Table 1 Summary configuration and flow data

Conical boattail		Base-flow variables										
$\bar{L}$	$-\beta_{2E}$	$\bar{X}_{1I}$	$\bar{R}_{1I}$	β_{1I}	γ_I	M_{1I}	$\bar{X}_{1E}$	$\bar{R}_{1E}$	γ_E	M_{1E}	$\mathcal{R}_I$	$\bar{T}_{0E}$
2	0–11.309	0	0.6	0°	1.4	2.5	0	1–0.6	1.4	2	1	1

that can be achieved with combined base bleed and boattailing as compared to base bleed only.

The foregoing results, which were presented to demonstrate the optimization and evaluation techniques, have been limited to a single boattail geometry and length, as well as a limited operating pressure range. However, these results are representative of the data which can be generated readily with existing computer programs[5,6] and of the bases for optimization and appraisal of over-all system performance.

References

[1] Sedney, R., "Review of Base Drag," *The Fluid Dynamic Aspects of Ballistics*, NATO-AGARD CP 10, Paris, France, Sept. 1966, pp. 211–240.

[2] Brazzel, C. E. and Henderson, J. H., "An Empirical Technique for Estimating Power-On Base Drag of Bodies-of-Revolution with a Single Jet Exhaust," *The Fluid Dynamic Aspects of Ballistics*, NATO-AGARD CP 10, Paris, France, Sept. 1966, pp. 241–261.

[3] Korst, H. H., Addy, A. L., and Chow, W. L., "Installed Performance of Air-Augmented Nozzles Based on Analytical Determination of Internal Ejector Characteristics," *Journal of Aircraft*, Vol. 3, No. 6, Nov.–Dec. 1966, pp. 498–506.

[4] Korst, H. H., Chow, W. L., and Zumwalt, G. W., "Research on Transonic and Supersonic Flow of a Real Fluid at Abrupt Increases in Cross Section (with Special Consideration of Base Drag Problems)—Final Report," ME-TN 392-5, Dec. 1959, Univ. of Illinois, Urbana, Ill.

[5] Addy, A. L., "Analysis of the Axisymmetric Base-Pressure and Base-Temperature Problem with Supersonic Interacting Freestream-Nozzle Flows Based on the Flow Model of Korst, et al., Part I: A Computer Program and Representative Results for Cylindrical Afterbodies," RD-TR-69-12, July 1969, U.S. Army Missile Command, Redstone Arsenal, Ala.

[6] Addy, A. L., "Analysis of the Axisymmetric Base-Pressure and Base-Temperature Problem with Supersonic Interacting Freestream-Nozzle Flows Based on the Flow Model of Korst, et al., Part III: A Computer Program and Representative Results for Cylindrical, Boattailed, or Flared Afterbodies," RD-TR-69-14, Feb. 1970, U.S. Army Missile Command, Redstone Arsenal, Ala.

Machine-Aided Photo Interpretation Techniques for Vegetation Analysis

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LARGE-SCALE "operational" survey missions, using Earth-orbital satellite sensing platforms, are planned to begin as early as 1972. Efficient data handling schemes are needed to keep pace with the rates at which such missions can collect and subsequently return or transmit remotely sensed data. This Note explores some of the capabilities which various remote sensing systems offer, in terms of spatial resolution and user requirements, for obtaining rapid land-use inventories.

Desired Inventory Information and Sensor Resolutions

With respect to vegetation-oriented resource inventories in the U.S., the land-use manager is mainly concerned with four broad categories: agricultural crops, forests, rangelands, and brushlands. The following lists of desired information for these categories suggest a need to examine spatial resolution requirements at the various possible remote sensing altitudes and corresponding sensor resolution capabilities.

Agricultural crops

For land-use inventory purposes, the following information, as a minimum, is desired at relatively frequent intervals: 1) total crop acreage by growing region, 2) acreage per crop type, by growing region, 3) state of vegetational maturity and yield, and 4) extent of crop-damaging agents, per crop type and by source for all growing regions.

