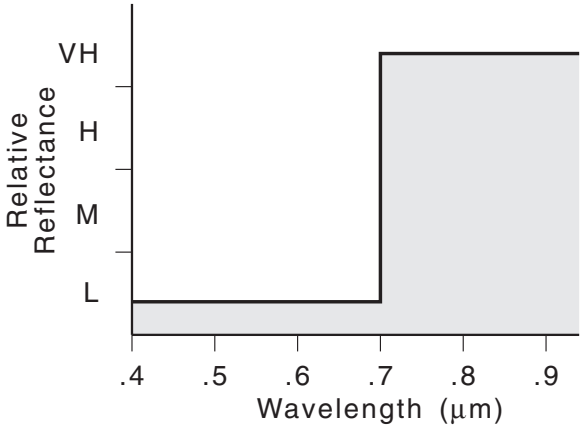
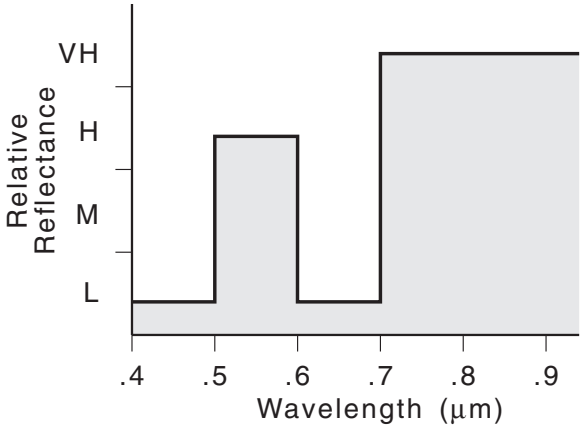
Question 4.



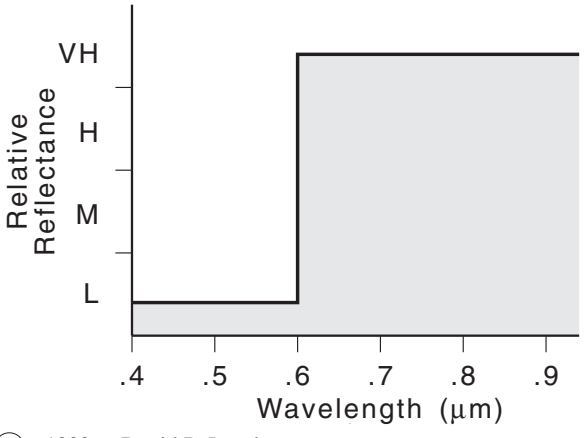
TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 5.



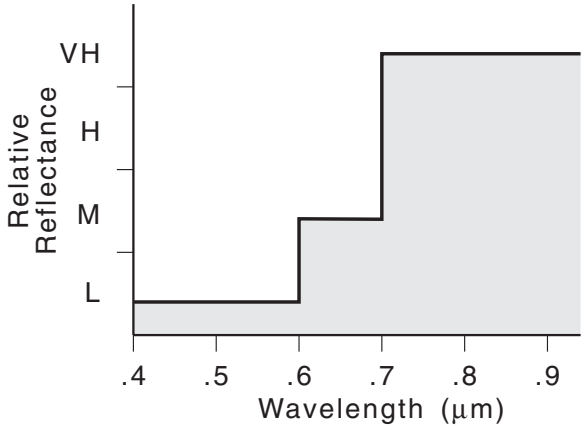
TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 6.



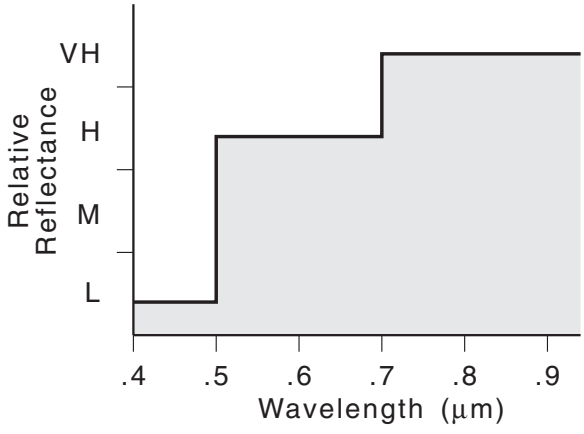
TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 7.



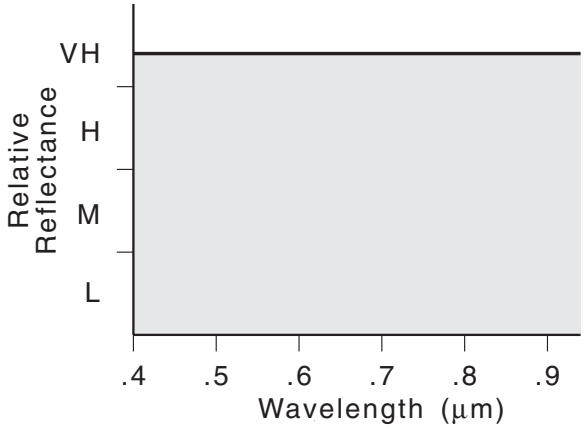
TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 8.



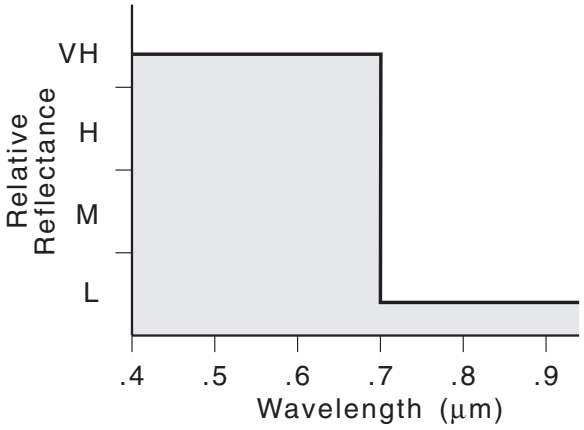
TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 9.



TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
Display Color	Display Color

Question 10.



TRUE COLOR	ST'D FCC
(R) _____	(R) _____
(G) _____	(G) _____
(B) _____	(B) _____
_____ Display Color	_____ Display Color

Color Glossary

Display Color	*Red*	*Green*	*Blue*
White	**VH**	**VH**	**VH**
Light Grey	**H**	**H**	**H**
Dark Grey	**M**	**M**	**M**
Black	**L**	**L**	**L**
Strong Blue	**L**	**L**	**VH**
Pale Cyan	**H**	**VH**	**VH**
Strong Cyan	**L**	**VH**	**VH**
Strong Green	**L**	**VH**	**L**
Dark Green	**L**	**H**	**L**
Very Dark Green	**L**	**M**	**L**
Light Yellowish-Green	**M**	**VH**	**L**
Dark Yellowish-Green	**M**	**H**	**L**
Strong Yellow	**VH**	**VH**	**L**
Dark Yellow	**H**	**H**	**L**
Reddish-Orange	**VH**	**M**	**L**
Light Reddish-Gray	**VH**	**H**	**H**
Dark Reddish-Gray	**H**	**M**	**M**
Strong Red	**VH**	**L**	**L**
Dark Red	**H**	**L**	**L**
Reddish Brown	**M**	**L**	**L**
Strong Reddish-Magenta	**VH**	**L**	**H**
Pale Magenta	**VH**	**H**	**VH**
Magenta	**H**	**L**	**H**
Dark Magenta	**M**	**L**	**M**

In this portion of the exercise, you will explore additive color formation in the context of a Landsat TM 5,4,3 composite. The TM 5,4,3 composite (or the SPOT HRVIR 4,3,2 composite) displays one image from each of the three spectral zones that are important for vegetation analysis (Visible, Near-Infrared and Shortwave Infrared). As such, this type of composite usually portrays the maximum amount of information about a vegetated landscape that can be created with "raw" imagery (as opposed to using, for example, the Tasseled Cap transformation or one or more band ratios). Table 6.1 provides a partial glossary of the color hues which dominate this 5,4,3 composite. Note that white is formed by the mixing of Very High strengths of Red, Green, and Blue. Black, on the other hand, is the sum of little or no Red, Green, and Blue light.

