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INVENTORY OF FOREST AND RANGELAND AND DETECTION OF FOREST STRESS

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TECHNICAL REPORT STANDARD TITLE PAGE

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16. Abstract Three small scales of CIR photography were interpreted to determine the number of bark beetle-killed trees detected in each of six spot size categories. A procedure was developed to predict the probability of detecting spots in each spot size category and in turn to estimate the number of infestations and dead trees even on the smallest scale. Statistical tests of the data indicated that the linear model did not fit the data and that other models should be tested. As a result of daily monitoring of Black Hills radiometric instruments we are able to show the spectral energy relationships in the ponderosa pine ecosystem over time. These data have been helpful for comparison with radiance signatures extracted from ERTS bulk 70 mm imagery using precision microdensitometry. Effects of atmospheric interference were shown by a 30 percent increase in scene radiance on channel 4 of the satellite imagery. A calibration and scaling technique was developed and tested to enable interpretation of ERTS bulk and precision data to proceed for the Atlanta test site. The technique includes calibration of a photographic copy system for the I^2S image combiner and the production of scaled overlays of grid coordinate systems, study area locations, geographic control points, and outline maps of county boundaries.

17. Key Words (Selected by Author(s)) Forest inventory; land use; forest stress; rangeland inventory.		18. Distribution Statement	
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Figure 2. Technical Report Standard Title Page

TITLE: Inventory of Forest and Rangeland and Detection of Forest Stress

ERTS Proposal Number 226

Black Hills Test Site (Forest Stress) 226A

Coinvestigator: Frederick P. Weber

GSFC Identification Number AG-014

Principal Investigator - Robert C. Heller

STATEMENT OF PROBLEMS:

1. Progress during the first eight months of this study has been governed by the availability of ERTS data and personnel. In the first case, Data Collection System (DCS) data have been received regularly since the first week in September with only minor problems. However, satellite imagery was slow in coming due in part to weather problems over the Black Hills on image days. One of the biggest problems was a shortage of personnel to handle tasks such as image interpretation, microdensitometer analysis, and image recombining.

2. There have been some minor problems with our field data collection system which feeds data to the Data Collection Platforms (DCP's). The 24-volt aircraft batteries we are using to power the DCP's have not stood up as well as expected. As a result we have lost data from time to time due to a low voltage state of the batteries. This problem is being corrected by replacement power packs consisting of rechargeable alkaline batteries. Some further data have been lost because of transitory problems with our multiplexer. This is the result of insufficient time for complete testing of the multiplexer unit in the laboratory before it was placed on the line. Most all of the field equipment which has been operating continuously in the field since September will be brought into the laboratory in March and April for modifications and recalibration. We hope to eliminate data acquisition problems at that time.

3. Perhaps the most perplexing problem encountered during the first eight months has been the loss of some data from magnetic tapes shipped to our office in Berkeley from the field site in South Dakota. These are the tapes which contain the data collected in parallel with the DCP on our Vidar 5304 digital data acquisition system. The tapes were okay when they left the field site but somehow became demagnetized in transit to California. We suspect that newly instituted airline inspection systems may have caused the problem. In the future we will take precautions to prevent this unfortunate loss of data.

4. A problem which remains high on the priority list is that Mission 56 data collected by the University of Michigan as an ERTS support multispectral scanner flight over the Black Hills test site in May 1972 still has not been processed. We cannot proceed on processing MSDS data from the C-130 until the M-7 data analysis is complete. We hope to begin processing Mission 56 data in the next month.

ACCOMPLISHMENTS DURING THE REPORTING PERIOD:

Interpretation and Analysis of Supporting Aircraft Photography:

1. For the past eight years we have worked in the Black Hills to develop remote sensing techniques for detecting and inventorying mountain pine beetle (*Dendroctonus ponderosae* Hopk.) infestations in ponderosa pine (*Pinus ponderosa* Laws.) stands. Our association with NASA has allowed us to expand research in detection and evaluation methods and especially to broaden our information base. Recent involvement in the ERTS program has provided an opportunity to work with small-scale synoptic imagery (obtained from ERTS 1) as well as supporting aircraft photography. We are currently using supporting photography, both from NASA aircraft and Forest Service aircraft, ranging from large-scale to microscale photography (Table 1).

2. Since resource managers recognize the value of air photos as an inventory tool, we have focused on the suitability of different scales of photography for detecting and monitoring bark beetle infestations. In addition we are looking at how much of an area (limited by statistical and budgetary constraints) must be covered to accurately represent it. Assuming heterogeneity of the area, how should the photo coverage be distributed? However, the prime concern is the determination of optimum scale (all factors considered) for interpreting the area of interest. Specifically, what is the smallest scale photography that can be used to detect and inventory bark beetle infestations and still maintain acceptable accuracy? The satisfactory answer to the last problem required development of a technique to use ground truth and very large-scale photography to adjust for interpretation inaccuracies.

3. The 11 townships listed below were chosen for study. These townships were picked because this part of the northern Black Hills is the principal area of bark beetle activity.

Township	Range	Township	Range
5N	1E	4N	3E
5N	2E	4N	4E
5N	3E	3N	2E
5N	4E	3N	3E
4N	1E	3N	4E
4N	2E		

Table 1. Supporting aircraft photography used in the ERTS-1 Black Hills study - 1972.

DATE	SCALE	FILM TYPE	AIRCRAFT	SOURCE
5/15/72	1:34,000	8443 CIR	Aero Commander	USFS
9/8/72	1:32,000	2443 CIR	Aero Commander	USFS
9/14/72	1:5,500	2443 CIR	C-130	NASA
9/14/72	1:100,000	2443 CIR	RB-57	NASA
9/14/72	1:400,000	2443 CIR	RB-57	NASA

Table 2. Number of trees by infestation size category, the probability of detecting an infestation by the photographic scale, and the proportion of spots by size category (ground truth) for seven test areas within the 11 townships.

Infestation Size		No. of infestations found at 1:5,500*	Proportion By Size (ground truth)	Probability of Detection by Photo Scale		
Category	No. of Trees			1:32,000	1:100,000	1:400,000
1	1 to 3	269	0.507	0.588	0.104	0.000
2	4 to 10	175	0.330	0.783	0.337	0.006
3	11 to 20	51	0.096	0.824	0.588	0.098
4	21 to 50	29	0.055	0.690	0.448	0.069
5	51 to 100	4	0.008	1.000	1.000	0.000
6	100+	2	0.004	1.000	1.000	0.000
TOTAL		530	1.000			

* Ground truth scale

All levels of infestation are represented from single trees to groups of several hundred trees. The two sets of 1972 Forest Service photography covered the 11-township infestation area completely, as did all NASA photography except that taken by the C-130 in September at a scale of 1:5,500.

4. The 1:5,500 scale color infrared (CIR) photography was chosen as the source of ground truth data although some actual checking was done on the ground to determine the reliability of the tree counts on the 1:5,500 scale photography (Figure 1). The quality of the 1:5,500 scale photography was very good, the color separation was excellent, and most single tree infestations were readily detected.

Since the coverage of the 11-township area at a scale of 1:5,500 was incomplete, the following criteria were used in selecting the large-scale photography for interpretation: (1) the photograph has to be inside the infestation area and (2) collectively, the photograph selected had to contain a representative sample of infestation size classes. Seven photographs were found to meet the above criteria.

5. Two interpreters examined the seven 1:5,500 scale photographs, and each photo was interpreted 100 percent for bark beetle infestations. The actual photo interpretation was done using stereo pairs and an Old Delft stereoscope. The test areas covered by the 1:5,500 scale photos were transferred precisely to each of the corresponding smaller scale photographs (1:32,000, 1:100,000, 1:400,000) which in turn were fully interpreted proceeding from the smallest scale to the largest scale. In all cases, both infestation location and tree counts were recorded. To avoid interpreter bias, an interpreter did not look at the same test area as he had interpreted on the preceding smaller scale, and a third interpreter was used to reconcile the data between scales. Reconciliation required matching the infestations such that infestations identified on 1:5,500 scale photography were matched exactly to the same infestation identified on 1:32,000 scale and so on. Although time-consuming, this system resulted in a consistent numbering system so that the analyses could answer two questions:

1. Was the infestation spot detected?

2. If detected, how accurate was the tree count at each scale?

6. Another important aspect of our work with supporting photography during the last eight months was the interpretation of medium-scale CIR photography taken by our Remote Sensing Work Unit. The 11-township infestation area was delineated on both the May and September photography. Two interpreters were used to locate and identify all infestations using

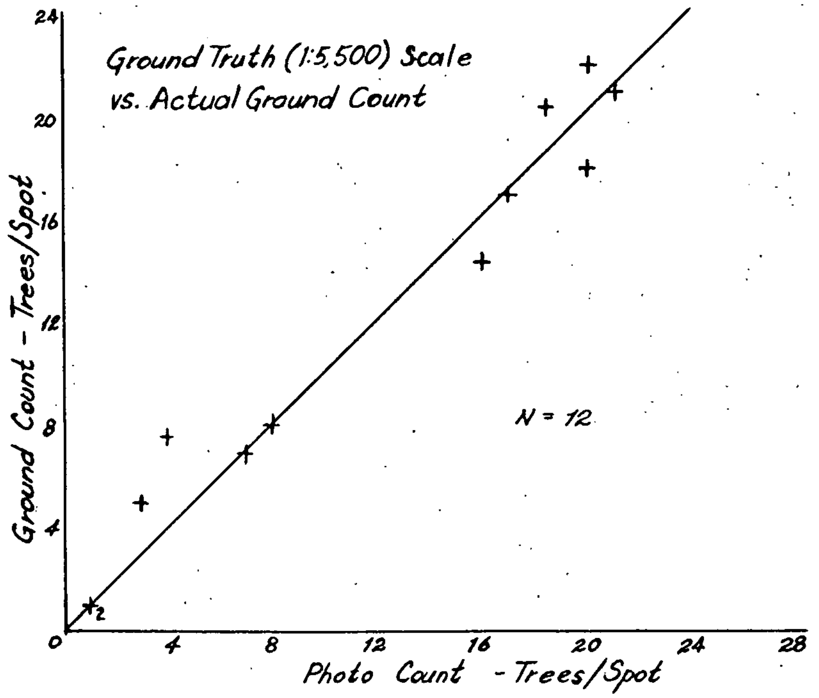

Figure 1. This graph shows the number of trees counted per infestation spot on the 1:5,500 scale versus the actual ground count.

