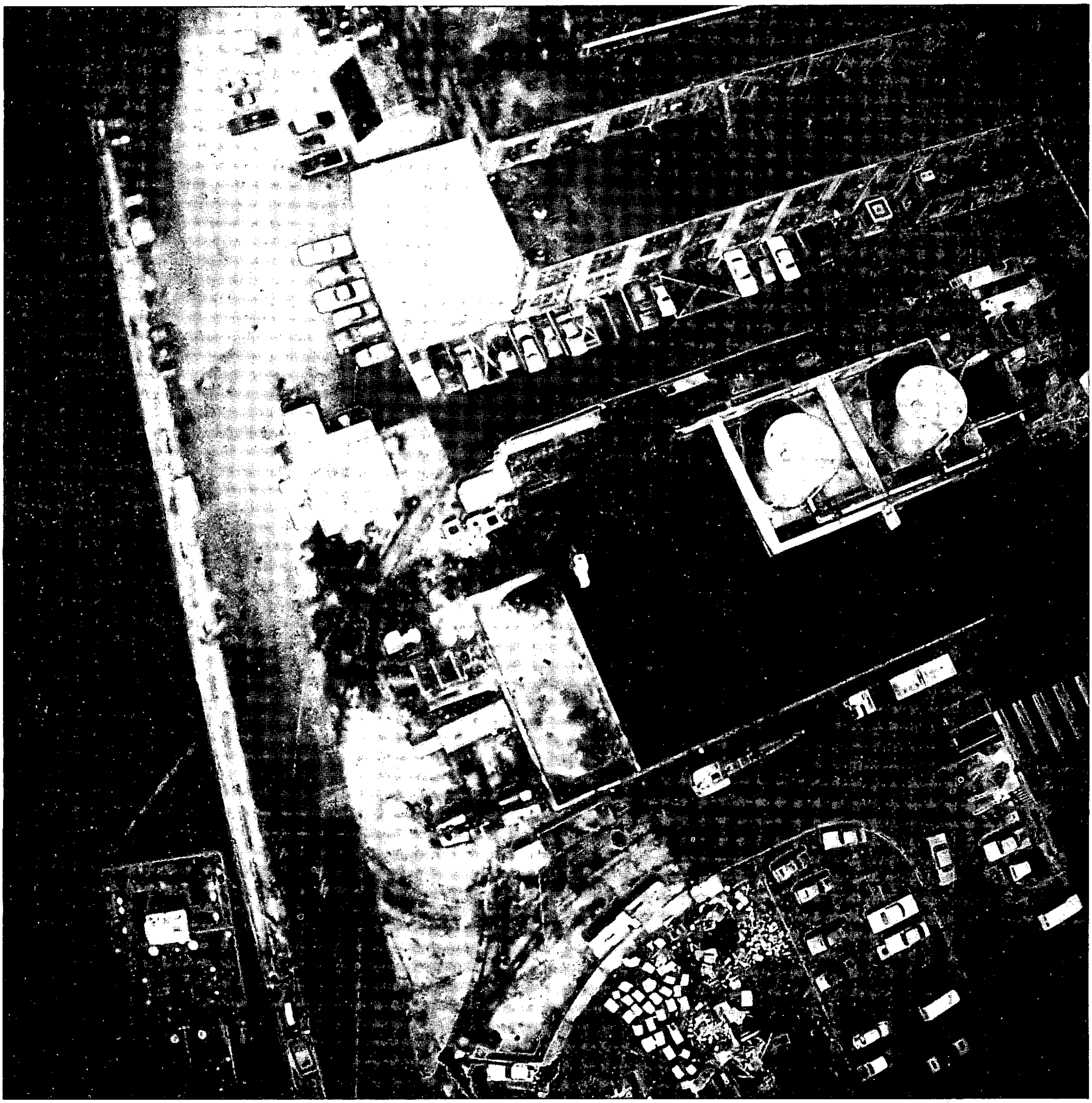

FIGURE A20. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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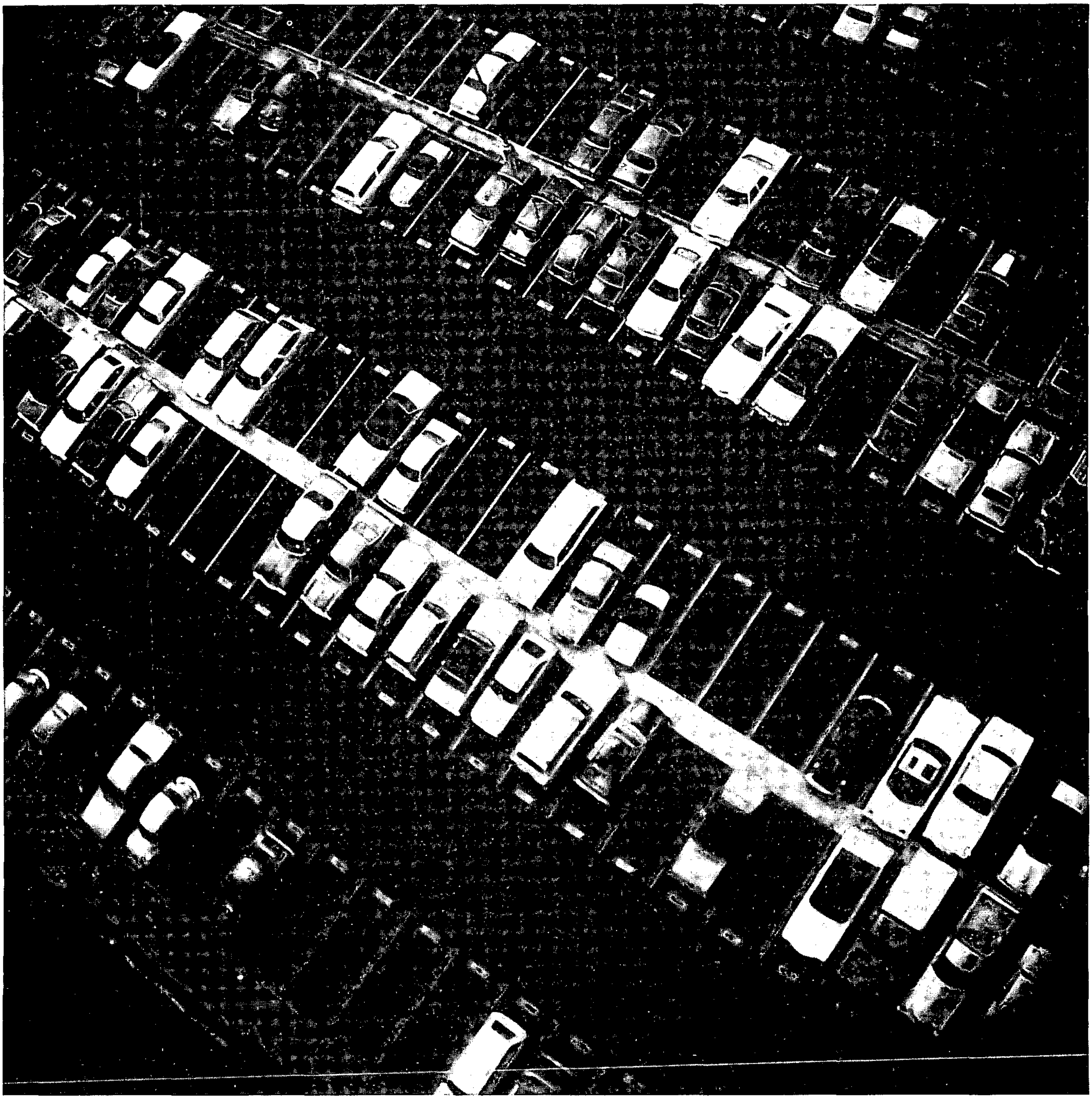

FIGURE A21. Washington Navy Yard—7/7/77
Adjacent Frames (with Figure A22)
Showing the Effect of Platform
Dynamics on Image Quality

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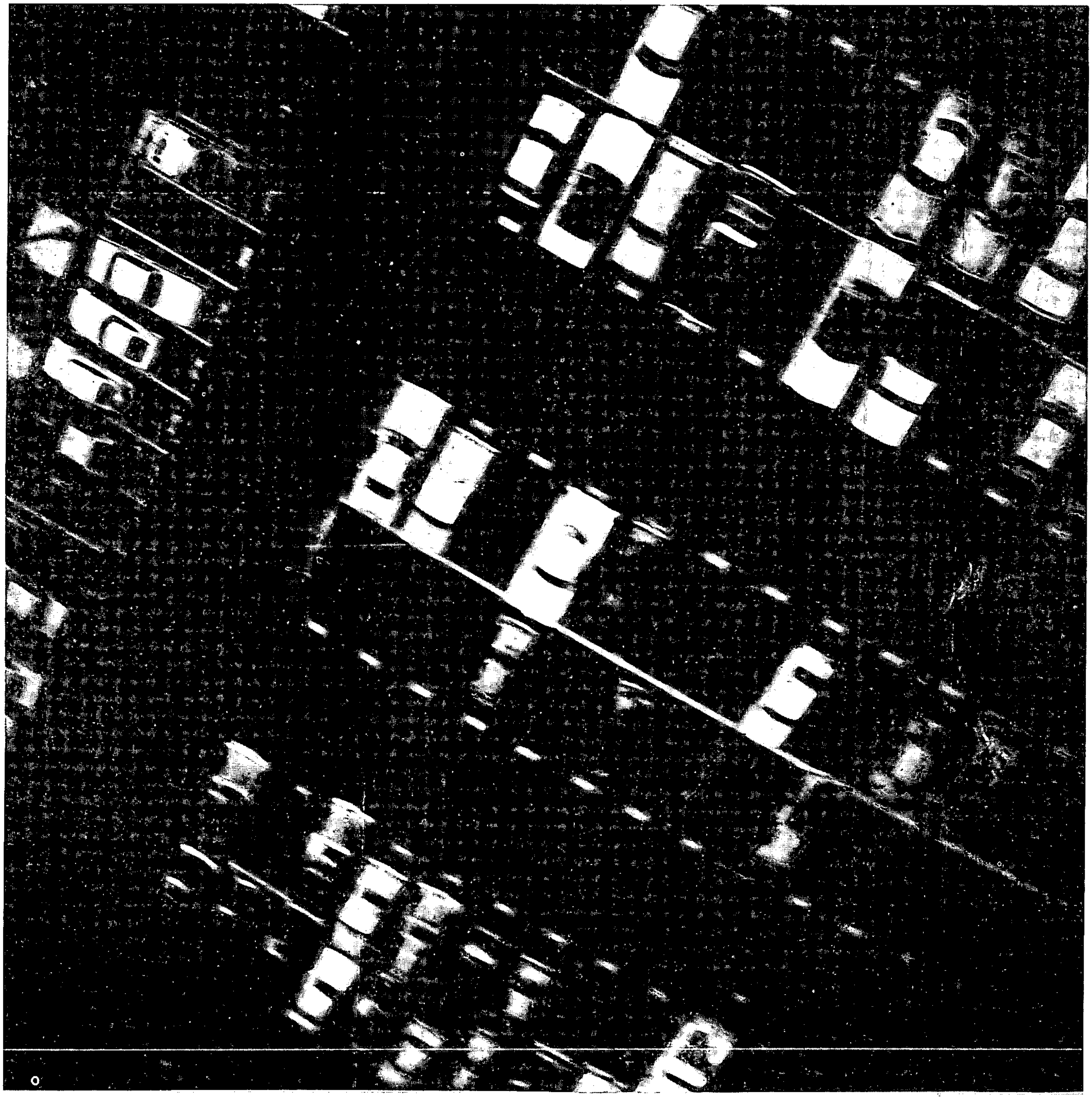

FIGURE A22. Washington Navy Yard—7/7/77
Adjacent Frames (with Figure A21)
Showing the Effect of Platform
Dynamics on Image Quality

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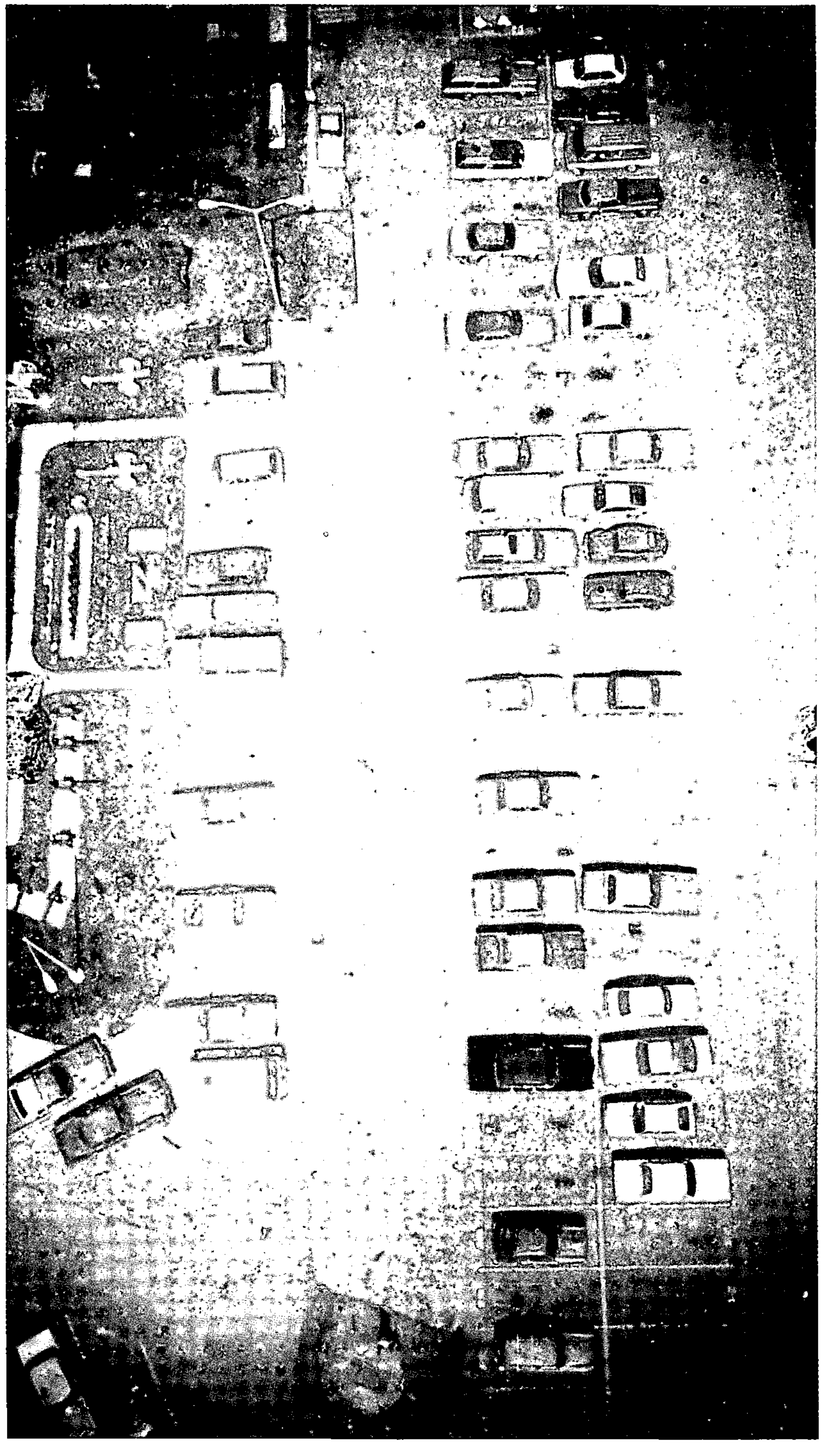

FIGURE A23. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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FIGURE A24. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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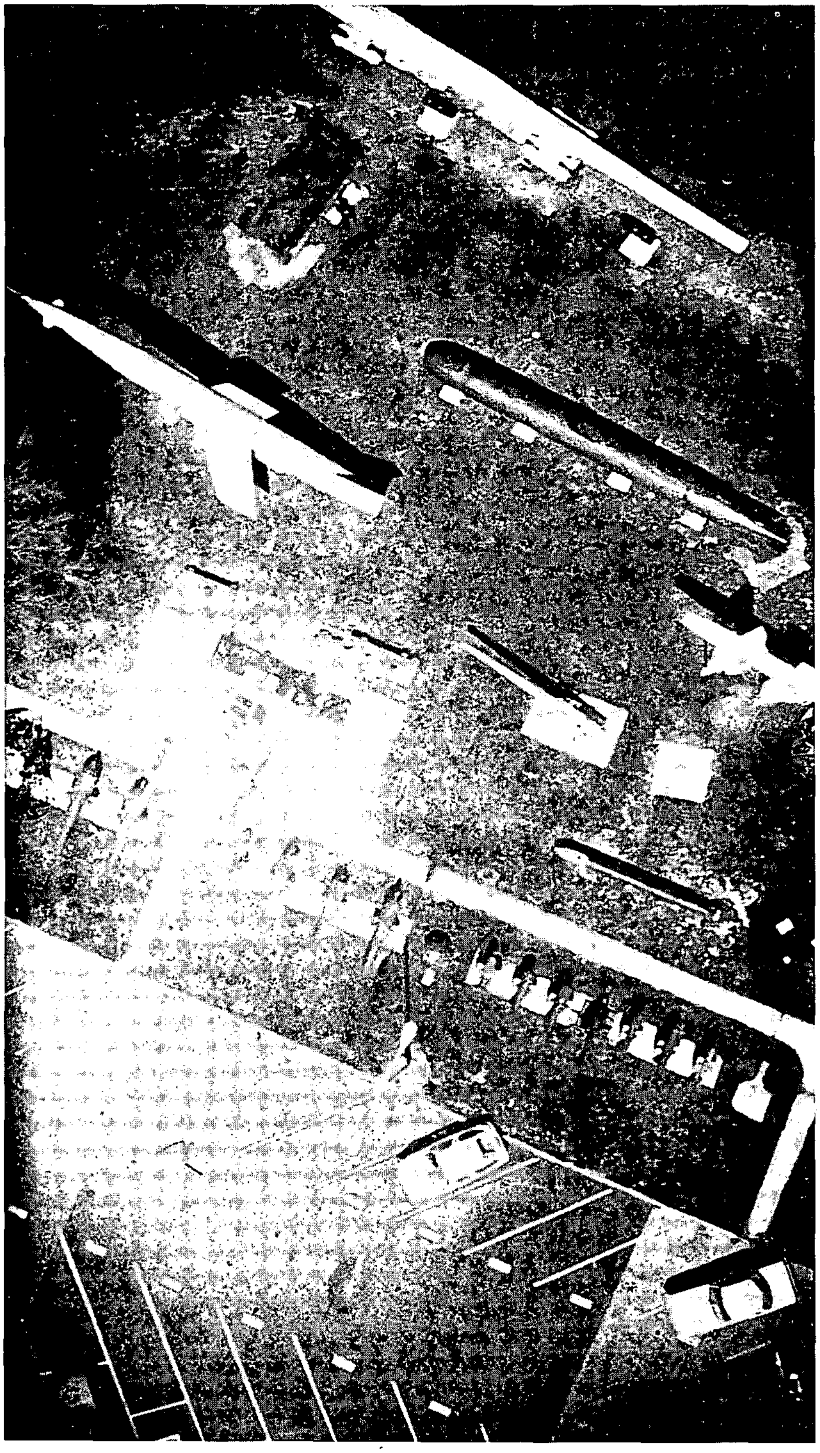

FIGURE A25. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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FIGURE A26. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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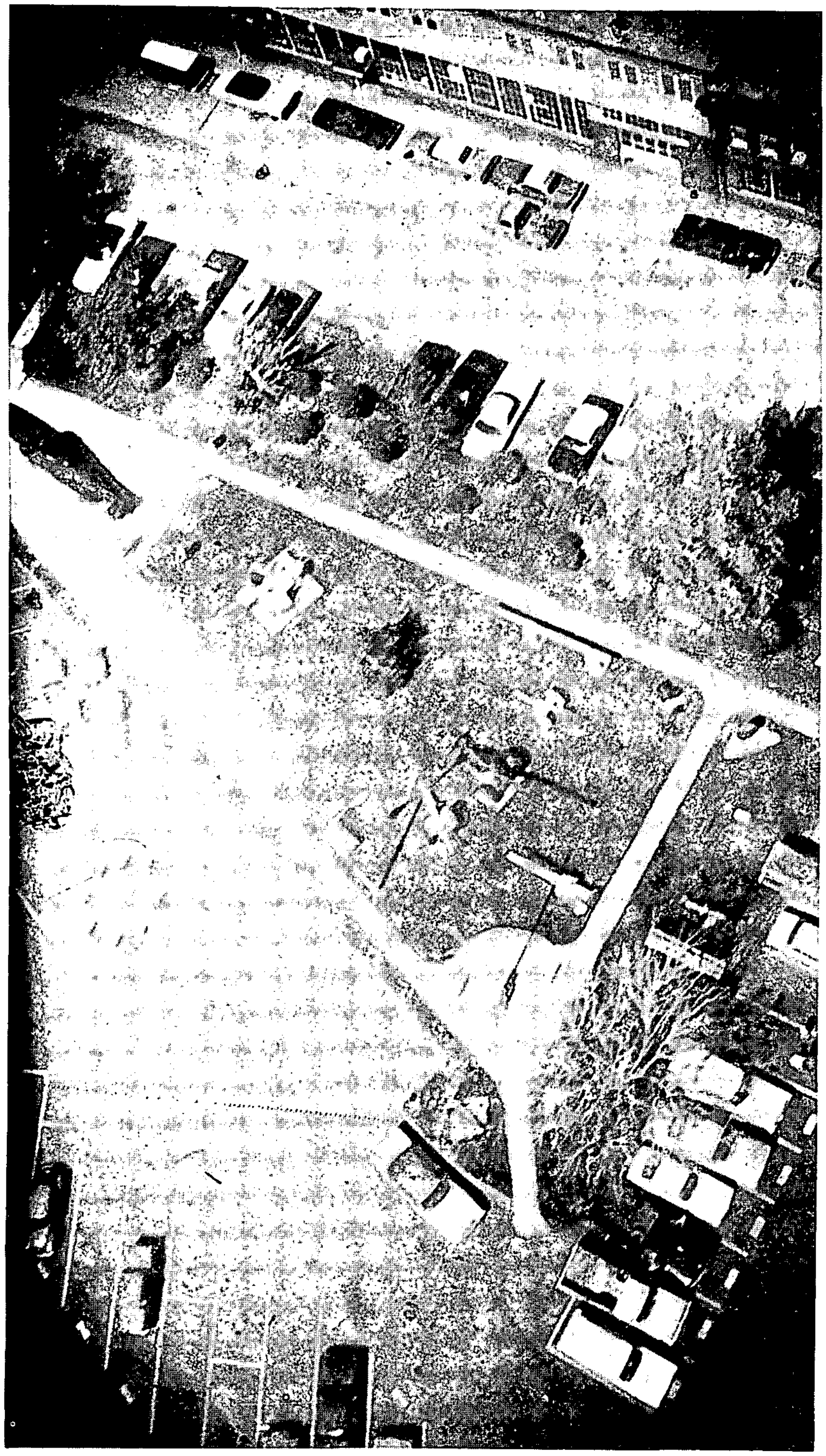

FIGURE A27. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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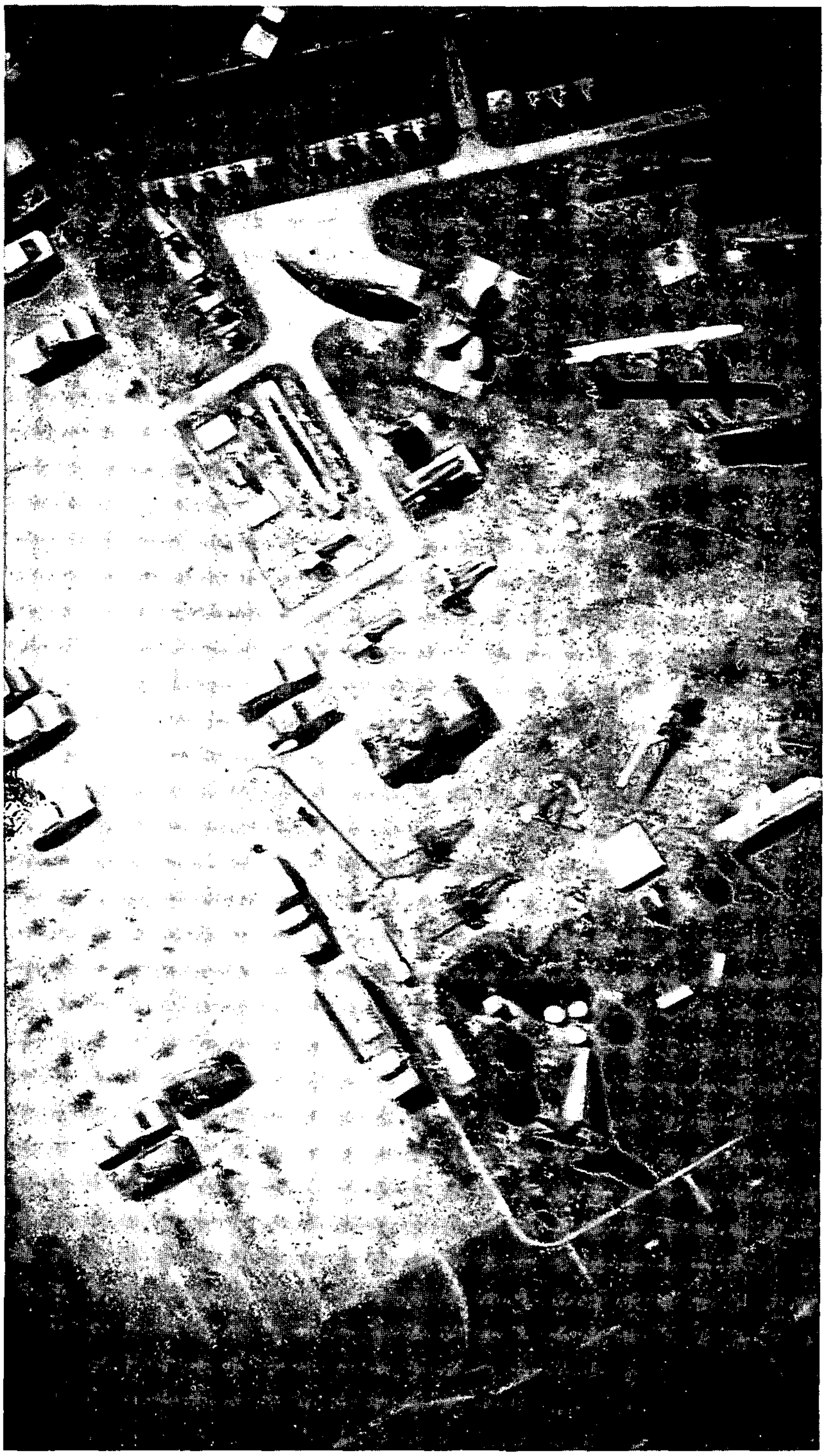

FIGURE A28. Navy Yard Display Area
..... Not Mensurated .....