Table 6.2 introduces the concept of the **Vegetation Index (VI)**, which is sensitive to the relative difference in reflectance between the near-infrared band (TM 4 or HRVIR 3) and the red light channel (TM 3 or HRVIR 2). Consulting Figure 6.4, you can observe that, of the major classes of earth-surface features, only vegetation exhibits a large reflectance contrast in these two bands with the near-infrared (TM 4 or HRVIR 3) reflectance dominating. This index helps to summarize the vegetative state of a landscape facet. A Very High **VI** implies a vigorous, high-biomass area of vegetation. Lower **VIs** suggest either 1) less vigorous plant growth, 2) lower biomass per unit area, or 3) plant senescence. Extremely low **VIs**, or reversals where the red reflectance dominates, are typical of non-vegetated surfaces.

Table 6.3 provides guidance in the physical interpretation of the shortwave-infrared reflectance (TM 5 or HRVIR 4) . In this portion of the spectrum, the influence of water (i.e. moisture content) is dominant. High water content results in low reflectance. Caution must be exercised, however, since other factors also play a role in controlling reflectance in the SWIR. Internal leaf structure, for instance, influences foliar reflectance in this portion of the spectrum. SWIR bands are also very sensitive to shadows, since atmospheric scattering is nil in the SWIR.

Using the TM 5,4,3 composite image with the appropriate overlay and Tables 6.1 - 6.3, complete the interpretation form provided (page 6-15).

Thematic Mapper Band Sensitivities

6.4

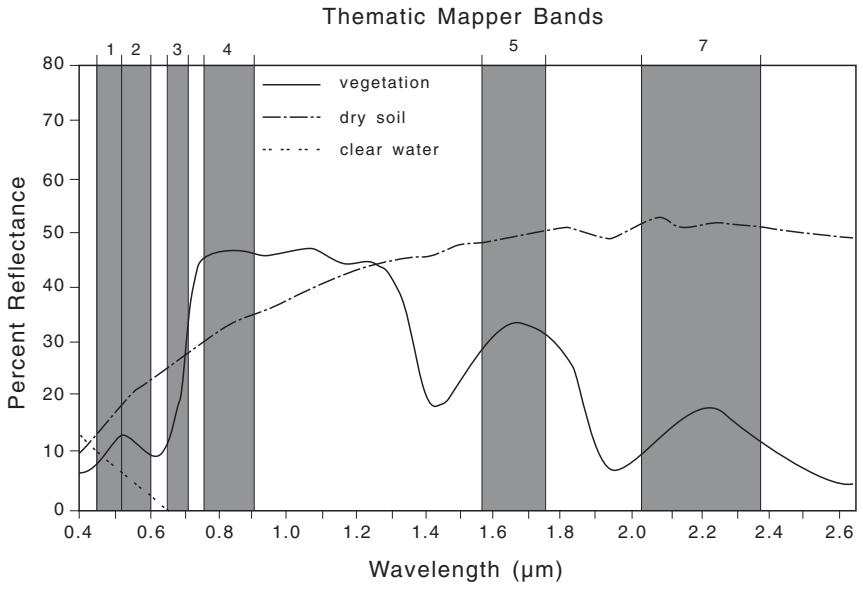


Table 6.1 Additive Color Glossary

Color	Red	Green	Blue
Pale Blue	**H**	**H**	**VH**
Purple	**M**	**L**	**H**
Pale Magenta	**VH**	**H**	**VH**
Lt. Magenta	**H**	**L**	**H**
Lt. Yellow-Green	**M**	**VH**	**L**
Dk. Yellow-Green	**M**	**H**	**L**
Green	**L**	**M**	**L**
Reddish-Brown	**M**	**L**	**L**
Blue-Black	**L**	**L**	**M**
Black	**L**	**L**	**L**
White	**VH**	**VH**	**VH**

Table 6.2 Vegetation Index

Band 4 BV	Band 3 BV	VI
VH	**L**	**VH**
H	**L**	**H**
M	**L**	**M**
L	**L**	**L**
all others		(non-vegetative)

Table 6.3 Moisture Index

Band 5 BV	Possible Moisture
VH	**Very Dry**
H	**Dry**
M	**Moist**
L	**Very Moist**

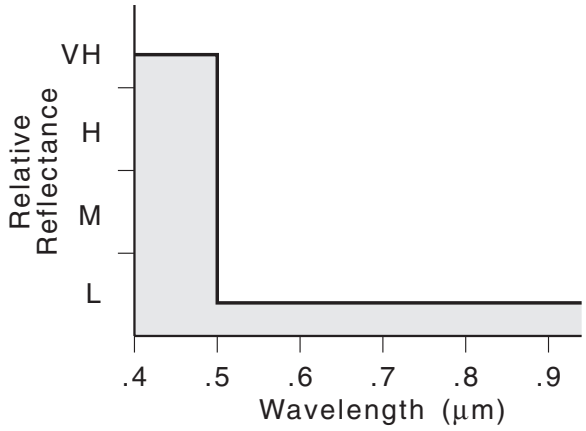
TM 5,4,3 Composite Interpretation

Location	Color	(___) 5 BV	(___) 4 BV	(___) 3 BV	VI	MI	
A	Dark Green						
B	Strong Green						
C	Dk. Yellowish-Green						
D	Lt. Yellowish-Green						
E	Pale Magenta						
F	Magenta						
G	Dark Magenta						
H	White						

Location	Color	Earth Cover Type
A	Dark Green	
B	Strong Green	
C	Dk. Yellowish-Green	
D	Lt. Yellowish-Green	
E	Pale Magenta	
F	Magenta	
G	Dark Magenta	
H	White	

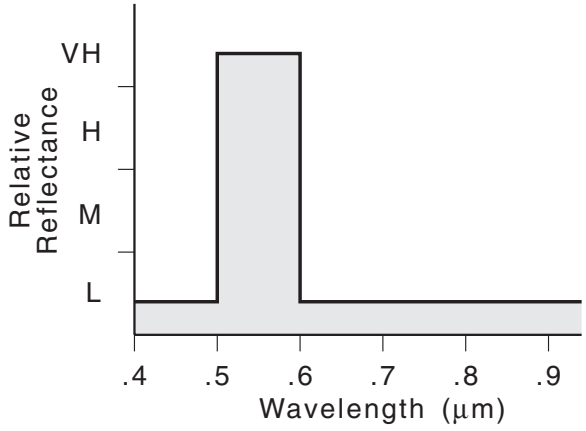
ANSWERS

Question 1.



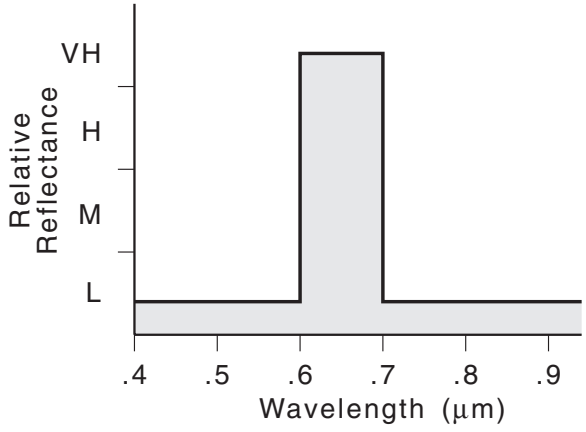
TRUE COLOR		ST'D FCC	
(R)	L	(R)	L
(G)	L	(G)	L
(B)	VH	(B)	L
Strong Blue		Black	
Display Color		Display Color	

Question 2.