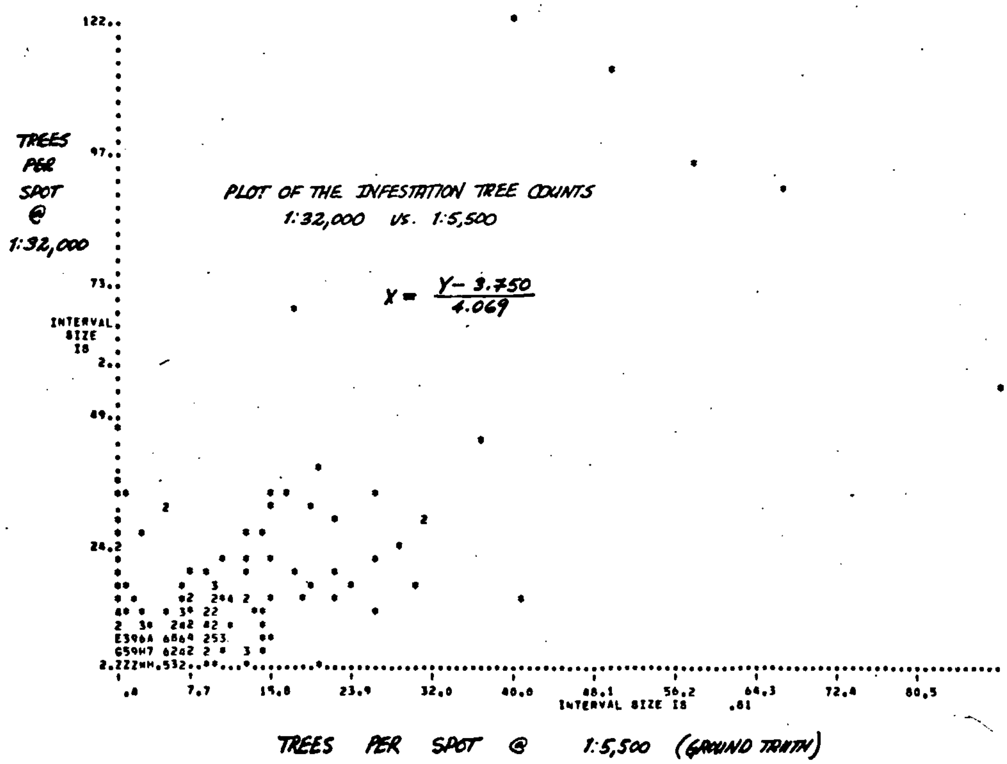

Figure 2. A plot of the number of trees counted per infestation spot on the ground truth (1:5,500) scale versus the 1:32,000 test scale.

stereo pairs viewed with an Old Delft stereoscope mounted on a Richards light table. All of the photographs covering the infestation area (257,000 acres) were interpreted for infestation spots and numbers of trees within each infestation spot. The data were punched on computer cards and subjected to a statistical analysis.

For purposes of this analysis the infestation spots detected on the 1:5,500 scale photography were assumed to represent all of the infestation spots in the area covered by the photography. Further, it was assumed (after looking at a comparison of some ground counts with counts made on the 1:5,500 scale photos) that the number of trees counted in each infestation was correct. This is a reasonable assumption since those few missed are usually suppressed trees with little commercial value.

7. Once we had completed the photo interpretation and defined the special criteria and assumptions to be used in handling the data, we proceeded with the analysis. The first step was to determine the relationship between the number of trees counted in each infestation spot on the test scale photography and the number of trees counted in the corresponding infestation spot on the ground truth (1:5,500) photography. Next, the data obtained from each test scale were plotted against the ground truth (1:5,500) data. Figures 2, 3, and 4 show the trees counted per infestation spot on the test scale versus the trees counted in the corresponding infestation spot on the ground truth (1:5,500) scale. With the exception of the 1:400,000 scale data (where there were too few samples) the configuration of the data appeared to be suitable for a linear regression analysis. Regardless, a linear regression analysis was made for each test scale. If a spot was not detected on the test scale, it was considered a zero count and included as such.

The next step was to determine the probability of detecting a spot of a given size. An infestation spot detected on the test scale was considered to be in the same category as its corresponding infestation spot on the ground truth (1:5,500) scale. The probability of detection in each size category is then the ratio between the number of spots counted on the test scale to the number of spots counted on the ground truth (1:5,500) scale. Then we determined the proportion of all spots in each size category on the ground truth (1:5,500) scale. The detection probabilities and proportions by spot size categories are shown in Table 2.

8. The techniques developed above can now be applied using photography of equivalent scale, film type, and season:

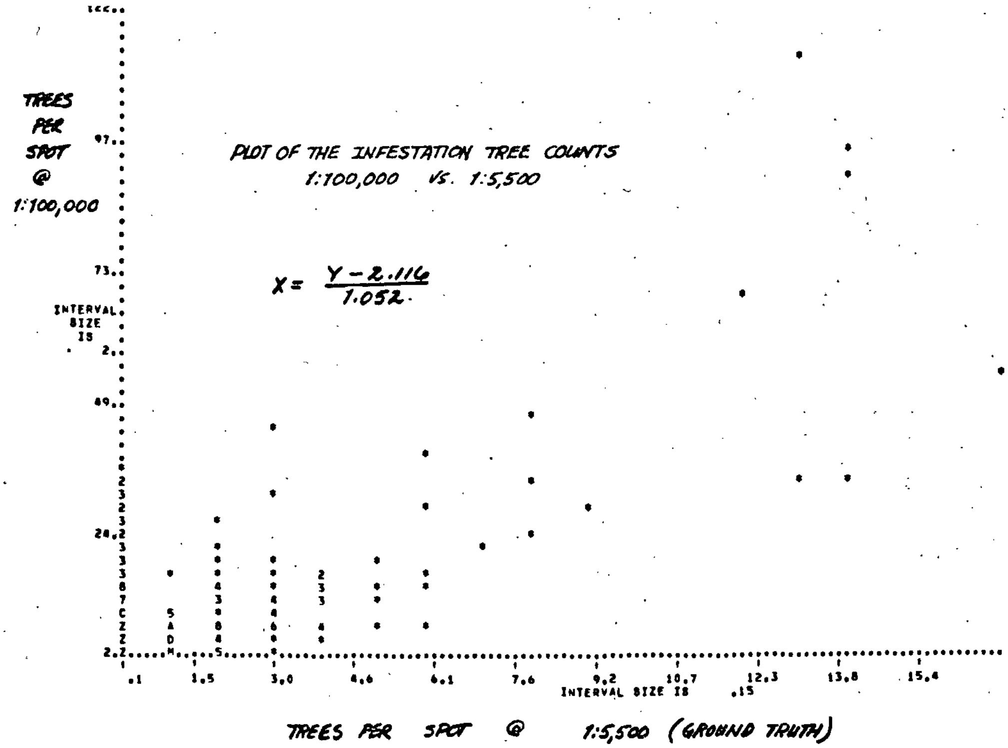

Figure 3. A plot of the number of trees counted per infestation spot on the ground truth (1:5,500) scale versus the 1:100,000 test scale.