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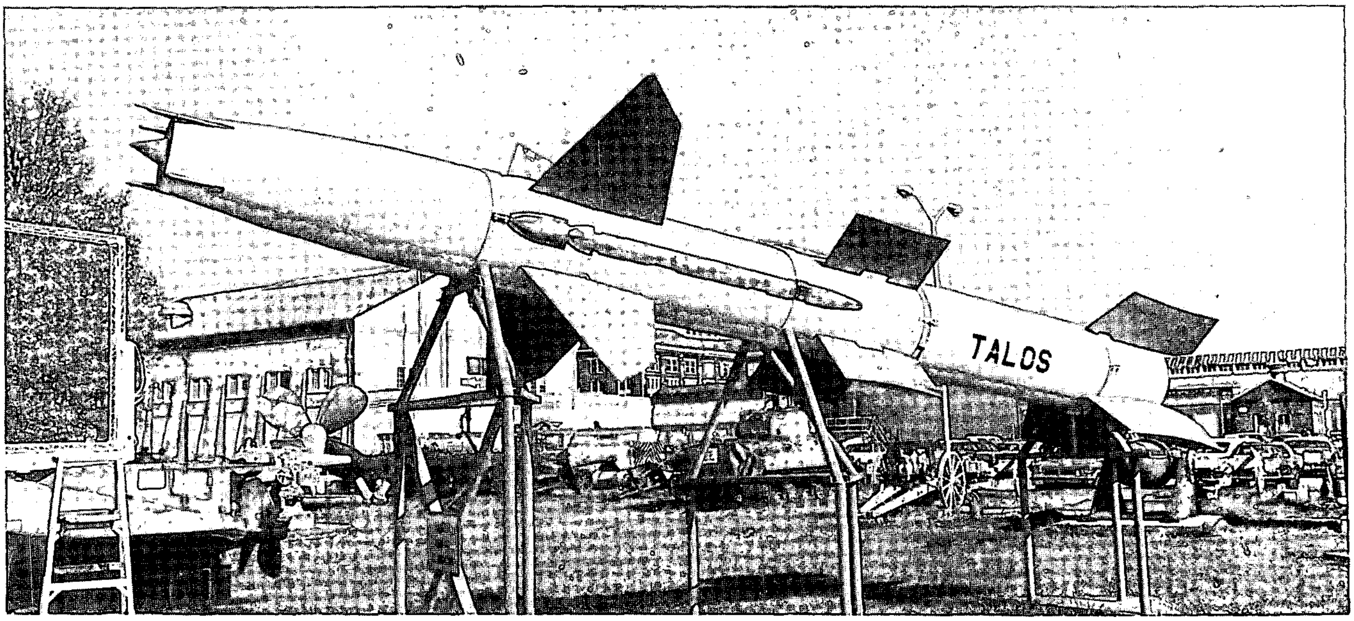


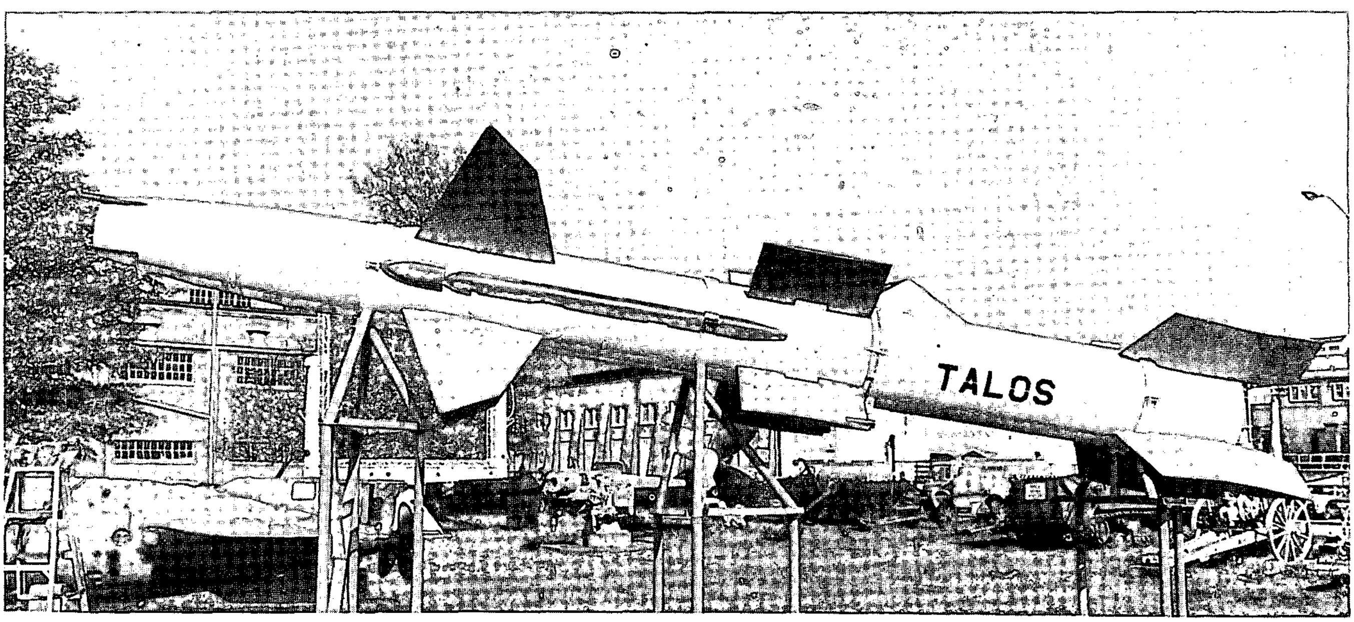


FIGURE A29. Ground Views of Talos Missile at the Washington Navy Yard

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3.3(h)(2)

FIGURE A30. KH-8 Coverage of the Navy Yard
Target Display Area

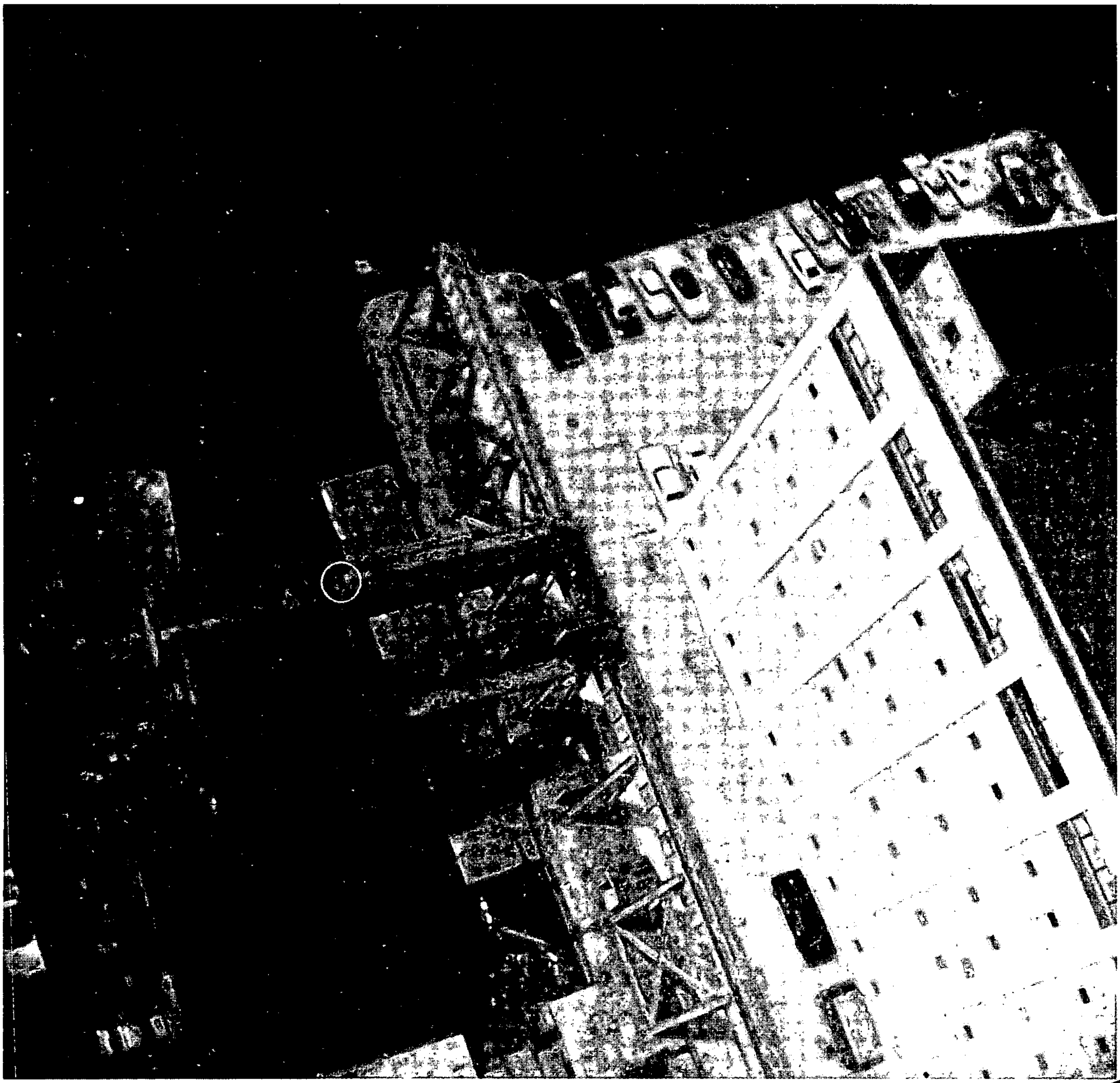

FIGURE A31. The Washington Navy Yard—7/8/77

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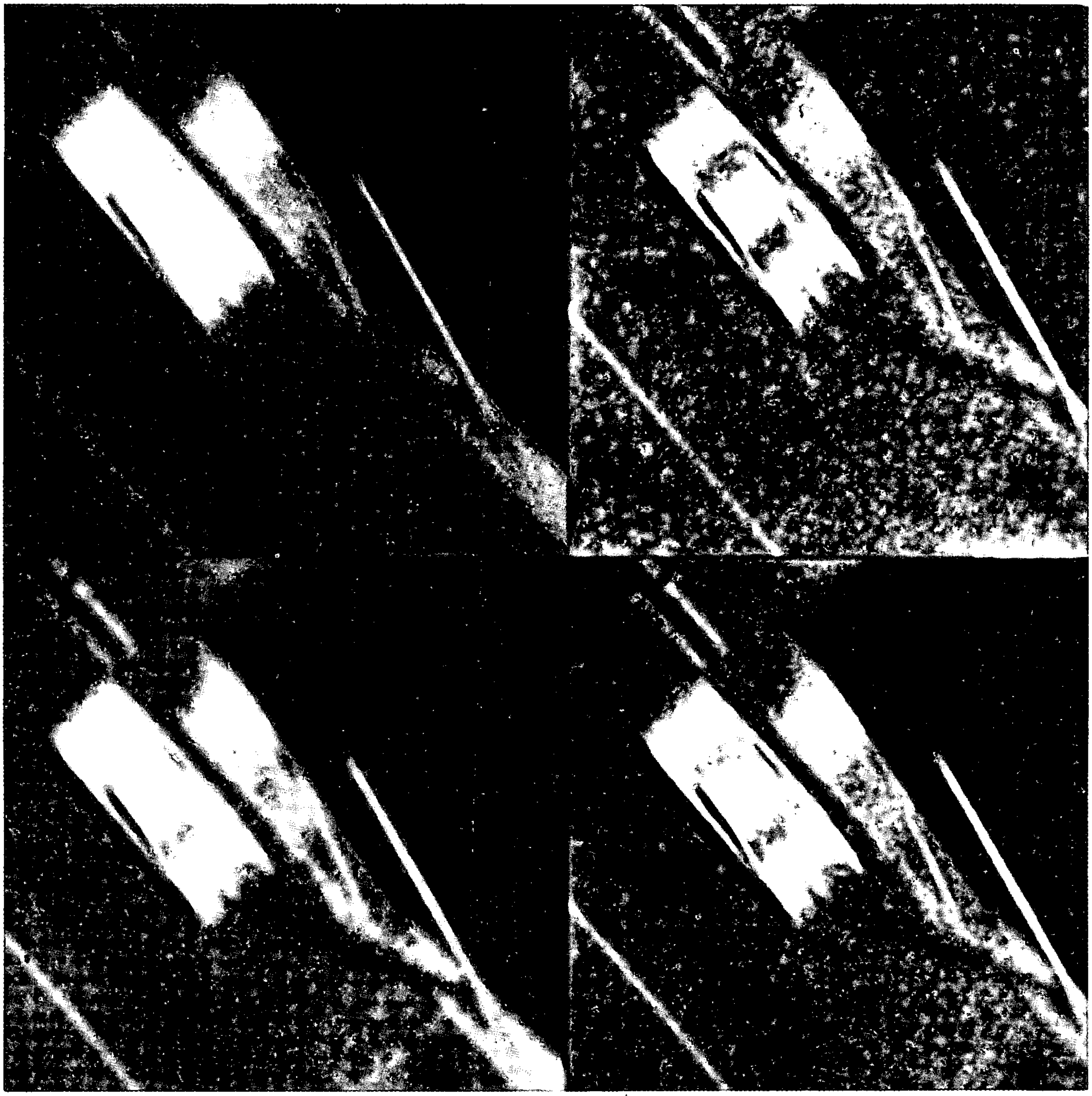
32(a). Original Scene Micro-d Scan

32(d). Rooting (Exp 0.5) 5x5 Convolution, TTC



32(b). Rooting (Exp 0.7) Gaussian Filter

32 (c). Rooting (Exp 0.7) Gaussian Filter Edge Enhancement

FIGURE A32. IDIMS Effect on Smeared Imagery

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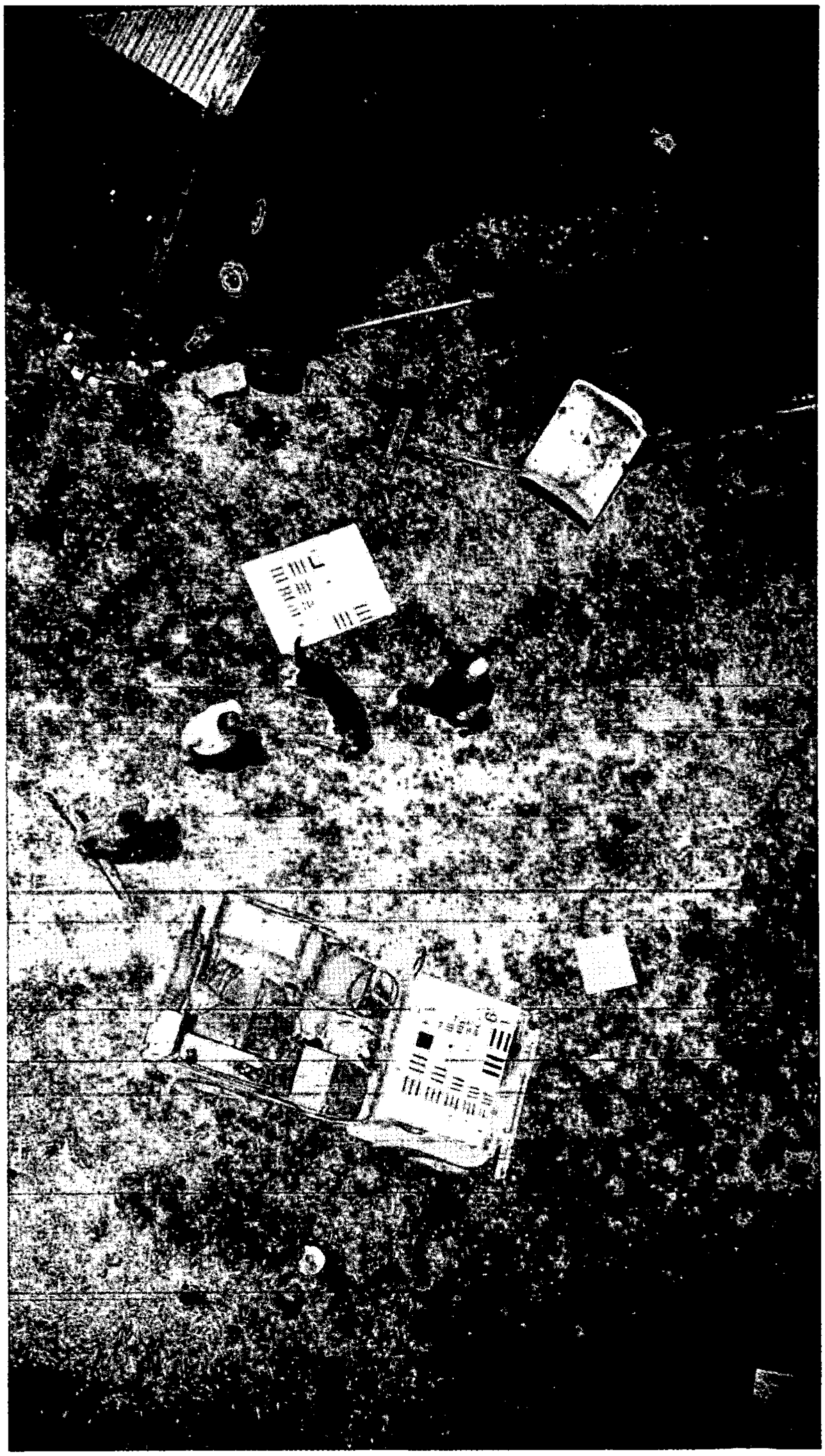

FIGURE A33. Camera/Film Analysis Test Imagery (From the Balloon Platform) SECRET NOFORN

# APPENDIX B

# CAMERA DETAIL AND SPECIAL DEVICES

~~(S)~~ This section gives some additional detail on avian cameras including results of some preliminary low temperature tests and a quote from Mallory on a lithium battery for use in extremely cold climates. Also discussed are the camera timer box, the camera harness, the small avian DF transmitter, and a Skinner box experiment for investigating the visual response of pigeons in the infrared. As a result of the success of the Skinner box experiment, an IR strobe was modified for use as a remote signaling device for calling the birds into the loft.

## *Camera*

~~(S)~~ Figures B1 and B2 are assembly drawings for the MCW-24 camera and the new [redacted] camera. Low temperature tests were conducted on each camera. It should be kept in mind, however, that

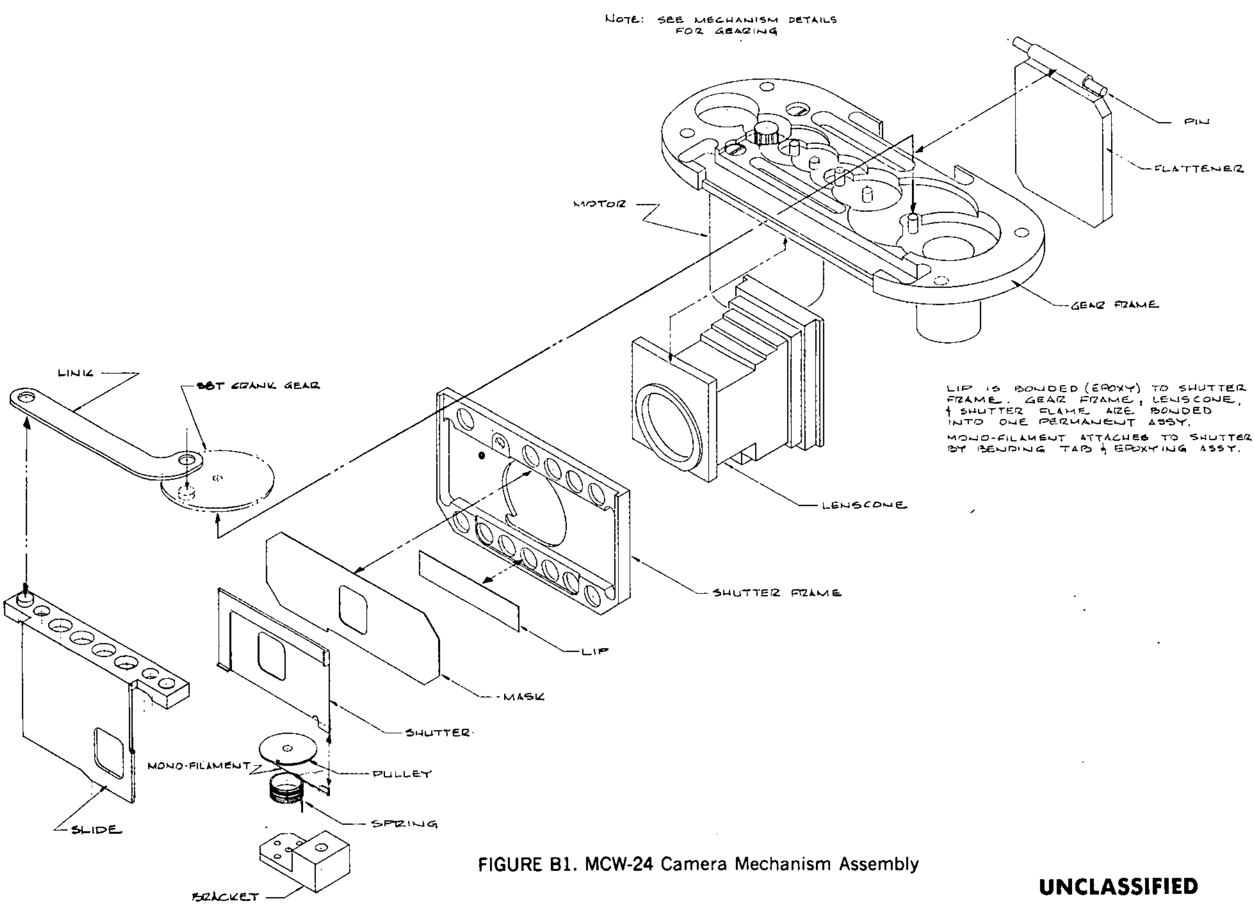


FIGURE B1. MCW-24 Camera Mechanism Assembly

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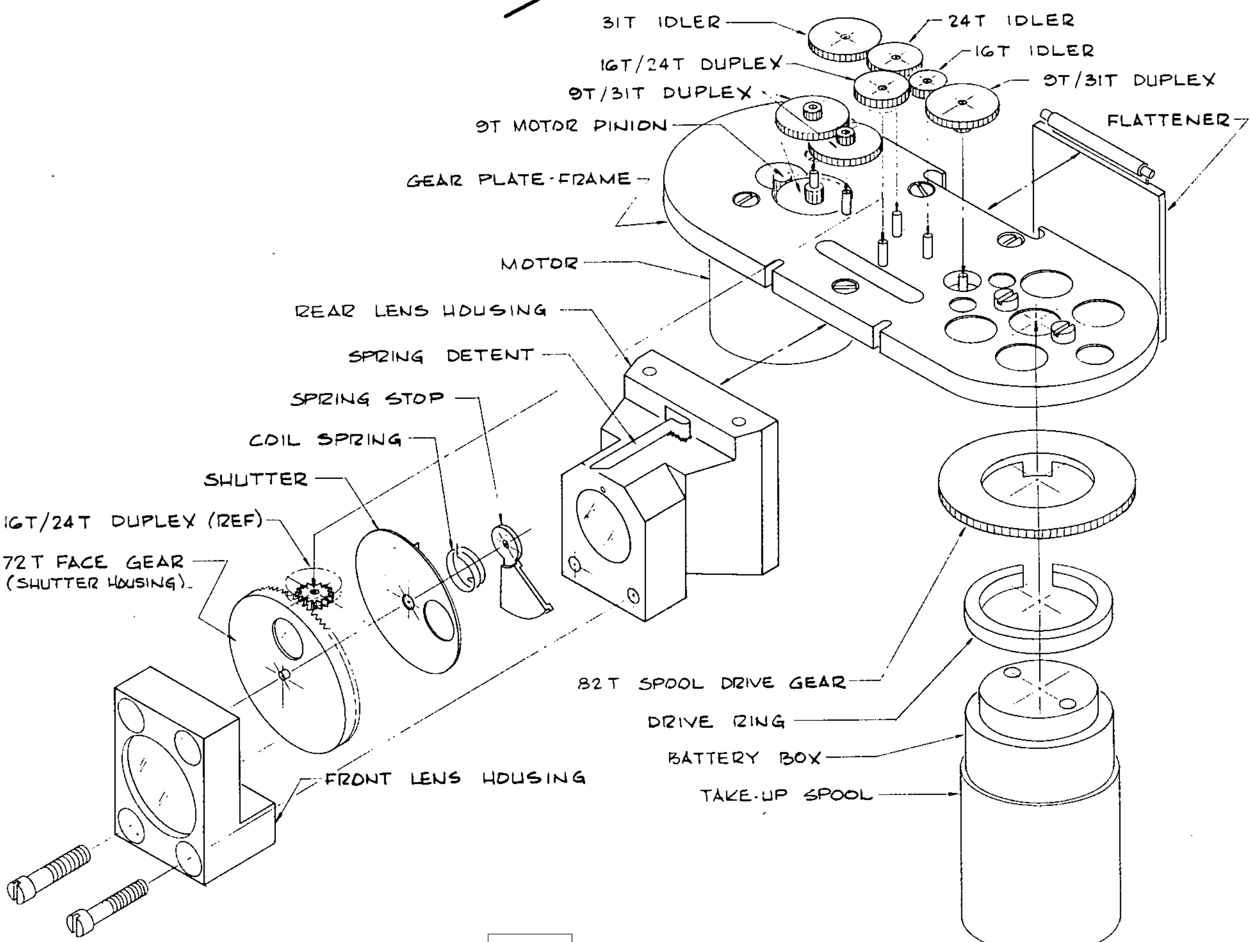


FIGURE B2. Camera Mechanism Assembly

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the MCW-24 was flown 12 times over Andrews Air Force Base during one of the coldest winters on record; typical temperatures were in the low twenties (°F).

