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RADAR DATA COLLECTION MISSION
Addendum to Final Report

by
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Radar and Optics Laboratory
Willow Run Laboratories
Institute of Science and Technology
The University of Michigan
Ann Arbor, Michigan

June 1970

prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASA Manned Spacecraft Center
Houston, Texas
Contract NAS9-10211

NOTICES

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ABSTRACT

This small University-funded effort was undertaken to demonstrate some of the useful information available in radar images. Observations on data gathered at Lawrence, Kansas with and without ground truth are presented. We conclude that changes of intensity and texture of fields, when observed repeatedly, can contribute to a history of field operations which would be significant in understanding the agricultural situation.

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UNCLASSIFIED

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1 INTRODUCTION

After completion of work on NASA Contract NAS9-10211, ground truth information became available for a part of the area shown in Figs. 17 through 25 of the Final Report. A small University-funded effort was undertaken to demonstrate some of the useful information available in the radar images. Two approaches were used: (1) the imagery was interpreted without any ancillary information except the knowledge and skills of an experienced radar systems designer and image interpreter; (2) additional interpretation and mensuration were carried out using the ground truth information supplied by CRES at the University of Kansas.

2 OBSERVATIONS WITHOUT GROUND TRUTH

The X-band radar imagery gathered at Lawrence, Kansas on September 24 and 26, 1969, has been studied to determine if it can be used to identify crops on the ground. The imagery includes Site 85 within a swath a few miles wide and several miles long, which allows the site to be viewed in relation to its surroundings, including a large river (Kansas), a neighboring city (Lawrence), and adjacent woodlands, fields, creeks and ponds.

Several old river courses can be seen, indicating that the area is not much above the river level. The meandering creeks denote flat terrain, and numerous dark areas west of the site indicate an extensive wet area, as do the ponds within the site. The bridge carrying the highway over what appears to be a dredged drain suggests large amounts of surface water at some seasons. Some ponds have surrounding areas of higher reflectivity which might indicate brush growth in the damp shore regions where cultivation is avoided.

The cultivated fields, varying in size with some up to a half mile long, are distinguishable by their different intensities and textures; their straight edges and the straight texture lines within them are distinctly man-made. Some have triangular sections at their ends that look like cultivation patterns, and some have strips of different intensity that probably result from cultivation or harvest operations.

Some fields have intensity variation that appears to indicate surface slopes. Illumination from different directions results in changes of prominence of these slope patterns, with local surface tilt toward the radar appearing brighter and tilt away appearing dimmer. Therefore, ridges, gulleys, and vertical edges of vegetation or fences are more prominent when viewed broadside than when viewed along their length.

Several areas exhibiting different intensity from surrounding surfaces appear unchanged at different aspects and probably result from different vegetation conditions rather than slope. Some field textures or areas of different intensity become more prominent with cross-polarized imagery, although the general level of the cross-polarized imagery is reduced from the parallel-polarized imagery.

The radar data show some fields appearing very different on the two days; this indicates that field operations are in progress. Changes were evident between different passes on the 26th, and one bright object in the imagery appears to be a farm vehicle moving in the field.

Without corollary information, the site can be recognized as part of a floodplain used for agricultural purposes. The land is in current use, and the fields with different reflectivities probably have differing crop cover. With repeated observations throughout the year, the history of planting and harvesting of various crops as well as reflectivity variations can be deduced from the radar imagery alone.

3
OBSERVATIONS WITH GROUND TRUTH

Identification of most numbered fields is possible by reference to the map of the area with the fields numbered (Fig. 1). One boundary is questionable; fields 15 and 16 in the radar imagery appear to be of equal width (east to west), but the map shows field 16 to be considerably narrower than 15.

Intensity measurements were made by scanning an aperture over the imagery at the output plane of the optical processor and recording light intensity. With a circular aperture with a diameter of 6 resolution widths, a record was traced showing several-db variations within fields, some of which can be correlated with visible texture in the imagery. One of these tracings is shown in Fig. 2. Low intensity areas can be identified as shadows on fields, and brightness variation due to reflectivity changes can be seen to change from field to field. Some bright imagery, of trees or other highly reflective objects, can be seen to limit at high level. The measured intensities were plotted for several crop types and are shown in Fig. 3. The total intensity variation between the brightest portions (fields) and the noise level was about 10 db, with no clear separation of crop types by intensity alone observed. Cross-polarized image intensities were all weaker than parallel-polarized images, but no significant crop signatures were noted. The number of samples was small, and additional measurements may indicate some significant differences. Soy bean fields were found to have the highest intensity imagery on the average, and emerging wheat fields the lowest. However, even with these extremes, there is overlap in the range of intensities for all crop types.