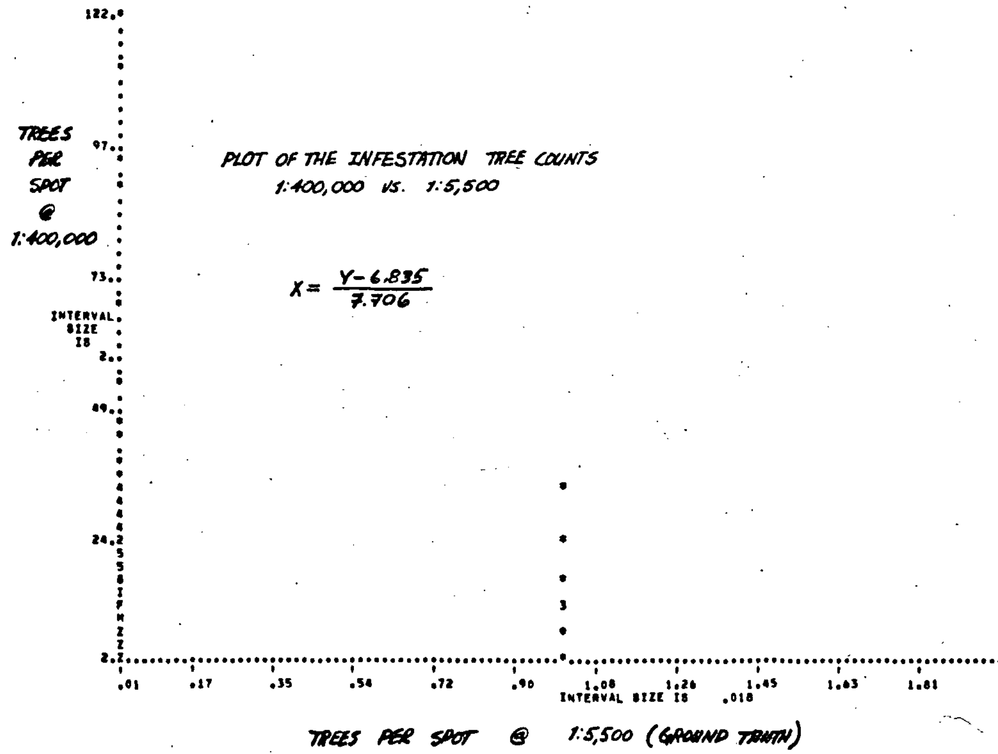

Figure 4. A plot of the number of trees counted per infestation spot on the ground truth (1:5,500) scale versus the 1:400,000 test scale.

a. First for each infestation spot detected, the photo tree count is adjusted using the appropriate regression equation.

b. Then using the adjusted tree count, each infestation spot is placed in the appropriate category.

c. The total number of infestation spots in a given category is then divided by the probability of detecting that category. This will give the estimated total number of infestation spots in that category.

d. Multiplying the estimated total number of spots by the average number of trees gives the total number of beetle-killed trees in the category.

e. The sum of the totals in each category will give the estimated total number of beetle-killed trees for the infestation area.

f. In the event a category is missed entirely (as on the 1:100,000 and the 1:400,000 scale photography), a proportion can be used to determine the number of beetle-killed trees that would be expected in that category.

9. Several tests were applied to the regression equation to determine its reliability (Table 3). First an F test was applied to determine the ratio between the regression mean squares and the residual mean squares, i.e., the ratio of the variation explained by the regression to the variation that is not explained by the regression. The F value obtained for the 1:32,000 scale data was significant at the 99 percent level. This level of significance is acceptable. The second test was to compute the correlation coefficient. In addition, the correlation coefficient was significant at the 95 percent level. However, it is understood that this test is not as powerful (statistically speaking) as the F test. The correlation test measures the degree of linear association between two variables, but it does not tell how well the regression line fits the data. In the final test we computed the coefficient of determination which is the correlation coefficient squared. In the case of the 1:32,000 scale data the value i 0.535. This indicates that 53.5 percent of the variation is accounted for by the regression. This is unacceptably low.

Based on our results to date we do feel that the simple linear regression model tested was suitable for the data. Additional work with the 1:32,000 scale data seemed to substantiate our belief. The shape of the residual plot in Figure 5 appears to indicate that a weighted least-squares model would be more appropriate than the simple

Table 3. Results of the regression analysis are shown in the calculated statistics.

Test Procedure	Scale of Photography 1:32,000	1:100,000	1:400,000
F test of the variances[1]	595.947[2]	609.405[2]	5.196[3]
Correlation coefficient[4]	0.728[2]	0.732[2]	0.099[3]
Coefficient of determination	0.530	0.535	0.010

[1] Degrees of freedom = 1/528

[2] Statistical significance greater than 99%

[3] Statistical significance greater than 95%

[4] Degrees of freedom = 528

Table 4. A large increase in bark beetle activity in the Black Hills is shown by the comparison of May and September 1972 photo interpretation results.

	MAY[1]		SEPTEMBER[2]		CHANGE	
Infestation Category	Total Spots	Total Trees*	Total Spots	Total Trees*	No. of Spots	No. of Trees
1	1,128	1,128	8,201	8,201	+ 7,073	+ 7,073
2	821	7,395	1,393	12,537	+ 572	+ 5,142
3	217	3,019	317	4,438	+ 100	+ 1,419
4	96	3,821	131	5,240	+ 35	+ 1,419
5	6	973	8	1,296	+ 2	+ 323
6	3	750	3	750	0	0
TOTAL	2,271	17,086	10,053	32,462		

* Total spots times the estimated average number of trees per spot

[1] 1:34,000, 2443 color infrared

[2] 1:32,000, 8443 color infrared

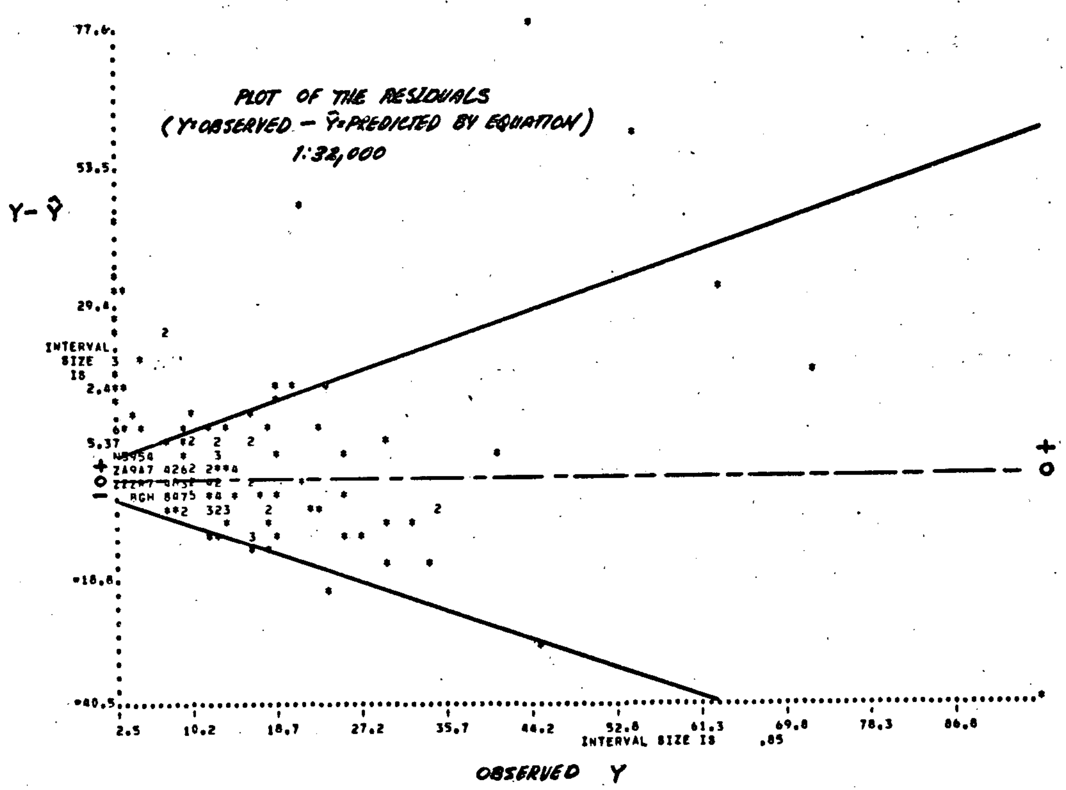

Figure 5. A plot of the residual values of Y for the 1:32,000 test scale. The plotted points represent the value obtained by subtracting the Y value predicted for a given X value, using the linear equation, from the corresponding observed Y value.

linear model. Analysis of the data interpreted from the 1:100,000 scale photographs was similar to that for the 1:32,000 scale. The problems with the 1:400,000 scale data are due to the small number of infestations actually identified. It was far too small a number to provide reliable results from the data analysis. The quality of the 1:400,000 scale photos was relatively poor, with only the center 20 mm of the frame (on 70 mm photos) being of sufficient quality for interpretation.

As might be expected, the probability of detecting an infestation spot increases with spot size and scale with the exception of data from the 1:400,000 scale (Table 2). However, an interesting exception was noted in that on both 1:32,000 and 1:100,000 scale photography the probability of detecting a category of 11 to 20 trees is greater than the probability of detecting a category of 21 to 50 trees. The explanation for this may be found in the grouping of spot sizes or it may be an artifact in the data due to insufficient sampling.

10. A separate problem that arose during the 1972 season involved the use of two different CIR film emulsions for aerial photography (Table 1). The May 1972 CIR photography was taken at a scale of 1:34,000 which makes it comparable to the September CIR photography at a scale of 1:32,000. However, the imagery in May was exposed on Eastman Kodak 8443 emulsion whereas September imagery was exposed on 2443 emulsion. In addition, there were conflicts caused by the biology of the mountain pine beetle in the Black Hills. Because the bark beetles produce just one generation a year and the successfully attacked trees begin fading in August of the following year, the two sets of Forest Service photography taken in 1972 represent detection of damage from two successive generations of beetles. The two sets of photos were used, therefore, to detect and inventory the change in the level of beetle activity from 1971 to 1972 within the 11-township infestation area. However, planned analysis of this data depended on the development of a successful analytical model for adjusting tree counts in the detected infestations. We do not believe our linear regression model, as it now exists, is adequate for that purpose, but work is continuing to improve it. Thus, we are limited to comparing the interpretation data as it was obtained from the photography without adjustment for scale error (Table 4). Because the data have not been adjusted for scale error, they should be viewed only as a comparison of relative numbers. With this in mind, it is quite clear that there was a sizable increase in the beetle activity and resulting infestation damage between 1971 and 1972.