Forests

The following data are desired, but at much less frequent intervals: 1) total forest acreage, 2) acreages of commercial vs noncommercial forests, 3) forest stand vigor and volume, per species and size class (commercial stands only), 4) predictable future volume yield, per species and size class (commercial forest stands only), and 5) extent of tree-damaging agents, per forest type and size class (commercial forest stands, primarily).

Rangelands

The following information is desirable, as a minimum, at infrequent prescribable intervals: 1) total acreage, 2) compositional structure of tracts in terms of animal "carrying capacity," 3) present and probable future animal carrying capacity, and 4) extent of range-damaging agents or causes (weeds, rodents, drought, etc.)

Brushlands

The following data are desirable at very infrequent intervals: 1) total acreage, 2) acreages of various brushland types, and 3) vegetative density, by type. (More specific brushland information will depend upon the primary importance of the vegetation to such uses as watershed protection, wildlife habitat, or potential conversion to forest stands, agriculture sites, recreation, etc.)

The proposed "operation" Earth resource technology satellite ERTS-A, which is scheduled for launch in March 1972, reveals fairly coarse resolution capabilities in terms of the total vegetation inventory data requirements. It will possess ground resolution capabilities ranging from 200–500 ft at the proposed orbital altitude of 496 naut miles. One of the sensors, an optical-mechanical scanning device, will have four-channel recording capability ranging in sensitivity from the blue-green to the near infrared wavelength intervals of the electromagnetic spectrum. The second sensor, a three-channel return beam vidicon system (RBVS), will record radiant wavelength energy from the blue-green through the red portion of the electromagnetic spectrum. The recorded data will be transmitted to various ground stations and subsequently transcribed to film emulsions for image analysis. These same data can remain in digital form for machine-aided interpretation as well. Due to the spatial resolution capability which this initial satellite sensor package will possess, it is suggested that general land-use classifications can be performed adequately. Note that when high-resolution films are used to sense and record the data (which is proposed in the follow-on ERTS-B and C satellites), considerably more information can be extracted. Such films possess a spatial resolution capability which will be at least one-order of magnitude better than that described previously for the ERTS-A sensors.

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As a result, ground resolutions of nearly 30 ft are expected from 500-mile altitude. While even this figure is considered limiting for accomplishing certain of the objectives sought by land-use and resource-use planners, it will afford a greater opportunity for performing more detailed vegetation inventories.

Optical Film Densities for Vegetation Classification

A film scanning system enabling the reduction of film-recorded remote sensing data to magnetic tapes for subsequent digital computer analyses is under study at the Forestry Remote Sensing Laboratory (FRSL). The film-recorded data input consists of positive or negative black-and-white film transparencies. Such transparencies can be scanned automatically (through the use of a computer-controlled X, Y coordinate scanning stage) to reduce the film's continuous tone density values to a discrete number of optical density intervals. At present, the specially constructed scanning microdensitometer can record nearly 1000 of these intervals (i.e., within the normal range of film-recorded optical densities). The maximum film format size which can be scanned is 4×5 in. (Y direction and X direction, respectively). With the addition of more optical elements, the scanning aperture will be refined to a diameter of 0.001 in. Sampling intervals for recording optical densities can be preset at the time of scanning and vary from the largest at 0.25 in. to the smallest, 0.001 in. A small computer is effectively employed to control scanner sampling intervals, calculate X, Y coordinate positions for these sampled and recorded points, enable on-line decisions to be made when interfaced by remote terminal with a large high-speed computer system, and control most of the desirable peripheral operations (which include producing various photo enhancements, sorting and manipulating data, delineating areal measurements, etc.). A future development of the scanning device will be the ability of recording optical densities of color transparencies. A very high-speed revolving filter disc is being devised which will enable up to seven different spectral filters to be used.

