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Ground Resolution of High Altitude Photographs

W.A. Befort, R.C. Heller, and J.J. Ulliman

ABSTRACT

Duplicate transparency images of ground targets on photographs taken with two different cameras, the Itek KA-80A Optical Bar Panoramic Camera and the Actron HR-732 Large Format Camera, were examined to determine the ground resolution available. Both systems yielded average resolutions in the neighborhood of 22-24 line pairs per millimeter of film, allowing contrasting ground objects about two feet wide to be distinguished at a nominal scale of 1:30,000.

INTRODUCTION

The U-2 aircraft of the National Aeronautics and Space Administration's Airborne Instrumentation Research Project have flown numerous photographic missions in recent years for the U.S. Forest Service's Nationwide Forestry Applications Program. From the 65,000-ft. altitudes at which the U-2 operates, two cameras in particular produce medium-scale "resource" photography: the Itek KA-80A Optical Bar Panoramic Camera and the Actron HR-732 Large Format Camera. Both have 24-inch focal lengths, and therefore yield images in the 1:30,000 scale range; both also produce photographs of unusual dimensions. The HR-732 yields conventional "frame" photographs which differ from standard aerial imagery only in being twice as wide (9 by 18 inch. rather than 9 by 9 inch.). The KA-80A produces a 120-degree panoramic photograph 50 inch. wide by 5 inch. long, which exhibits considerable convergence and foreshortening across much of the field of view.

These cameras have been employed in a number of forestry-related studies in various parts of the country. Klein et al. (1978) in California and Dillman et al. (1979) in Houston undertook controlled comparisons of the efficiency of the two cameras in detection of tree mortality. However, little published information has been available concerning the ground resolution obtainable on the products with which resource managers must work—duplicates of normal color and color infrared transparencies. When flights were scheduled over northern Idaho in 1979, ground targets of known size and standard arrangement were set out in order to measure actual resolution.

The authors are Research Associate, Research Professor and Professor of Remote Sensing, respectively, College of Forestry, Wildlife and Range Sciences, University of Idaho.

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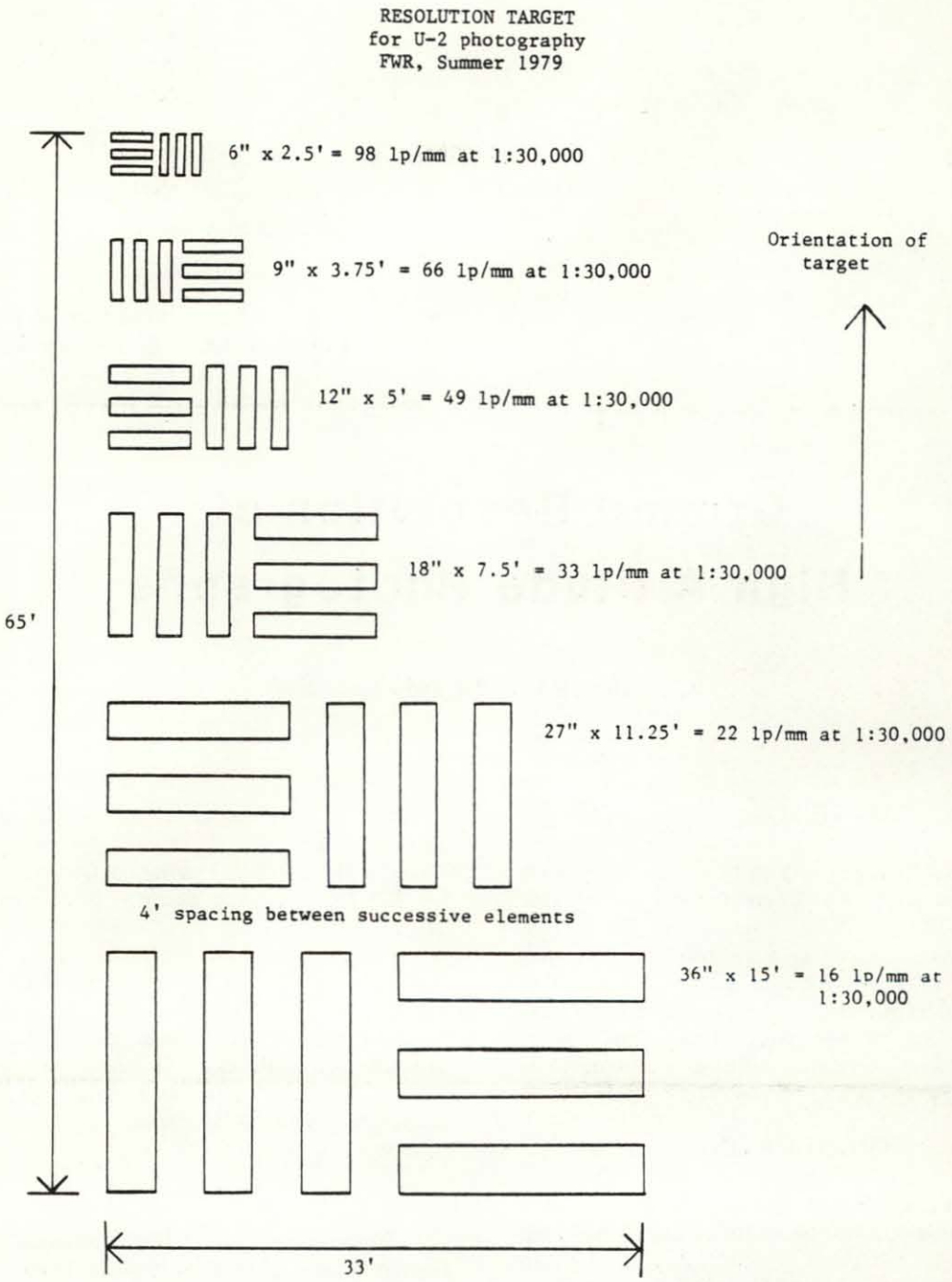