Application of DCP-Collected Ground Truth Data:

1. Establishment of an ERTS-1 intensive study site was begun during May 1972 for the purpose of measuring radiometric responses of

the principal components of the Black Hills, South Dakota, ponderosa pine ecosystem. Our primary concern was to provide closeup spectral radiometric ground truth of the relation between healthy ponderosa pine and the trees which were under stress from attack by the mountain pine beetle. It was deemed important to monitor spectral radiometric information on two additional ecosystem components: (1) open pastures and grasslands which occupy the majority of nonforest land in the Black Hills and (2) soil and rock outcrops which provide the targets of greatest reflectance contrast with the forest. The rock outcrops provide important control points because they are easily identifiable within the forest on small-scale imagery.

2. Many different biophysical and atmospheric parameters were measured throughout the test site (Tables 5, 6, and 7), but the most important was absolute target reflectance. These data were obtained in terms of scene radiance and irradiance as measured with our RS-2 ERTS-1-matched spectral radiometers. One of the four-channel radiometers was positioned over each of four locations within the study site (over healthy pine, beetle-killed pine, grassland pasture, and rock outcroppings). Each instrument was positioned at the top of an instrument tower in a way that would provide a clear vertical (downward-looking) view of the target from a height of 7 meters (m).

In practice, the RS-2 spectral radiometers (Figure 6) provide continuing information of importance in each of the ERTS multispectral scanner (MSS) bands for each of the ecosystem targets. Figure 7 shows the calibrated radiance output at five levels for each radiometer detector. Due to the slightly different spectral responsivities of each detector-filter combination, there is a different calibrated radiance for a given neutral density level. For the calibration data (Figure 8), the detector response was measured for each channel as a function of changing target exitance, with target exitance being the energy in watts per unit area of each target. Detector response levels are for unamplified signals from Pin 10 DP detectors with a 10° field-of-view. In operation the output signals from each of the spectral radiometer channels is amplified with a UDT-101 (M) at a gain of 10 before entering the recording system. Figure 9 shows the spectral responsivities of the RS-2 detectors for five levels of absolute target reflectance.

3. In addition to recoding target reflectances at each test site with the RS-2 radiometers, additional data collected include net allwave radiation and upwelling shortwave radiation. At one central location, instruments measure the spectral components of downwelling radiation, atmospheric water vapor content, temperatures, and windspeeds.

4. Instrumentation data from all four sites are wired into a central data recording facility where sensor signals are amplified and

Table 5. Channel assignments for ground truth sensors and multiplex hookup are shown for data collection platform number 71 located at the Black Hills, South Dakota, test site (N44° 16' 103°47'W)

Channel Number	Multiplexer Commutation Level 1	2	3
1	scene radiance (0.5 to 0.6 μm) healthy pine	scene radiance (0.5 to 0.6 μm) grass pasture	irradiance (0.5 to 0.6 μm)
2	scene radiance (0.6 to 0.7 μm) healthy pine	scene radiance (0.6 to 0.7 μm) grass pasture	irradiance (0.6 to 0.7 μm)
3	scene radiance (0.7 to 0.8 μm) healthy pine	scene radiance (0.7 to 0.8 μm) grass pasture	irradiance (0.7 to 0.8 μm)
4	scene radiance (0.8 to 1.1 μm) healthy pine	scene radiance (0.8 to 1.1 μm) grass pasture	irradiance (0.8 to 1.1 μm)
5	scene radiance (0.5 to 0.6 μm) beetle-killed pine	scene radiance (0.5 to 0.6 μm) rock outcrop	evapotranspiration
6	scene radiance (0.6 to 0.7 μm) beetle-killed pine	scene radiance (0.6 to 0.7 μm) rock outcrop	rain gauge
7	scene radiance (0.7 to 0.8 μm) beetle-killed pine	scene radiance (0.7 to 0.8 μm) rock outcrop	air temperature
8	scene radiance (0.8 to 1.1 μm) beetle-killed pine	scene radiance (0.8 to 1.1 μm) rock outcrop	water temperature

Table 6. Channel assignments for ground truth sensors and multiplex hookup are shown for data collection platform number 63 located at the Black Hills, South Dakota, test site (N44°16' 103°47'W)

Channel Number	Multiplexer Commutation Level 1	2	3
1	downwelling radiation (0.4 to 4.1 μm)	net allwave radiation rock outcrop (0.4 to 15 μm)	wind speed, forest (22-meter level) downwind component
2	upwelling radiation healthy pine (0.4 to 4.1 μm)	thermal exitance healthy pine (8.0 to 15.0 μm)	wind speed, forest (22-meter level) crosswind component
3	upwelling radiation beetle-killed pine (0.4 to 4.1 μm)	thermal exitance beetle-killed pine (8.0 to 15.0 μm)	wind speed, forest (22-meter level) vertical component
4	upwelling radiation pasture (0.4 to 4.1 μm)	forest dewpoint 3-meter level	soil temperature, forest 1 (surface)
5	upwelling radiation rock outcrop (0.4 to 4.1 μm)	forest dewpoint 22-meter level	soil temperature, forest 1 (0.15 meter)
6	net allwave radiation healthy pine (0.4 to 15.0 μm)	pasture dewpoint 1-meter level	soil temperature, forest 2 (surface)
7	net allwave radiation beetle-killed pine (0.4 to 15.0 μm)	soil temperature, pasture (surface)	soil temperature, forest 2 (0.15 meter)
8	net allwave radiation pasture (0.4 to 15.0 μm)	soil temperature pasture (0.15 meter)	air temperature, forest (22-meter level)

Table 7. Channel assignments for ground truth sensors and multiplex hookup are shown for data collection platform number 85 located at the Black Hills, South Dakota, test site (N44°16' 103°47'W)

Channel Number	Multiplexer Commutation Level 1	2	3
1	soil moisture, F-1 (0.05-meter level)	soil moisture, F-1 (1.0-meter level)	soil moisture, F-3 (0.5-meter level)
2	soil moisture, F-2 (0.05-meter level)	soil moisture, F-2 (1.0-meter level)	soil moisture, F-4 (0.5-meter level)
3	soil moisture, F-1 (0.15-meter level)	soil moisture, F-3 (0.05-meter level)	soil moisture, F-3 (1.0-meter level)
4	soil moisture, F-2 (0.15-meter level)	soil moisture, F-4 (0.05-meter level)	soil moisture, F-4 (1.0-meter level)
5	soil moisture, F-1 (0.5-meter level)	soil moisture, F-3 (0.15-meter level)	leaf temperature healthy pine
6	soil moisture, F-2 (0.5-meter level)	soil moisture, F-4 (0.15-meter level)	leaf temperature beetle-killed pine
7	totalized wind speed	totalized wind speed	totalized wind speed
8	totalized wind speed	totalized wind speed	totalized wind speed