~~(S)~~ The first low temperature test was with the MCW-24 camera, using two Mallory 10L14B silver cells. The unit was placed in a (−5°F) freezer with a three-minute delay in the timing unit. A thermocouple attached to the side measured camera case temperature. After three minutes, the camera started (case temperature 52°F) and ran for an additional four minutes (case temperature 40°F) at which time it stopped.

~~(S)~~ A second test was run under the same conditions, but with a 30 mph wind blowing over the unit. Here, the case temperature was (35°F) after three minutes (when the camera started) and was (23°F) after five minutes (when the camera stopped).

~~(S)~~ In both the above experiments, the camera did not pull a full load of film through before stopping. It is apparent that the (107°F) body temperature of the bird kept the camera sufficiently warm to work properly during the flights over Andrews Air Force Base.

(S) An additional temperature test was performed on ths MCW-24 using a constant three volt power supply. Here, the camera stopped when the case temperature reached (32°F) and the current drain was approximately double that at normal temperatures. The 10L14B silver cells were tested at low temperatures through a 39 ohm resistor. The voltage varied from 3.2 V (60°F) to 2.8 V (32°F) to 2.0 V (0°F).

(S) The [redacted] camera was tested (no timer) with a constant 3-volt supply and continued to operate down to (−1°F). The current drain increased from 36 ma (28°F) to 92 ma (−1°F). This, however, was after considerable attention had been given to selecting a low temperature gear lubricant.

(U) Three factors contribute to the low-temperature performance of the camera:

1. The current drain of the motor as a function of load and voltage.
2. The viscosity of the gear lubricant at low temperatures.
3. The performance of the battery at low temperature.

(U) A 6-volt motor was found which had considerably better efficiency than the current 3-volt motor. Tests with the 6-volt motor gave 18 to 22 ma at (20°F) and 45 ma at zero. However, once a suitable low-temperature lubricant is found, the critical item in the systems is battery performance.

(S) It is known that lithium cells have twice the voltage as silver cells with virtually no performance degradation at low temperature. Therefore, if lithium cells could be made in the same size containers as the present 10L14B silver cells, the high efficiency 6-volt motor could be used to compose a system with adequate performance at zero degrees Fahrenheit (or lower). This problem was given to Mallory with the following response:

1. ***Size.*** Same as the 10L14B silver cell.
2. ***Weight.*** 2.6 grams/cell (same as 10L14B).
3. ***Current Drain.*** 100 ma at 2.6 v/cell for 15 minutes.
4. ***Cost.*** $180/cell recurring (in lots of 50), and $12,000 nonrecurring.
5. ***Availability.*** Four to six months.
6. ***Shelf-life.*** One to two years.

*Camera Time Box*

(S) The camera timer box is used to program the camera timer electronics, which contains two E-cells for providing the "delay" and "run" times. Figure B3 is a schematic, and Figure B4 is a photograph of the control panel and the three timer leads. Figure B5 is a picture of the camera electronics showing the positions for connecting the timer leads. The following is a list of steps for using the timer box:

1. With S-1 on and S-2 in "volts" position, the condition of the batteries in the box can be determined. It should be three volts, read on lower scale above the meter.
2. With S-1 on, S-2 in "milliamp" position, and S-6 in "open" position, the camera should not run. If it does, it is because there is accumulated time (charge) in the E cells of the camera timing circuit. This should be allowed to run out before proceeding further, preferably with the camera not attached to the E cells, so as to save wear and tear on the shutter.
3. With S-1 on, S-2 in "milliamp" position, and S-6 in "short" position, the camera should start running and continue running until S-6 switch is placed in "open" position.
4. To put run or delay time in camera, S-1 must be on, S-2 must be in "microamp" position, and S-3 must be in "time"

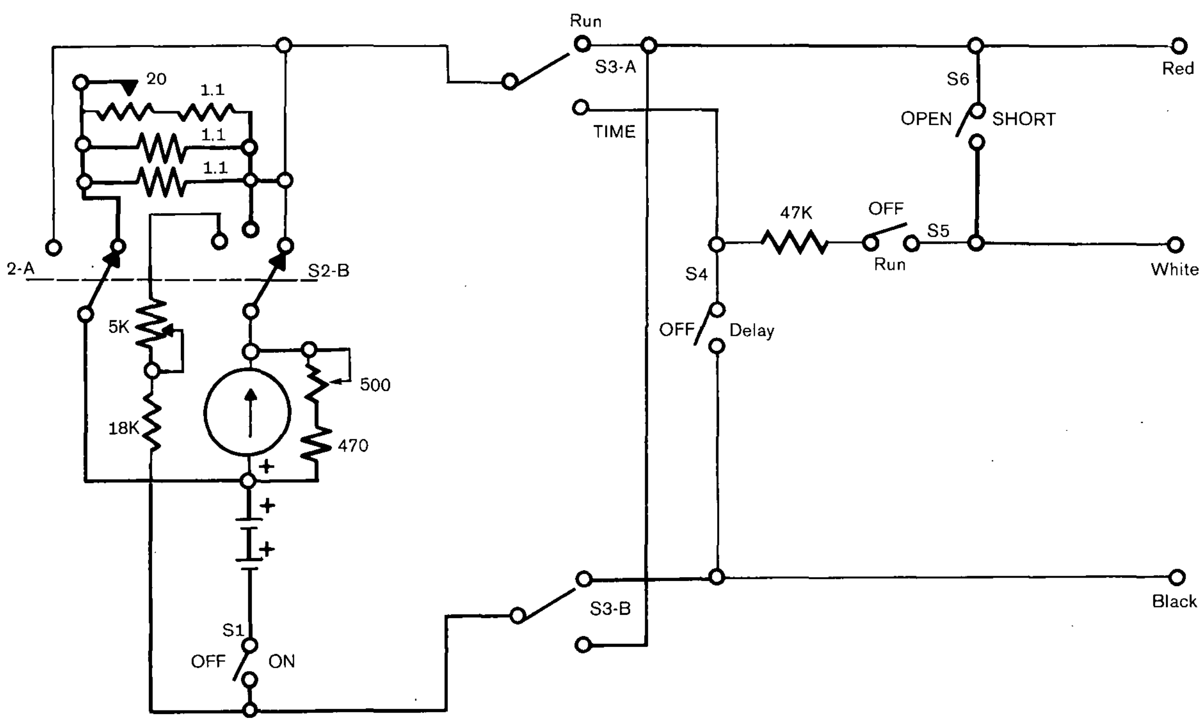


FIGURE B3. Timer Box Schematic

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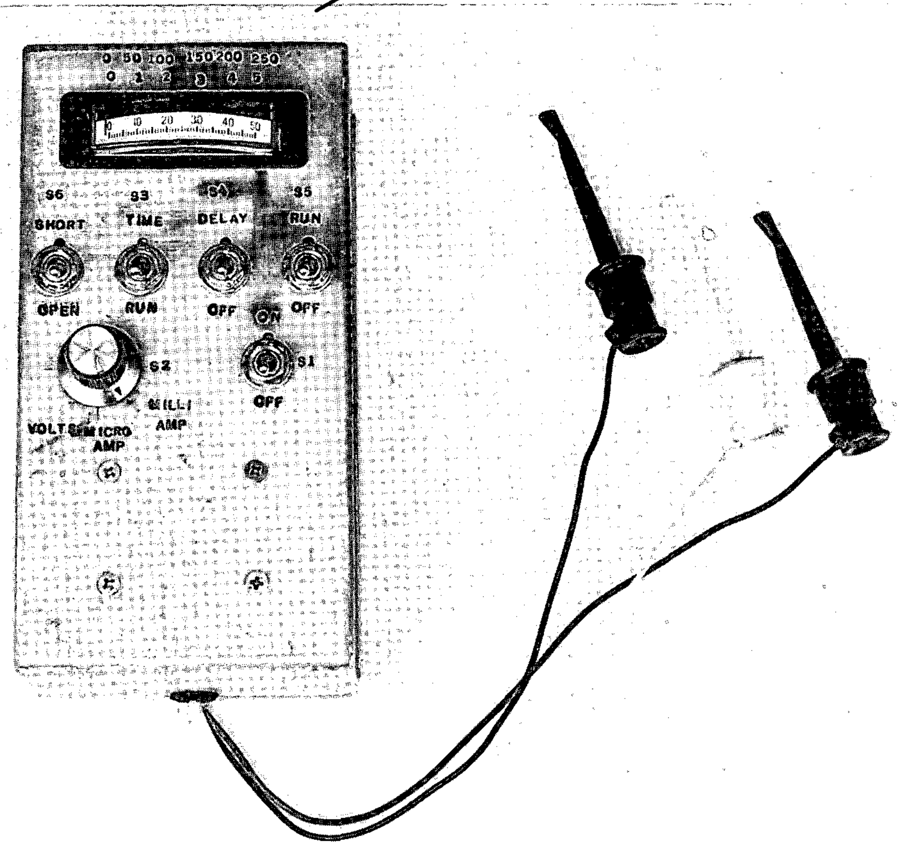


FIGURE B4. Timer Box Controls **UNCLASSIFIED**

position. Further, if this is for an actual flight, batteries must be in camera and a tab must be between ground and contact points leading to batteries on camera.

5. ***Putting Delay Time in Camera:*** With timer set as described in 4 above, S-4 switch is put in "delay" position for amount of time desired. The meter should read approximately 175 microamps (upper scale above meter) while delay time is being put in. At the end of that period, S-4 switch should be put back in "off" position.

6. ***Putting Run Time in Camera:*** With timer set as described in 5 above, and with S-4 switch in "off" position, turn S-5 switch to "run" position for desired length of time. Meter should read approximately 60 microamps (upper scale above meter) while time is being put in. At the end of that period, switch S-5 to "off" position.

7. To check delay and run time, disconnect three leads from the camera and pull tab. Camera should delay running until delay time is over, then run the amount of time programmed.

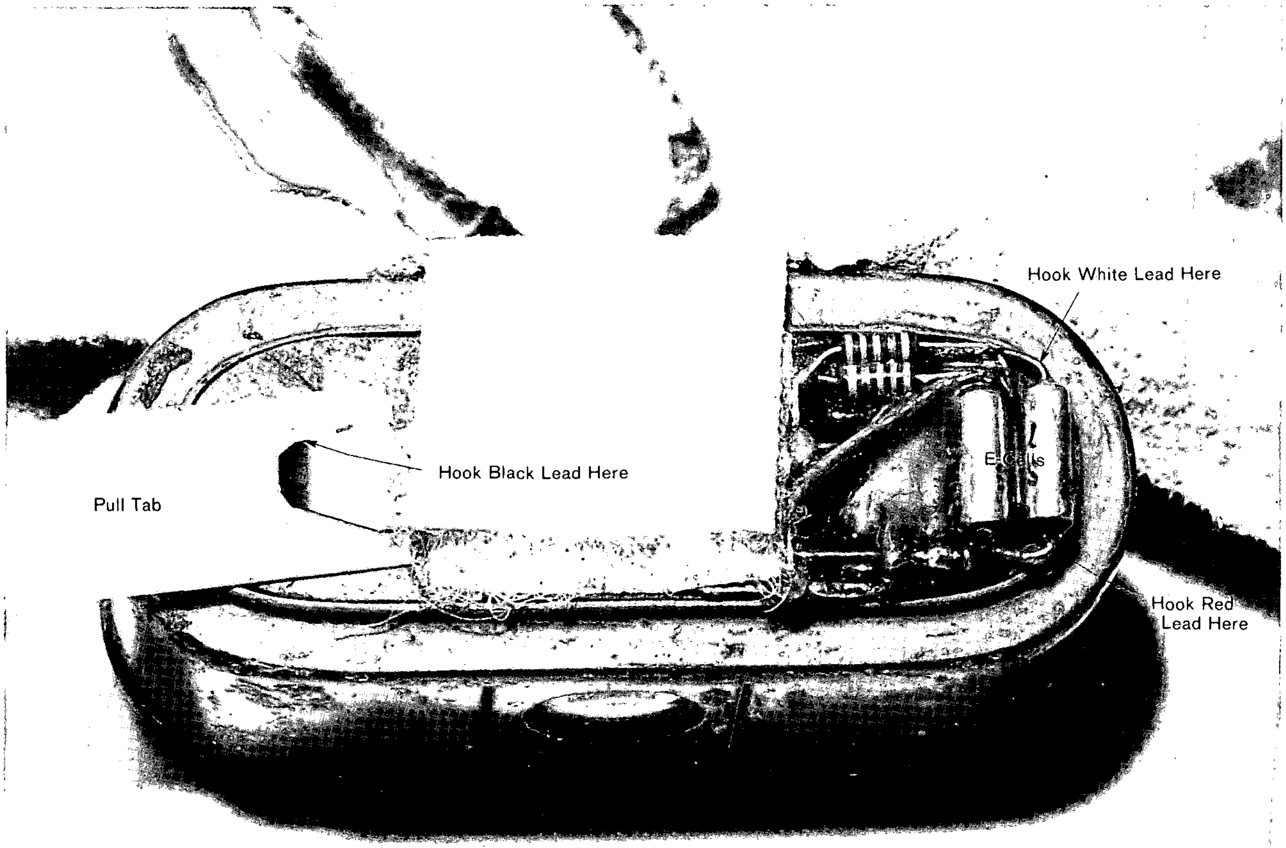


FIGURE B5. [redacted] Camera Electronic Timer

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8. To heal E cells, first disconnect the E cell portion from the rest of the camera. Then with S-1 on and S-2 in "milliamp" position, leave it for a period of time, first in "open" position for S-6, then in "short" position for S-6.

9. After camera is loaded with film and prior to putting in time for actual flight, five seconds of delay time and five seconds of run time should be put in to test if camera is functioning properly.

10. Unloaded, camera should be pulling around 75-85 milliamps when running. Loaded, it should be pulling around 100-125 milliamps when running.

### *Camera Harness*

(S) Figure B6 shows a bottom- and top-view sketch of the harness. Several types of material were used with varying degrees of success. The weight should not exceed 4.5 grams and a soft leather, such as suede, is preferred which does not stretch with use or after becoming wet. A heavy chammy was tried (the long axis of the harness must be aligned with the direction that does not stretch much), but it must be prestretched prior to cutting out the harness and is prone to stretching with excess use.

(S) The harness is connected (and adjusted) by use of Velcro tabs on each end. The right side in Figure B6 winds up on top, pointing aft, so that aerodynamic pressure does not peel the tabs apart. On at least one occasion, the bird reached back and peeled the tabs apart with its beak. For safety, the tabs should be tied together with lacing cord after the final adjustment. Since the harness will loosen after the bird preens and works it into its feathers (it becomes almost invisible from the bottom), the final adjustment should be made in about ten to twenty minutes after first being put on the bird. A light blue or gray colored material will blend in well with the underside of the bird. The cameras were painted with a dull gray "automotive primer" which worked well.

(S) The Velcro camera tabs were used for rapid and convenient attachment and removal of the cameras and weights from the harness. However, this increased the total weight considerably and was responsible for the loss of at least one camera. The first designs of the MCW-24 cameras used small metal clips. Though this was less convenient, it weighed less and was far safer.

(S) A loose harness will cause the camera to bang against the breast bone of the bird (a severe source of irritation) and result in excessive photographic blurring due to high-angular rates. If the

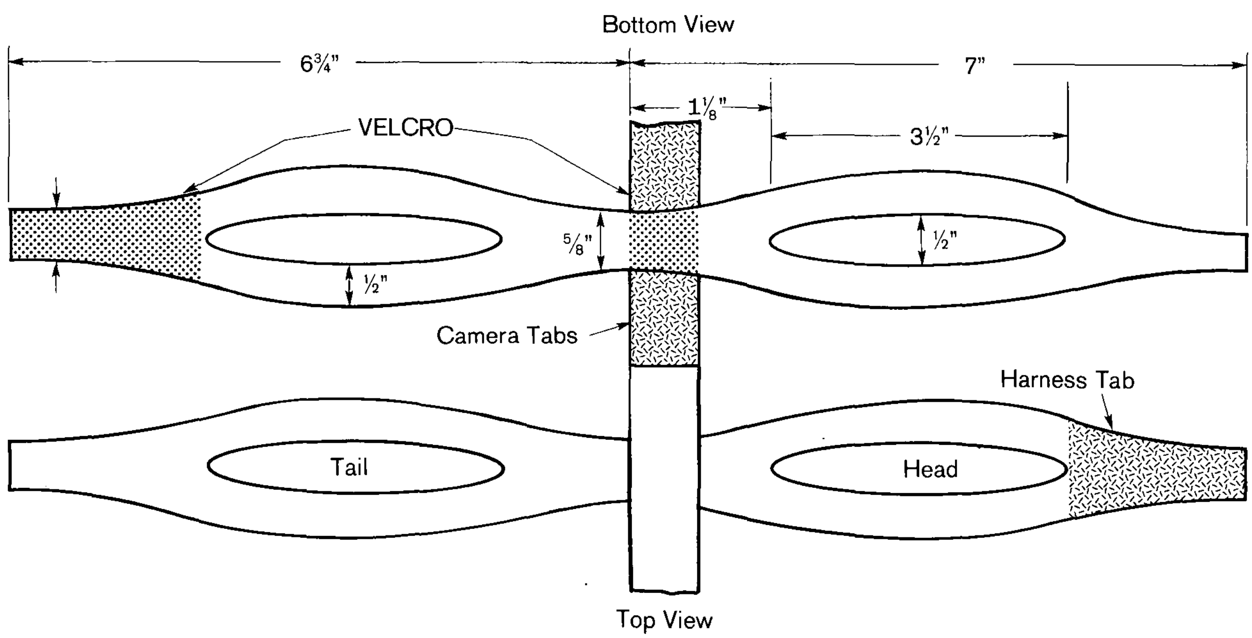


FIGURE B6. Camera Harness

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bird has a deep keel (breast bone), a small piece of foam should be wedged between the harness and the belly. This will act as a shock absorber for the vertical acceleration due to flapping. The bird will move up and down about an inch, six times a second.

(S) One size harness will not fit every bird. At the beginning of the project, a large- and medium-size harness was used. As the birds lost body fat and put on muscle, a third small-size harness was necessary. It was found convenient to put the bird's number on its harness. It is important to remember that the camera pull tab in Figure B5 goes forward.

### *Avian Transmitter*

(S) Two types of avian transmitters (SM1 and SB2) were obtained from: [redacted]

Figure 12 shows the SB2 (with batteries, antenna, and ground plane wire) attached to the harness. The SM1 weighs less than a gram (no battery, antenna or ground plane wire) and can be detected (ground-to-ground) at about one mile range; the typical life is over one month. The SB2 weighs about 6 grams and can be detected at several miles (ground-to-ground) with a life of about 10 days.

(S) The SB2 was used with every [redacted] camera flight at the beginning of the project and was responsible for the recovery of one camera. However, it was noticed that the birds' performance with the [redacted] camera was not as good as with the MCW-24 or the simulated camera weights. On several occasions, the birds would go down before returning home and pull the antenna and ground wires off. Also, it is felt that the combination of the heavier [redacted] camera and the transmitter weight affected performance. Toward the end of the program, no transmitters were used and performance improved, though still less than with the MCW-24 or weight. Both irritation (wires or floppy transmitter) and excess weight degrade performance. If a transmitter must be used, the lighter the better for performance.

### *Skinner Box Experiment*

(S) The loft in Missouri was managed primarily by [redacted] with a degree in psychology, was familiar with much of the classic "Skinner Box Experiments" with pigeons, had access to most of the scientific reports, and had several professional acquaintances at the State

University at Roanoke. Her ultimate goal was to train the pigeons (on the loft or in the air) to respond to an infrared flashing light by quickly coming into the loft. Her experiments progressed in several stages listed below:

1. There are three "light buttons" in the Skinner box which can be illuminated with red, white, and green light. These buttons close a contact switch when pecked by the birds. A small computer was programmed to randomly illuminate one of the buttons with red light and to feed the bird when the red button was pecked. Figure B7 shows the bird about to peck the red button, and Figure B8 shows the bird receiving its food reward. The computer also recorded data pertinent to the rate of learning and differences between individual birds. The TV camera in these two figures was used for remote observation of behavior.

2. Once all the birds were trained to the visible red light, it was replaced with an invisible (to humans) infrared light with no detectable change in learned behavior. The wave length was about 0.9 microns.

3. In the next experiment, an IR flashing light was installed over the feeder in the pigeon loft. This was a commercial IR

FIGURE B7. Bird Responding in Skinner Box

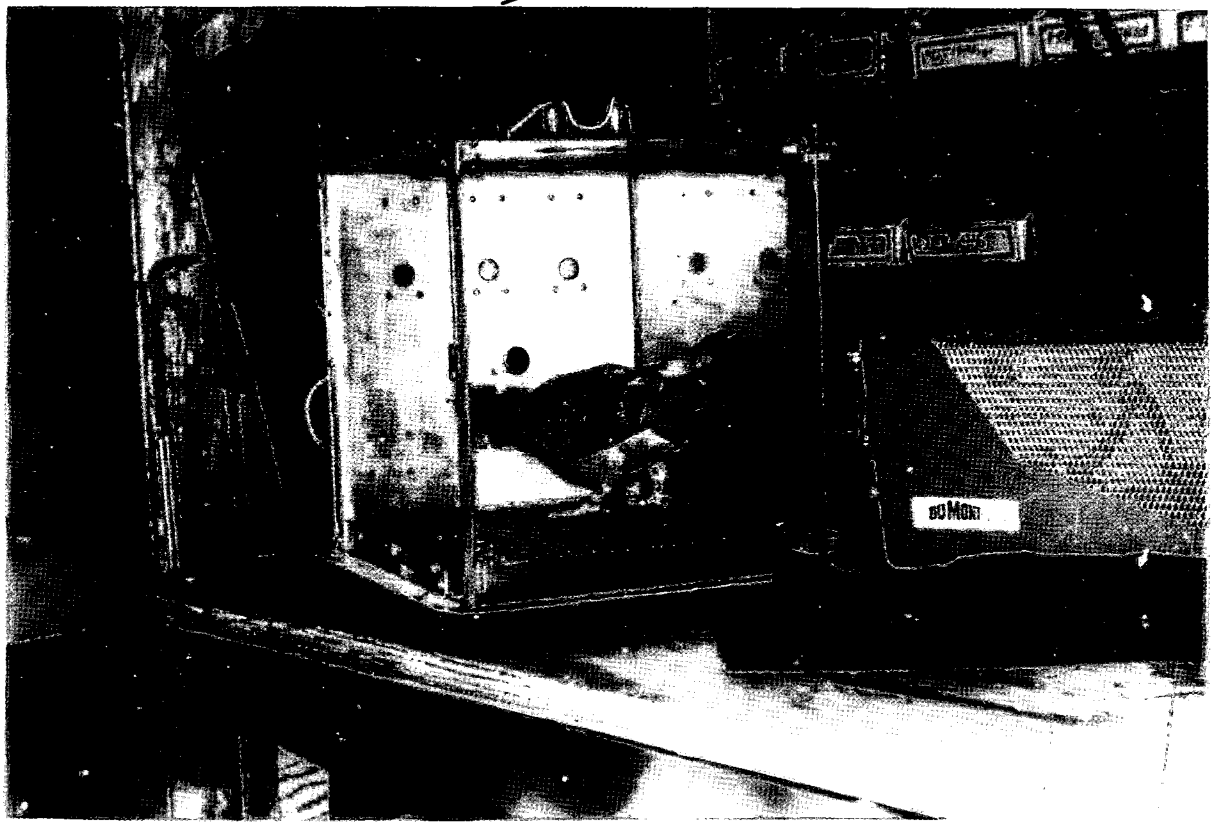

FIGURE B8. Bird Receiving Food Reward

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camera strobe (see Figure B9) fitted with a two-second strobe timer. The purpose was to form an association between the flashing light and dinner time. This concept worked well with the "dinner music" tape used by all the project lofts (also developed by [redacted]

4. The last phase was to place a flashing light outside the loft as a cue to the birds that food was being served. The project terminated before this phase was completed, but it appeared that some birds did make the transfer in cue while others did not. A pair of squabs (very young birds), raised during experiment three, did come into the loft in response to the flashing light after they had returned from their first flight and looked as though they intended to spend the night on the roof.