Measurements made with a larger aperture showed less variation within fields and a total spread between brightest and dimmest fields of about 5 db. This is in good agreement with the average value changes when using a small aperture.

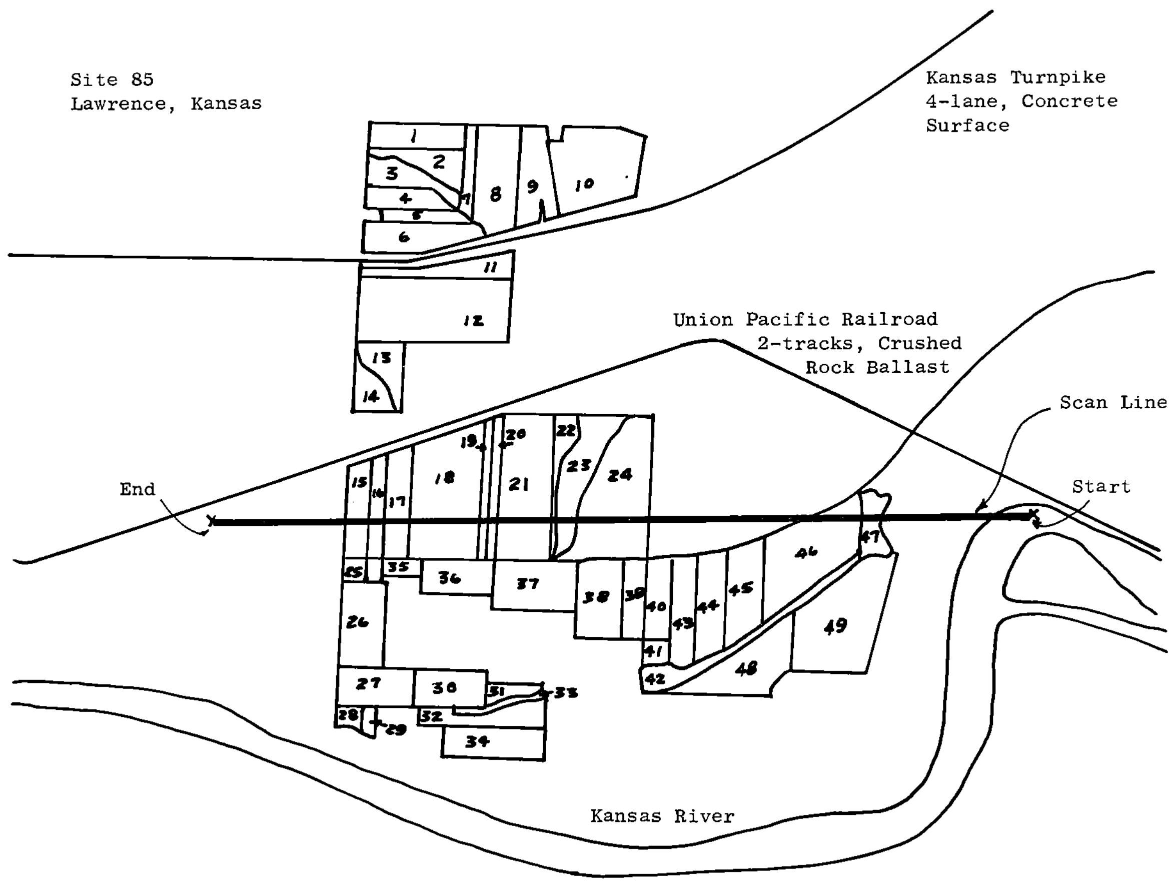

FIGURE 1. GROUND TRUTH MAP OF AREA NEAR LAWRENCE, KANSAS. (Corresponds to Images in Figs. 17-23 of Final Report.)