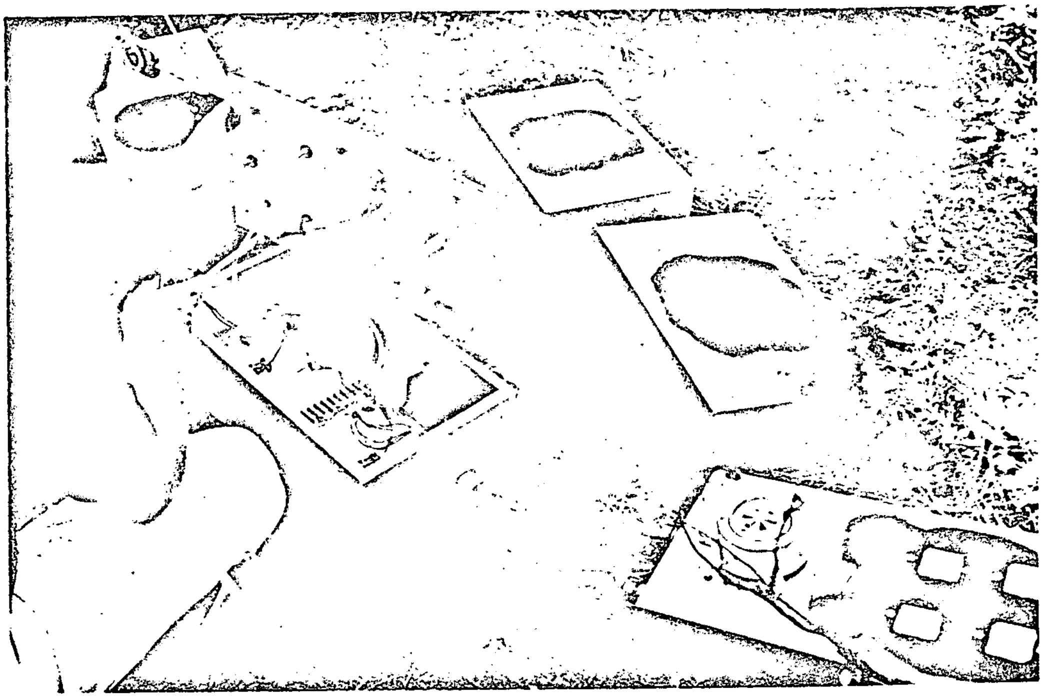

Figure 6. RS-2 spectral radiometers

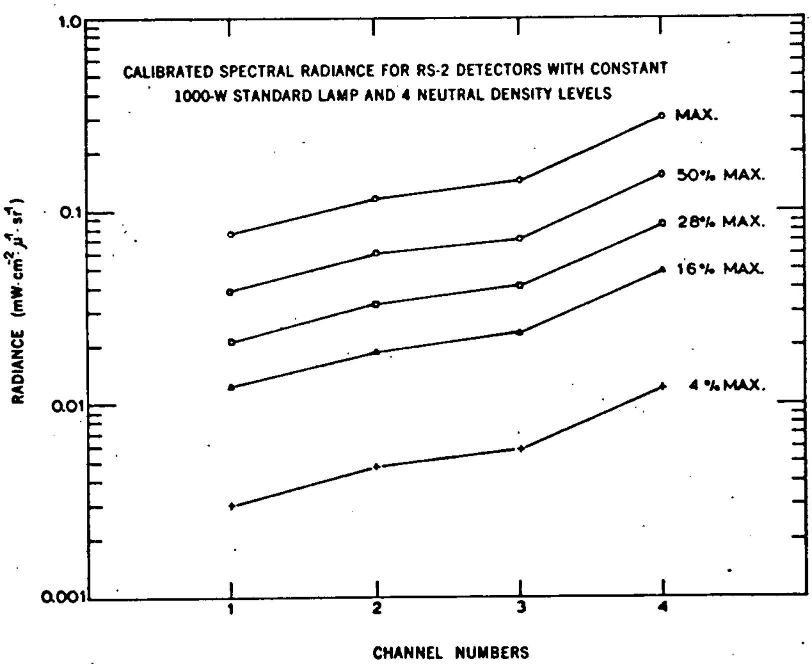

Figure 7. Calibrated spectral radiance for RS-2 detectors

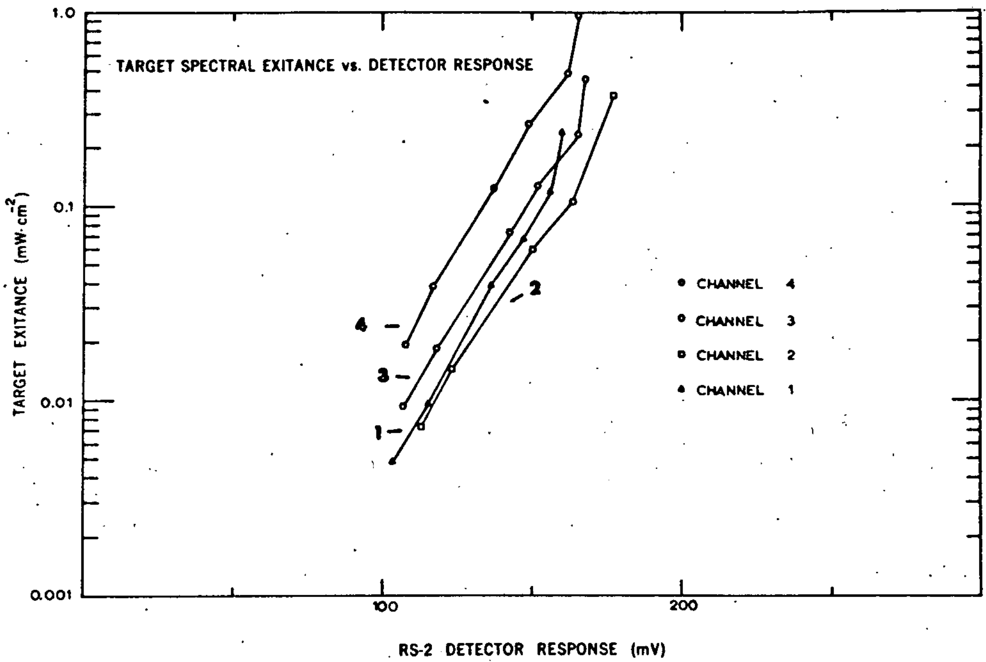

Figure 8. Target exitance versus detector response for RS-2 radiometers.

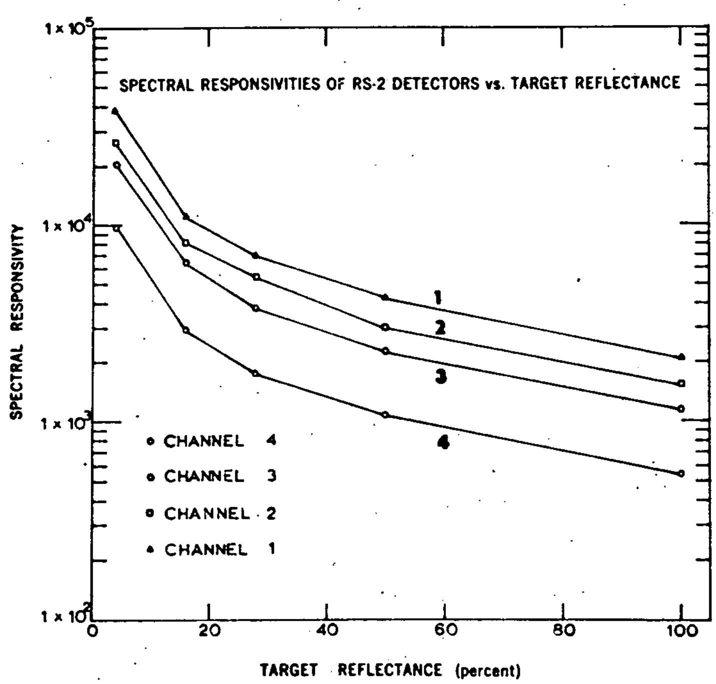

Figure 9. Spectral responsivities of the RS-2 detectors for five levels of absolute target reflectance.

multiplexed for broadcast over the ERTS DCS via three DCP's (Figure 10). In all, 72 channels of data are multiplexed over 24 DCP channels. At the same time that instrumentation data enter the DCP buffers they are recorded in parallel on a digital data acquisition system (D-DAS). As the instrumentation laboratory is located within the forest, it was necessary to mount the DCP antennas at the top of a 32 m instrumentation tower, as shown in Figure 11.

5. Two satellite images of the Black Hills were selected for the purpose of scene correlations between ground truth data and ERTS MSS scene radiance data. Scene 1047-17175 provides clear coverage of the western Black Hills for September 8, 1972, on MSS channels 4, 5, and 7. Ground truth data collected the same day on the data collection system and the data acquisition system are shown in Table 8. Scene 1065-17175 provides partially open coverage of the north-central Black Hills on September 26, 1972, when all channels of the MSS were working well. Table 9 shows the ground truth data collected simultaneously by the D-DAS and the DCS.

For the purpose of scene radiance analysis of the ERTS images, microdensitometer scans were made of several transects on each image and all available spectral bands. Scan densities were converted to scene radiance for each 70 mm bulk data scene using calibration data taken from the 15 step wedge on each scene. Several of the scans made on the September 26 scene are transects across our intensive study sites. Radiance data were correlated to scene points using proportional distances from control points which could positively be identified on both the satellite images and the RB-57 small-scale photography taken on Mission 211, September 14, 1972.

As a result of daily monitoring of Black Hills radiometric instruments we are now beginning to get a clearer picture of spectral energy relationships in the ponderosa pine ecosystem over time. For example, Table 10 shows how albedo of the rock outcroppings was unchanged from September 8 to 26, whereas the albedo of the pasture increased 3 percent. During the same period healthy ponderosa pine showed a 1 percent decrease while bark beetle-killed pine increased by 1 percent. In addition to knowing trends, the implication is that we now know for any satellite scene the relation of absolute reflectances between different ecosystem components.

Scene radiance data obtained from the September 8 imagery of the Black Hills is shown in Table 11.

The 70 mm bulk imagery is fully adequate for extracting the scene radiance signatures of some ecosystem targets such as healthy ponderosa pine and rock outcroppings, using precision microdensitometry.

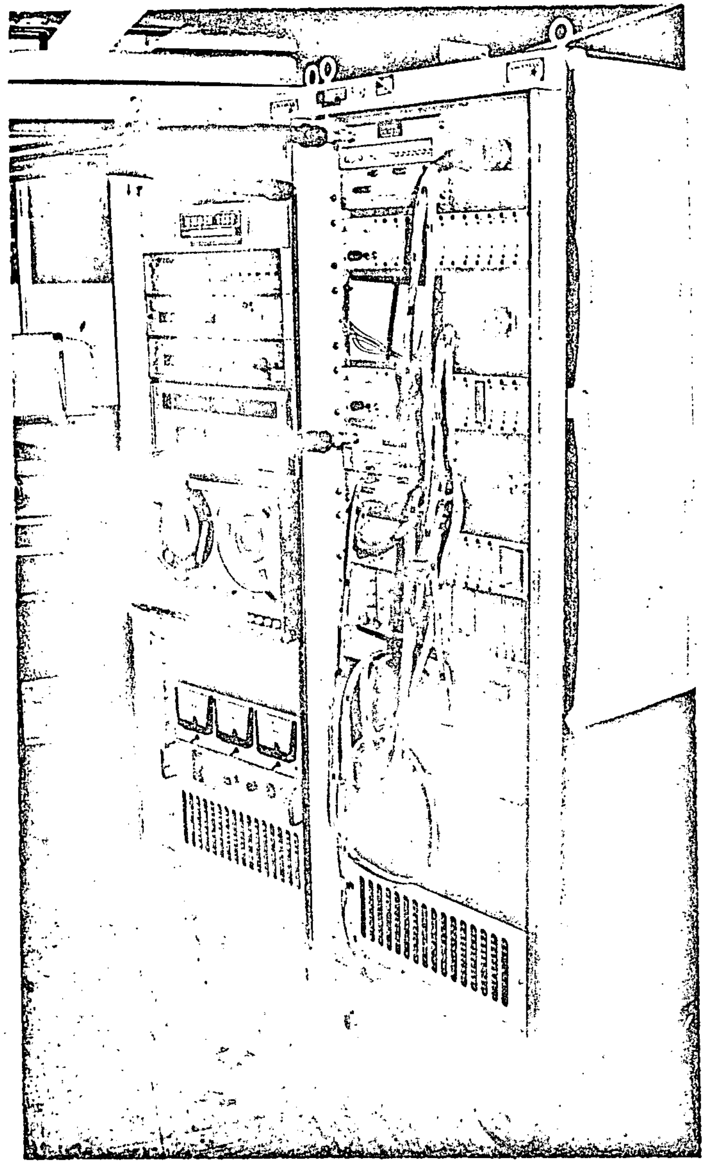

Figure 10. Digital data acquisition system (left) DCP and multiplexer console (right).