~~(S)~~ Whether it is a young bird out for the first time or a relocated bird at its new home, the outside of the loft is strange and unfamiliar compared to the inside. The IR flashing light could be used as a signal of home. A similar method was used by the U.S. Army. A particular colored symbol was used on top of each of the small mobile lofts (which were moved as much as 20 miles a day) so that the birds could not only find home, but distinguish one loft from another. This method, or some other visible cue, could aid greatly in relocation. It was also noticed that there was some correlation between the rate of learning in the Skinner box and the flight performance in the field. Since the learning and recordkeeping in the Skinner box is automated, a large number of birds could be "graded" in a fairly short time.

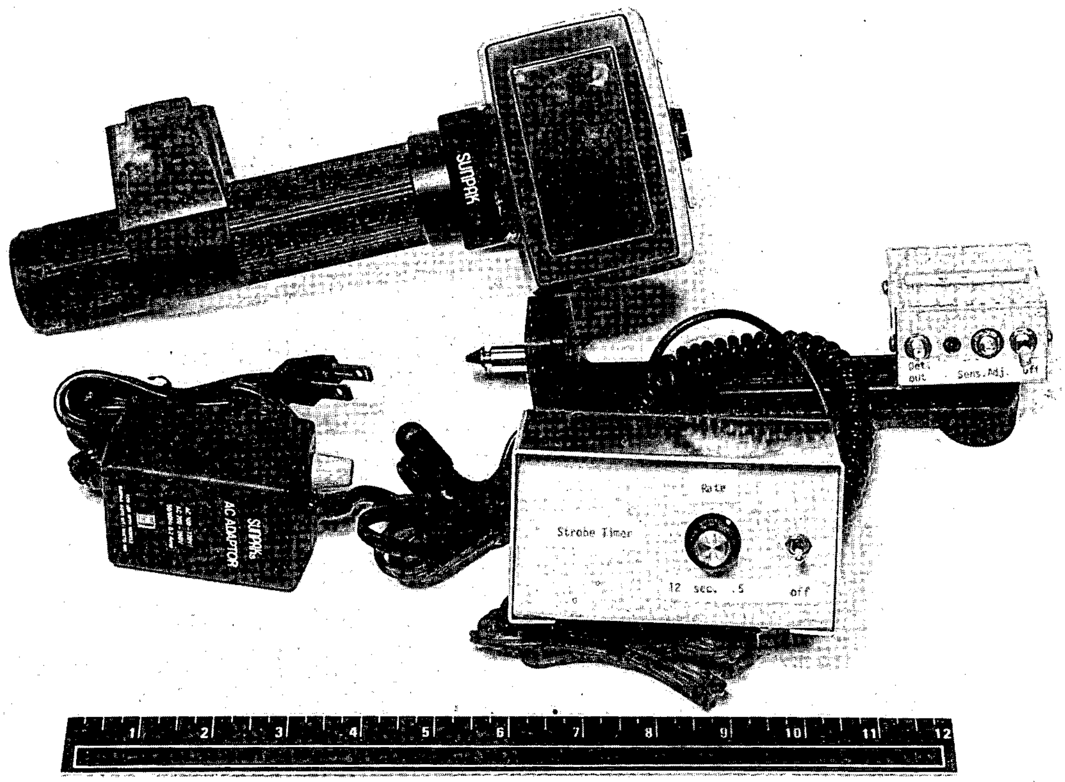


FIGURE B9. Infrared Strobe and Timer

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# APPENDIX C

# CARE AND HANDLING OF HOMING PIGEONS

### *Sanitation and Disease Prevention*

(C) One of the most important aspects of this project has been guaranteeing the health of the pigeons involved. This effort has not been a total success because initially we were operating out of a local existing loft and did not have complete control over our pigeons. Consequently, during the project, we encountered three of the most common pigeon diseases: Canker, Pigeon Pox, and Roundworms. We lost two birds to Canker but survived the Pox and Roundworms with no casualties; the birds were out of form for several days. At one point during the project, Paratyphoid was present in the loft, but our birds were not affected. A list showing the symptoms and recommended treatment for these four diseases, plus another very common pigeon disease, Coccidiosis, is given at the end of this section. With complete control over our birds and their environment, most if not all of these diseases could almost certainly have been prevented. Over 90 percent of most pigeon diseases can be prevented outright through proper methods of sanitation and care.

(C) Following are some of the most basic tenants of sanitation and disease prevention:

1. The pigeon loft should have good ventilation with no drafts. This ensures a constant source of fresh, clean air and helps to keep the floor dry, which is imperative for pigeons to thrive.
2. It is essential that pigeons receive fresh water at least once, and preferably twice, a day. Water should be placed in the loft so there is no possibility of contamination by pigeon faeces, which contain the bacteria for most common pigeon diseases.
3. Pigeons need fresh, clean grain that is fed in the proper quantity (overfeeding leads to overweight, out-of-condition birds), and that cannot be contaminated by the birds' feet, which come in frequent contact with faeces. (Feeders can be built which almost entirely eliminate the possibility of pigeons walking in the grain the eat).

4. Fresh grit should be provided daily, though this is not mandatory. Pigeons use grit to digest their food. It is also a source of vital minerals that the birds can get in no other way. If grit is kept before the birds, it should be checked periodically to be sure it has not turned rancid.

5. The loft must be kept clean and should be scraped daily, which takes only a few minutes.

6. Common body insects must be controlled. This is imperative. Birds afflicted with lice and mites cannot perform properly. If they do not become anemic, they will be worn out from the constant drain of pecking at the source of irritation. Affected birds can be heard stomping their feet at night in an effort to rid themselves of the pests. Pigeons have been known to desert their eggs rather than sit in an infested nestbox. Virtually all body pests can be eliminated completely by the application of roost paint in the loft once a month and by hanging a Vapona bar (Shell Pest Strip) in the loft. (It should be replaced every three months.) The above six points are basic to proper loft management. In the project loft, constructed for kit 2F, these points were adhered to and not one of the diseases present in the first loft appeared. These and other important points of loft management are treated in greater detail in Chapter 15 of Dr. Leon F. Whitney's book, Reference 9. Several books and periodicals are given in the list of references which contain useful material on the care of homing pigeons.

(C) In addition to basic sanitation methods, some fanciers have established a system of disease prevention by treating their birds quarterly for Canker, Coccidiosis, Paratyphoid, and worms. This type of treatment is the same as treating for the disease itself as discussed later. These and other supplies can be purchased from the following pigeon supply companies:

1. Racing Pigeon Bulletin
   94-G Compark Road
   Centerville, Ohio
   45459

2. Foy's Pigeon Supplies
   Box 166
   Golden Valley, Minn.
   55427

3. Charles Siegel and Son
   1011 E. Middle Street
   South Elgin, Illinois
   60177

4. C. A. Hammer Company
   1512 S. 34th Street
   Milwaukee, Wisconsin
   53215

(U) A very useful plastic-colored marking band, that cannot be obtained from the above supply houses, was used extensively in the project. It can be ordered from:

Boddy-Ridewood
41 Aberdeen Walk
Scarborough Yorks
United Kingdom

### *Factors Affecting the Performance of Project Birds*

1. (C) The Moult. Pigeons renew all of their feathers once a year. The moult is continuous from the daily moulting of the fluff feathers until the heavy moult in the fall of the year. It takes at least six months to moult the entire body of feathers. The moult should not affect the performance of pigeons over short distances, with the possible exception of the #10 primary feather—the last and longest feather on each wing. It can be very painful for a pigeon to fly when this feather is coming in.

(C) At one point during the project, one of our best birds had three or four of the primary feathers on one wing broken off, and we were unable to fly her for several months. These were pulled out over the course of several weeks, except for the #10 (which should never be pulled). After the bird grew new feathers in their place, we resumed flying her.

2. (C) Laying Hens. A hen about to lay should not be sent to any distance. More than likely she will stay someplace along the route home for several days until she has laid both eggs. After laying the second egg, she will desert them and come home when her cock does not relieve her at the time when he is supposed to come on the eggs. The cock in a mated pair will begin to drive the hen to the nest about five days prior to laying (this is called a "driving cock"). The hen can be successfully flown up to two to three days before laying. The hen can be successfully flown to short distances within one or two days after laying. Most sitting hens are highly motivated to return home at some point while they are sitting on eggs—usually about 14 days—and again when the eggs begin to hatch.

3. (C) Raising Young. Both hens and cocks usually fly well to their young, and their performance under this condition will usually meet or exceed normal expectations.

4. (C) Driving Cocks. A driving cock should not be flown. He may follow the first hen he sees to wherever she is headed.

5. (C) Hunger. Virtually all pigeons will respond well to motivation through a restricted diet and will hurry home and trap quickly once they learn food awaits them there.

6. (C) Launch Site Familiarity. The more familiar with the launch site, the more uniform the departure for home will become. After 5-10 tosses, a bird will depart in a fairly predictable manner, although not nscessarily covering the same ground as before. The danger of launch site familiarity is that as the bird tires of the harness and weight routine, he will be more inclined to land in the increasingly familiar area of the release site, unless proper motivation, (i.e., hunger) is maintained.

7. (C) Wind. Winds under 10 mph do not seem to affect bird performance. Pigeons tend to tack into the wind, however, when it is over 10 mph. This can be advantageous where winds are coming from the target area, resulting in a slower ground speed.

8. (C) Single Tossing. Pigeons are very gregarious and when single-tossed tend to remain in the area of the release waiting for other birds with which to fly home. This could be advantageous if lingering in the area were desirable. Double tossing was used with good success in the project to get the birds to move out quickly for home.

9. (S) Harness and Payload Devices. When initially fitted with a harness inside the loft, most pigeons in the project either went into wild gyrations trying to get it off or sulked quietly in a corner. After the harness had been on a day, all birds were functioning normally around the loft, except for occasional picking at the harness with their beaks. Later, when a 40 gram weight was attached to the bottom of the harness, it did not seem to have any affect on their performance on the ground, other than a high "goose-stepping" walk as their feet brushed the sides of the weight. Most birds even successfully sat on their eggs with the weight on without breaking them. The weight definitely slowed them down on the wing, however. The harness alone seemed to have little effect on their desire to fly once the birds became used to it. Some harness and weight training can be done in the loft.

### *Relocation*

(C) Because of its strong urge to "home," a good homing pigeon will make every effort to do so when released in strange territory. Nevertheless, for various reasons fanciers periodically attempt to relocate homing pigeons to a new loft at some distance from the old. It has been done successfully many times, but the danger of losing the bird is high. Dr. W. E. Barker in his book, Pigeon Racing, (see Reference 6) mentions the following points as essential in relocating pigeons:

1. The better the bird, the easier it will be to settle to a new home.
2. It is generally useless to attempt relocating birds which have bred elsewhere to a new home until they have been allowed time to breed again amidst their new surroundings.
3. Birds to be relocated should be given the opportunity of becoming acquainted with the outside appearance of the new loft and as much as possible with the new neighborhood.
4. Birds in the process of being relocated must be handled with great care and gentleness. They should never be startled when allowed out for the first time.
5. Do not attempt to relocate hens between eggs or cocks while driving. Rather, give them their liberty while sitting and allow them to find their own way out of the loft without interference.
6. Never attempt to relocate birds that have small youngsters in the nest. They will almost invariably return to their original home.
7. So long as relocated pigeons are allowed to remain undisturbed in their new quarters, they frequently exhibit little tendency to return to their old surroundings. Once they are disturbed or unsettled in any way, however, for instance being sent to races, the desire to return to their old home is apt to reassert itself, and they may return to their original home.

~~(S)~~ With relationship to this project, the difficulty of relocating pigeons is especially evident from point 7 above, inasmuch as relocated project birds were "disturbed" when fitted with a harness and weight and released in unfamiliar surroundings.

~~(S)~~ Following are the methods used in this project to assist in relocating pigeons:

1. All birds were kept in confinement a minimum of three weeks.
2. Birds were not allowed to see the outside of their new loft prior to release because of operational considerations.
3. Some birds were allowed to raise a round of youngsters before being released in an effort to cement the bond to

their new home. However, most were not on eggs at the time of release.

4. Some birds had one wing "hobbled" with a rubber band the first few times out until they became familiar with their immediate surroundings.
5. Three birds were placed on the "Widowhood" system of flying (to be explained later) in an effort to relocate them.

(S) Most of the birds that we attempted to relocate were eventually lost, most likely for the following reasons:

1. They were not able to familiarize themselves with the outside of their new loft and, consequently, many were lost almost immediately upon release.
2. Those birds kept in confinement the shortest period of time (three weeks) were the most likely to be lost. In general, the longer the birds were kept in the new loft, the better the chance of successful relocation, although still poor.
3. Many of those birds that survived the initial release were subsequently lost when fitted with harnesses and weights. Generally, they did not leave while "in harness" but did so on training flights while not harnessed or without weights. In other words, they were disturbed and left at the first opportunity when they were not encumbered with a harness or weight. In terms of initial success in the relocation process, the best statistics were obtained with the three cocks on the Widowhood System—three out of three. Nevertheless, two of these birds were subsequently lost—one off the loft just prior to a severe thunderstorm and the other, while wearing a harness only, from the nine-mile training station (again, see Barker's point #7).
4. A contributing factor in the loss of many birds was the location and appearance of the new loft compared to the old. In no case were the two similar. Moreover, in at least one relocation series, the loft was so surrounded by trees that most birds were lost as soon as they took flight. Hobbling at this location gave better results.

## *The Widowhood System*

(C) The following is a brief and over simplified description of the system:

1. Allow X number of mated pairs to pick their own nest boxes in the loft (no other birds are allowed in the loft) and raise

one round of youngsters; two rounds is better if the birds are yearlings, but it takes a long time (about two months).

2. After the birds go back down on eggs, allow them to sit for about one week, then remove the hen and throw the eggs away.

3. Hens should be kept in a place where the cocks can neither see nor hear them. After separation, do not allow the cocks to see their hens for at least a week, then take the cocks out of the loft, lock the hens in half of the nest box, and leave the other half open (so the cocks cannot get to the hens when they are allowed in the loft). When the cocks are allowed to enter the loft they will be in a high state of excitement when they see their hens. Let the cocks in with their hen but for no more than five minutes. Do not allow the cocks to mate with their hen or the system will be ruined. After five minutes remove the hen and put her back in her loft.

4. After several weeks of doing this, the cocks will learn that when they are taken from the loft, the hen will always be waiting for them when they return. When the cocks are let out for daily exercise, they will fly long and far searching for their hen and will come into excellent physical shape. When taken away for a race (or whatever) cocks will speedily come home and trap in quickly, assuming the system is working at its best. The disadvantage to the system is that there are many variations, each quite complicated. Hens play a vital role; if they are not good, the cocks will not work properly. Moreover, the system takes too long to implement. It is recommended that widowhood not be considered for operational use at this time.

## *Disease*

(C) The following is a list of the symptoms, medication, and methods of treatment for five of the commom pigeon diseases:

1. Canker (Trichomoniasis):

Symptoms— Failure of bird to swallow larger grains; swelling of the throat; cheesy growths in the mouth area; loss of flesh and ambition, loss of appetite. Navel in youngsters occasionally becomes infected and fills with the cheesy deposits.

Medicine — Emtryl powder for flock treatment. Tricoxine tablets made by Fabry for individual treatment.

Treatment— Powder: 1 Tbsp. per gal. of drinking water. Leave in loft for 5 days.

2. Coccidiosis:
   Symptoms— Droopy, diarrhea (which may be bloody), lack of energy, loss of weight, anemic appearance. Appetite diminished but not thirst. Loss of ambition. Leg weakness, i.e., bird prefers to rest on heels rather than stand.

   Medicine — NFZ Soluble (powder).

   Treatment— Add powder to drinking water according to directions on packet. Keep treated water before birds for 2-3 weeks. Clean loft daily. Change water at least once a day. Apply roost paint once every month or so and install Vapona pest strips in loft.

3. Paratyphoid:
   Symptoms— Old Birds: Loss of weight, decrease in appetite. Droopy, green, loose droppings. Slight lopsidedness in flight. Swelling in wing and leg joints.

   Young Birds: Copious diarrhea; dizziness or evidence of brain inflammation. Twisting the head sidewise. Disease worse in damp weather. Caused by unsanitary conditions.

   Medicine — NFZ Soluble.

   Treatment— Same as above. On old birds lance swellings and disinfect as often as necessary.

4. Roundworms (Ascaridia Columbae):
   Symptoms— Droopy appearance. Loss of weight.

   Medicine — Piperazine Citrate. Also sold with an additive for hairworms (Capillaria).

   Treatment— 8 grams per gallon of drinking water of Piperazine Citrate over a period of 60 hours. Scrupulous sanitation to prevent reinfection.

5. Pigeon Pox:

   Symptoms— Wart-like lesions on unfeathered portion of body.

   Medicine — Pox vaccine prior to infection.

   Treatment— Vaccinate prior to disease. No cure.

# APPENDIX D

## A BRIEF HISTORY OF THE PIGEON

(U) Most of the following is taken from Chapter I of Reference 7, which is an encyclopedic treatise on every aspect of pigeons.

(U) The earliest recorded use of the pigeon (or dove) to obtain information was by Noah, who sent out a dove knowing it would return if it found no land. Instead, it did find land and returned with an olive leaf, a demonstration of its love for home which remains the most endearing quality of pigeons to this day. It is speculated that King Solomon (about 1000 B.C.) used pigeons, but the first documented evidence of their use in war begins with the conquest of Gaul (over 2000 years ago) by Julius Caesar.

(U) During the War of Independence in Holland (1574), the besieged people of Leyden were saved by messages of relief carried by pigeons. Pigeons were also used by the Venetians during the siege of Venice in 1849.

(U) It was during the siege of Paris (1870-71), during the Franco-Prussian War, that the modern day Homer came into international note. Balloons were released from Paris containing, among other things, Parisian pigeons. These birds were retrieved and taken to London, Tours, and other cities and subsequently released with messages to the besieged Parisians. It was here that one of the first uses of microphotography enabled the transport of as many as 40,000 messages by a single homing pigeon. During the four-month siege, 150,000 official and 1,000,000 private communications were carried into Paris by homing pigeons.

(U) In 1909, an international photographic exhibition was held in Dresden, Germany. As invited delegates began their speeches, pigeons with automatic miniature cameras harnessed to their bodies made low-altitude photo passes over the exhibition hall. The exposed film was quickly processed and converted into souvenir-postcard enlargements for immediate sale to the delegates. This photo, and a picture of the pigeon with camera, can be found on page 28, first edition, of the "Manual of Remote Sensing," Volume 1, 1975, published by the American Society of Photogrammetry.

### *World War I*

(U) The Germans developed military lofts as early as 1887 and were quite prepared for the First World War, as were the French and Belgians. It was the Belgians who first developed the modern-day racing homing pigeon during the Industrial Revolution for the purpose of carrying detailed messages of financial import between England and Europe. Over 1,000,000 Belgian pigeons were taken by the Germans during their occupation. To this day, many of the better racing pigeons come from Belgium.

(U) It was not until 1916 that the first British birds were sent to the front. British air force records show that 717 messages from planes fallen in distress upon the seas were delivered by pigeons and about 95 percent of several thousand pigeons came through with messages. By the end of the war, British war Homers numbered 9,000 to 10,000 birds.

(U) When the United States entered the War, we had no organized pigeon force. By 1916 birds were being trained to mobile lofts. It was found that the birds soon came to recognize distinctive markings on the roof of their lofts, which could be moved some distance before their return. War Department records show, during the Aisne-Marne offensive, mobile lofts enabled 72 birds to carry 78 important messages with no losses. In the St. Mikiel drive, 90 important messages were delivered by pigeons. Twenty-four of 202 birds were lost or killed, but every message was delivered since it was sent in duplicate. In the Meuse Argonne offensive, 442 birds delivered 403 messages safely from distances of 12 to 30 miles; not a single message was lost. One bird, Cher Ami, was credited with saving the "Lost Battalion," and his body was mounted and placed on exhibition in the Smithsonian. A second bird, "The Mocker," was awarded the D.S.C. as well as the French Croix de Guerre for several outstanding feats of performance.

### *World War II*

(U) The British were well prepared by the outbreak of World War II. British breeders gave over 200,000 young birds to the National Pigeon Service between 1938 and 1945. They were used by the R.A.F. (standard equipment on all bomber and reconnaissance planes) and the Army and Intelligence Services. Special Section of the Army Pigeon Service (Secret Service) parachuted 16,554 birds onto the continent. An outstanding example was the location of German buzz-bomb sites. Pigeons were standard equipment for both paratroopers and agents. Through the use of microphotography, large quantities of plans and information could be delivered without the severe risk of radio communication. The British furnished our

U.S.A. Signal Corps, based in England, with 46,532 pigeons.

(U) Early in 1938, the U.S. Signal Corps had completed 20 lofts for a new pigeon center at Fort Monmouth, New Jersey. Shortly after Pearl Harbor, the War Department issued a call for champion homing pigeons, one qualification being they must have flown 200 miles. The pigeon corps grew until, at its peak, it contained 54,000 pigeons, 3,000 enlisted men, and 150 officers. Major Otto Meyer, as Commander of the Signal Pigeon Corps, supervised preparation of the Army Technical Manual No. 11-410, "The Homing Pigeon," and also Field Manual 11-80, "Pigeons for Combat Use."

(U) Pigeons were used extensively in the North African and Italian campaigns. Here, pigeons were used by G-2 section (Intelligence), and command posts who were so near the enemy that it was impossible to string wire or use radio. They were also used by armored patrols, night patrols, Ranger raids, etc. During the year 1944, the pigeons of the 209th Signal Pigeon Company serving with the Fifth Army carried 10,286 messages. Of the 20,202 birds used during this year, only 266 were lost.

(U) During the Luzon campaign, 2,594 messages were carried by birds of the first Combat Platoon, 281 Signal Pigeon Company. All messages were sent in duplicate, and not one was lost in spite of mountainous terrain, rain, fog, hawks, and enemy shotguns.

### *Office of Strategic Services*

(U) The O.S.S. made outstanding use of pigeons in the Burma campaign. One detachment, O.S.S.S.U. 101, operated behind Japanese lines in Burma and was commanded by Captain Morris Y. Lederman. It was with this detachment Jungle Joe and Captain Lederman achieved their renown. After only ten weeks in the location, birds returned 225 and 250 miles when released by agents who parachuted into the vicinity of Mandolay, Shwebo, and Maymayo. The most outstanding flights were made by two five-month old youngsters from a point near the Thailand border to the loft at Bhamo. The distance was 325 miles.

(U) All agents, parachuted behind enemy lines, carried pigeons. During January, 1945, nine groups were parachuted in and pigeons either beat the radio or were the only means of contact for seven of these groups. The distances flown were 175 miles, 225 miles, and 300 miles. The pigeons were held in jump containers from one to three days. On another occasion, a pigeon was tossed from 150 miles after 11 days on location and, although a resettled pigeon, it returned in six and a half hours. A new shoulder message carrier was developed, and pigeons flew 50 miles with a full roll of negatives. Out of hundreds of messages flown, only four were lost and all were from distances greater than 150 miles. On several occasions, pigeons were received from agents with urgent messages for radio replacement parts.

### *Two-Way Pigeons*

(U) These are pigeons which were trained to fly between two lofts, eating at one and sleeping or drinking at the other. The U.S. considered the method of training as Secret, though it is described in the German Army Technical Pigeon Manual, published about 1925. The records of the 1308 Signal Pigeon Company shows they flew two-way birds 55 miles.

### *Korea*

(U) Pigeons were used by G-2 (Intelligence) of the Eighth Army. During a four-month period, pigeons were used by seven groups of agents parachuted from 75 to 200 miles north of enemy lines. During this operation, not a single message was lost.

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# *Feasibility Research on a System to Provide High Resolution Photography Over Denied Areas*

## *(Supplement)*

*Handle via*
*TALENT-KEYHOLE Channels*

Top Secret
RD-10-77
April 1978
TCS 35974-77
(Supplement)

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Approved for Release: 2019/07/31 C06527327

# Feasibility Research on a System to Provide High Resolution Photography Over Denied Areas

## (Supplement)

A Research Study

By

Charles N. Adkins

Operations Technology Division
Office of Research and Development

APPROVED:

Chief, Operations Technology Division, ORD

April 1978
Date



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*TCS 35974-77*

This supplement contains high resolution prints of the Avian Photography shown in the main report. The following table of contents includes the page numbers of the main report where these figures are printed at lower resolution.