Software development for the type of system just described is proceeding along two main courses: 1) automatic feature recognition (*and* data reduction techniques which facilitate the overall photo interpretation task), and 2) on-line man/machine interaction for statistical decision making in the selection of optimum interpretation material. Both of these objectives are highly desirable programs to pursue in terms of vegetation analysis.

In the case of automatic feature recognition, numerous possibilities can be explored. The work done at the Laboratory for Agricultural Remote Sensing, Purdue University (LARS), is an excellent example of how agricultural features can be discriminated and classified using multichannel optical-mechanical scanner imagery obtained at low to intermediate aircraft altitudes. A preliminary feasibility study was conducted by the principal author early in 1969 to determine the adaptability of the LARS pattern recognition program for classifying wildland environments. While it was possible to obtain reasonable success using nine different features (including four vegetation categories), it was extremely difficult to obtain an accurate measure of the classification success using the LARS point-by-point classification technique, because the nonhomogeneous nature of the wildland environment made it very hard to select suitable training samples. A number of potential problems need special consideration when dealing with automatic wildland vegetation interpretation, each of which was also noted in the preliminary feasibility study using line-scanned remote sensing data. For example, the problem of highly variable terrain slopes and aspects can introduce different signals for the same feature, causing errors in classification; also, times and dates of data acquisition, which are sometimes overlooked as important variables, can be exploited to yield information of optimum value in terms of discriminating vegetation types and conditions.

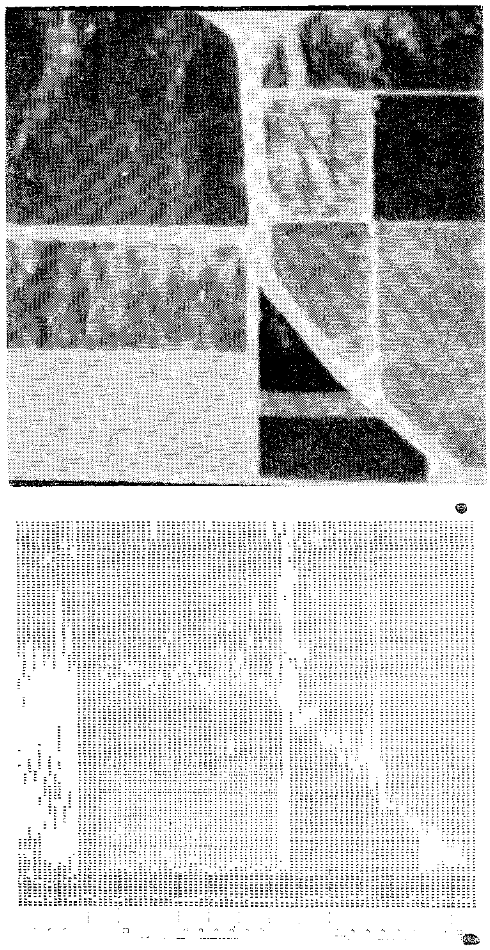

Fig. 1 Agricultural crops as seen on enlarged high-altitude photography (top) and digital output from scanning microdensitometer (bottom).

Figure 1 illustrates an initial optical density scan of agricultural crops. While admittedly quite crude (scanning aperture was 0.06 in.), it indicates the advantages of having a very sensitive instrument to measure optical densities. When refined spot size optics are incorporated, sensitivity will still remain at an acceptable signal-to-noise level to enable meaningful classifications.

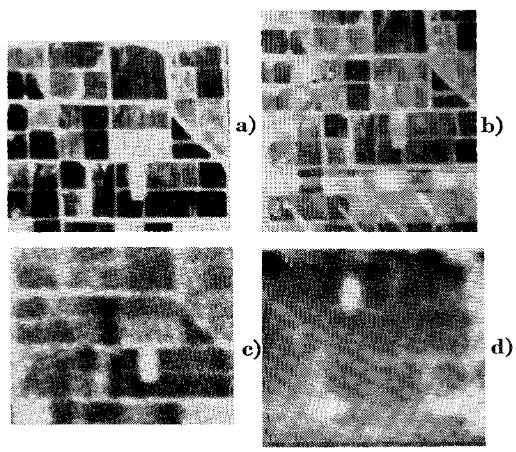

Fig. 2 Resolution differences between high-altitude panchromatic and color infrared photography [a) and b)] and Apollo 9 photography [c) and d)].