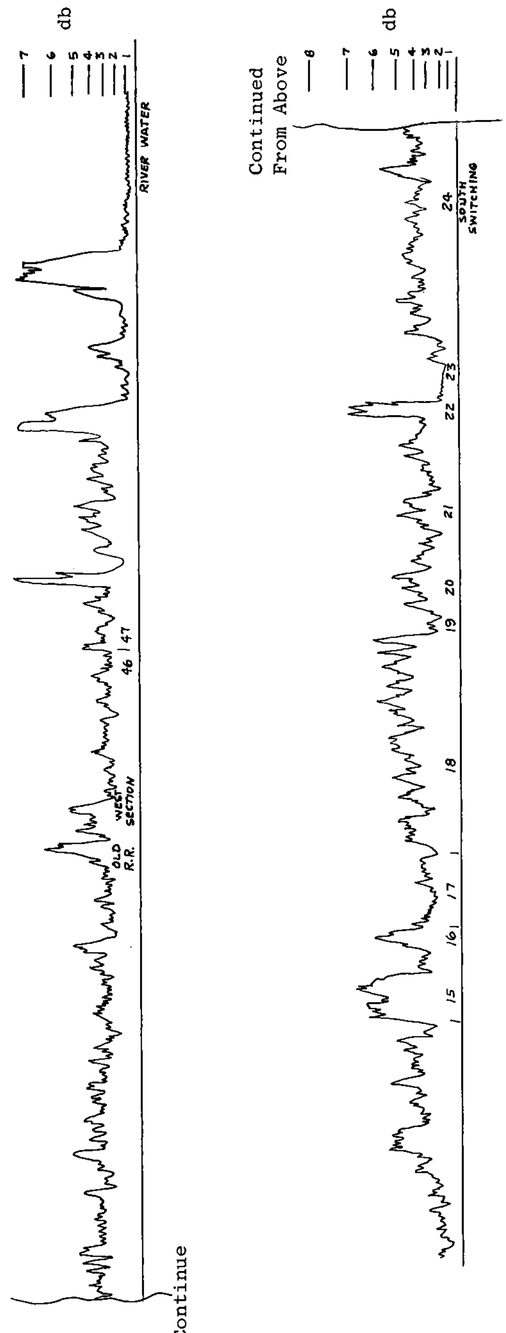

FIGURE 2. RECORDING OF TARGET INTENSITY OF LINE SHOWN IN FIG. 1

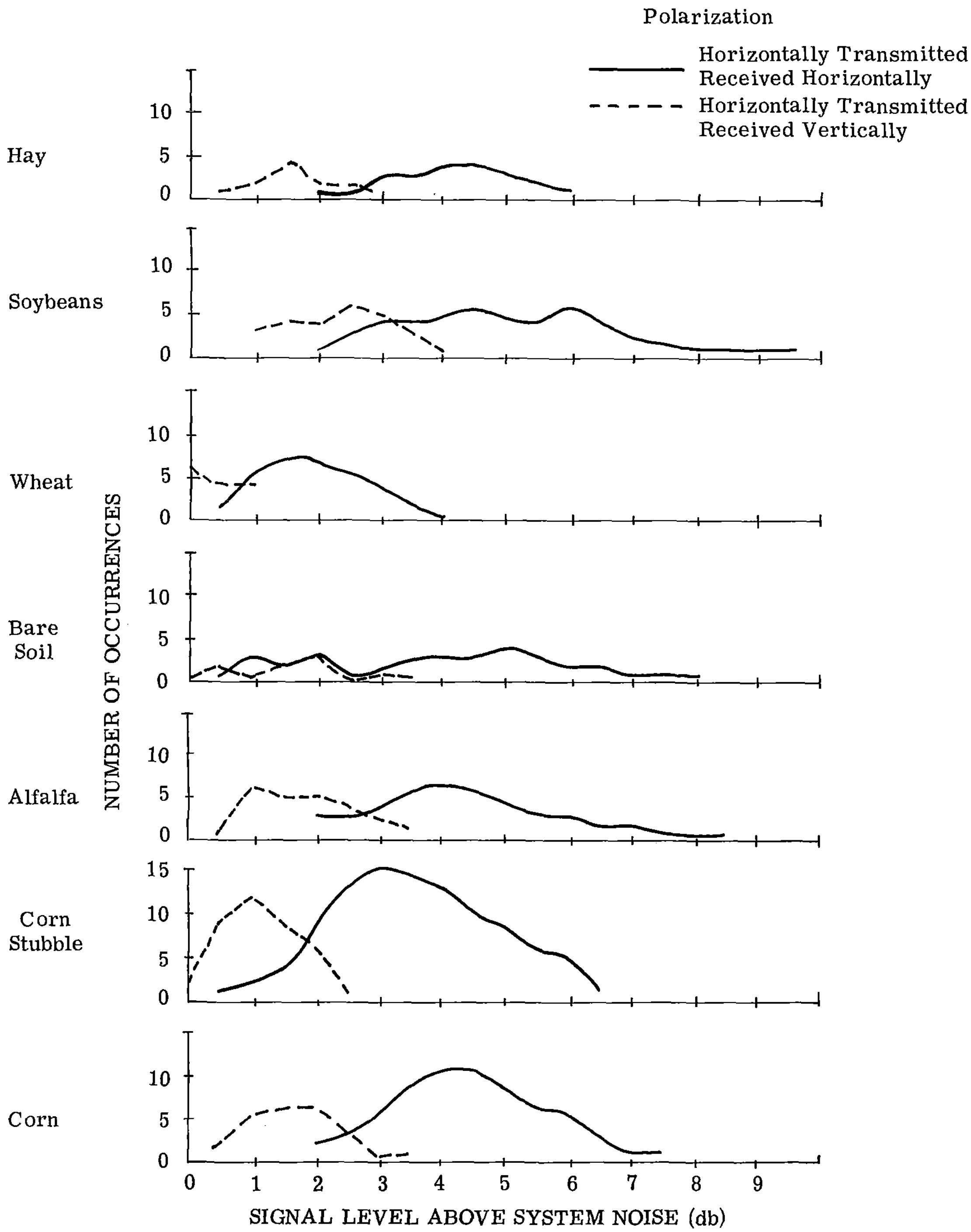

FIGURE 3. IMAGE INTENSITY DISTRIBUTION OF VARIOUS CROPS APPEARING IN LAWRENCE, KANSAS DATA

This small range of intensity values for various crop types keeps the imagery intensities within a nearly linear region of the radar system which can be recorded on photographic film without excessive distortion. Measurements of photographic density of recorded field imagery should be nearly as accurate as the intensity measurements made on the optical processor. Brighter images, such as those of trees or river banks, cannot be measured accurately on photographic copies; therefore, attempts to measure relative intensities should be made in the processor output plane before the limiting implicit in the transfer function of the film has been allowed to compress the dynamic range of the system. Texture boundaries within fields observed in the radar imagery were confirmed by aerial photographs. Texture in field 24 was most noticeable in cross-polarized imagery and also appeared in aerial photos which were made simultaneously with the radar images. The division of field 12 into north and south sections (which appears only in the radar images made on the 26th) is also visible only in photos of the 26th. Additional objects verified by aerial photos include the ponds with surrounding brush in fields 12 and 17 and the strips running north and south in fields 18 and 21.

Ground truth obtained by simultaneous oblique aerial photography correlates well with radar imagery, since the area is viewed at the same aspect as the radar. This allows correlation between the two images by field shape recognition, but does not provide detailed information, such as crop type, height, and moisture content, which can be obtained only by ground observers.

Several errors and omissions were found in the ground-observer notes. No reference is made by ground observers to divisions of the numbered fields into different subregions, but the radar imagery and often aerial photos show that one part is distinctly different from another. Local variations of elevation and contour are ignored in the ground truth, but are fairly prominent in the radar imagery. The ground-party notes seem to place equal emphasis on each numbered field, although the areas of the fields differ widely (by a factor of about 30). Only one reference is made to current activity along with some comments that field operations were recently accomplished. It is possible that no activity was in progress when the ground observers were in the field on September 27 and 30.