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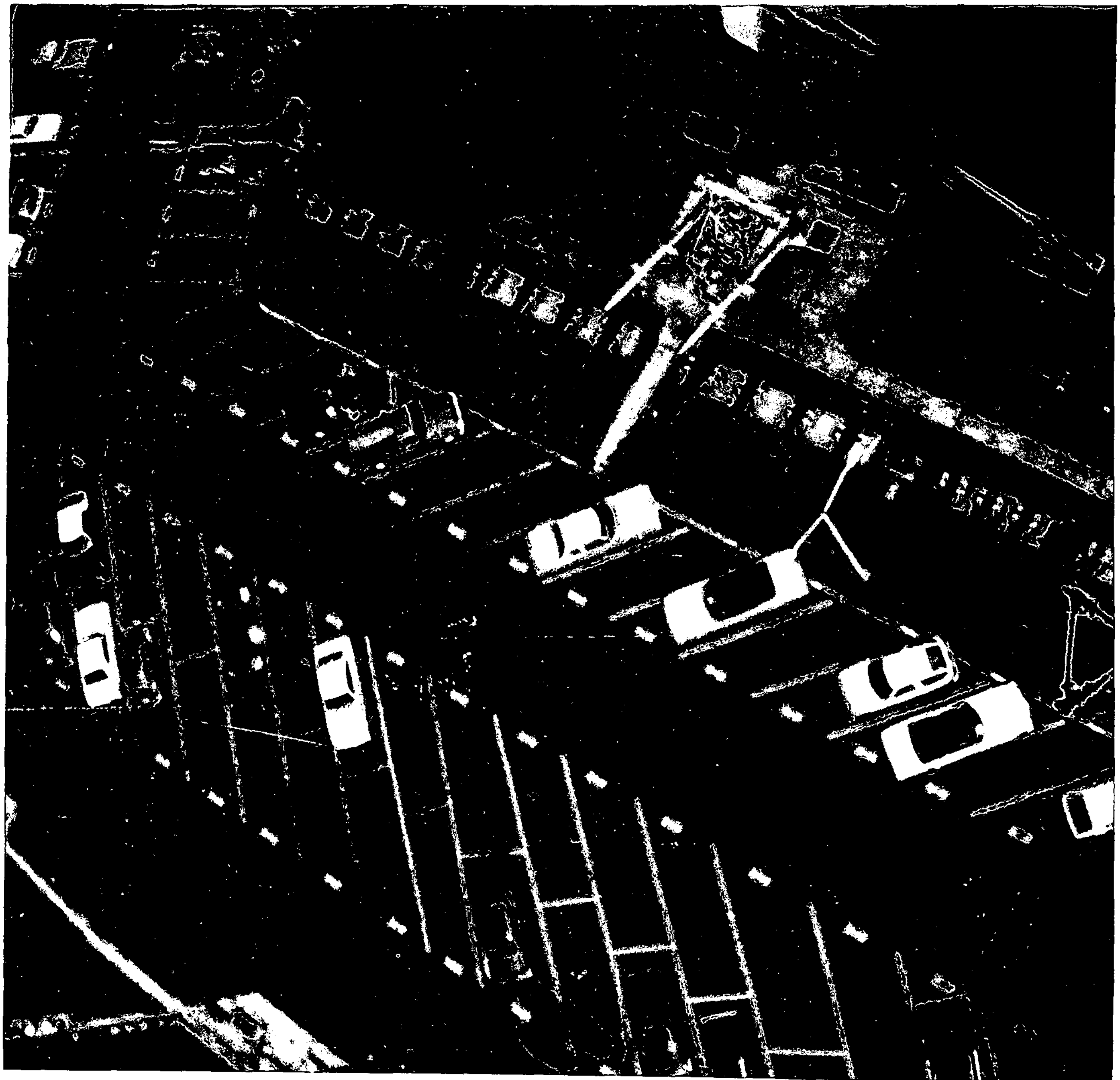

2445 Color of Museum Park

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FIGURE 10. Balloon Picture Using 3400 Film

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FIGURE 14. Mobile Home Complex on Andrews Air Force Base

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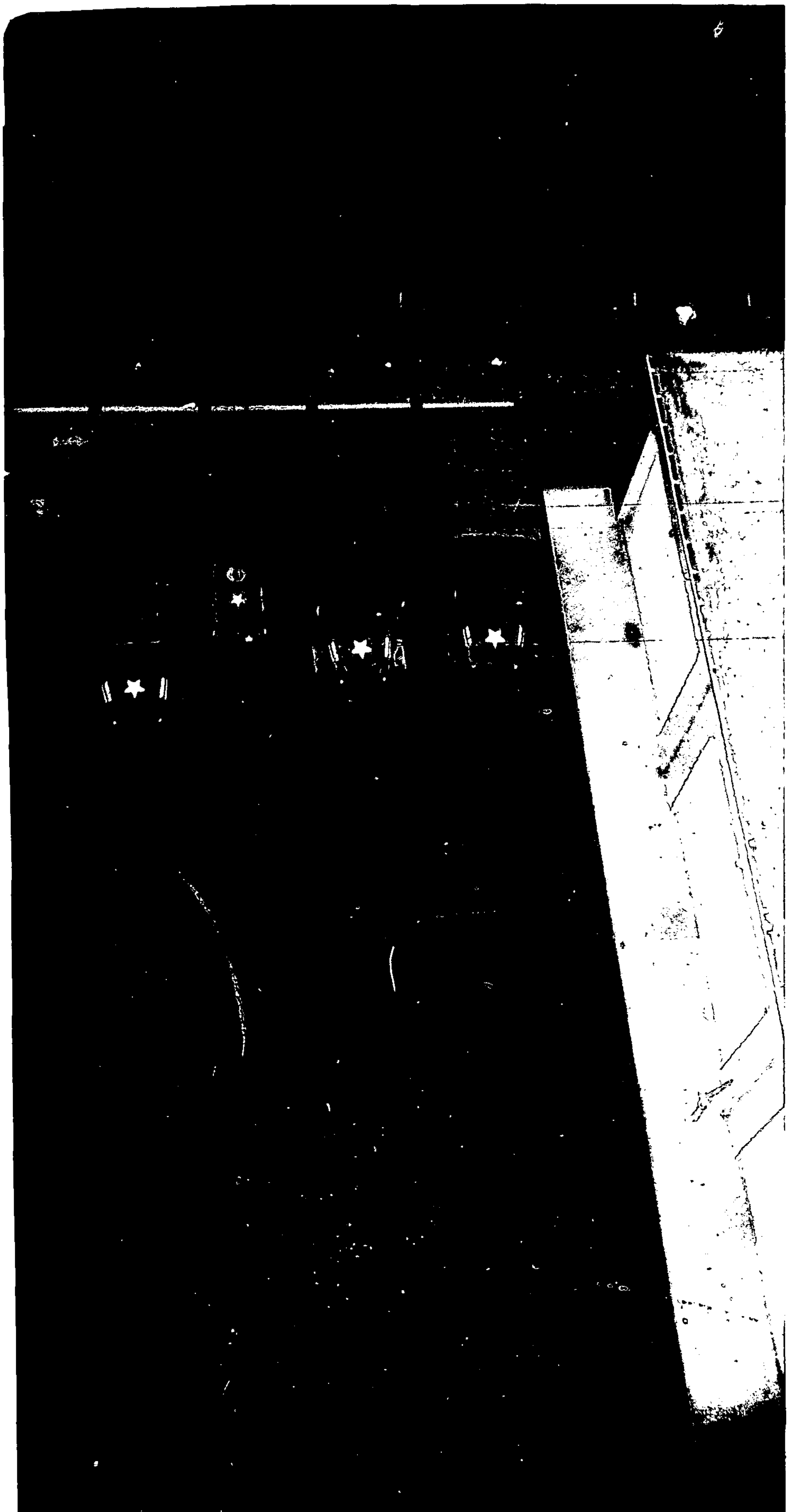

FIGURE 15. Military Trucks on Andrews Air Force Base

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FIGURE 16. Incinerator Plant on Andrews Air Force Base

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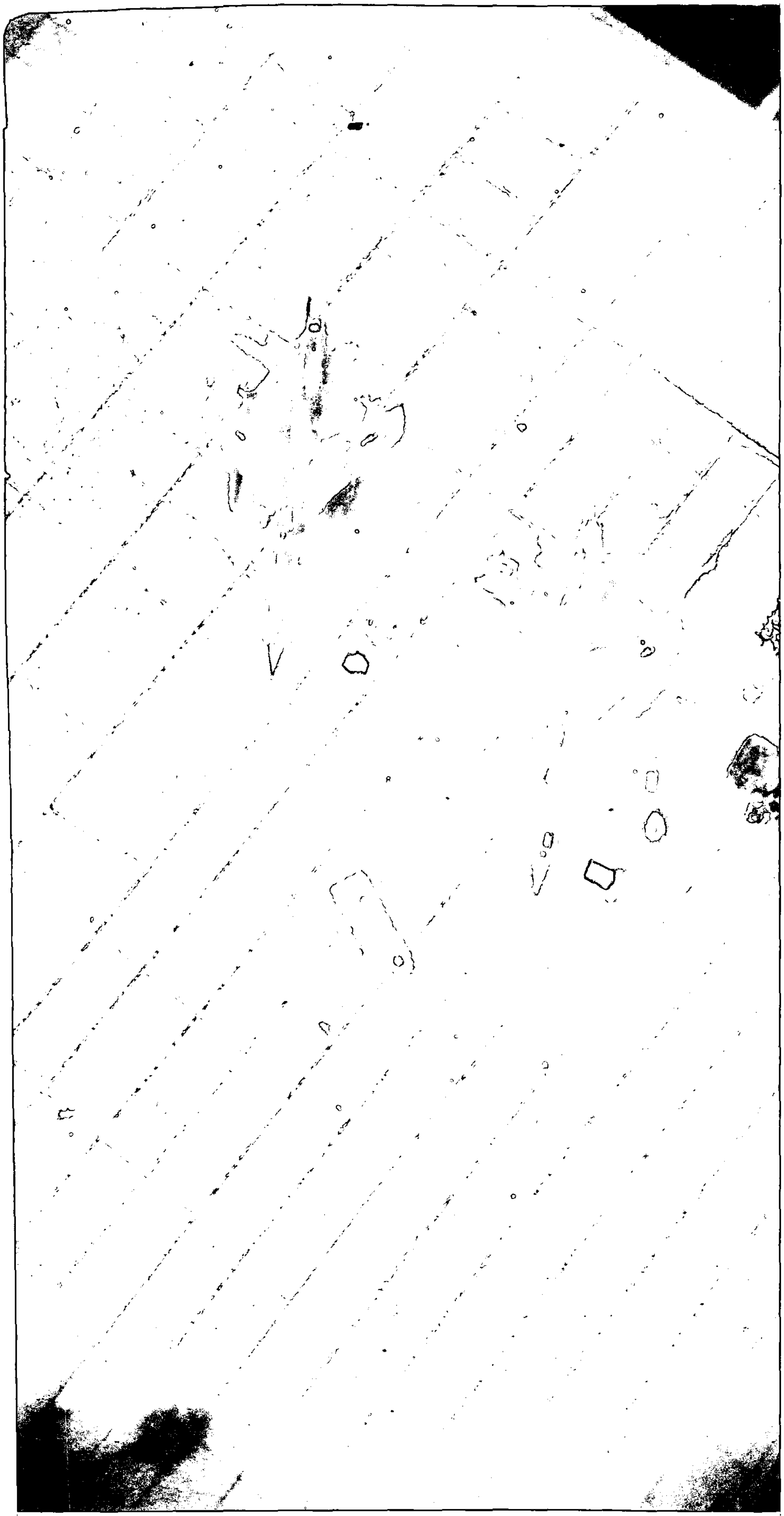

FIGURE 17. Military Aircraft on Andrews Air Force Base

FIGURE 20. Corner with People Walking to Work

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FIGURE 21. Alley Way

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FIGURE 22. Roof Top with Air-Conditioner

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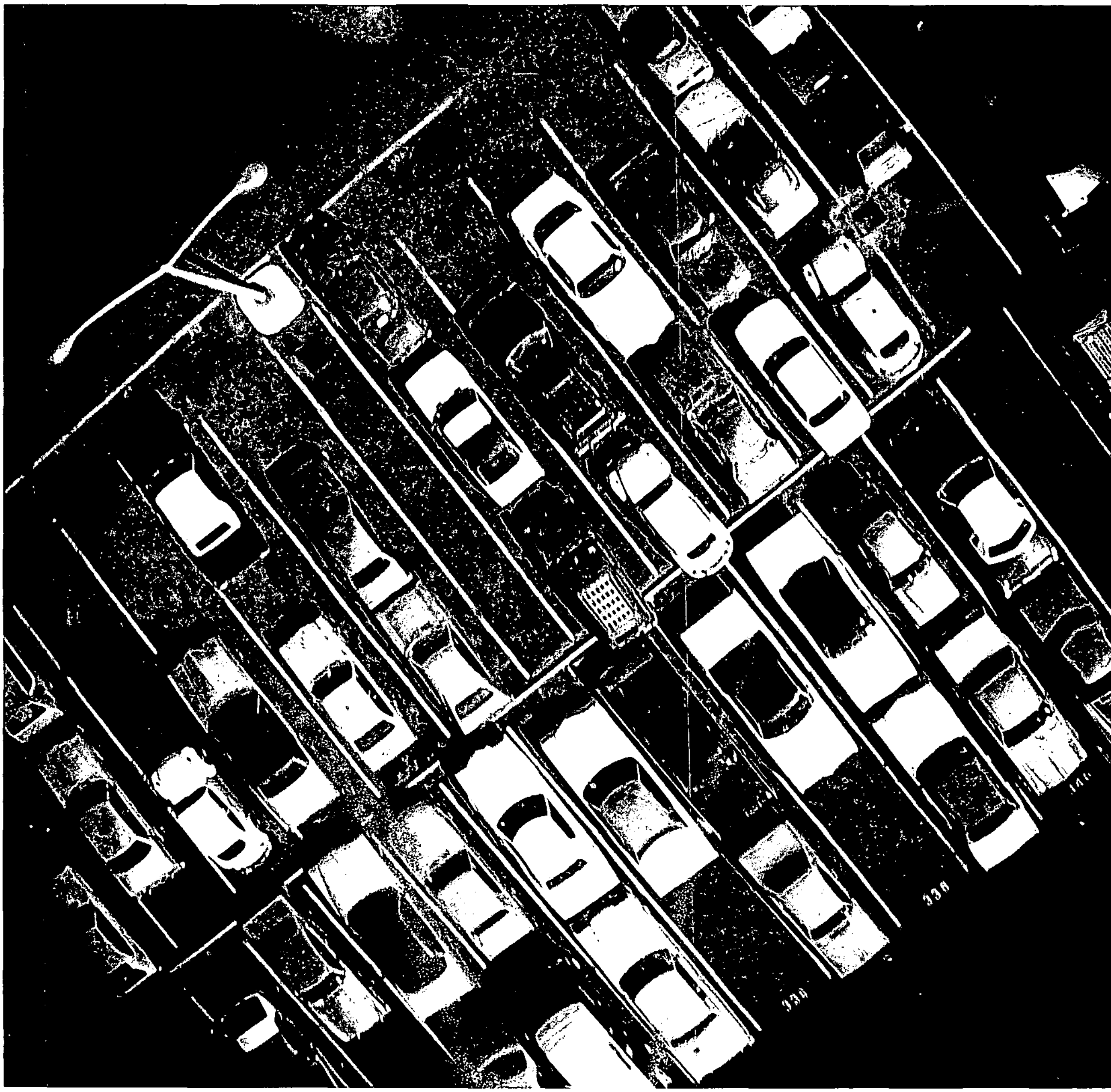

FIGURE 23. Parking Lot

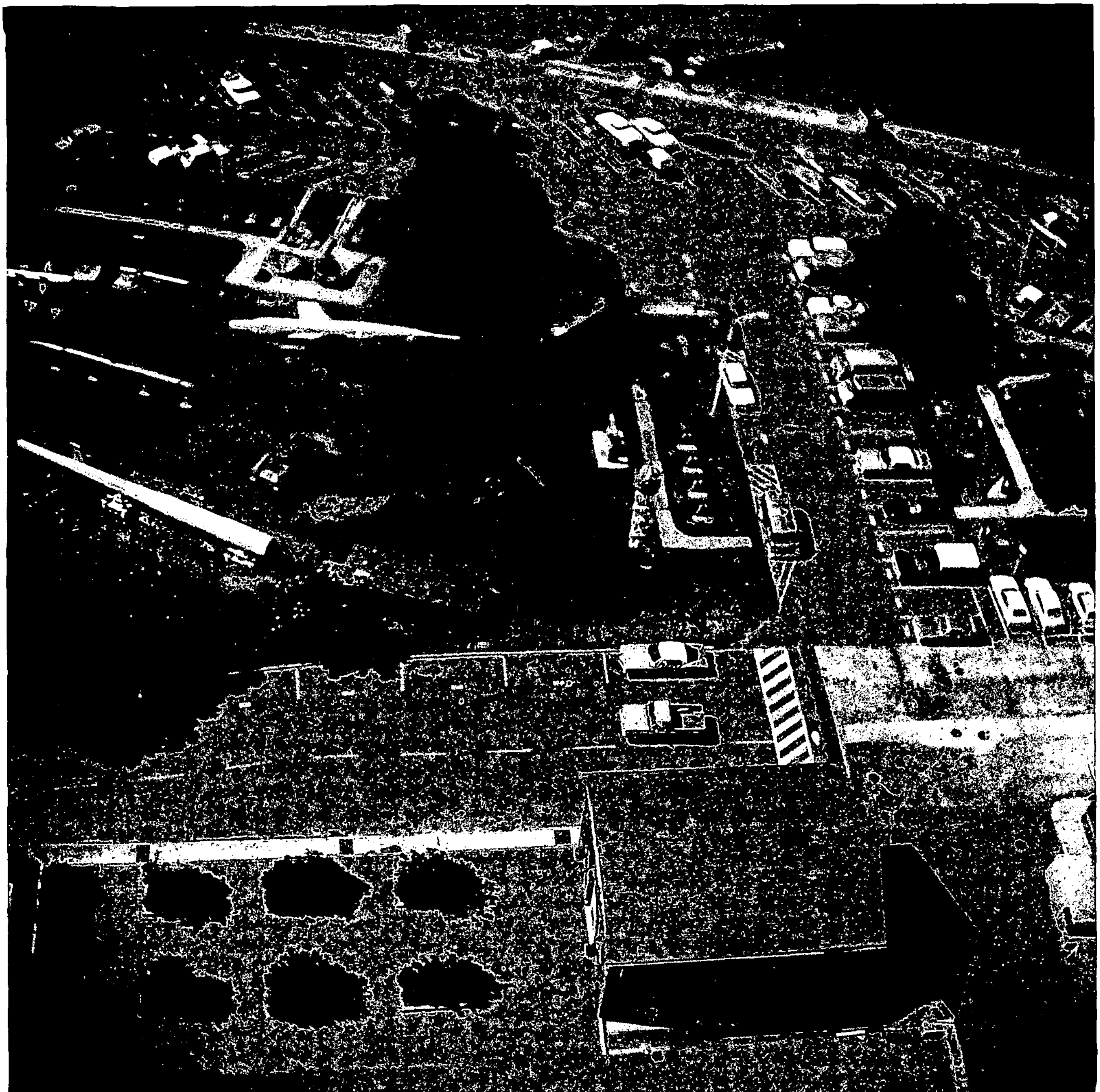

FIGURE 24. Oblique Shot of Museum Park

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FIGURE 25. Navy Yard Main Gate

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FIGURE 26. Old Naval Gun Factory

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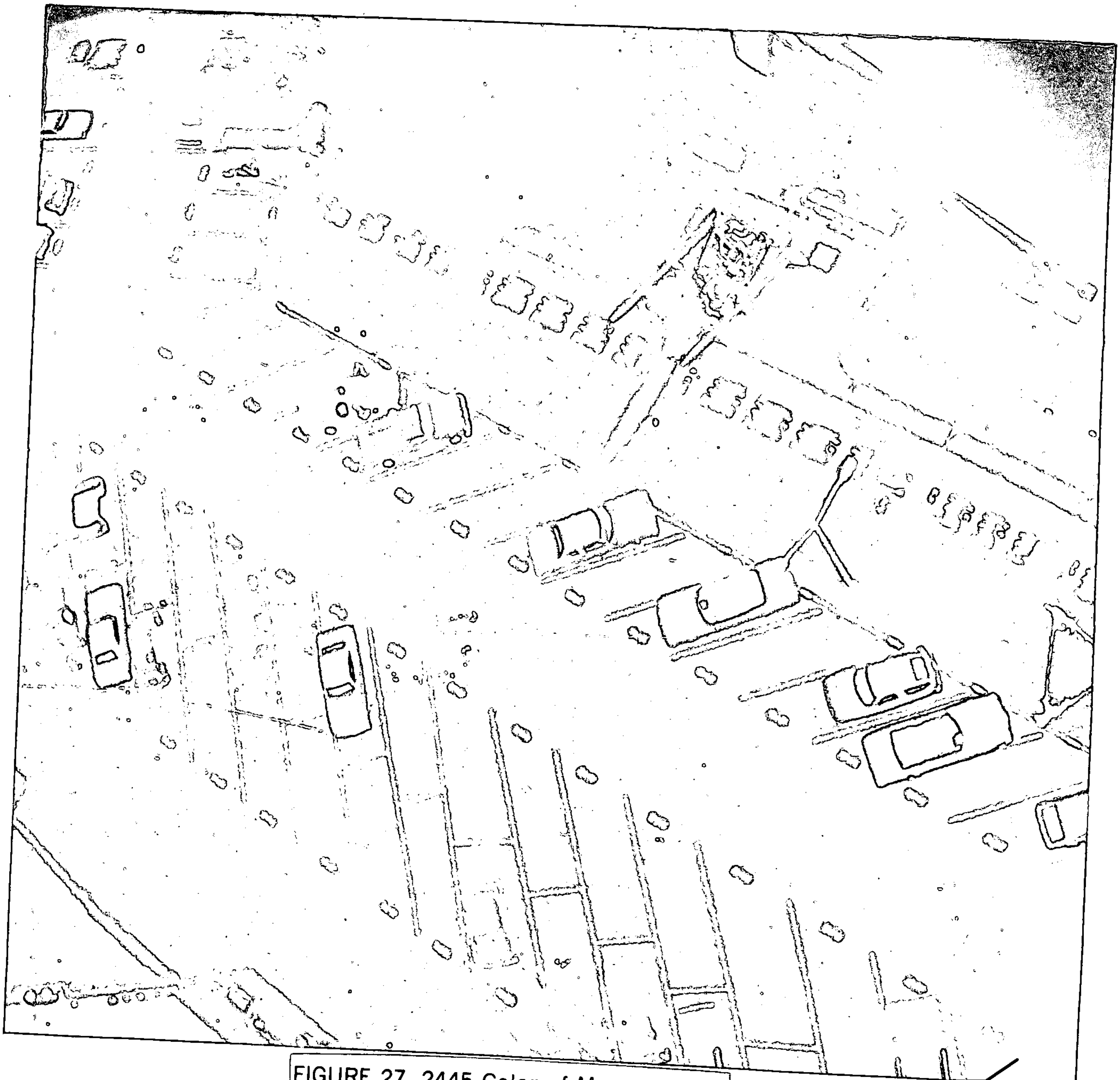