TRUE COLOR		ST'D FCC	
(R)	L	(R)	L
(G)	VH	(G)	L
(B)	L	(B)	VH
Strong Green		Strong Blue	
Display Color		Display Color	

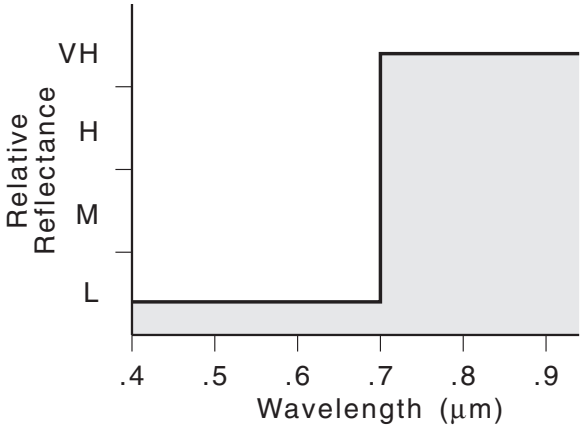
Question 3.



TRUE COLOR		ST'D FCC	
(R)	VH	(R)	L
(G)	L	(G)	VH
(B)	L	(B)	L
Strong Red		Strong Green	
Display Color		Display Color	

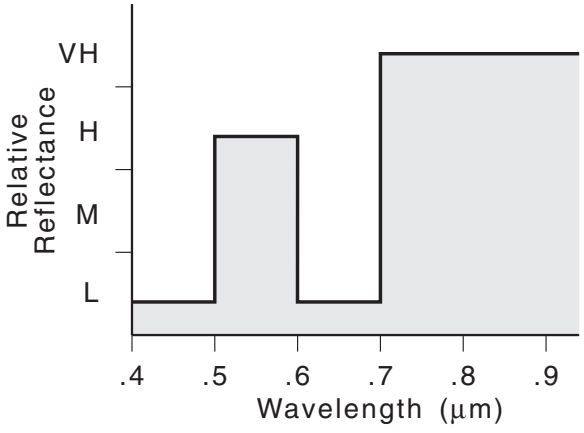
ANSWERS

Question 4.



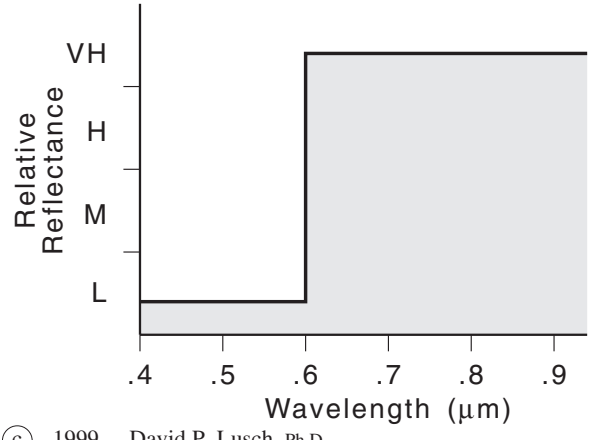
TRUE COLOR	ST'D FCC
(R) L	(R) VH
(G) L	(G) L
(B) L	(B) L
Black	Strong Red
Display Color	Display Color

Question 5.



TRUE COLOR	ST'D FCC
(R) L	(R) VH
(G) H	(G) L
(B) L	(B) H
Dark Green	Strong Reddish-Magenta
Display Color	Display Color

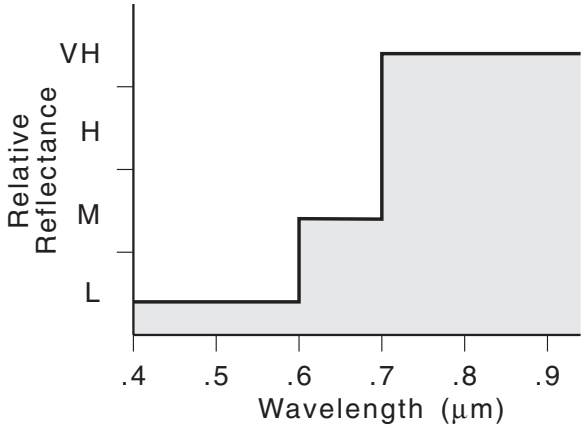
Question 6.



TRUE COLOR	ST'D FCC
(R) VH	(R) VH
(G) L	(G) VH
(B) L	(B) L
Strong Red	Strong Yellow
Display Color	Display Color

ANSWERS

Question 7.



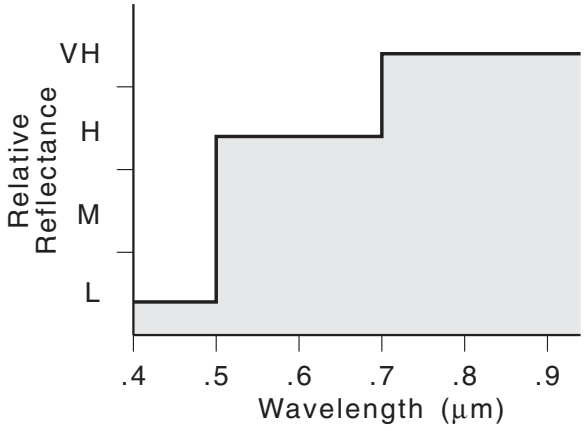
TRUE COLOR	
(R)	M
(G)	L
(B)	L

Reddish Brown
Display Color

ST'D FCC	
(R)	VH
(G)	M
(B)	L

Reddish-Orange
Display Color

Question 8.



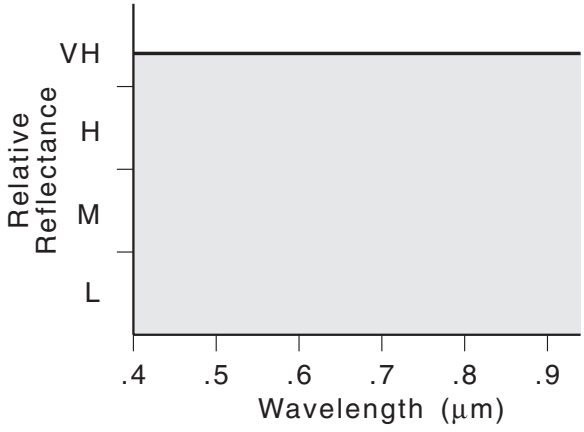
TRUE COLOR	
(R)	H
(G)	H
(B)	L

Dark Yellow
Display Color

ST'D FCC	
(R)	VH
(G)	H
(B)	H

Lt. Reddish-Gray
Display Color

Question 9.



TRUE COLOR	
(R)	VH
(G)	VH
(B)	VH

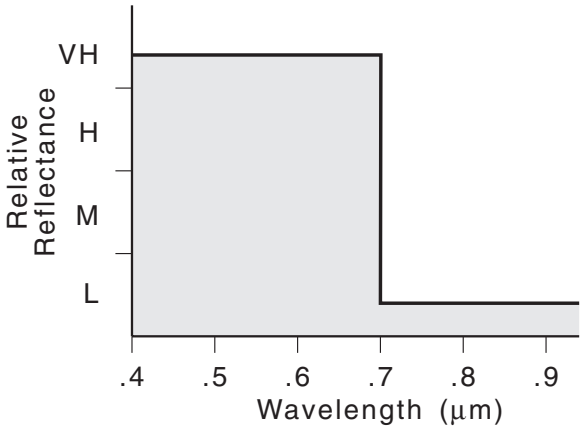
White
Display Color

ST'D FCC	
(R)	VH
(G)	VH
(B)	VH

White
Display Color

ANSWERS

Question 10.



TRUE COLOR	ST'D FCC
(R) VH	(R) L
(G) VH	(G) VH
(B) VH	(B) VH
White	Strong Cyan
Display Color	Display Color

ANSWERS

TM 5,4,3 Composite Interpretation

Location	Color	(___) 5 BV	(___) 4 BV	(___) 3 BV	**VI**	**MI**	
A	Dark Green						
B	Strong Green						
C	Dk. Yellowish-Green						
D	Lt. Yellowish-Green						
E	Pale Magenta						
F	Magenta						
G	Dark Magenta						
H	White						

Location	Color	Earth Cover Type
A	Dark Green	Forest
B	Strong Green	Healthy Pasture
C	Dk. Yellowish-Green	Pasture; less moist and somewhat stressed compared to B [note the lower NIR reflectance]
D	Lt. Yellowish-Green	Pasture; less moist compared to B (shorter grasses ?)
E	Pale Magenta	Bare soil; lower moisture / organic matter compared to F
F	Magenta	Bare soil; nominal moisture / organic matter
G	Dark Magenta	Bare soil; higher moisture / organic matter compared to F
H	White	Bare soil; freshly disturbed -- low moisture / organic matter

Chapter 7	Digital Image Processing

Contents

7.1 Objectives

- Define image classification.
- List the two basic approaches to classifying remotely sensed imagery.
- Explain which of the various image elements are predominately used in digital image processing.
- Describe the minimum-distance-to-means classification process.
- Describe the maximum-likelihood classification process.
- Explain the concept of unsupervised clustering as a classification technique.
- Describe at least one accuracy assessment technique and explain why it is used.