Figure 1. Resolution targets were designed to cover the range of likely results. Targets were oriented in cardinal directions so that elements would lie parallel or at right angles to the planned flight lines.

METHODS

Targets were designed after the standard U.S. military pattern (U.S. Govt. Printing Office 1963), with perpendicular sets of triple parallel bars (Figure 1). The largest target bars measured 3 ft. by 15 ft., and the smallest measured 6 inch. by 30 inch. Each target covered a resolution range from 16 to 98 line pairs per millimeter (lp/mm), at a nominal 1:30,000 scale.

Seven identical, complete targets were set out along a 40-mile northwest-southwest line (Figure 2). Troy, Idaho, where north-south and east-west U-2 flight lines were to intersect, was at the midpoint of the line of targets. The two outermost targets were intended to test resolving power near the limits of the panoramic camera's scan; the next pair toward the center would be photographed at moderate scan angles. The three targets at and near the midpoint would be viewed almost vertically on both flight lines by the panoramic camera, and would appear on the large format photographs as well.

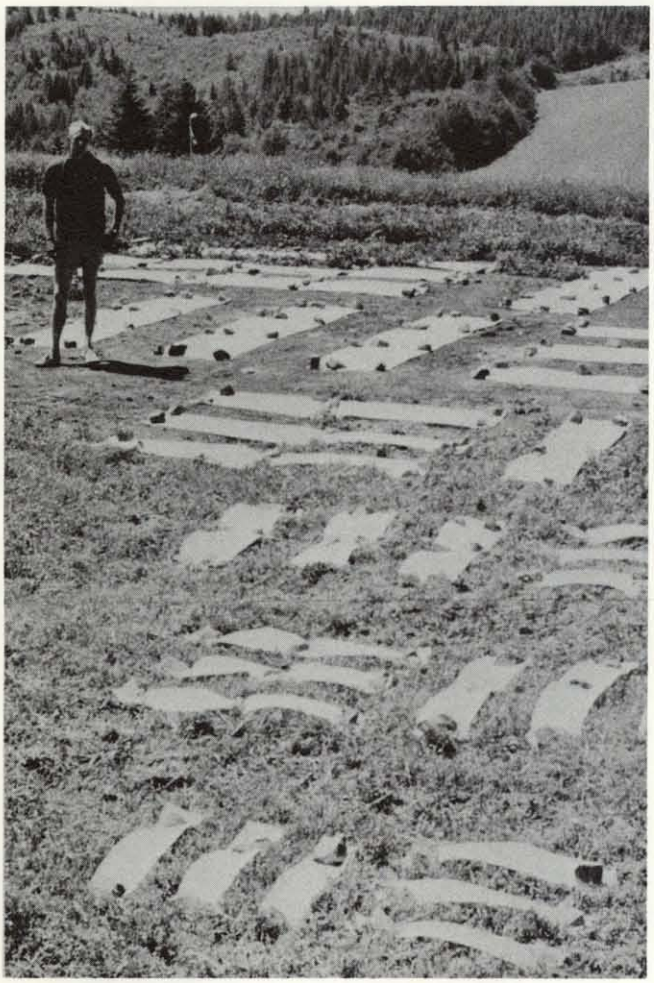

Figure 2. Seven target arrays were constructed, maintained in the field for a week, and removed. Damage from weather and domestic animals was repaired before each U-2 flight. Labor costs were about $900; materials about $300.

The white paper targets were oriented in cardinal directions, as were the planned flight lines. Target elements were held down with stones; the ground surface–grass, soil, or rock–provided the background. Location, elevation and orientation were recorded as the targets were constructed. Reflected light from target and background was measured with an Asahi Spotmeter. Approximate contrasts ranged from 6:1 against a disked summer-fallow field to 14:1 against thick lawn grass.