FIGURE 27. 2445 Color of Museum Park

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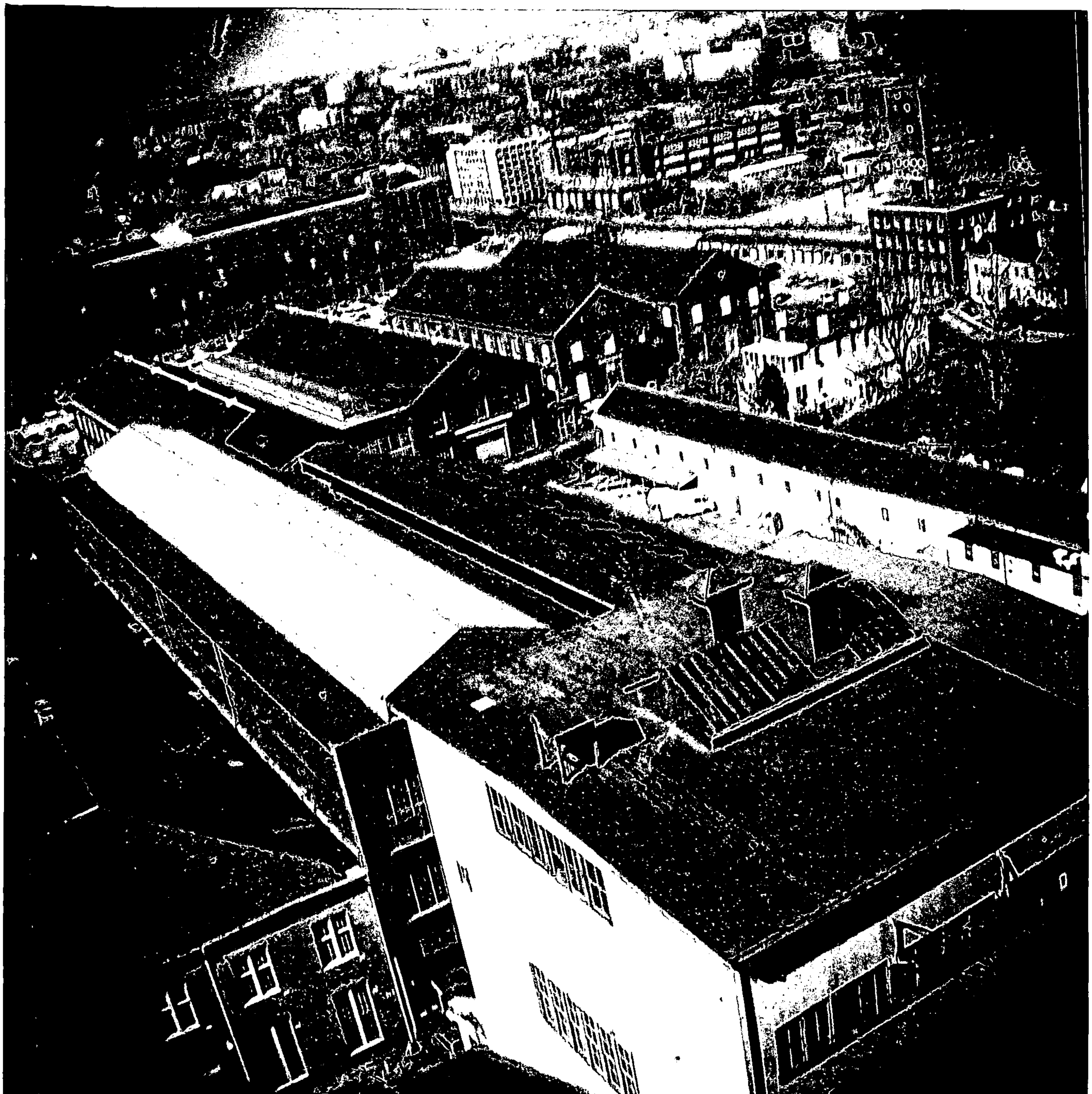

FIGURE 28. Oblique Photograph Over the Navy Yard

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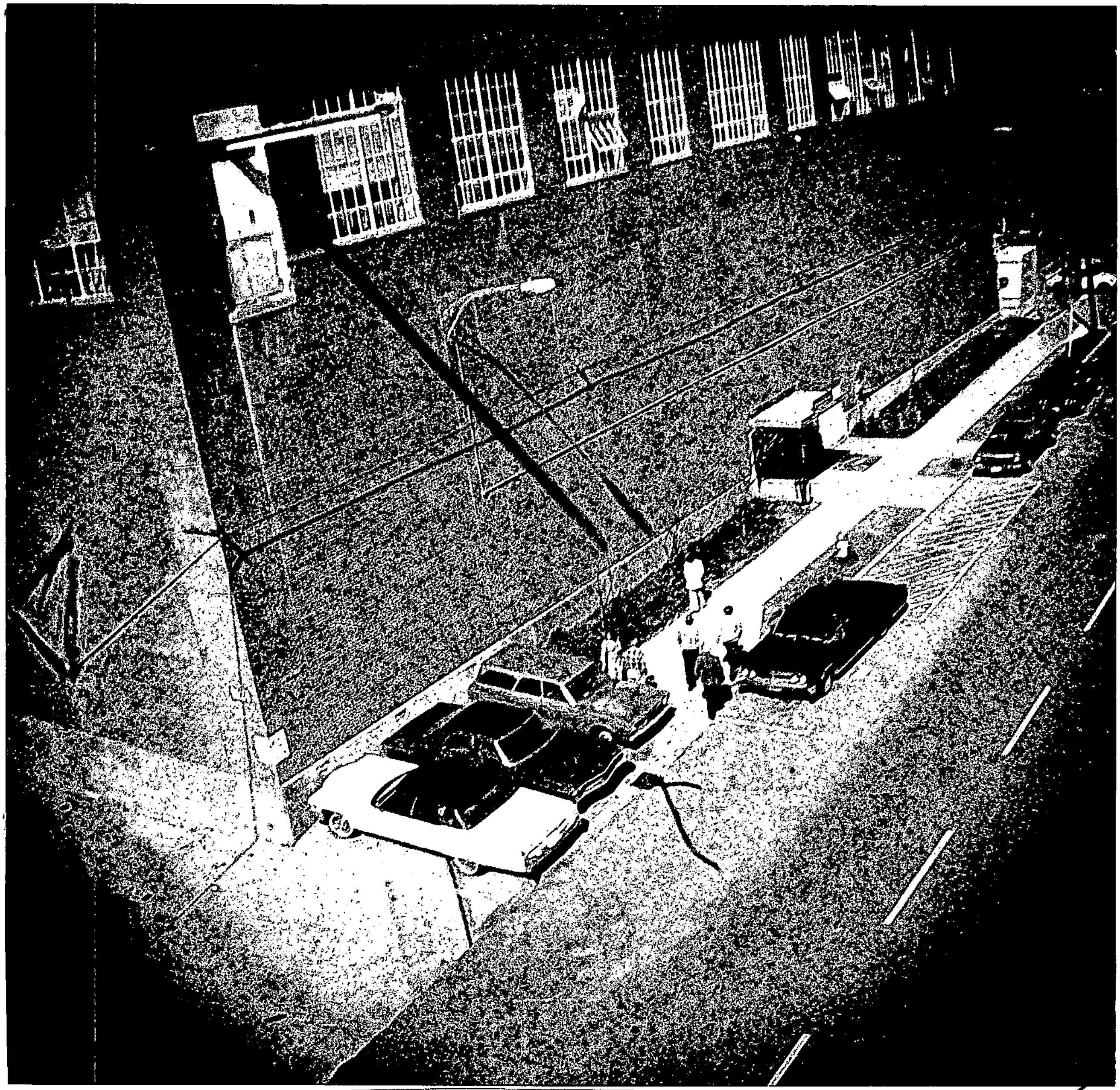

FIGURE A10. Washington Navy Yard—3/17/77
Rated NIIRS 9

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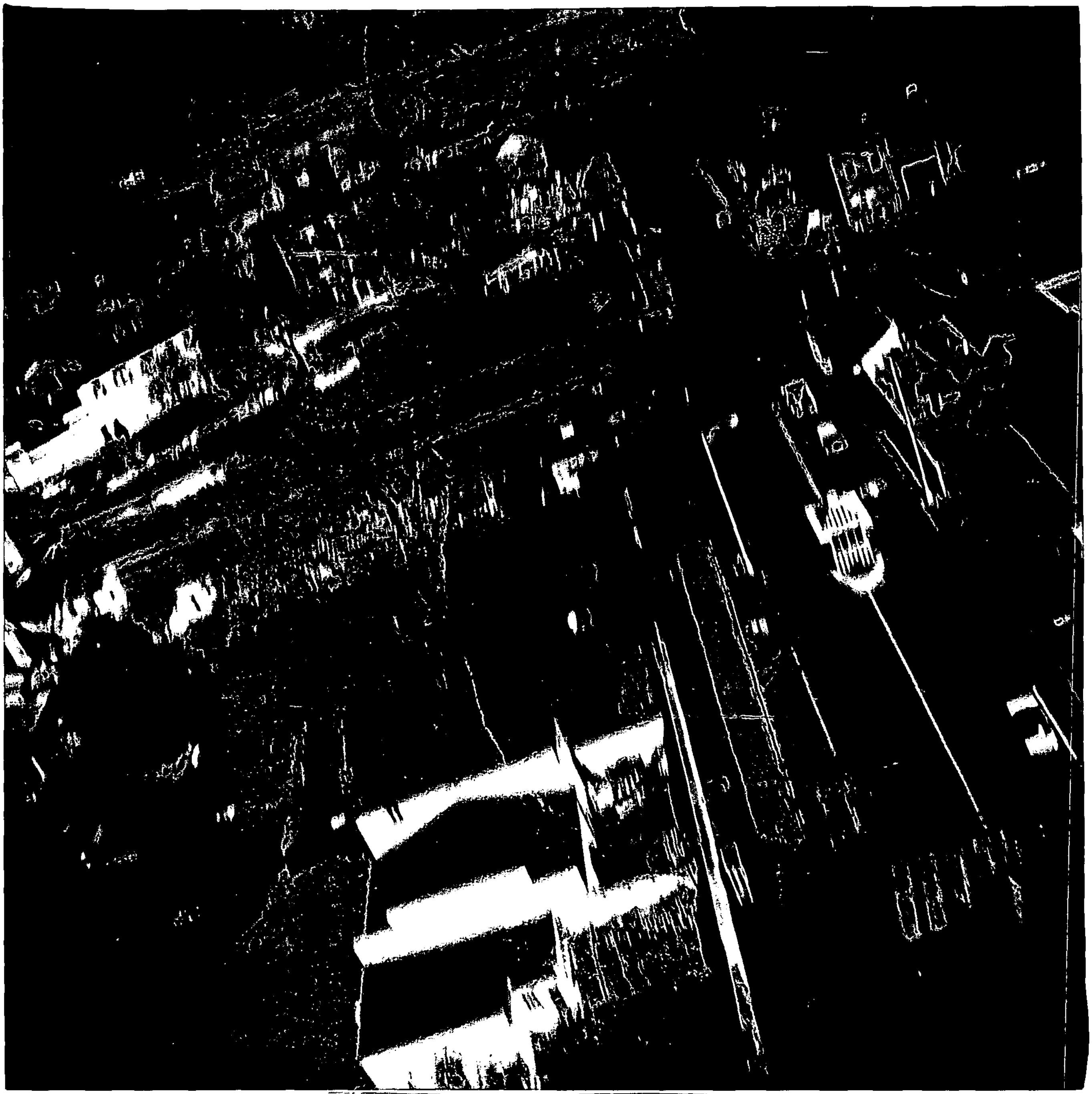

FIGURE A11. Washington Navy Yard—3/17/77
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FIGURE A12. Washington Navy Yard—3/17/77
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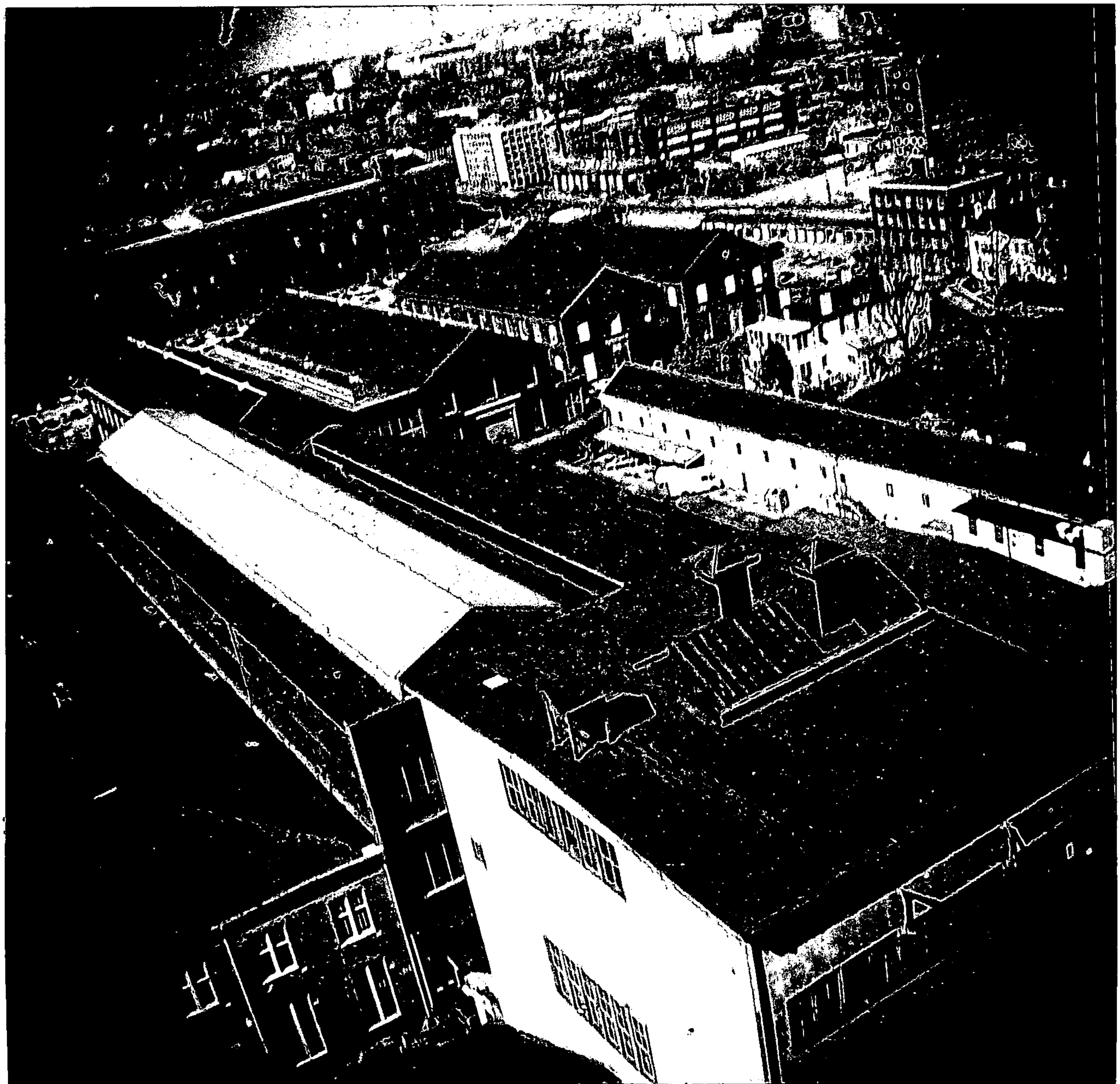

FIGURE A13. Washington Navy Yard—3/17/77
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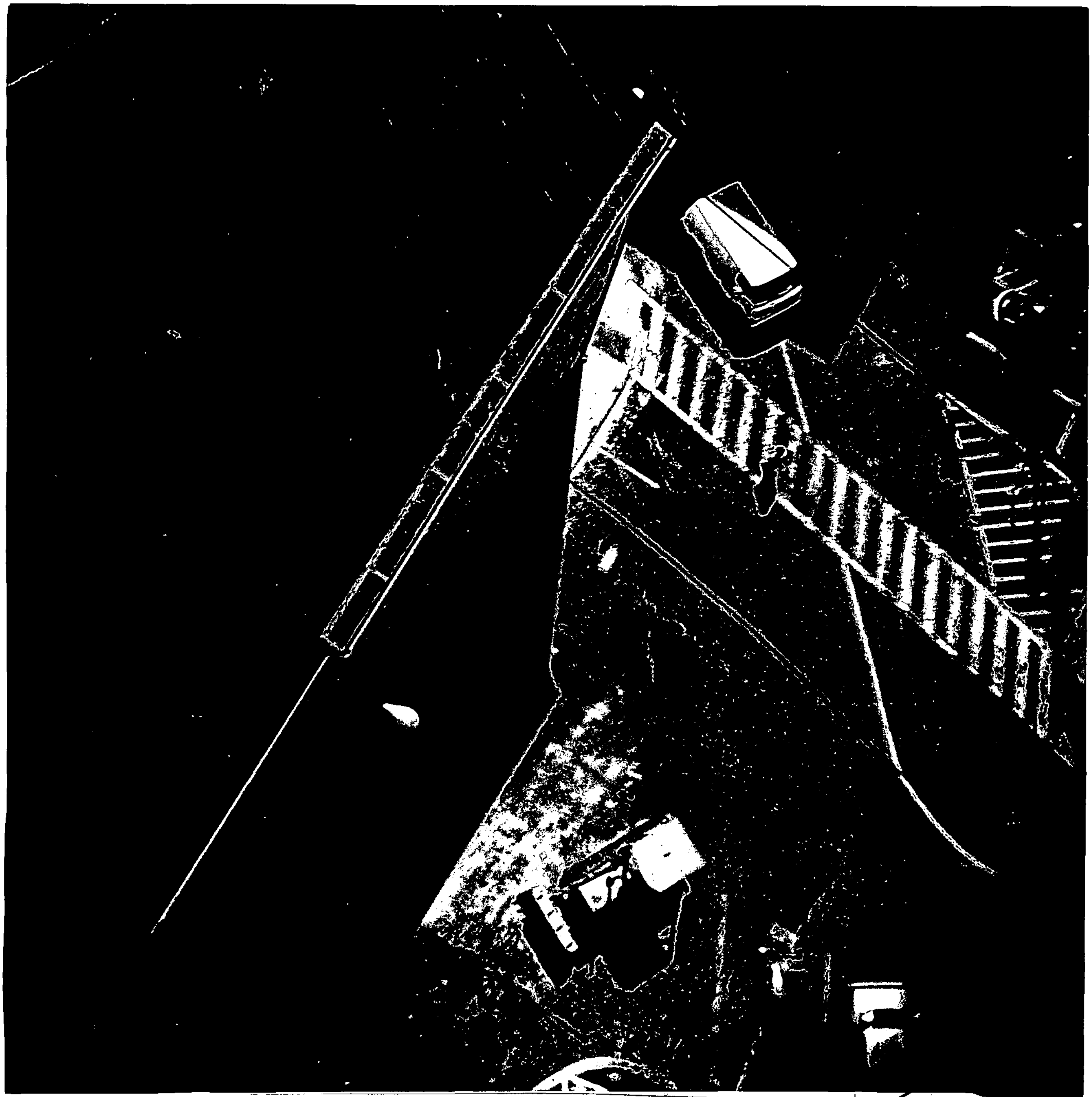

FIGURE A14. Washington Navy Yard—3/17/77
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FIGURE A15. Washington Navy Yard—3/17/77
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FIGURE A16. Washington Navy Yard—3/17/77
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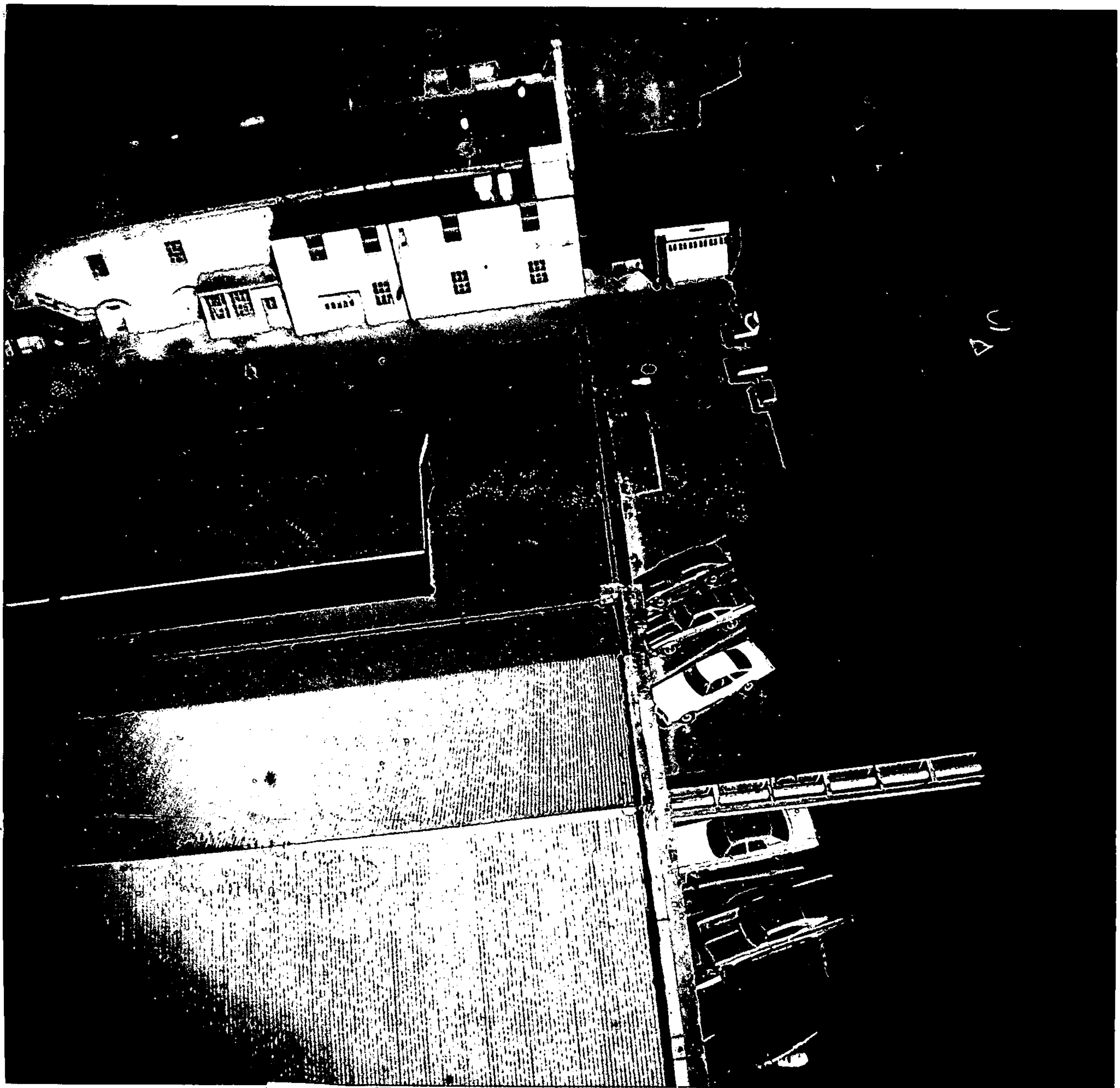

FIGURE A17. Washington Navy Yard—3/17/77
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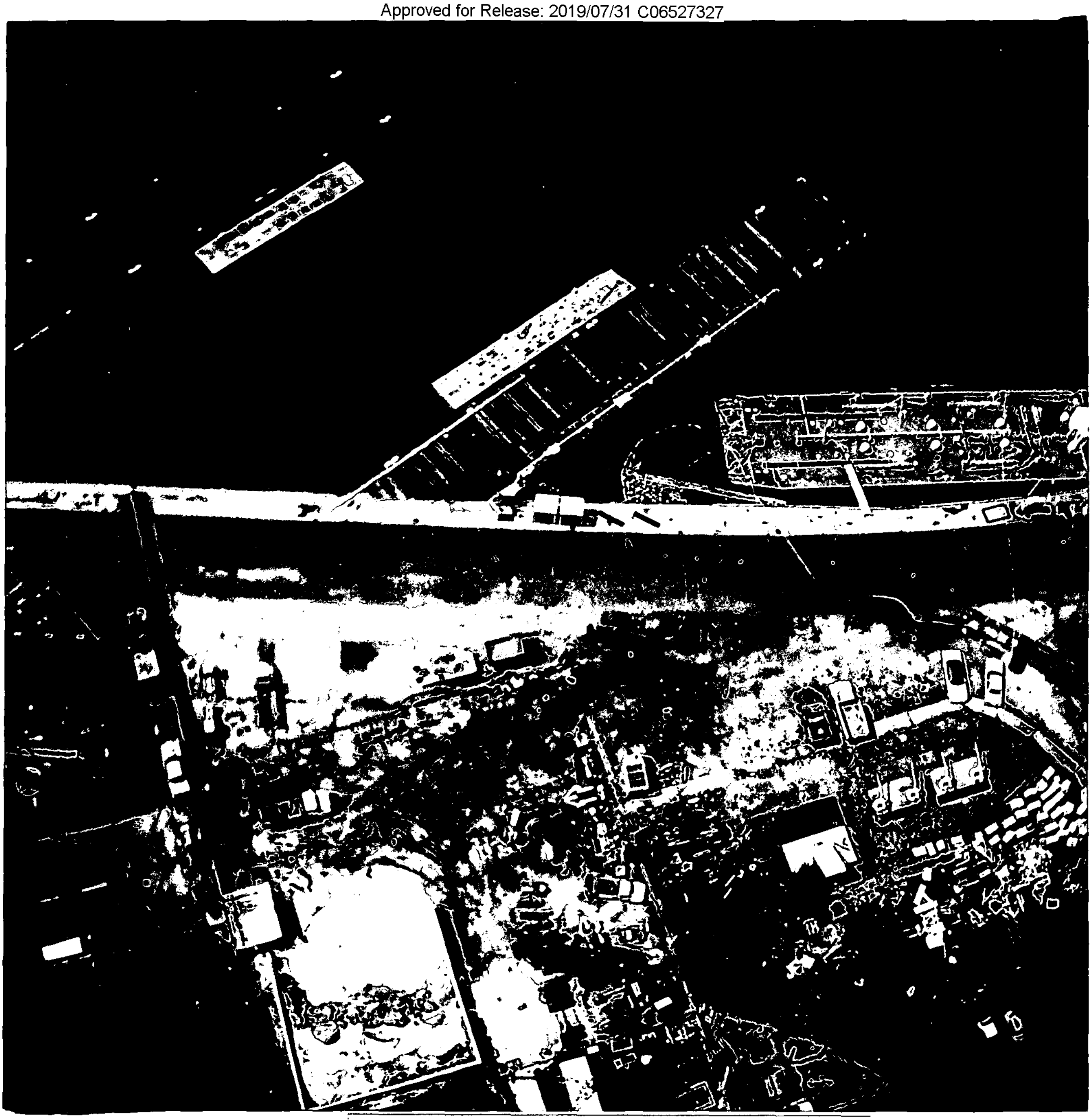