7.2 Introduction

Digital images are first discussed with respect to rectification and restoration and then image enhancement (Table 7.1, 7.2, 7.3, and 7.4). Under Image classification, both supervised, minimum distance-to the-means and maximum likelihood, and unsupervised techniques are introduced (Figure 7.1). The final topic includes a brief discussion of accuracy assessment techniques.

Table 7.1 Image Processing Sequence of Remotely Sensed Data

1. **Image Restoration**
2. **Image Enhancement**
3. **Image Classification**
4. **Accuracy Assessment**

7.3 Image Rectification and Restoration

Lillesand and Kiefer, 1987 Chapter 10, Section 10.2, Image Rectification and Restoration, pp. 612-625.

- Geometric Correction
- Radiometric Correction
- Noise Removal

Table 7.2 Image Restoration

- **Periodic Noise Removal**
- **Random Noise Removal**
- **Atmospheric (Haze) Correction**
- **Geometric Correction**
- **Radiometric Correction**

7.4 Image Enhancement

Lillesand and Kiefer, 1987 Chapter 10, Section 10.3, Image Enhancement, pp. 626-650.

- Contrast Stretching
- Level Slicing
- Edge Enhancement
- Ratioing
- Vegetation Indexes
- Principal Components Transformations
- Intensity/Hue/Saturation Color Transformation

Table 7.3 Image Enhancement

- **Contrast Stretching**
- **Density Slicing**
- **Edge Enhancement**
- **Spatial and Directional Filtering**
- **Band Ratios**
- **Data Transformations**
  - **Principal Components**
  - **Canonical Analysis**

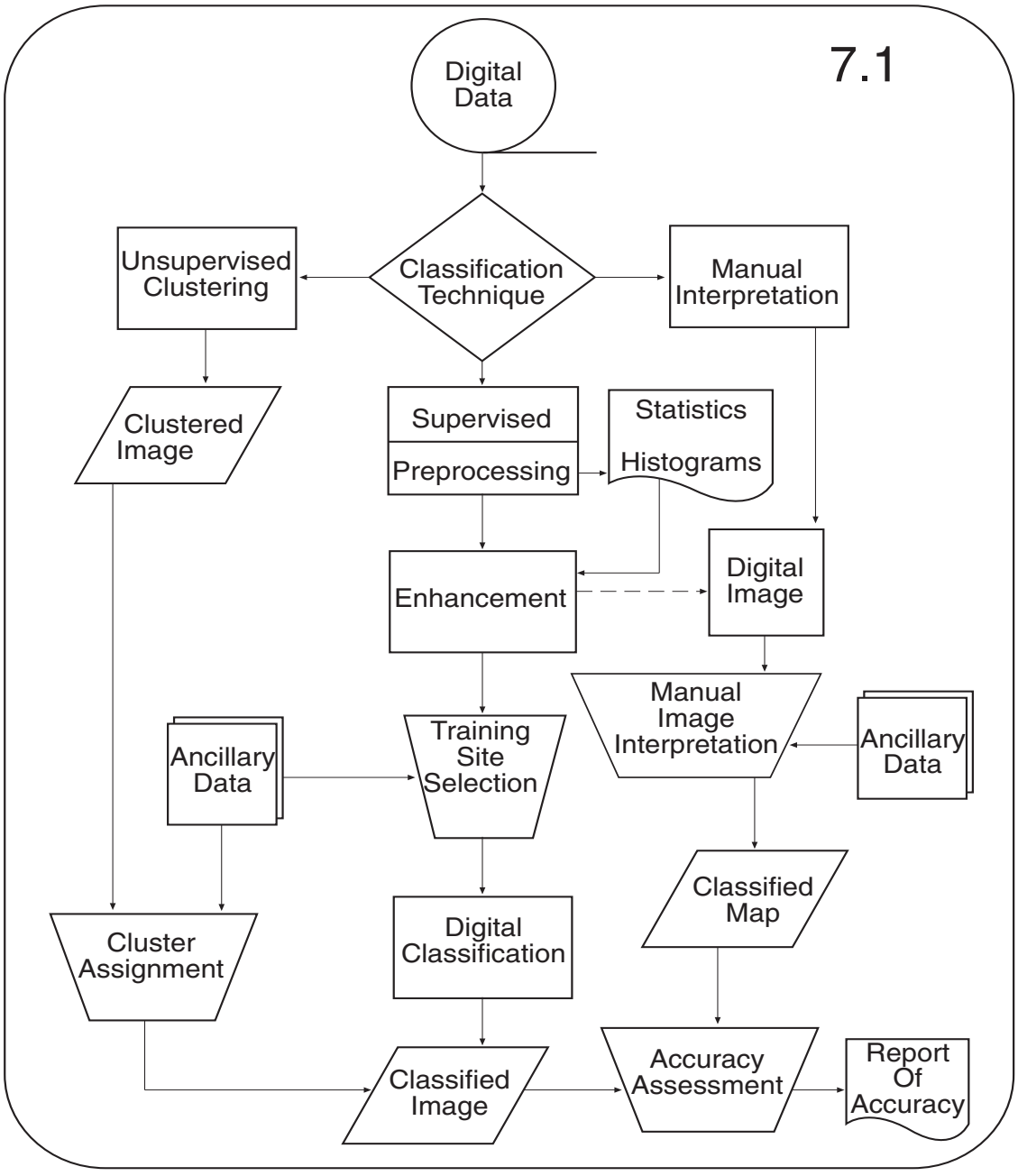


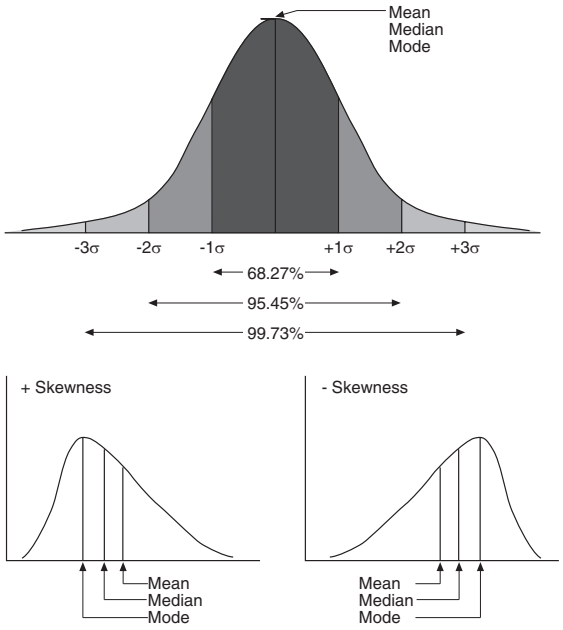
Table 7.4 Basic Image Statistics

(see Figure 7.2)

- **MINimum / MAXimum value**
- **Range**
- **Frequency**
- **Histogram (graph of Frequency distribution)**
- **Mean, Median, Mode**
- **Normal (Gaussian) Population Density Function (Bell-shaped curve)**
- **Variance**
- **Covariance**
- **Standard Deviation**

Descriptive Statistics

7.2



7.5 Image Classification

1. Introduction to Image Classification

A fundamental goal of remote sensing analysis is the classification of an image or scene. Classification, the partioning of the image into discrete, pre-determined classes, can be accomplished either manually (photo or image interpretation) or with the aid of computers (digital processing). Both approaches require the use of decision rules. These rules (or keys) are generally derived from an analysis of areas considered representative of the various classes. Photointerpreters utilize image elements such as size, shape, shadow, tone or color, texture, pattern, site, and association to characterize a particular class, whereas digital techniques rely on numerical parameters.