Table 1 Percentages of images identified correctly.

TEST NO.	IMAGERY TYPE & DATE	TOTAL %	BARLEY %COR	ALFALFA %COR	SUGAR BEETS %COR	WHEAT %COR	BARE SOIL %COR	CEREAL %COR
1	25-A Apollo 9 March	43	34	56	16	0	83	39
2	89-B Apollo 9 March	47	27	71	43	0	89	42
3	25-A High-Flight March	47	34	53	43	0	88	40
4	58-High-Flight March	41	30	61	00	25	62	35
5	89-B High-Flight March	45	33	57	25	0	86	40
6	CIR Apollo 9 March	65	50	80	25	50	98	83
7	CIR High-Flight March	64	33	76	46	0	100	36
8	CIR High-Flight April	60	57	75	33	0	96	66
9	CIR High-Flight May	72	90	72	40	0	81	87
10	FRSL Color enh. H.F. March	58	36	81	22	0	100	37
11	FRSL Color enh. A9 March	50	39	72	21	0	97	43
12	Philco/Ford Color enh High-Flight March	46	23	62	8	25	98	29
13	Philco/Ford Color enh Apollo 9 March	33	24	44	33	50	42	27
14	Multidate 25-A H.F. Composite March, May	76	86	74	0	0	88	86
15	Concurrent tri-date CIR: Mar, Apr & May	81	82	83	35	25	98	81

Conventional Photo Interpretation for Vegetation Classification

In order to evaluate the usefulness of performing automatic feature recognition and man/machine interactions which facilitate the image analyst's interpretation task, the following photo interpretation test results are presented. These tests were conducted at the FRSL in the summer of 1969, using 45 skilled and unskilled interpreters. The principal objectives were 1) to determine the value of multiband black-and-white photography for detecting agricultural and other resource features on high altitude and spacecraft photography, 2) to perform additive false-color enhancements from the multiband photos, and 3) to compare these enhancements with a conventional color film.

The multispectral photographic experiment which was conducted during the Apollo 9 mission had the following four film-filter combinations prescribed: Camera "AA": IR Ektachrome, Wratten 15 filter; Camera "BB": Panatomic X, Wratten 58 filter; Camera "CC": Infrared B&W, Wratten 89B filter; Camera "DD": Panatomic X, Wratten 25A filter.

It was thus possible to evaluate the visual interpretability of each of the black-and-white photos in comparison with a conventional color film. In addition, numerous false-color enhancements were produced by various optical and electronic additive color devices for further studies of the increased interpretability value of performing multiband and multidate combinations. Representative black-and-white photos as well as color combinations are illustrated in Fig. 2. Some of the results of the interpretability of these kinds of test images are presented in Tables 1 and 2. In these tables, it can be seen that a wide range of success was achieved with the different types of test material. For example, when over-all success of feature interpretability is considered, the various types of test images are roughly ranked in an increasing order. As one might expect, the better ground resolution obtained with the high-flight photography yielded better results than the Apollo 9 space photography of the same area. In addition, color photos were found to be, on the average, more interpretable than black-and-white photos. In more specific examples, note that certain feature categories are more interpretable in comparison to others at specific times during their growing season. Bare soil, for instance, was discriminated from all vegetative categories with nearly 90% accuracy by the interpreters—even for Apollo 9 black-and-white space photos. The real impact of these interpreter results, however, rests with one's evaluation of how good these test performances might be for an operational survey of the various vegetation resources. Most of the success of these preliminary interpretability tests will probably prove to be inadequate for operational surveys. It is felt that with the aid of an optical density recording device (such as the one described earlier) and the appropriate software to analyze the recorded data, greater classification success can be achieved by 1) eliminating all variability attributable to the interpreter's performance, 2) using the computer's tireless capacity to handle large volumes of data at dimensional levels that humans cannot duplicate, and 3) facilitating the interpreter's and resource manager's over-all task by editing and summarizing the data that is to be interpreted by visual means to a more manageable amount. The concluding remarks of this paper constitute an explanation of each of the three points made above and how they can serve to justify the development of machine-aided techniques.