FIGURE A18. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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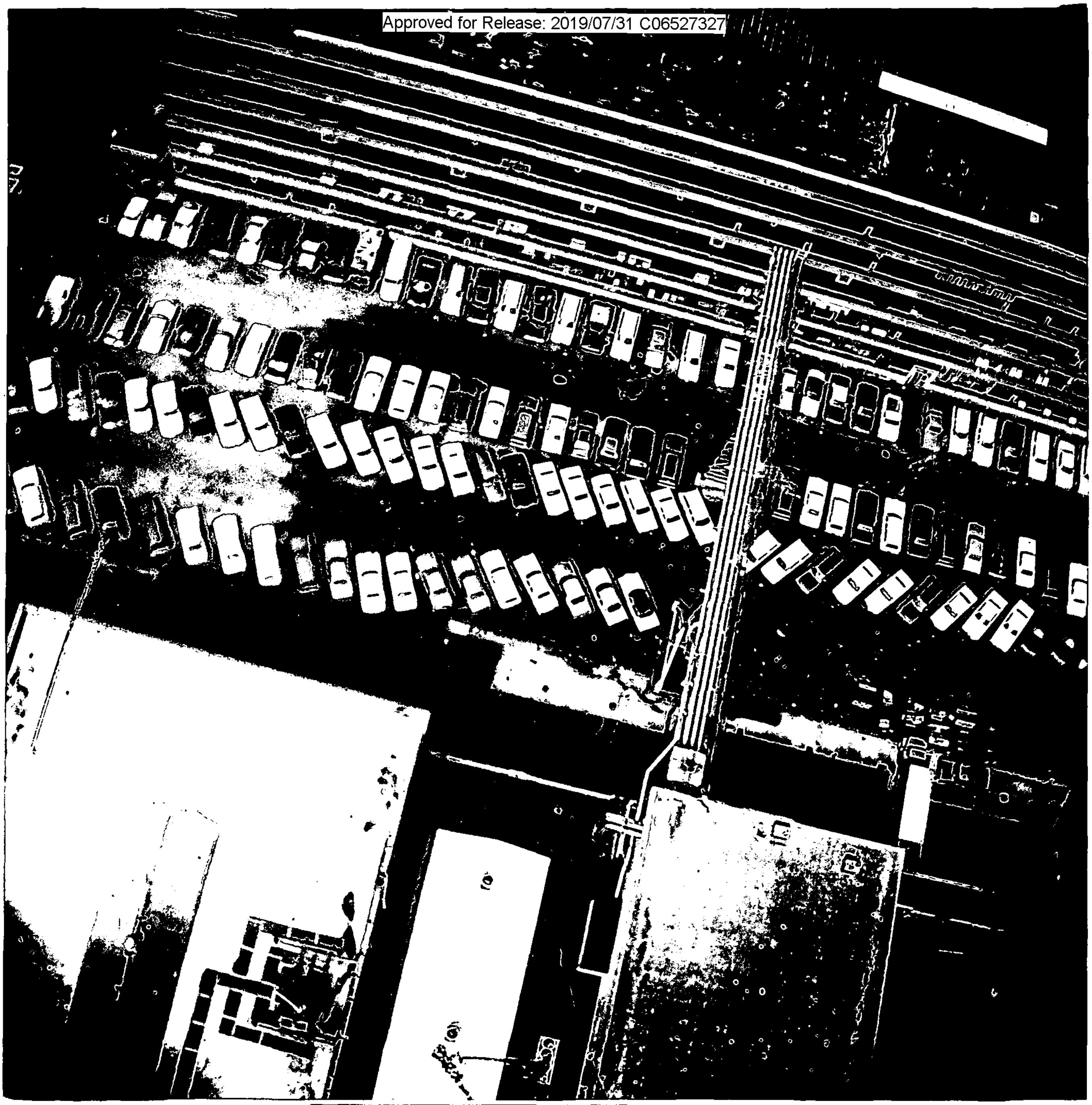

FIGURE A19. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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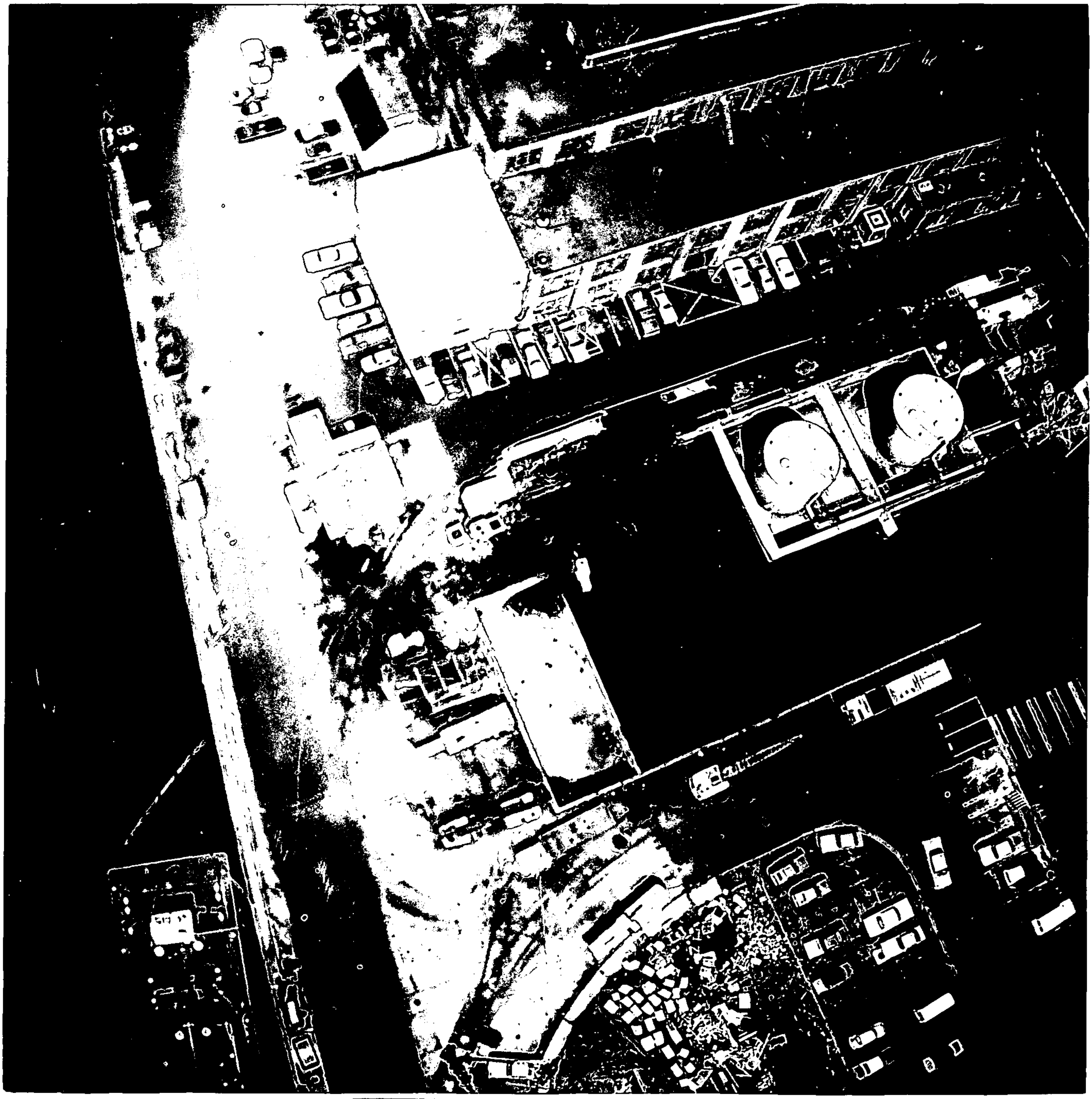

FIGURE A20. Washington Navy Yard—7/7/77
Maximum Observed Flying Height
300 Ft. (91 M.)

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FIGURE A21. Washington Navy Yard—7/7/77
Adjacent Frames (with Figure A22)
Showing the Effect of Platform
Dynamics on Image Quality

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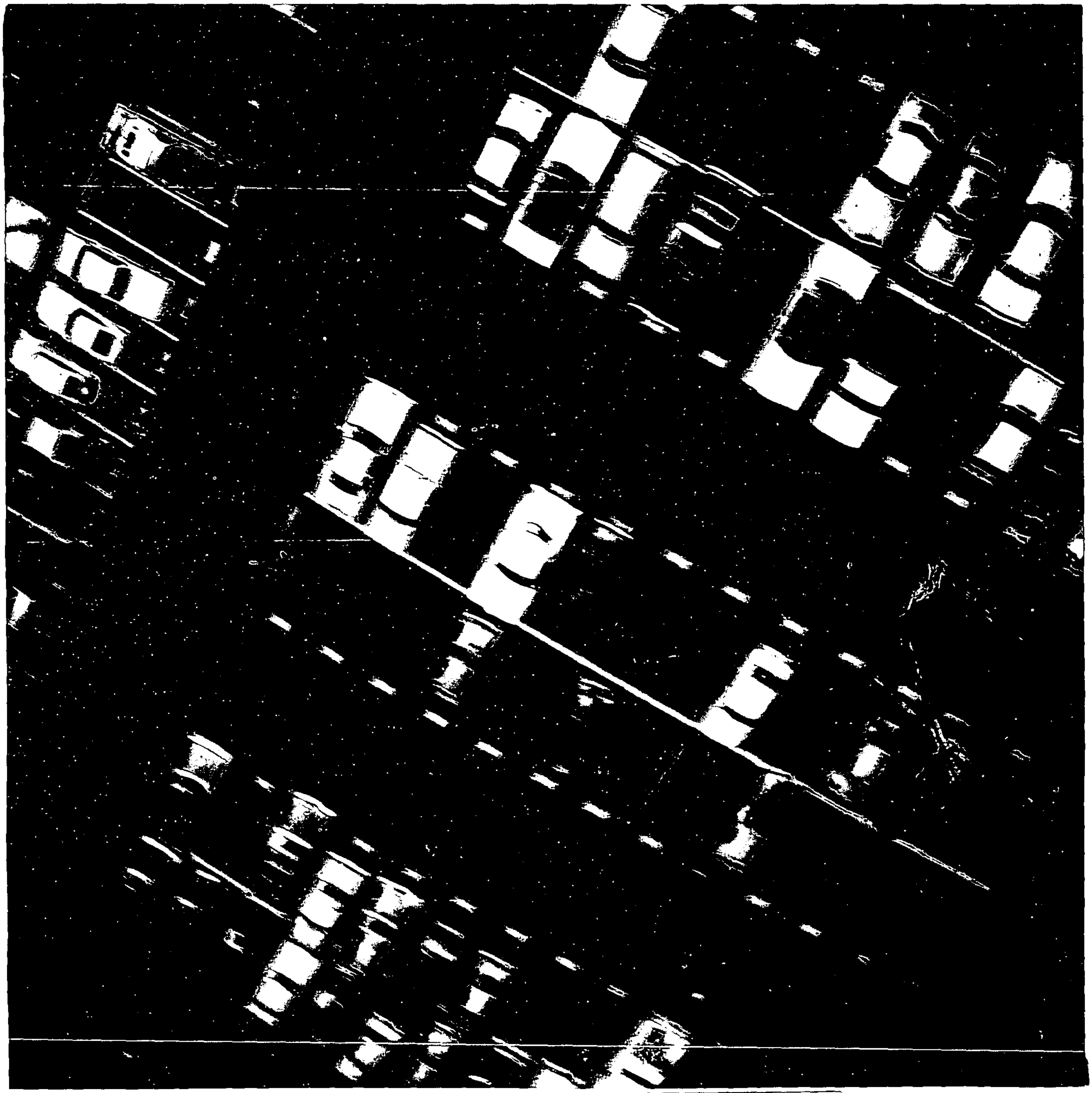

FIGURE A22. Washington Navy Yard—7/7/77
Adjacent Frames (with Figure A21)
Showing the Effect of Platform
Dynamics on Image Quality

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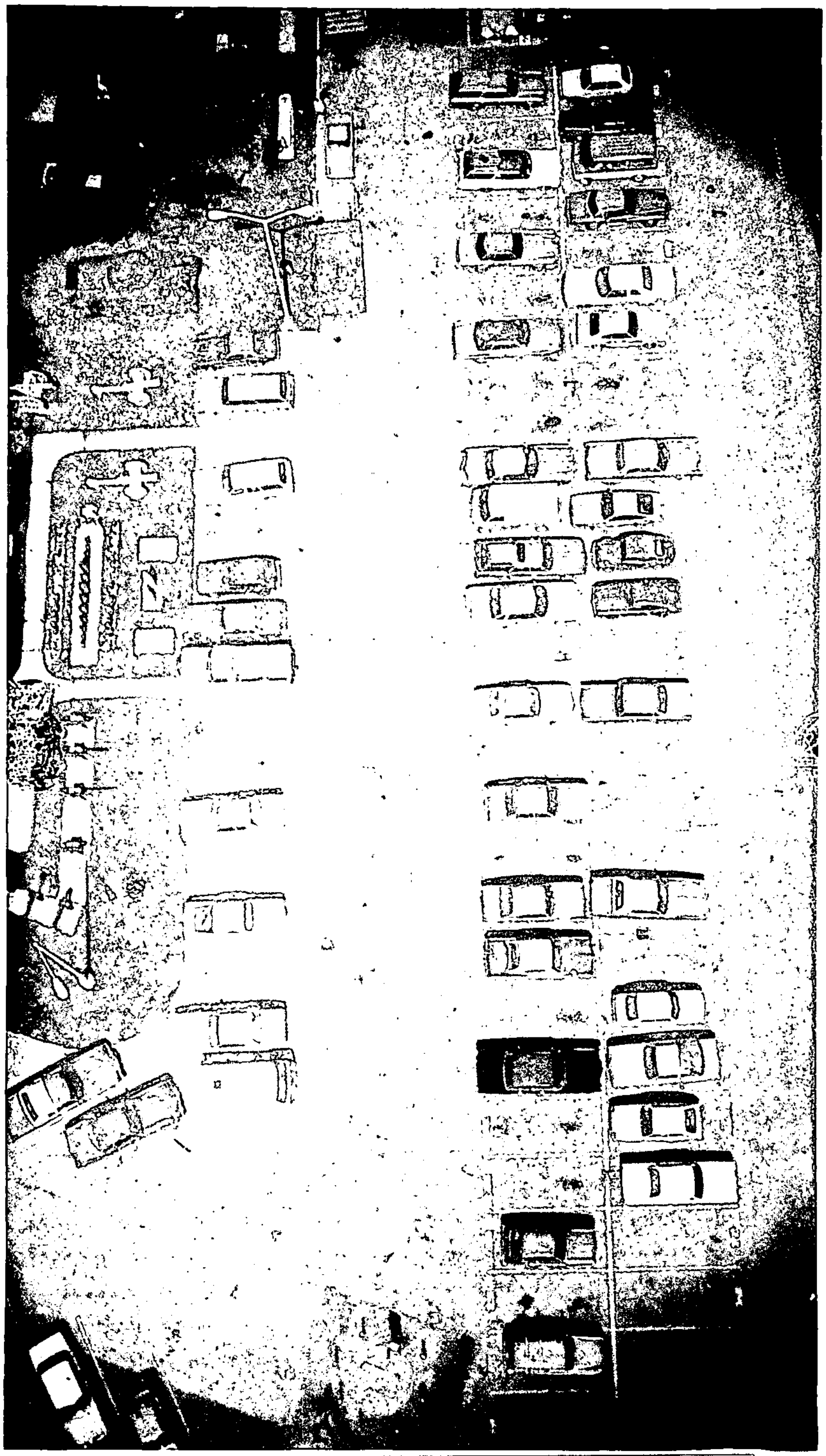

FIGURE A23. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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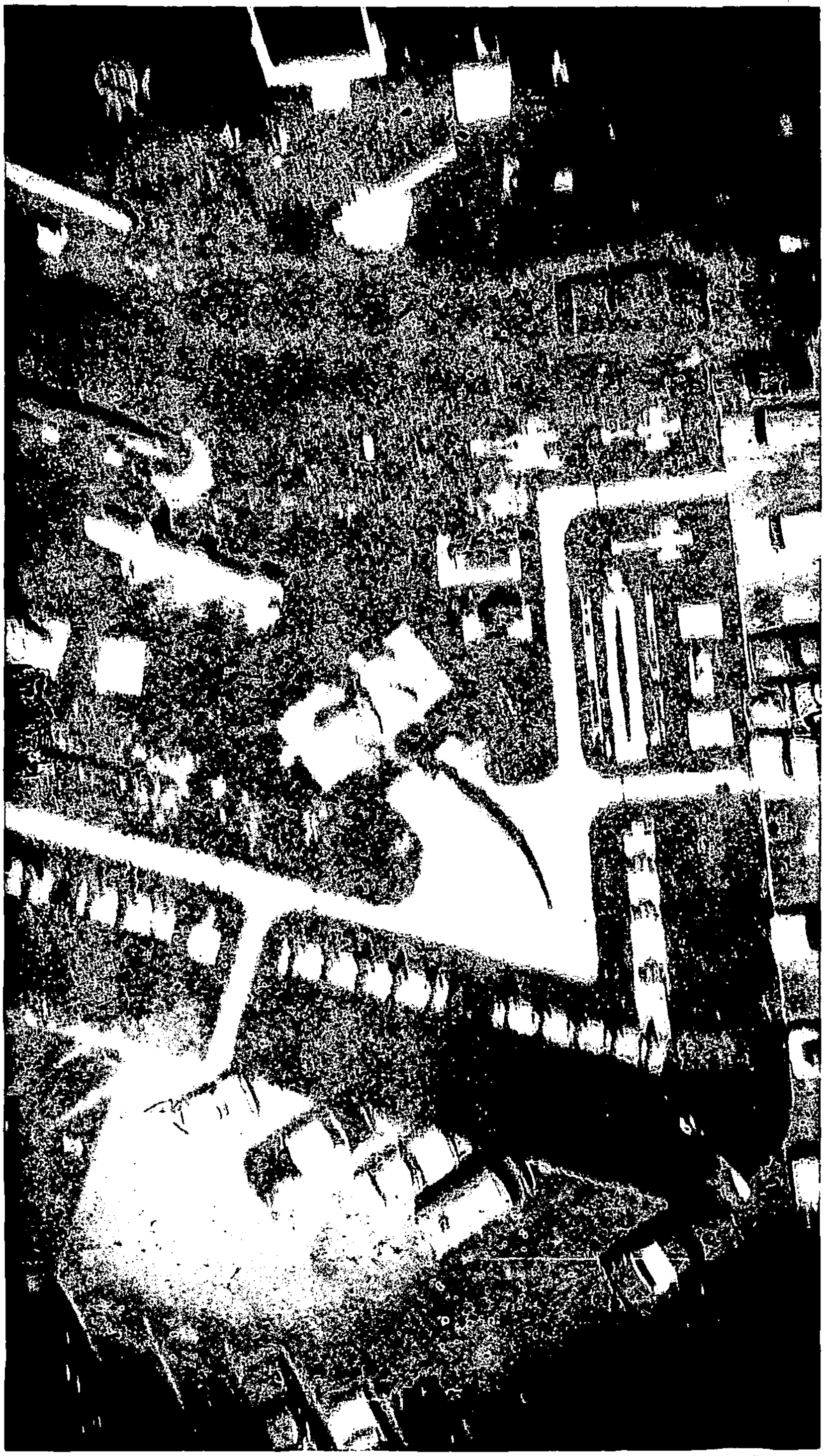

FIGURE A24. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

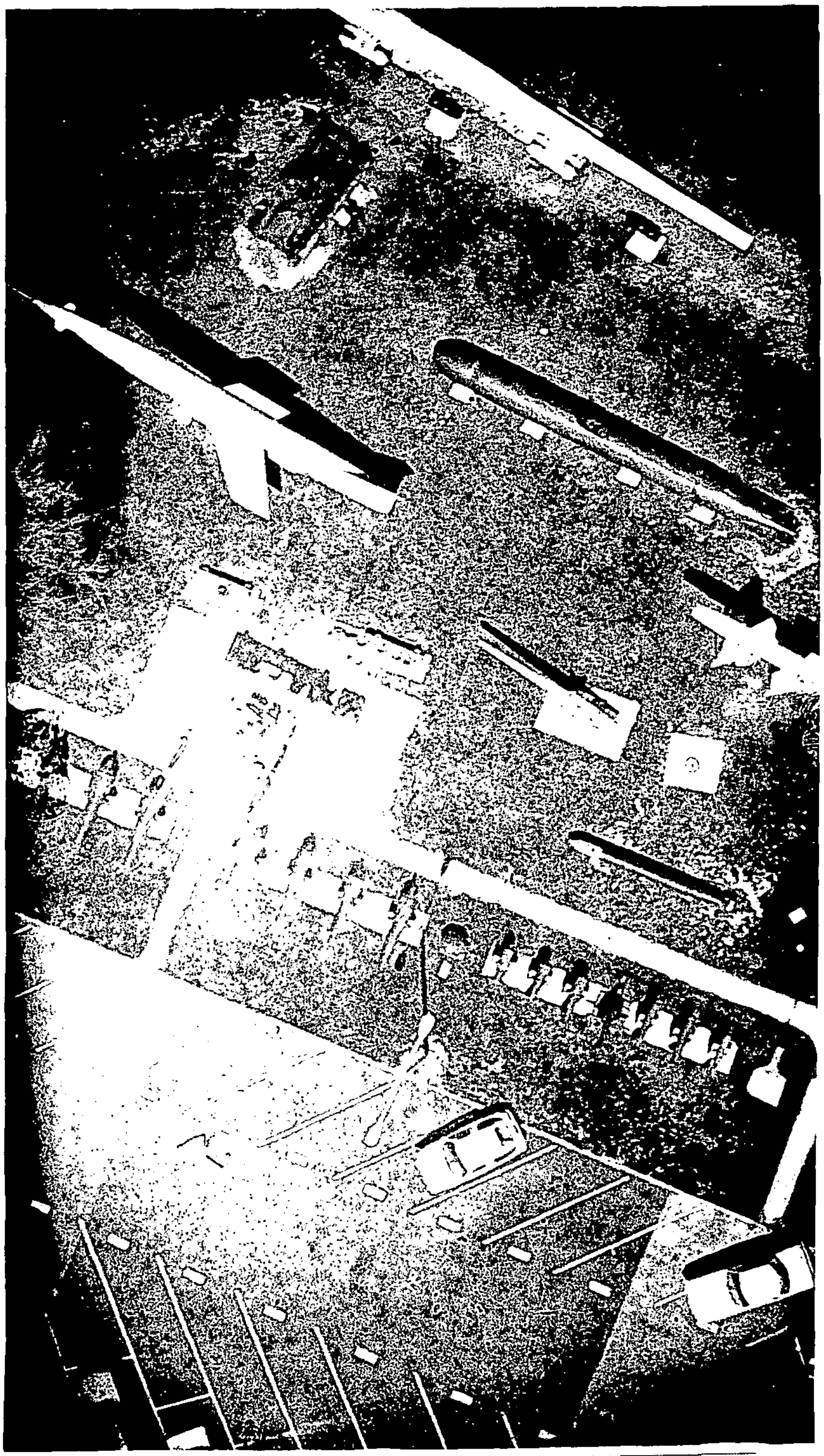

FIGURE A25. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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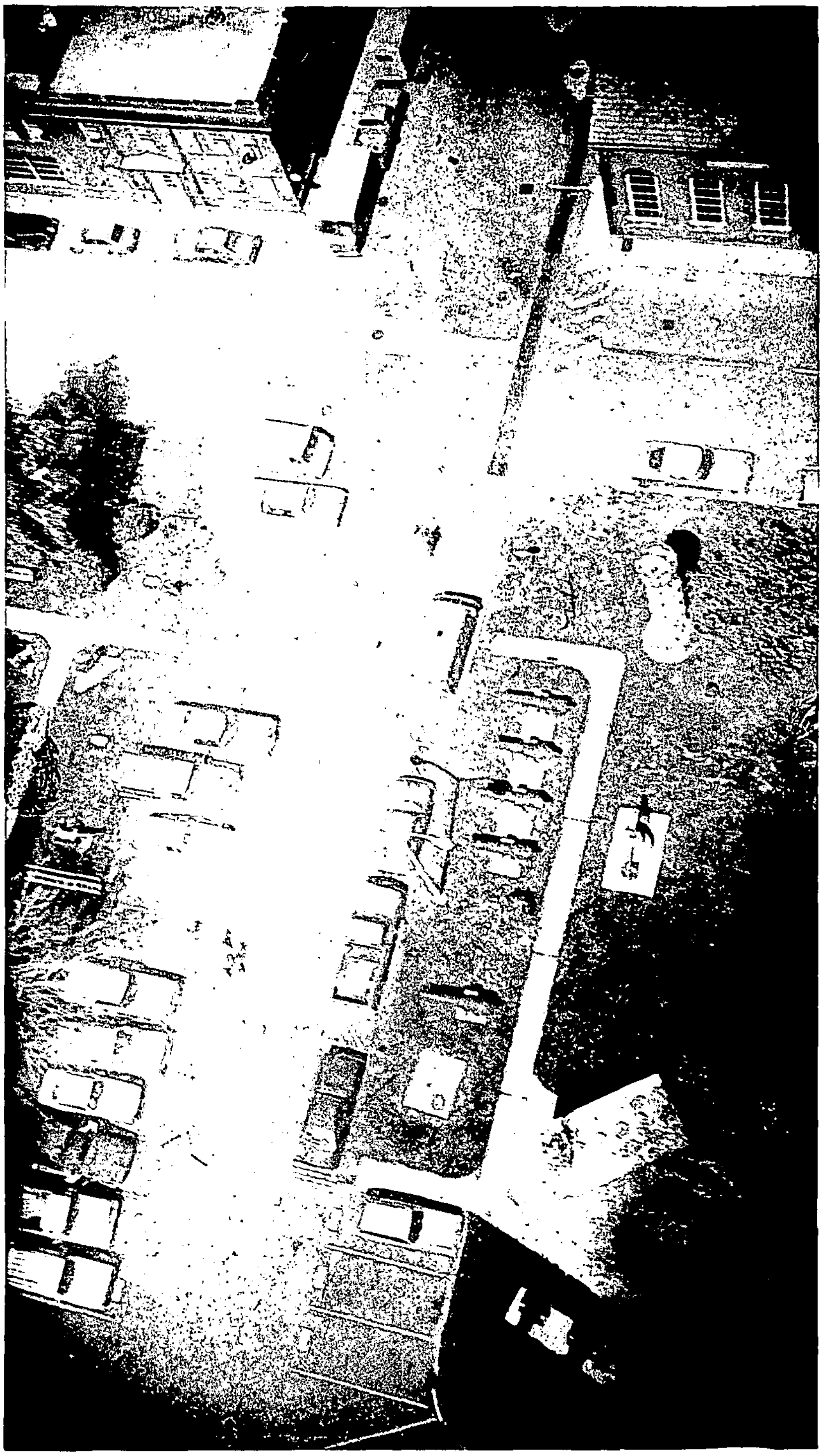