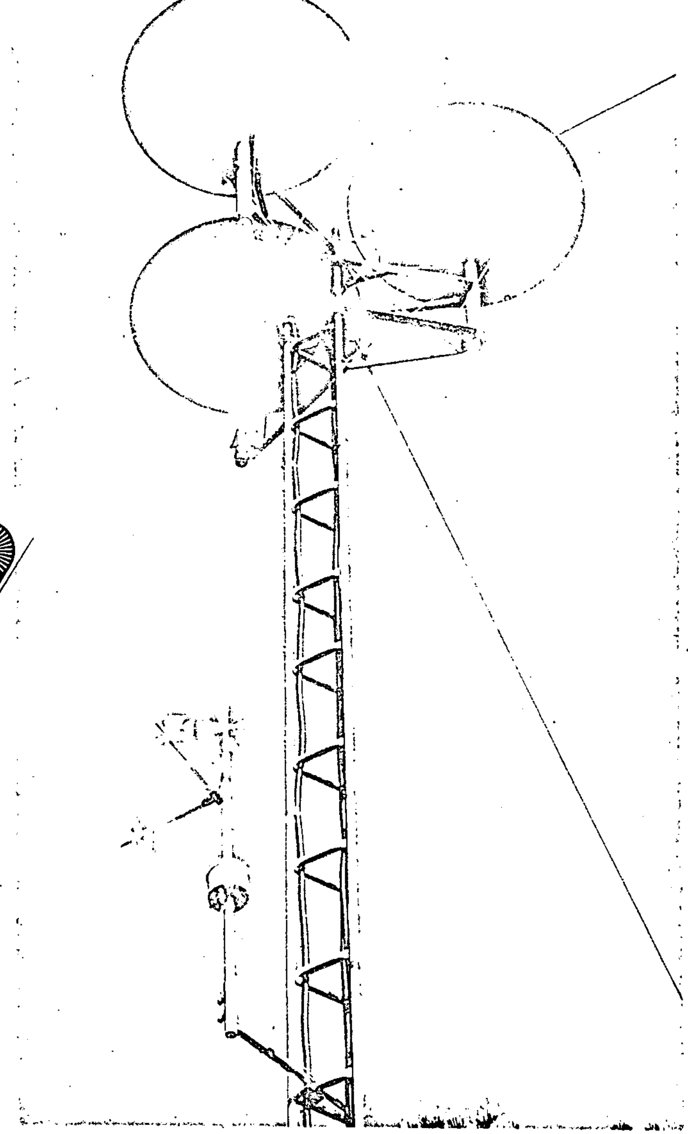

Figure 11. The 401.55 MHz data collection platform transmit antennas are located at the top of a 23-meter instrument tower.

Table 8. Energy balance data as monitored on the Vidar 5403 digital data acquisition system is shown for four ecosystem components on September 8, 1972. Comparable data transmitted through the ERTS 1 data collection system from the Black Hills, South Dakota, test site are shown for three daytime transmissions.

ENERGY BALANCE (milliwatts/cm^2)

		Shortwave radiation (0.4 to 4.1 μm)			Net allwave radiation (0.4 to 15 μm)			
		Downwelling	Upwelling					
Time	System		Healthy	Dead	Healthy pine	Dead pine	Pasture	Rock outcrop
0800	D-DAS	47.46	4.46	7.35	41.67	41.38	40.08	38.46
0833*	D-DAS	51.61	5.15	7.66	45.22	44.91	43.43	41.65
	DCS	51.47	5.41	7.95	45.22	44.78	43.41	41.90
0900	D-DAS	55.81	5.88	9.01	48.95	48.52	46.89	41.64
1000	D-DAS	67.96	7.48	10.20	57.02	59.13	57.09	54.79
1017*	D-DAS	71.67	7.88	10.75	62.89	62.29	59.96	57.73
	DCS	73.20	7.95	10.99	63.15	63.05	60.71	58.03
1100	D-DAS	77.85	8.58	11.70	68.25	67.53	65.21	62.69
1200*	D-DAS	80.35	8.84	12.06	70.40	67.79	67.39	64.79
	DCS	79.82	8.65	12.00	71.05	70.54	67.00	64.01
1300	D-DAS	78.14	8.60	11.74	68.51	67.74	65.58	62.98
1400	D-DAS	69.63	7.67	10.47	60.89	60.52	58.49	56.13
1500	D-DAS	53.47	5.44	8.10	46.93	46.60	45.00	43.18
1600	D-DAS	30.98	3.26	4.49	27.24	27.03	26.14	25.06

* Simultaneous recordings from ground DAS and ERTS DCS.

Table 9. Energy balance data as monitored on the Vidar 5403 digital data acquisition system is shown for four ecosystem components on September 26, 1972. Comparable data transmitted through the ERTS 1 data collection system from the Black Hills, South Dakota, test site are shown for three daytime transmissions.

ENERGY BALANCE (milliwatts/cm^2)

		Shortwave radiation (0.4 to 4.1 μm)			Net allwave radiation (0.4 to 15 μm)			
		Downwelling	Upwelling					
Time	System		Healthy	Dead	Healthy pine	Dead pine	Pasture	Rock outcrop
0800	D-DAS	23.65	2.16	3.32	21.58	20.47	19.47	19.14
0834*	D-DAS	26.63	2.39	3.91	24.29	22.95	21.82	21.47
	DCS	26.65	2.67	3.85	24.52	22.18	21.56	21.10
0900	D-DAS	31.06	2.73	4.96	28.45	26.81	25.49	25.08
1000	D-DAS	40.46	2.94	6.48	36.78	34.91	33.20	32.66
1017*	D-DAS	46.59	4.58	7.46	42.33	40.00	38.17	37.52
	DCS	45.98	4.50	7.19	42.01	39.85	38.00	37.25
1100	D-DAS	48.92	4.99	7.84	44.40	42.12	40.02	39.34
1202*	D-DAS	69.17	6.85	11.24	62.90	59.60	56.67	55.76
	DCS	70.00	6.98	11.52	63.58	59.93	56.65	56.17
1300	D-DAS	51.59	5.11	8.26	46.91	44.48	42.26	41.61
1400	D-DAS	46.04	4.58	7.35	41.82	39.69	37.74	37.10
1500	D-DAS	35.51	3.19	5.32	32.27	30.66	29.15	28.65
1600	D-DAS	12.79	1.02	1.79	11.68	11.06	10.52	10.33

* Simultaneous recordings from ground DAS and ERTS DCS.

Table 10. The relationship between albedos is shown for four Black Hills, South Dakota, ecosystem components at the time of two ERTS-1 passes in September 1972.

	Percent Albedo[1]	
Target	September 8	September 26
Healthy pine	11	10
Beetle-killed pine	15	16
Pasture grass	19	22
Rock outcrop	24	24

[1] Albedo is the ratio of upwelling to downwelling shortwave radiation

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Table 11. Black Hills scene radiance data for September 8, 1972, are derived from microdensitometer analysis of black-and-white 70 mm bulk data positives for scene 1047-17175.

	Scene Radiance (milliwatts/cm^2-SR)		
		MSS Channel[1]	
Target	4	5	7
Healthy pine	0.333	0.188	0.847
Beetle-killed pine	0.344	0.229	0.983
Lake	0.339	0.200	0.675
Rock outcrop	0.418	0.270	1.218
Macadum road	0.394	0.194	0.953
Concrete highway	0.339	0.239	1.062
Mine tailings	0.354	0.239	1.062
New logging road	0.333	0.243	1.014
Tornado area	0.414	0.300	1.206

[1] Imagery received for channel 6 was unusable because of the large number of data dropouts.

However, even better calculations can be made from measurements of hard-to-pinpoint targets like bark beetle infestation areas when the 9 1/2-inch black-and-white bulk imagery becomes available.

When it became apparent, with the first heavy snowfall of the season, that we were not going to get ERTS-1 imagery of the Black Hills that was free of clouds over the entire study area during 1972, we settled on the September 26 scene for intensive analysis. We have examined color recombinations of this scene created to optimum illumination levels in our I^2S viewer. The best enhancements of the enlarged color recombination were photographed on color transparency film for further study in a VARISCAN viewer where scene point correlations were made. Significantly, we were able to retain good quality ecosystem scene point recognition when the image was enlarged to a viewing scale of 1:32,000 on the VARISCAN screen. This was a useful step in becoming familiar with scene points before measuring the scene radiance with the microdensitometer scans. Table 12 shows the calculated scene radiance for the September 26 imagery of the Black Hills.