Classification by both techniques will be illustrated for a Landsat MSS sub-scene acquired on February 26, 1979 over Wexford County, Michigan. A fairly direct visual classification technique would characterize each class by tone: white = snow, gray = hardwoods, and black = pines. The image would then be portioned into classes based upon tonal comparisons. The decision rule is simple; assign each area to the class with the same, or most similar, gray tone. The numeric equivalent of this technique would utilize digital values, obtained from a densitometer, or brightness values from the Landsat CTT in place of gray tones (Figure 7.3).

The decision rule may now be stated mathematically; assign the unknown area x to the class to which the distance is numerically minimum (H). Distances are simply the absolute value of the unknown area minus the class to which it is being compared (Figure 7.3):

$$d = | x - H |$$

The use of tone in the above analysis was chosen since it illustrated the concept of spectral pattern recognition. **Of the three major image characteristics (spectral, spatial, and temporal attributes), spectral patterns are the most commonly utilized feature in digital classification.**

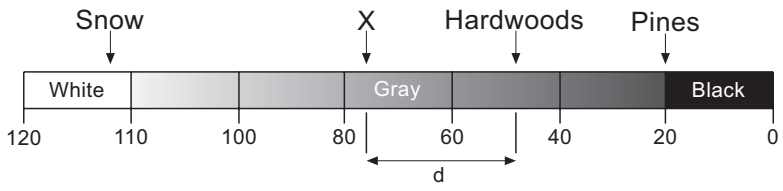
2. Spectral Pattern Recognition

A Geometric Interpretation

When more than one band of Landsat MSS data are to be analyzed, individual bands may be represented by color images and superimposed to create color composite images. This technique is

Landsat MSS Image Gray Scale

7.3



limited to three bands for any single composite. It is also not capable of rendering the full range of tonal information available from the MSS data. Digital classification techniques utilize the full range of spectral data (brightness values) available from multiple bands simultaneously.

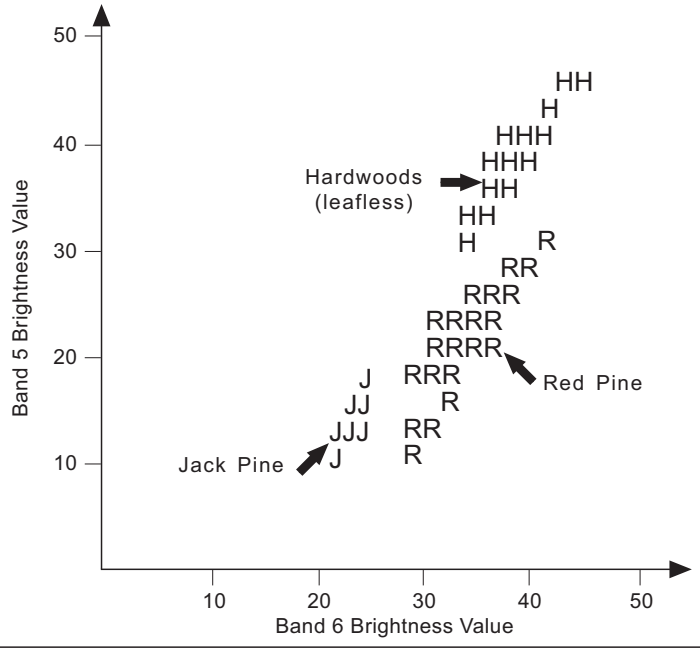
Although the computer operates strictly in a numerical mode, graphical techniques will be used to introduce geometric concepts in image classification (this technique is adopted from one presented by Lillesand and Kiefer, 1979). The portrayal of spectral responses, and thus spectral patterns, is limited to two dimensions, whereas computer implementation of these techniques is mathematical and can be applied to almost any number of bands.

All subsequent data represent digital brightness values extracted from the CCT corresponding to a subscene. Individual areas, called "training sites," were identified from ancillary data sources (maps and aerial photography) as being "representative" of the various cover types. These sites, therefore, represent a sample of pixels which will be utilized to characterize (numerically) the individual cover types. Individual pixel values have been plotted onto a two-dimensional graph; letters indicate to which category the value pertains (Figure 7.4). Band 6 brightness values are plotted on the x axis with the corresponding value for band 5 on the y axis. Visually, each class displays a variable range of possible values, although the spectral responses tend to form discernible patterns. These three training sites will be utilized to illustrate several classification strategies.

An extension of the tonal classification technique, illustrated in Figure 7.3, utilizes two or more brightness values (the numerical equivalent of gray tones). Each class is characterized by a set of mean values obtained from the pixels located within the training areas in each spectral band. The decision rule is a direct extension of the one band (gray tone) technique: assign an unknown pixel to the class with the same, or most similar, brightness values (gray tone). This strategy, known as the minimum distance-to-means classifier, is illustrated in Figure 7.5. Class means were determined and those for band 5 and band 6 are shown as a + on Figure 7.5. To classify an unknown pixel, such as points 1,2, and 3, the distance between the unknown pixel and the mean value for each class is determined. For point 1, these distances are shown by lines connecting the point to each class mean position. The decision rule would be: assign the unknown pixel to the "closest" (i.e. minimum distance) class. Point 1 would therefore be classified as belonging to the hardwood class.

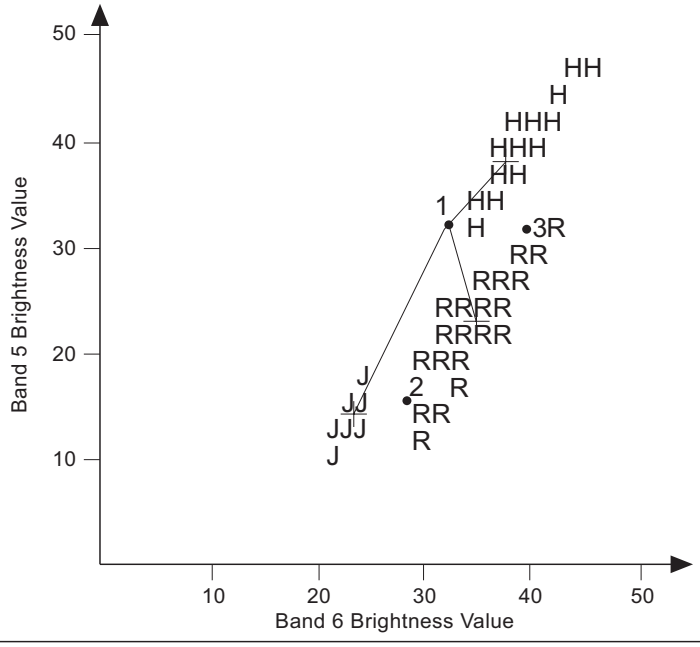
Training Site Pixel Values

7.4



Minimum Distance–to–Means Classification

7.5



The mathematics for expressing the distance measure numerically are illustrated in Figure 7.6. Since the x (BV6) and y (BV5) axes are perpendicular, the Pythagorean theorem for right triangles can be used. Since the square of the hypotenuse is equal to the sum of the squares of the sides:

$$d = \sqrt{(x_2 \quad x_1)^2 + (y_2 \quad y_1)^2}$$

For n dimensions, or bands, the generalization is:

$$d = \sqrt{(x_2 \quad x_1)^2 + (y_2 \quad y_1)^2 + ...(n_2 \quad n_1)^2}$$

or, expressed in terms of BVs:

$$d = \sum_{i=1}^{n} (\overline{BV}_i - BV_i)^2$$

Therefore, the formula for calculating the distance between an unknown pixel and mean value for a specific class, using 4 band MSS data, would be:

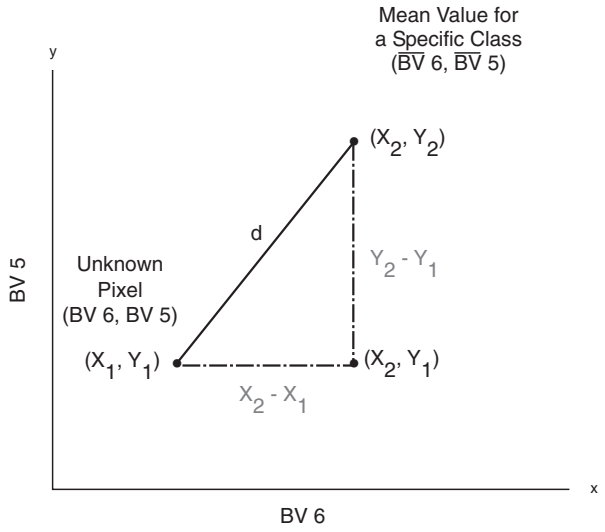
$$d = \sqrt{(\overline{BV}4 \quad BV4)^2 + (\overline{BV}5 \quad BV5)^2 + (\overline{BV}6 \quad BV6)^2 + (\overline{BV}7 \quad BV7)^2}$$

Note also that the above formula for one dimension, $d = \sqrt{(x_2 \quad x_1)^2}$ is equivalent to the distance measure developed for the one band tonal classification. Although the calculation of distance as presented above, known as Euclidean distance, may be intuitively the "best" measure, other distance measures have been applied in remote sensing data analysis.

While the minimum distance-to-means classifier is relatively straightforward, its reliance on mean values alone to characterize classes ignores the variance exhibited within the classes. For example, point 2 (Figure 7.5) would be classified as belonging to jack pine, the closest class mean, when, in fact, it "appears" to belong to the red pine class. The classification strategy is thus insensitive to differential variance exhibited by classes.

Geometric Derivation of Distance

7.6



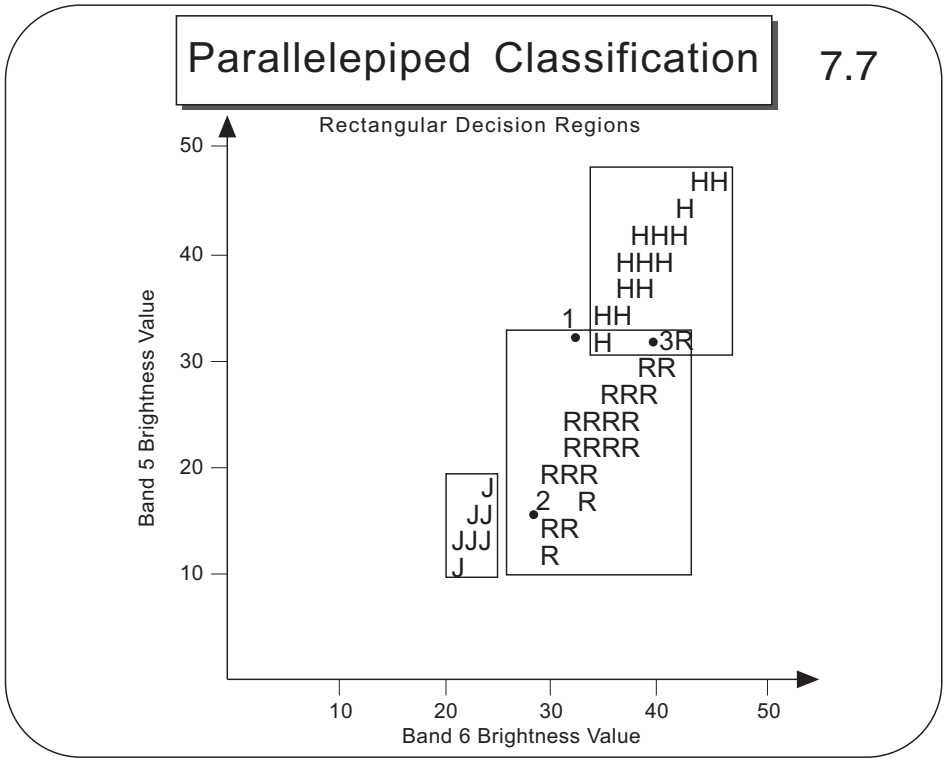
Statistically, the simplest measure of variability for a set of data values is the range. The minimum and maximum values (i.e. range) are obtained from the training set and are used to bound a category. Thus, a rectangular decision region, for each class, is defined by the class range (Figure 7.7). The decision is straightforward: assign an unknown pixel to the class decision region in which it occurs. By introducing a measure of variability, this strategy would now assign point 2 (Figure7.7) to the red pine class. Note that point 1 is also classified as red pine and that point 3 lies in two decision regions. Overlapping decision regions commonly occur whenever classes display correlation between bands. Both hardwoods and red pine are highly correlated in band 5 and band 6, thus producing a positively slanted series of pixel observations. It can be seen that highly correlated categories are ill-defined by rectangular decisions regions. The more general situation for this classifier occurs whenever opposite sides of the class boundaries are parallel to each other, but not necessarily to the coordinate axis, producing parallelograms (Figure 7.8), or, for multi-dimensional data sets, parallelepipeds.