There is evidence that the ground truth is not only incomplete but in some cases inaccurate, since both the radar imagery and aerial photos show row orientation in several fields that does not conform to the ground-party notes. This difference in emphasis and disagreement between information provided by ground and air survey is probably an indication of the advantage of airborne surveillance. Large areas may be covered rapidly and accurately from the air, while ground surveys are time-consuming and often faulty.

4
UTILITY OF RADAR OBSERVATION

The X-band radar quickly images large areas of terrain containing many cultivated fields and their surroundings and shows different shading for different crop types. However, the variation in shading caused by local terrain slope, illumination depression angle, and azimuth aspect is great enough to cause overlap of intensity values associated with different crops. The prospects for crop identification by image intensity differentiation alone are poor, while texture within images of various fields provides some clue to cultivation and harvest operations. Orchards and vineyards can show significant row structure, but grain crop rows are not resolved. While closely planted crops such as grain, beans, beets, and potatoes are unresolved, they still have intensity variation dependent upon aspect relative to their rows. Changes of intensity and texture of fields, when observed repeatedly, can contribute to a history of field operations which would be significant in understanding the agricultural situation.

The potential for crop differentiation with the aid of radar rests upon the possibility of observing the manner in which reflectivity and texture vary with some or all of the following: (a) wavelength, (b) polarization, (c) aspect and depression angle, and (d) time. The critical question is whether one can find sufficient change, using a minimum number of these variables coupled with intelligent data processing, to make the radar approach economically feasible. Knowledge of local geographic, climatic, and economic context can expedite this process. A multifrequency radar offers promise, provided the required number of channels does not become prohibitively large. It is hoped that a maximum of 3 wavelengths might suffice. The utility of IR and photographic sensors, when weather and/or illumination conditions permit, is already well established, and methods which correlate radar images with the outputs of these other sensors warrant investigation. However, a single-frequency radar by itself appears to be of limited utility for crop differentiation, and is not an adequate approach to the problem.

This Addendum to the Final Report represents an extremely limited additional effort, and the author recognizes its shortcomings. It is being submitted at this time, despite the many unanswered questions, in order to provide the author's current thoughts for the sponsor.

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