Table 2 Results for classifying land areas (Mississippi/Louisiana) using color infrared photographs from Apollo 9 in March 1969; the ten land categories studied were: D = deciduous forest, P = pine forest, M = mixed deciduous and pine forest, C_r = ground condition, vegetated, C_b = ground condition, bare, C_f = ground condition, fallow, W_0 = water bodies, open, W_r = rivers and canals, R = roads and U = urban, industrial

PHOTO INTERPRETER'S RESULTS	GROUND TRUTH D	P	M	C_V	C_B	C_F	W_O	W_R	R	U
D	49		7				2			
P	1	27	13	4			1			
M	5	2	28				1			
C_V				74						5
C_B		1		2	20					3
C_F						18				1
W_O	1						36			1
W_R								18	6	
R								2	34	
U	4		2			2				20
TOTAL ITEMS	60	30	50	80	20	20	40	20	40	30
PERCENT CORRECT	81	90	56	92	100	90	90	90	85	67

Concluding Remarks

The intent of this Note has been to discuss how machine-aided interpretation for vegetation analysis can be useful in high-altitude and space-altitude inventories of Earth resources. The concept is *not* to eliminate the image analyst from operational surveys which rely on photography and ground truth, but to facilitate some of his tasks and improve his interpretation results by reducing the total amount of data to be viewed. A scanning microdensitometry can tirelessly screen the data for particular features of interest which can then be carefully interpreted, and, under reasonably controlled environmental conditions, it can consistently record relative optical densities without being influenced by surrounding contrasts. Hence, feature classification can be applied to many important categories of Earth resources in addition to vegetation features. Moreover, successful feature discrimination for certain Earth resources may require information from many spectral bandwidths—more than a human interpreter can handle readily. A computer's memory core can store large amounts of information for rapid retrieval and analysis operations. As long as the information so stored is not destroyed, it will continue to be available for further analyses, whereas the human mind—though potentially containing an almost infinite information storage capacity—tends to lose bits of information in time.

Work is progressing at the FRSL to perform automatic feature discriminations using high-altitude and space-altitude photography. Initial efforts have been with single black-and-white transparencies from which 1000 separate density levels could be recorded. In the near future the addition of color recording filters will yield further analytical power to the film scanning device. The extent to which this type of approach to facilitating image analysis will be of great interest to land-use managers when the time comes for operational satellites to fly.

Determination of Radiation Properties of a Transparent Sheet Using Monte Carlo Method

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RECENTLY the Monte Carlo Technique has been shown to be a powerful tool in the analysis of complex radiative heat transfer problems involving absorbing and emitting gases.[1] We have postulated a model for determining the radiation characteristics of dielectric body with a complex geometry. To substantiate this model, the theoretical radiation characteristics—absorptance, transmittance, and reflectance—were obtained by the Monte Carlo Method for a flat plate. These results were compared with Gardon's values obtained by a classical approach for emissivity.