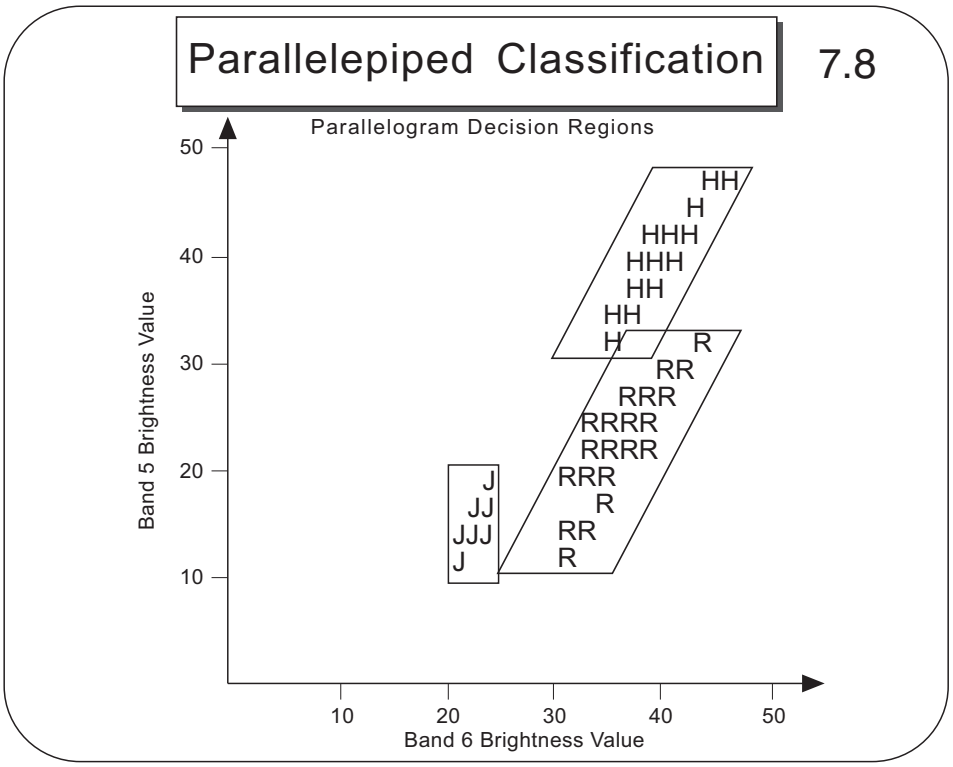
The Statistical Approach

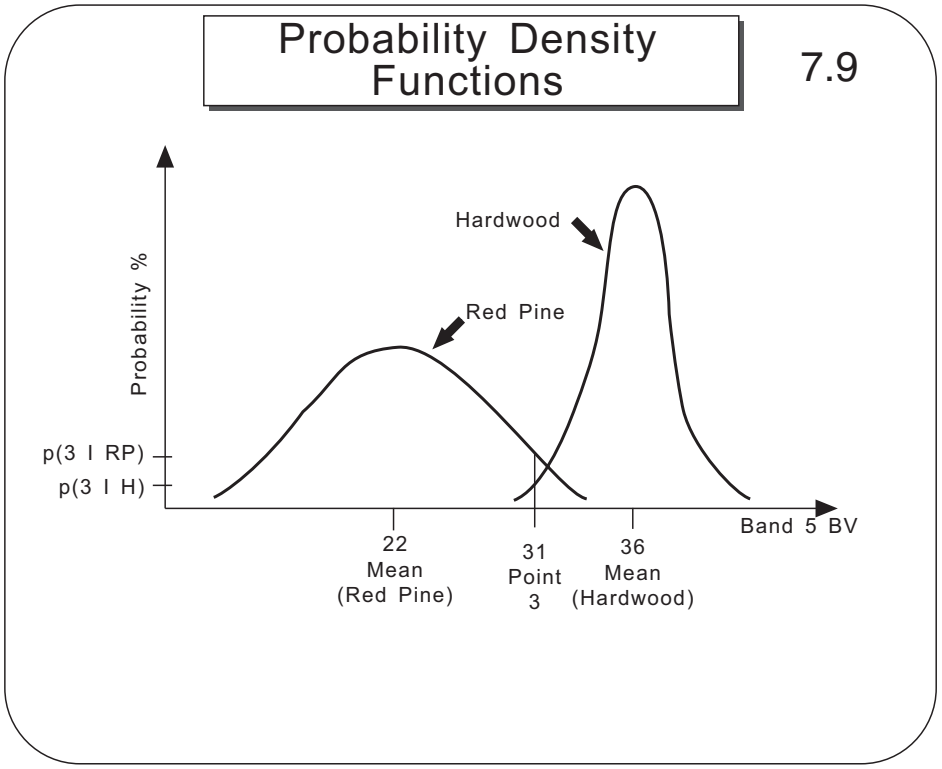
Statistical decision theory, as opposed to the geometric techniques presented above, quantitatively account for both variance and correlation in the data set. With parametric techniques, the distribution of the various categories must be specified, with the most common assumption being that the data is normally (Gaussion) distributed. Probability density functions are used to compute the statistical probability that an unknown pixel belongs to a particular category. The decision rule is to assign the unknown pixel to the category with the highest probability. For the univariate case, the maximum likelihood classifier will function as illustrated in Figure 7.9. Note that point 3, from Figure 7.5, is closer to the mean for the hardwood class but has a higher probability of belonging to the more variable red pine class. The estimated probability density function for the univariate case (ie. considering only one band of data as in Figure 7.9) is:

$$p(x|c_i) = \frac{1}{(2\pi)^{1/2} S_i} \exp \frac{1}{2} \frac{(x - m_i)^2}{S_i^2}$$

where: $p(x|c_i)$ = probability that x is from class $_i$
m_i = the mean BV for class $_i$
s_i = the variance for class $_i$







and the decision rule is: decide that x is from class $_i$ if and only if:

$$p(x|c_i) \geq p(x|c_j) \text{ for all j.}$$

Note that each category is characterized entirely by its mean(s) and variance (-covariance).

Whenever two bands of data are analyzed, the bivariate probability density function is utilized to compute probabilities:

$$p(x_1, x_2|c_i) = \frac{1}{2p\,(s_{i11}\, s_{i22} - s_{i\,12}^{2})^{1/2}}$$

where: m_{ij} = the mean BV in band j (for class $_i$)
s_{ijj} = the variance in band j (for class $_i$)
s_{ijk} = the covariance between bands j and k (for class $_i$)

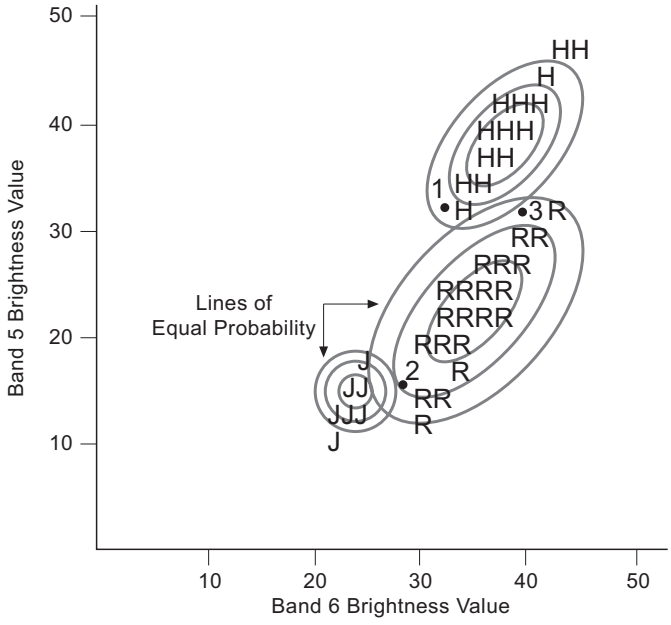
The probability density function for two bands may be thought of as defining a series of points of equal probability about the mean (Figure 7.10). The center of a class is determined by the mean and shape by the covariance matrix, points of equal probability are therefore elliptical (hyperellipsoids for more than two bands). The maximum likelihood decision rule would classify points 2 and 3 as red pine and point 1 as hardwood (Figure 7.10). Probability density functions for more than two bands are presented in the section on matrix notation.

The formal derivation of the maximum likelihood decision rule is based upon the Bayesion principal to minimize the average loss over the entire classification process. The Bayesian technique is theoretically an optimum classifier which applies two additional weighting factors to a probability; an *a priori* probability of occurrence and a loss function. If, as is often the case, the *a priori* probabilities are unknown and assumed equal , and if the loss due to an incorrect classification is simply defined as being inversely proportional to the *a priori* probability, then the Bayes optimal strategy generalizes to the maximum likelihood classifier previously presented.

Matrix algebra provides a means for condensing large mathematical manipulations into a much smaller set of symbols. Vectors, matrices, and their manipulations (matrix algebra) are commonly used in multivariate statistical analysis. Therefore, many of the image classification techniques will be presented in matrix notation.

Maximum Likelihood Classification

7.10



A Landsat scene is recorded on a computer-compatible tape as a Matrix L, composed of four-dimensional spectral vectors, P*ij*, which represent brightness values of individual pixels in four MSS bands:

$$L = \begin{bmatrix} P_{1,1} & \cdots & P_{1,3548} \\ \vdots & & \vdots \\ P_{2983,1} & \cdots & P_{2983,3584} \end{bmatrix}$$

where L = Landsat MSS scene; and

$$P_{ij} = \begin{bmatrix} BV4i_j \\ BV5i_j \\ BV6_{ij} \\ BV7_{ij} \end{bmatrix}$$

where P_{ij} = four-dimensional vector corresponding to a single pixel and defined by the digital counts (or brightness values) in the four MSS bands.

Pixels located within a training site, x_c, are used to estimate a mean spectral vector for a specific category:

$$x_c = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

where
$x_i = [BV4_i \ BV5_i \ BV6_i \ BV7_i]$

and n = sample size

The mean spectral vector, X_c, of class c, is defined as the arithmetic means, BV_c, of the brightness values, in four bands, from the pixels within the training site:

$$X_c = \begin{bmatrix} \underline{BV4}_c \\ \underline{BV5}_c \\ \underline{BV6}_c \\ BV7_c \end{bmatrix}$$

The computation of the mean spectral vector is:

$$\overline{X}_c = \frac{1}{n}(X_c' 1)$$

The variance-covariance matrix, S_c, for a training site class is defined as follows:

$$S_c = \begin{bmatrix} \text{var(BV4)} & \text{cov(BV4,BV5)} & \text{cov(BV4,BV6)} & \text{cov(BV4,BV7)} \\ & \text{var(BV5)} & \text{cov(BV5,BV6)} & \text{cov(BV5,BV7)} \\ & & \text{var(BV6)} & \text{cov(BV6,BV7)} \\ & & & \text{var(BV7)} \end{bmatrix}$$

The computation of the variance-covariance matrix is:

$$S_c = \frac{1}{n \quad 1}\left[X_c' X_c \quad \frac{1}{n}\left(X_c'\right)\left(1' X_c\right) \right]$$

The probability density function, employed in the maximum likelihood classifier, for a particular class is:

$$p\left(P_{ij}|C\right) = \frac{1}{(2\pi)^{n/2}|S_c|^{1/2}}\left[\exp \quad ½(P_{ij} \quad X_c)' S_c \quad 1(P_{ij} \quad X_c) \right]$$

where: $p\left(P_{ij}|C\right)$ = probability of pixel P_{ij} belonging to class C
n = dimension of vector, P_{ij} (4 in the case of Landsat MSS data)
X_c = mean spectral vector for class C
S_c = variance-covariance matrix for class C

3. Unsupervised Clustering

Most clustering algorithms involve two passes through the entire data set. During the first pass, clusters are created by an iterative process. The final cluster means, form the first pass, are then utilized to assign each pixel in the data set to a cluster based on quadratic distance.