FIGURE A26. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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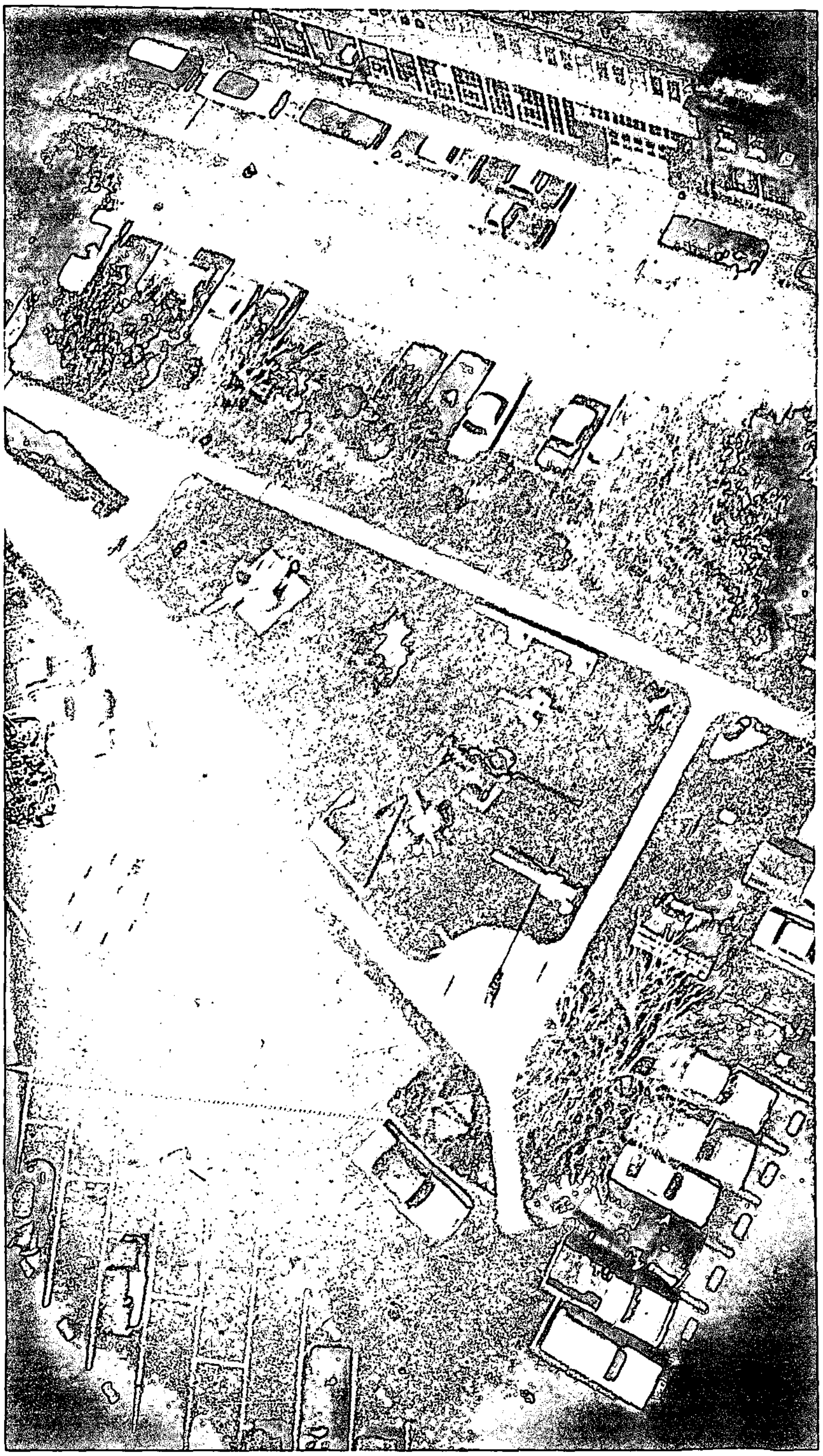

FIGURE A27. Successive Frame Coverage of the Navy Yard Target Display Area (Figure Series A23-A27)

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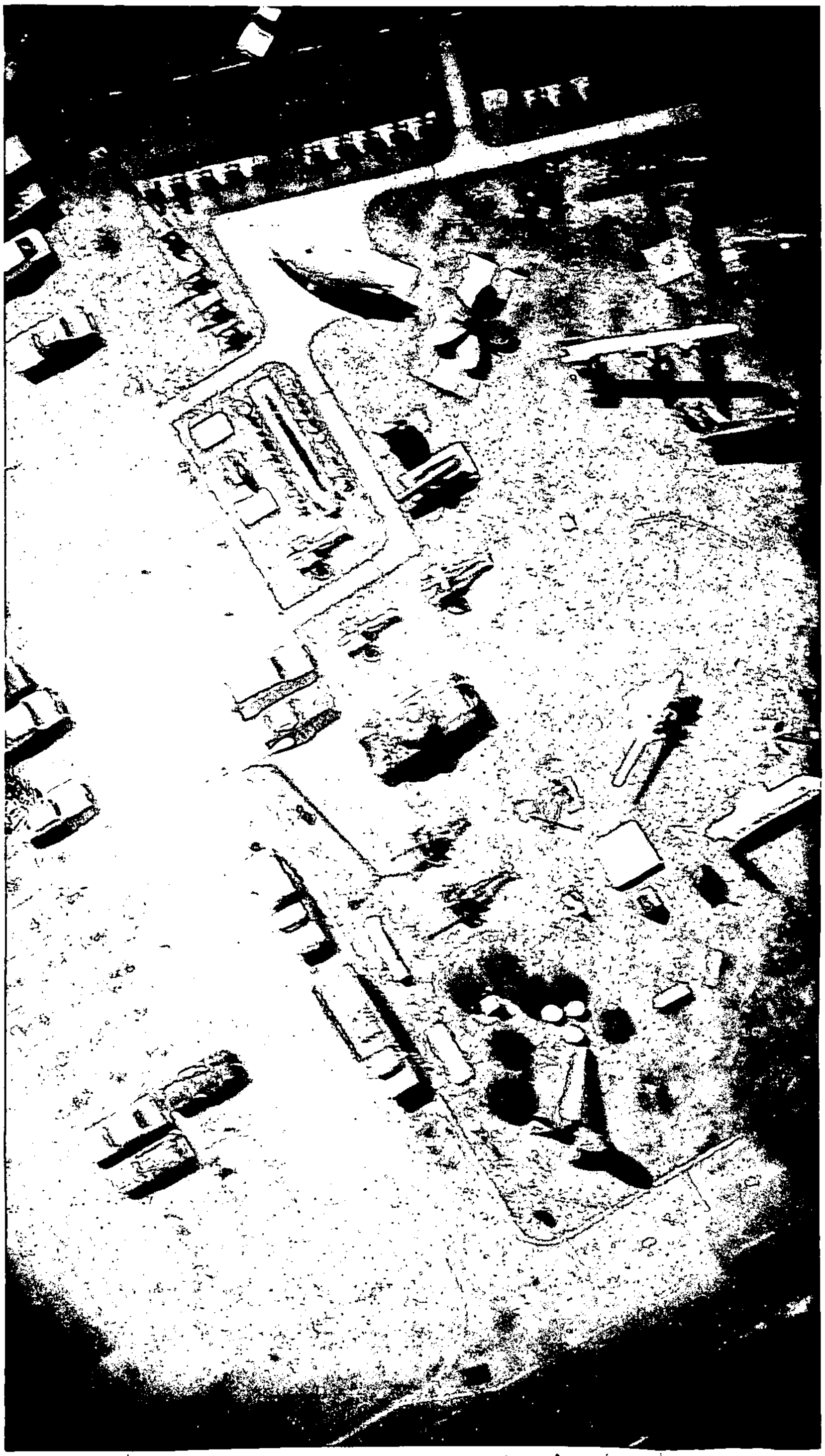

FIGURE A28. Navy Yard Display Area
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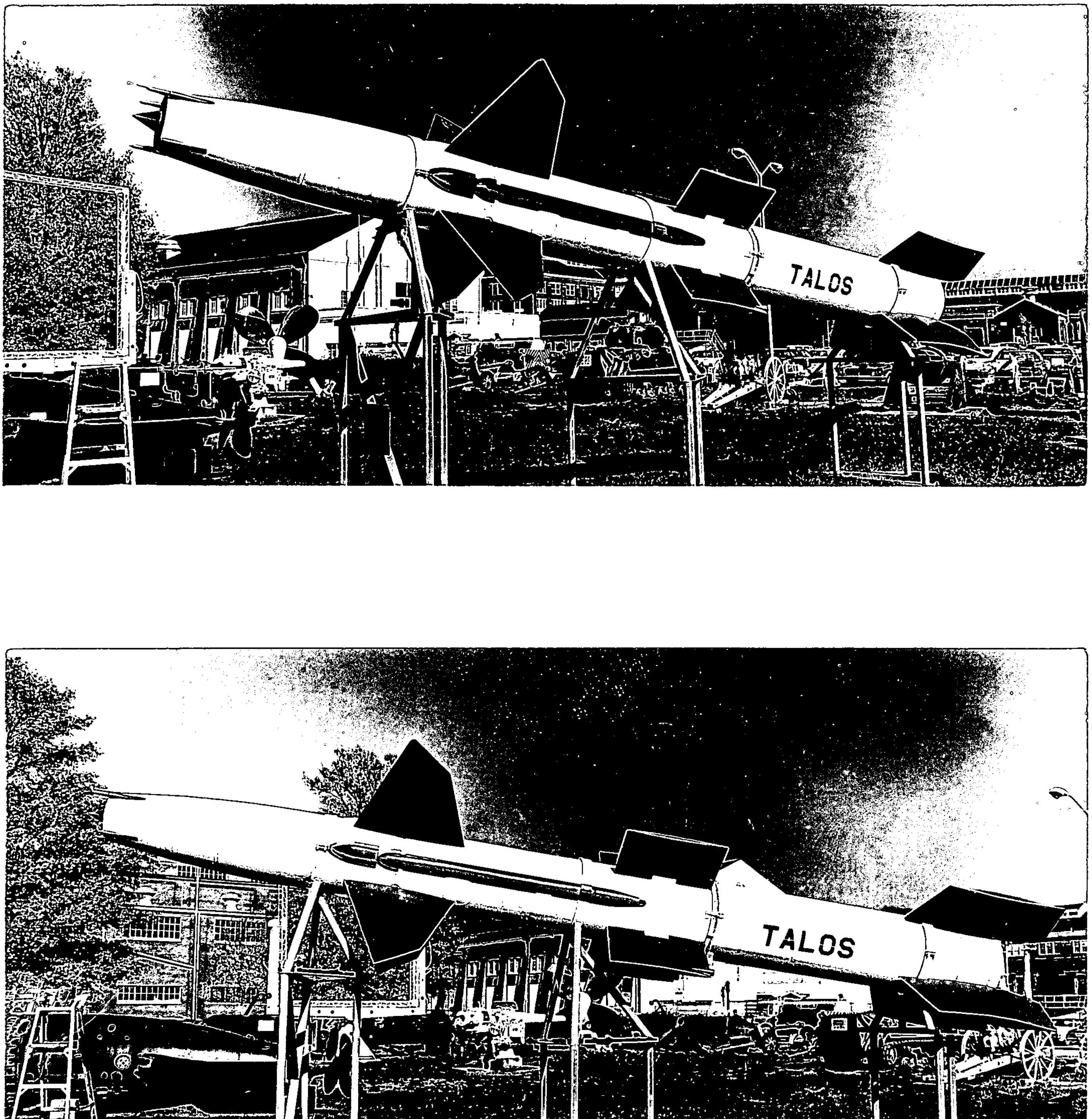


FIGURE A29. Ground Views of Talos Missile at the Washington Navy Yard

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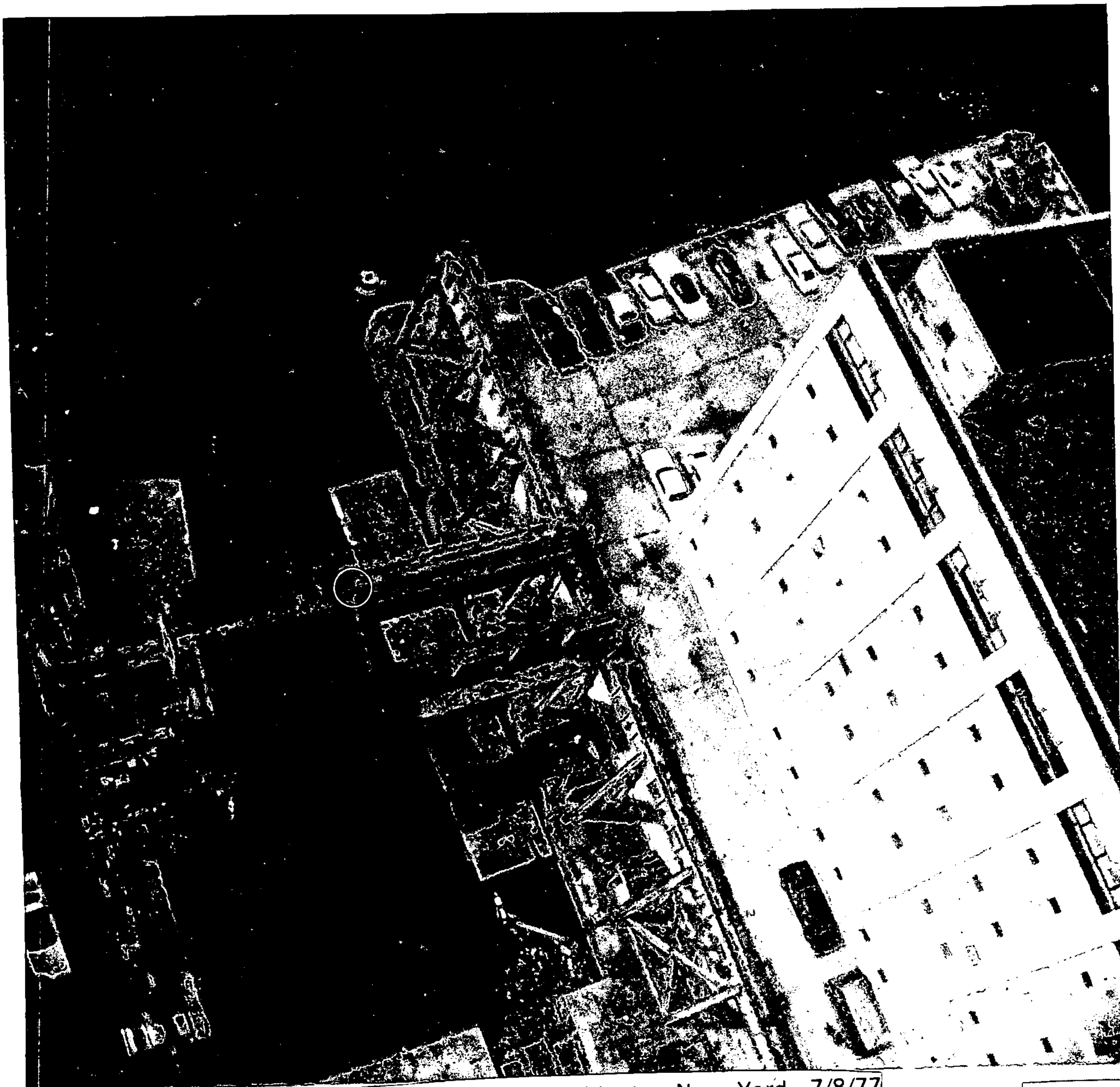

FIGURE A31. The Washington Navy Yard—7/8/77

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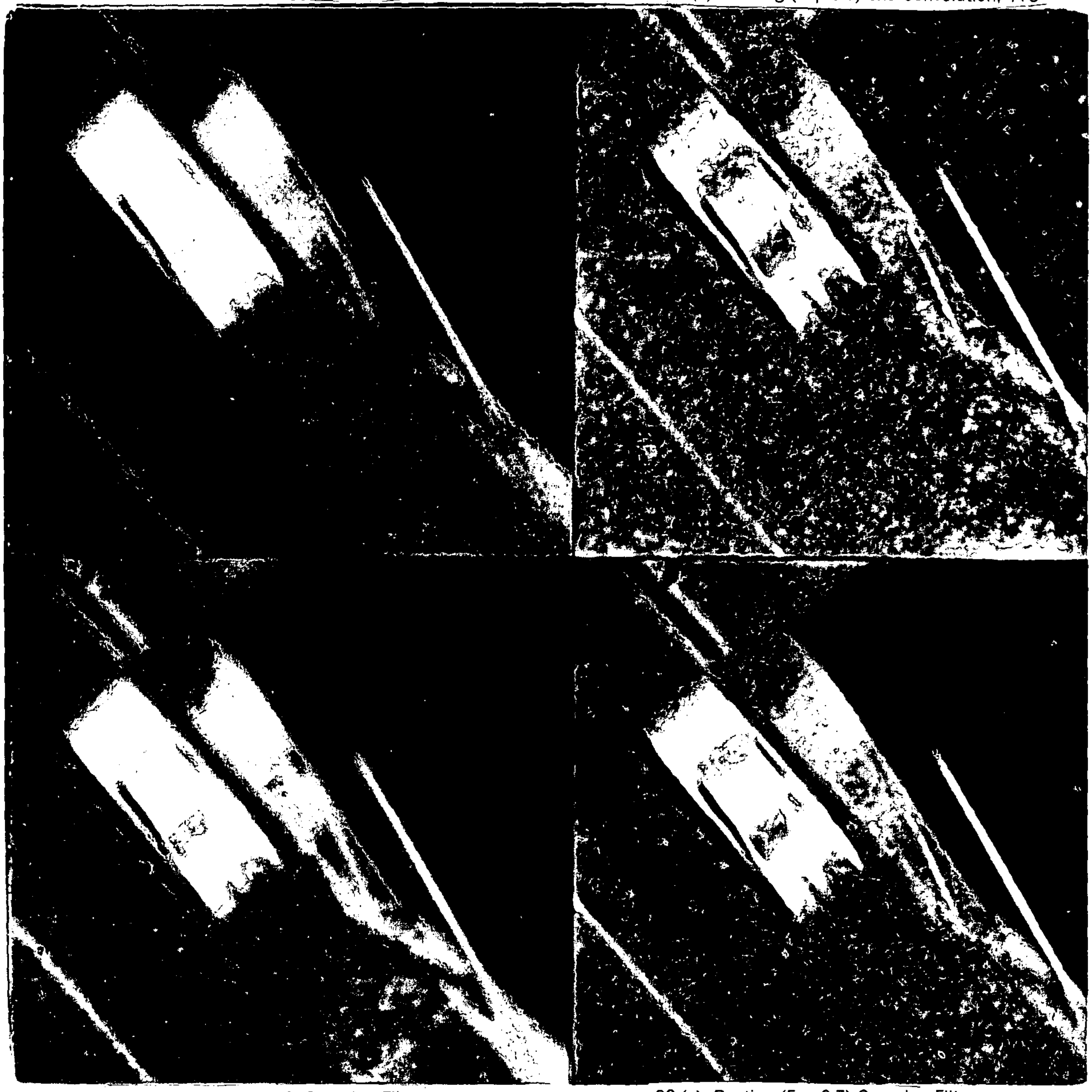
32(a). Original Scene Micro-d Scan

32(d). Rooting (Exp 0.5) 5x5 Convolution, TTC



32(b). Rooting (Exp 0.7) Gaussian Filter

32 (c). Rooting (Exp 0.7) Gaussian Filter Edge Enhancement

FIGURE A32. IDIMS Effect on Smeared Imagery

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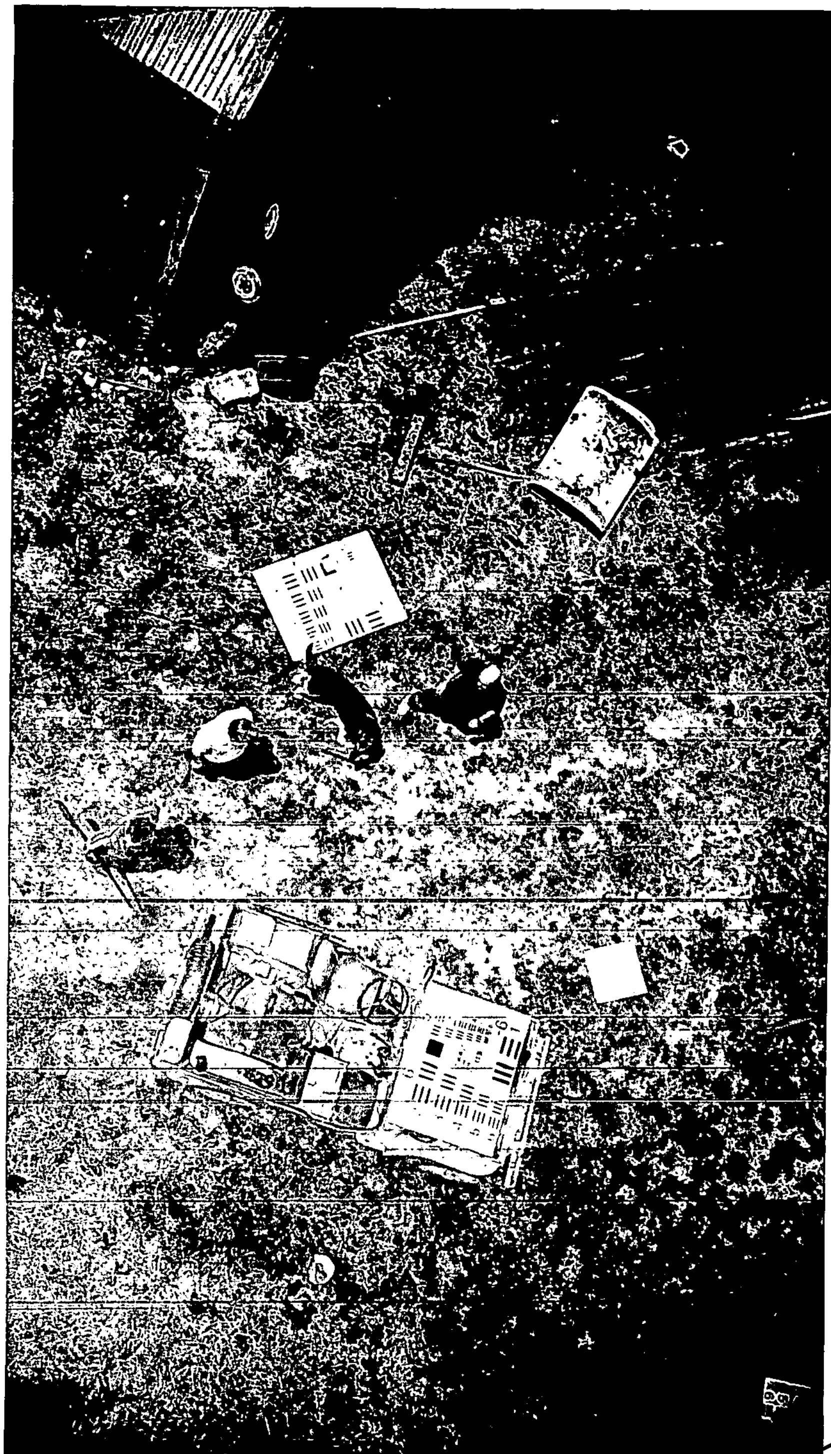

FIGURE A33. Camera/Film Analysis Test Imagery
(From the Balloon Platform)

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