The Monte Carlo Method is based upon following the probable path of a single energy bundle or particle history from initiation to termination.[2] Following this basic premise, consider the interaction of a single energy bundle at a fixed angle of incidence, with a sheet of dielectric material of uniform thermal and physical properties. The bundle of energy impinges on the top surface of the sheet at an angle of incidence η with respect to a normal to the surface. The angle of transmission β of the bundle of energy if it were transmitted into the sheet is given by Snell's law:

$$\sin\eta = n_{12} \sin\beta \tag{1}$$

where n_{12} is the relative index of refraction of the surrounding medium and sheet, respectively. The external reflectivity of the interface is given by Fresnel's equation:

$$\rho_{\perp} = \sin^2(\eta - \beta)/\sin^2(\eta + \beta) \tag{2a}$$

and

$$\rho_{\parallel} = \tan^2(\eta - \beta)/\tan^2(\eta + \beta) \tag{2b}$$

where $\rho_{\perp}$ and $\rho_{\parallel}$ are the reflectivities for radiation polarized perpendicular and parallel to the plane of incidence, respectively. At this point in the particle history, a random number

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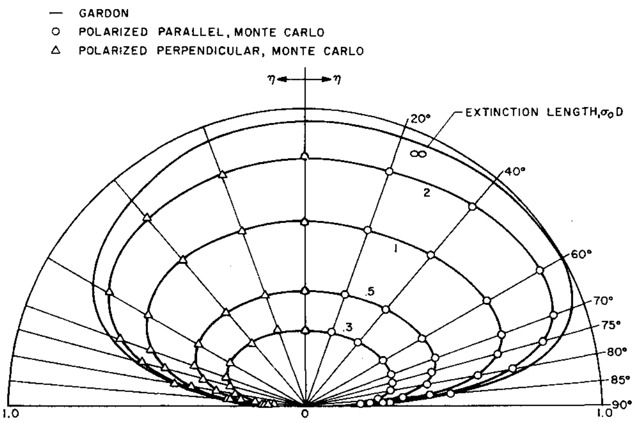

Fig. 1 Absorptance of a sheet to perpendicular and parallel incident radiation.

R_n from a uniformly distributed set of numbers between zero and one is obtained. If the value of the random number obtained is less than or equal to the interfacial reflectivity, the particle is assumed to be reflected back into space and counted as such. If, however, the random number is greater than the interfacial reflectivity, the particle is assumed to be transmitted through the interfacial layer into the body at an angle β with respect to a normal. The maximum path length the particle will travel within the sheet while in transit from the top to bottom surface is:

$$L = D/\cos\beta \tag{3}$$

However, there is the probability that the bundle of energy will be absorbed before it reaches the bottom surface. Howell and Perlmutter[1] have shown that the actual path length of the particle, giving the same distribution of path lengths as the fractional absorption distribution in a medium of uniform absorptivity τ, is:

$$l = (1/\tau) \ln R_n \tag{4}$$

where R_n is a different random number from a uniformly distributed set of numbers between zero and one. If the actual path length is equal to or less than the maximum path length, the energy bundle is absorbed within the sheet and counted as such. If, however, the actual path length l is greater than the maximum path length L, the energy bundle interacts with the bottom interface. The bundle of energy can either be transmitted through the interface or reflected up towards the upper surface. Assuming the two surfaces of the sheet are parallel, the angle of incidence of the energy bundle on the bottom interface is β and the angle of transmission will correspondingly be η. The reflectivities of the energy bundle

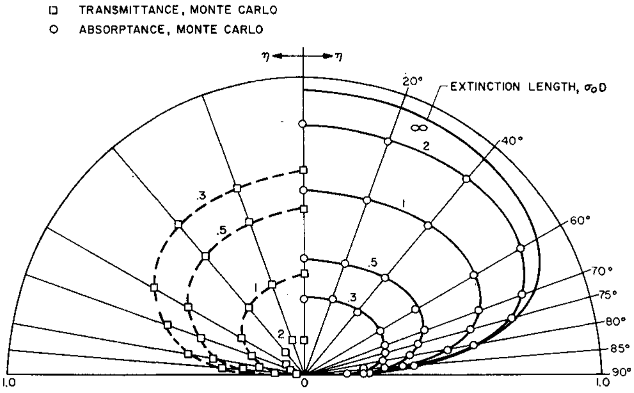

Fig. 2 Absorptance and transmittance for diffuse radiation.