The HR-732 photo mission was flown on 28 June 1979. One of the cameras aboard was loaded with Kodak Aerial Color Film (Estar thin base) SO-242 and not fitted with a filter. Another, aligned with the first and making simultaneous exposures, carried Kodak High Definition Aerochrome Infrared Film (Estar base) SO-127 and a CC .30B filter. The aircraft flew at an average altitude of 66,000 ft. above mean sea level. The KA-80A mission on 3 July was flown at about 61,000 ft.; the panoramic camera carried Kodak High Definition Aerochrome Infrared Film (Estar thin base) SO-131 (like SO-127 but with a thinner base) and a CC .50C filter.

ANALYSIS

First-generation duplicate transparencies of the KA-80A and HR-732 photographs were received a few weeks after the flight. Targets were imaged 49 times on the panoramic photos and 38 times on the large format photos. Five interpreters viewed each target image monoscopically on a Bausch & Lomb Zoom 70 microscope, and identified all target elements in which they could distinguish three separate bars at any level of magnification. Elements aligned with the flight line were recorded separately from those oriented across the flight line. When results were collated for analysis, three interpreters had to agree before a given target element was counted as "resolved."

Altitude of the aircraft for each flight line was determined from measurements of ground objects of known size. Interpreters' results were then translated into line-pairs-per-millimeter (lp/mm) terms at photo scales derived from the flight altitudes and the mapped elevations of the targets. This was a straightforward process with the large format imagery; on panoramic photos, however, the value of a "resolved" target element in line pairs per millimeter depended upon its location on the photograph and its orientation with respect to the flight line. If an interpreter could resolve 36-inch-wide target bars lying across the flight path at a nadir scale of 1:30,000, he was observing an image resolution of 16.4 lp/mm. If the same element were oriented parallel to the aircraft track (so that the operation of distinguishing the separate bars would be performed in the cross-track direction), and lay at the extreme 60-degree scan angle, an observer who distinguished the same bars would be reporting a 65.6 lp/mm image resolution.

RESULTS

Itek KA-80A Optical Bar Panoramic Camera

On the SO-131 color infrared (CIR) film, average reported resolution was 24 line pairs per millimeter, with a standard deviation of ± 5 lp/mm. (This resolution would enable an interpreter to distinguish 2-ft.-wide objects of similar contrast at a nominal 1:30,000 nadir scale.) Highest resolution value reported by at least three interpreters was 35 lp/mm.

There was no appreciable loss of image resolution (in line-pair terms) with distance from the flight line. This is characteristic of panoramic cameras (Amer. Soc. Photogrammetry 1975:283).

There was no significant correlation of resolution with ground-measured target contrast differences ranging from 6:1 to 14:1. These contrast ratios are approximate, because targets of standardized reflectance could not be used. Ground contrast ratios greater than 10:1 are seldom encountered on high altitude photography (Heller 1970).

Targets to the south of the east-west flight line averaged 5 lp/mm better resolution than targets to the north. This is probably attributable to differential lighting. The resolution difference was significant at the .05 level. In general there was no difference between resolution averages from east-west and from north-south flight lines.

Measured average resolution tallies well with system resolution predicted from published component capabilities, using the conventional approximation in which the reciprocal of system resolution equals the sum of the reciprocals of the components' resolving power:

Contrast	Lens	SO-131 CIR film	2447 Duplicating film		Predicted system resolution
1000:1	1/250	1/160	1/100	=	1/49
1.6:1	1/160	1/50	1/50	=	1/22

HR-732 Large Format Camera

Average reported resolution with normal-color (SO-242) film was 22 lp/mm, with a standard deviation of ± 2 lp/mm. Highest value reported by at least three interpreters was 24 lp/mm.

Average resolution with color infrared film (SO-127, equivalent to SO-131) was 21 lp/mm, with a standard deviation of ± 2 lp/mm. Highest value was 23 lp/mm.

Paired comparison indicates that the difference between normal-color and CIR resolutions, though very slight, is significant at the .05 level. Published resolving power of SO-242 film at low (1.6:1) object contrast is 100 lp/mm; for SO-127 it is 50 lp/mm, which probably accounts for the difference.

There was no appreciable correlation of resolution with distance from the central point (principal point) of the photograph, or with ground-measured contrast on either film.

Paired comparison of targets appearing on both panoramic and large-format CIR photography showed a small advantage in resolution for the panoramic system (24 lp/mm) over the large-format system (21 lp/mm), significant at the .05 level. A similar comparison of CIR panoramic imagery with normal-color, large-format imagery showed no significant difference. Comparisons are likely to be confounded by the 5,000-ft. difference in altitudes at which the two missions were flown.

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