The significance of scene radiance calculations on the MSS imagery is illustrated in Table 13 where they are compared to scene radiance measurements made of similar ecosystem targets on the ground which were transmitted to us by the data collection system. It is noteworthy that here we are getting the first data which show the effect of atmosphere on radiance values as measured on imagery when compared to that which exists near the ground. Prior to this time we have only had predictions of what should happen using a generalized model. We see the greatest effect of atmosphere on MSS channel 4 where there is greater than 30 percent overall increase in scene radiance on the satellite imagery. For the infrared channel 7 there is less than 10 percent overall difference in measured values, with the ground-measured radiance being the higher.

At this time much detailed work remains with extracting data from the September 1972 imagery. However, we feel there is a practical limit to the effort which will be expended. First, the all-critical MSS channel 6 data is missing or unusable for the September 8 image, in addition to the fact that this scene misses the major part of our test site. As for the September 26 scene, the atmospheric conditions were somewhat less than favorable over the Black Hills, although a small area directly over our intensive study site was open and in the sun. However, analysis of the DCP-collected data from that satellite pass showed that the atmospheric water content was high. (Relative humidity measured at the test site at the time of the satellite overflight was 82 percent.)

Table 12. Black Hills, South Dakota, scene radiance data for September 26, 1972, are derived from microdensitometer analysis of black-and-white 70 mm bulk data positives for scene 1065-17175.

Target	Scene Radiance (milliwatts/cm^2-SR) MSS Channel 4	5	6	7
Healthy pine	0.154	0.087	0.158	0.392
Beetle-killed pine	0.140	0.093	0.144	0.399
Pasture grass	0.214	0.148	0.239	0.601
Macadum road	0.213	0.105	0.173	0.440
Rock outcrop	0.316	0.204	0.353	0.920
Open pit gold mine	0.250	0.170	0.311	0.805
Golf course	0.217	0.156	0.244	0.628

Table 13. The relationship is shown between scene radiance data measured on ERTS-1 MSS imagery (scene 1065-17175) and that measured on the ground in the Black Hills by the RS-2 spectral radiometers.

	Scene Radiance (milliwatts/cm^2-SR) MSS Channel 4		5		6		7	
Target	ERTS	Ground	ERTS	Ground	ERTS	Ground	ERTS	Ground
Healthy pine	.154	.102	.087	.065	.158	.179	.392	.468
Beetle-killed pine	.140	.093	.093	.101	.144	.135	.399	.506
Pasture grass	.214	.141	.148	.149	.239	.280	.601	.646
Rock outcrop	.316	.219	.204	.199	.353	.358	.920	.999

Assistance Provided to Related ERTS Projects:

1. F. P. Weber spent one week during January in Alaska providing training assistance to the Resource Planning Team of the Alaskan Land Commission, the Geophysical Institute of the University of Alaska, and the Institute of Northern Forestry. Since returning, he has provided continuing assistance through consultations and analysis of two ERTS-1 scenes of the Cook Inlet Basin of Alaska. Within these scenes, large spruce beetle infestations, which have already killed two billion board feet of spruce, occur and are indicative of forest stress conditions. Approximately 50 color recombinations of the Alaskan satellite scenes were made on our I^2S color recombiner, and the best 10 were subjected to scene analysis on the VARISCAN viewer. After providing preliminary interpretation analysis of the scenes, the color recombinations ranging in scale from 1:3,500,000 to 1:35,000 were sent to the Geophysical Institute in Fairbanks for further analysis.

WORK PLANNED FOR NEXT REPORTING PERIOD:

1. We expect to complete interpretation of the 1:32,000 CIR transparencies of the Black Hills and transfer locations of bark beetle infestations and other ecosystem components to 1:24,000 USGS maps with the Zoom Transfer Scope. UTM coordinates will be determined as part of the same task.

2. Further refinement of the photo interpretation analysis will be continued using transformations of the data to get a better regression predictor for numbers of trees and numbers of infestations versus photo scale.

3. All of the field instrumentation will be brought into the laboratory in Berkeley for six weeks of modification work and recalibration. We expect to have the site in full operation again by May 10.

4. If the precision tapes of scene 1047-17175 and 1065-17175 are received in Berkeley, we will begin analysis and mapping work.

SIGNIFICANT RESULTS:

1. Comparisons of scene radiance data calculated from ERTS-1 images with that measured on the ground show the image-measured values to be more than 30 percent higher for the green channel and 20 percent higher for the red channel for the same scene targets. Radiance values for channels 6 and 7 are nearly the same from the ground data and from the imagery.

PUBLICATIONS:

1. Weber, F. P. 1973. DCP-collected absolute target reflectance signatures assist accurate interpretation of ERTS-1 imagery. To be published in the Proceedings from the first annual ERTS review meeting, Greenbelt, Maryland, March 5-9, 1973.

RECOMMENDATIONS FOR CHANGES: None at present

STANDING ORDER FORM CHANGES: None

ERTS IMAGE DESCRIPTOR FORMS: 13 submitted

DATA REQUEST FORM CHANGES: None

TITLE: Inventory of Forest and Rangeland and Detection of Forest Stress

ERTS Proposal Number 226

Atlanta Test Site (Forest Inventory) 226B

Coinvestigator: Robert C. Aldrich

GSFC Identification Number AG-014

Principal Investigator - Robert C. Heller

STATEMENT OF PROBLEMS:

1. One major problem continues to be obtaining adequate ERTS imagery to cover the test site. The best scene that we have received to date has been 1084-15440 (October 15, 1972). This scene covered the eastern two-thirds of the site. A more recent coverage, for almost the identical area, is scene 1174-15440 (January 13, 1973).

2. Precision data for scene 1084-15440 ordered on November 8, 1972, has been received in part. We are still waiting for the color composite to complete this order.

3. Errors in the location of 50,000 UTM internal coordinate intersections were noted on the black-and-white precision data. This was reported to the Technical Monitor, Ed Crump, and Dick Holmes of User Services on February 21.

4. A retrospective order for bulk data products made on December 20 has not been completed. RBV and MSS color composites for scene 1002-18131 (July 25) were received but were of poor quality. The RBV composite shows unexplainable dark blotches throughout the scene. The MSS composite appears to be overexposed in processing (washed out) with little green color saturation. These images appear poorer than any we have seen for the same scene.

5. Because of government hiring restrictions, we have been unable to hire a computer programmer required for our digital data analysis plan.

ACCOMPLISHMENTS DURING THE REPORTING PERIOD:

1. A vertical slide adjustment was made for the plexiglas film platen on the Zoom Transfer Scope (ZTS). The platen now slides between

aluminum channels on each side of the illuminator and allows the operator to change the vertical position of an ERTS film transparency, or aerial photograph, without removing the photograph.

2. A mapping table with illuminator was completed for the ZTS. This table allows us to compare ERTS images from different dates, or compare ERTS images with high-altitude aerial photography. This will make it possible to map changes in forest area or detect disturbances such as logging, land clearing, fire, and possibly insect damage.

3. A calibration technique was completed for the I^2S copy camera system. This system includes a precisely constructed 9- x 9-inch duplicate of the ERTS registration marks printed on stable base photographic film. The distances between registration points ("cross track" and "in track" distances) were measured on 70 mm bulk film for scene 1084-15440 using a three micrometer accuracy comparator. Each measurement was replicated four times on each of the four MSS bands. The mean of 16 comparator measurements, ERTS manual specified distances, and the differences between the two are shown below:

Direction	Mean Comparator Measurement	ERTS Specified Distance	Difference
	———	millimeters	———
Cross track	58.818	58.6	+ 0.214
In track	59.857	59.5	+ 0.353

The mean values were scaled to 1:1,000,000 by multiplying by 3.369. This resulted in the following:

Cross track distance	198.157 mm
In track distance	201.645 mm

These measurements were used to plot the four registration points to the nearest 0.01 mm on stable base material using a coordinatograph. This plot in turn was printed on photographic film as a negative. A transparency made from the negative was attached to the I^2S viewer screen during camera calibration, and a four-time positive reduction made from the same negative was attached to the focusing back of a Crown Graphic camera. By adjusting the camera position, the four registration marks on the camera back were made to agree with the four registration marks on the viewer screen.

To complete the calibration, each of the four MSS bulk 70 mm film bands was placed in its proper position in the I^2S projector and registered with the calibration transparency on the viewer surface. Calibration began with band 4 and progressed to band 7. Once band 4 was calibrated it was never changed; all other bands were aligned with band 4 to complete the calibration.

4. The geometric fidelity of both bulk and precision data for ERTS scene 1084-15440 were given a cursory check. However, attempts to check accuracy against control points must await completion of our retrospective order for precision film products and bulk film products (orders dated November 8 and December 20, 1972, respectively).

Seventy millimeter bulk data for scene 1084-15440, combined and calibrated on the I^2S viewer to a 1:1,000,000 scale, was compared with several overlay maps made on photographic film to the same scale. These overlays were prepared with both geographic and UTM intersections for comparison with ERTS tick marks. The overlays include the following:

a. A grid of 10,000-meter UTM coordinate intersections for the test site.

b. A grid of 15-minute geographic coordinate intersections for the test site.

c. Fifteen 4-mile-square study areas used in the ERAP program and the Chattahoochee River, significant lakes, and centers of several towns within the site.

d. An outline map including seven counties that will be used in the ERTS-1 study extension.

In general the results show that our calibration and scaling technique is quite accurate. That is, the geographic coordinate intersections on the overlays coincide with the spacing of geographic tick marks on the ERTS bulk image displayed on the I^2S viewer screen. However, we found that when geographic details in our overlays coincide with the same details on the ERTS image, there is a considerable discrepancy in the location of the geographic latitude tick marks. The 30-minute latitude tick marks are approximately four minutes south of their correct position. The 30-minute longitude tick marks seem to be correct.

When the overlays were superimposed on precision 10- x 10-inch film transparencies (band 5), we found that geographic coordinates and the 50,000-meter UTM tick marks were in close agreement. Again, this means that our 1:1,000,000 scale map overlays will be useful in interpretation of both bulk and precision data products. However, unless geographic grid coordinates are more accurately placed on the bulk data we will have to rely on matching control points (well-defined and recognizable points) in the ERTS scene with map locations scaled from 1:250,000 topographic map sheets.

3. All 800 data points located on ERAP Mission 191 photography have been located on 1:60,000 color infrared (CIR) from ERTS Support Mission 214. Each land use and forest classification was carefully reexamined and recorded. Any changes in classification will be corrected in the ground truth records so that ERTS data tapes for scene 1084-15440 can be processed according to our data analysis plan.

4. During this period we received additional ERTS bulk 70 mm film data which will be useful in comparisons with scene 1084-15440. Until now, this was our only source of ERTS data. A cursory examination of the new ERTS data indicates seasonal changes that should be useful in land use and forest classification. These new scenes are listed below:

Scene	Date
1102-15442	November 2, 1972
1157-15500	December 27, 1972
1174-15440	January 13, 1973

5. Early in February we received our first usable bulk CCT's. The data, representing our Atlanta test site, was acquired by ERTS on October 15, 1972. An error at the Lawrence Berkeley Laboratory computer center resulted in the loss of our data for Study Block 4. This is the same area that we have used in the past for developing automated interpretation methods on RB-57 CIR imagery. For expediency we switched our efforts to another study area--Block 2--for which we have ground truth information.

Pseudo gray scale images of Block 2 and the surrounding area were printed out for each of the four channels. The standard computer printer output was difficult to read so we color coded it by hand. Two types of noise were apparent from this coding. On the CCT for channel 5 we found two scan lines containing values out of the range of the normal values and with no usable information. We corrected this by averaging values from adjacent lines. On the CCT for channel 4 we found noise of a period of six scan lines. This caused lighter and darker streaks in our output 6 lines apart. We have made a correction for this by averaging all data values for every sixth scan line. Each of the resulting six means has been subtracted from every line of the same index, modulus 6.

The resulting gray scale image of the channel looks much improved. Histograms of the scaled radiance values were made before and after the correction. Before correcting the data the distribution was bimodal. After the correction the distribution was unimodal. The shape of the distribution is more like those of the channels without noise than it had been before the correction was made.

Progress is being made now on phase I clustering. This is the clustering of picture elements with similar scaled radiance values for all channels. This will be done in several ways. The first is to put elements into one of 16 classes depending upon their values for each of the four channels. A map is printed out and color coded; each class had a unique color. The 16 classes are determined by selecting features from the raw data such as unstandardized scaled radiance values and values standardized for brightness. A number of feature selection methods will be tried and evaluated. The evaluation is done by a photo interpreter. He will look at each color-coded map and describe what each stratum (or combination of color classes) represents. Feature selection techniques are evaluated by choosing the maps whose strata correspond to land use classes of interest to our study. The first of our phase I maps have been printed, and they are now being color coded.

Phase II clustering will compare clusters of unknown land use with clusters of known attributes. From this phase thematic maps will be produced.

WORK PLANNED FOR NEXT REPORTING PERIOD:

1. A two-man crew will spend a week to ten days in the Atlanta test site gathering ground truth. This trip will be made in conjunction with an aircraft support mission scheduled in April.

2. We will check the positional accuracy of both ERTS bulk and precision data using as control points well-defined features present on both maps and ERTS scenes. Distances between UTM coordinate intersections and control points measured (1) on the 1:1,000,000 overlay (map base) and (2) on the ERTS image will be compared.

3. Dependent upon the positional accuracy that we can expect from ERTS bulk and precision data, we will proceed with our data analysis. Interpreters will be trained to interpret eight land use and forest classes on the ERTS color-combined images made on the I^2S. The images will be enlarged for this purpose to a 1:500,000 scale on a projection viewer (8X enlargement).

4. New ERTS imagery will be examined and evaluated as it is received.

5. Work will continue on both unsupervised clustering and supervised classification procedures for automated land use classification using ERTS MSS digital data (scene 1084-15440).

SIGNIFICANT RESULTS: None

PUBLICATIONS: None

RECOMMENDATIONS FOR CHANGES: None at present

STANDING ORDER FORM CHANGES: None

ERTS IMAGE DESCRIPTOR FORMS: 5 submitted

DATA REQUEST FORM CHANGES: None

TITLE: Inventory of Forest and Rangeland and Detection of Forest Stress

ERTS Proposal Number 226

Manitou Test Site (Rangeland Inventory) 226C

Coinvestigator: Richard S. Driscoll

GSFC Identification Number AG-014

Principal Investigator - Robert C. Heller

STATEMENT OF PROBLEMS:

1. Standing order and retrospectively ordered products for site 226C have been sent to the Principal Investigator, Robert C. Heller. These products should be sent to the Coinvestigator, Richard S. Driscoll, to avoid delay in data processing, unnecessary handling of the products, and potential losses in the mail.

2. A major problem in meeting the objective of the rangeland inventory part of the experiment has been the delay in receiving retrospectively ordered ERTS-1 imagery of the Manitou test site. Rectified MSS 70 mm System Corrected Imagery (SYCI), Observation ID 1009-17075, was received February 20, 1973. The information is good, and the data from the four MSS channels match. The Scene Corrected Imagery (SCCI) in 9.5-inch positive transparency format was received March 3, 1973. The geometric fidelity of the data is good, and the imagery can be used for geographic mapping purposes. However, the radiometric data in the imagery, although expected to be inferior to the SYCI products, are not suitable for our precision analysis plans--that is, pattern recognition of plant communities using training and testing samples which have been identified by UTM coordinates.

3. Six sets of MSS SYCI data have been received that include at least a part of the Manitou test site. Only one, however, Observation ID 1028-17135, includes sufficient cloud-free area of the test site, for which we have significant ground truth, that will be suitable to use with our analysis plans. The other data sets do include small portions of the test site, but either (1) that portion of the test site included in the data is cloud covered or (2) the portion of the test site that is cloud-free is so small that the cost of doing the analyses would not be efficient for the return. Therefore, prime effort at this time will be devoted to analysis of Observation ID 1028-17135. Additional SYCI and the retrospective SCCI have been ordered for this observation but have not yet been received.

ACCOMPLISHMENTS DURING THE REPORTING PERIOD:

1. Selected training and testing cells representing different land use and plant community types, and identified by UTM coordinates, have been transferred from base maps to the supporting ERTS-1 multispectral aircraft photography. Image descriptors of the training cells are now being defined for use in (1) subsampling expected ERTS-1 imagery and (2) determining what level of integrity in the hierarchical scheme of plant community classification can be defined in ERTS-type and multiscale photographic imagery.

2. Optical imagery density measurements of ground cells imaged in three different film types with known information on multispectral radiance, standing crop biomass, and ground cover of four different grassland classes have been completed using the GAF 650 microdensitometer (MDT). Information for each cell was secured using the four (blue, green, red, and visual) standard MDT filters. These data are now being prepared for analysis to determine the relationship between spectral density, spectral radiance, and ground conditions for quantifying the ERTS and supporting aircraft imagery in relation to selected plant community parameters.

3. We made a color composite of the 70 mm SYCI MSS bands 4, 5, and 6 from Observation ID 1028-17135 using the I^2S color enhancement equipment at our Pacific Southwest Forest and Range Experiment Station remote sensing laboratory. This material was received only recently and will be used for visual analyses through projection and enlargement.

WORK PLANNED FOR NEXT REPORTING PERIOD:

1. Complete the image descriptors of multispectral/multiscale aircraft photography for land use and plant community systems and begin visual interpretation and analysis. We also plan to analyze these photographs through microdensitometry.

2. Initiate visual interpretation and analysis of our existing color composite (see Item 3 under ACCOMPLISHMENTS).

3. Initiate analyses secured from Item 2 - ACCOMPLISHMENTS.

4. If they are received, initiate computer pattern recognition analyses of the SYCI and SCCI digital tapes for Observation ID 1028-17135.

SIGNIFICANT RESULTS: None

PUBLICATIONS: None

RECOMMENDATIONS FOR CHANGES: Send all ERTS data for the Manitou test site (226C) to the coinvestigator:

Richard S. Driscoll
Rocky Mountain Forest & Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521

STANDING ORDER FORM CHANGES: Send two copies of all standing order products.

ERTS IMAGE DESCRIPTOR FORMS: 6 submitted

DATA REQUEST FORM CHANGES: Send two copies of each retrospective order except the CCT's. Send a new pad of Data Request Forms.