Figure 7.11 is a diagrametric representation of the method used to create clusters during the first pass. Pixel values are read, one at a time, and assigned to an existing cluster or used to create a new cluster.

After the entire data set has been processed, cluster means are frozen. During the second pass, pixels are assigned to a cluster based on quadratic distance. If r > R, the pixel is unclassified.

The following example utilizes data from the Wexford County test site (Table 7.5) to illustrate the assignment of individual pixels to specific clusters. Figure 7.12 is a plot of mean brightness values for the 27 clusters, while Table 7.6 lists the mean brightness values, by band, for each cluster. To classify pixel **A**, the quadratic distance between it and each cluster mean would be calculated as:

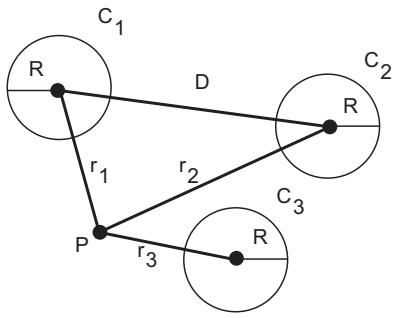
$$d = \sqrt{(w_2 \quad w_1)^2 + (x_2 \quad x_1)^2 + (y_2 \quad y_1)^2 + (z_2 \quad z_1)^2}$$

where: d = quadratic distance
w, x, y, z = BVs in four bands
$_2$ = unknown pixel
$_1$ = cluster mean

the following values are obtained:

cluster no.	d	cluster no.	d
1	46.82	14	65.80
2	122.38	15	149.60
3	71.21	16	53.38
4	21.79	17	20.21
5	37.91	18	189.41
6	133.01	19	90.63
7	144.56	20	174.99
8	66.31	21	165.64
9	27.98	**22**	**11.13**
10	110.58	23	85.56
11	117.14	24	185.70
12	12.93	25	181.76
13	163.38	26	160.87

Unsupervised Clustering 7.11



if $r < r_{max}$, P is assigned to a current cluster using r_{min}

if $r > r_{max}$

if $C_n < C_N$, a new cluster is formed

if $C_n = C_N$

if $C_{small} < C_{min}$, C_s is deleted and the new cluster replaces it

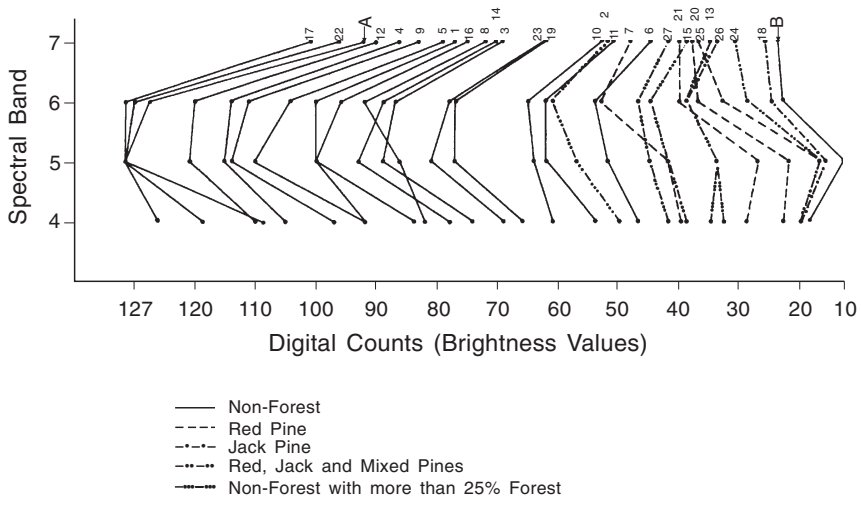
if $C_{small} \geq C_{min}$, the new pixel P is discarded

at merger M, distance D between all cluster means are computed

if $D < D_{min}$, the two clusters are merged systematically.

Brightness Value Plot for 27 Clusters

7.12



Based on these measures of distance, pixel A would be classified as belonging to cluster number 22. Note also that pixel A is least like (maximum distance) cluster number 18, which is most like pixel B, jack pine.

Upon completion of assigning each pixel to a cluster the analyst must assign appropriate category labels to each cluster or group of clusters. This is usually accomplished by reference to supplemental data such as existing maps or aerial photography.

Table 7.5 Digital Data from the Wexford County test site

Digital values for bands 4, 5, 6, 7, and 8

Band	Row	SNOW Pixels				A	BOUNDARY		JACK PINE B			
4	**80**	113	114	111	111	105	74	26	15	16	16	16
5	**80**	126	127	127	127	127	87	27	9	11	13	12
6	**80**	125	122	122	119	123	90	38	19	21	20	12
7	**80**	90	88	91	90	88	65	31	20	21	20	21
8	**80**	12	18	18	14	15	15	15	15	15	15	15
4	**81**	112	112	110	110	109	89	38	15	16	18	17
5	**81**	127	127	127	127	127	104	42	12	16	18	17
6	**81**	125	123	123	122	124	99	44	17	20	22	18
7	**81**	89	89	89	87	90	73	33	20	29	22	21
8	**81**	12	13	19	14	15	15	15	15	15	15	15
4	**82**	111	111	112	112	115	102	47	14	16	19	19
5	**82**	127	127	127	127	127	122	57	14	12	16	17
6	**82**	123	124	124	125	126	110	55	18	20	25	22
7	**82**	86	89	88	87	91	81	41	18	22	23	23
8	**82**	12	13	13	14	15	15	15	15	15	15	15
4	**83**	116	116	116	116	120	118	72	19	12	19	19
5	**83**	127	127	127	127	127	127	85	19	9	16	17
6	**83**	124	126	126	126	127	125	78	27	21	24	25
7	**83**	88	90	90	88	91	91	64	25	18	24	26
8	**83**	16	16	14	15	15	16	16	16	16	16	16
	Column	**123**	**124**	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**

Table 7.6 Results of clustering Wexford County test data

Mean brightness values, by band, for 27 clusters

	#1	#2	#3	#4	#5	#6
%	1.02	5.31	3.48	1.37	2.44	6.71
4	87.81	46.17	70.37	101.26	88.28	42.79
5	96.11	52.78	84.68	110.88	106.14	47.78
6	96.31	56.60	82.90	110.31	99.56	49.68
7	72.88	48.02	64.95	81.68	74.85	41.43

	#7	#8	#9	#10	#11	#12
%	3.60	.31	2.44	6.59	4.57	3.71
4	36.09	77.50	92.56	56.45	49.98	106.24
5	38.22	82.20	110.48	59.90	57.52	116.51
6	48.54	87.68	106.71	61.19	58.13	115.91
7	44.82	68.36	75.53	48.64	47.27	85.68

	#13	#14	#15	#16	#17	#18
%	2.54	2.53	4.62	8.13	2.06	1.18
4	28.57	74.31	35.38	80.18	122.43	15.82
5	29.55	88.57	37.96	95.63	127.00	12.14
6	33.44	85.09	40.58	92.16	126.95	21.08
7	30.26	66.24	34.98	70.74	97.21	22.10

	#19	#20	#21	#22	#23	#24
%	6.80	4.34	5.43	8.35	3.62	3.48
4	61.59	19.18	24.68	114.73	65.05	15.76
5	72.91	17.68	23.35	126.97	77.00	12.79
6	72.88	32.59	36.17	126.33	74.49	24.50
7	58.13	34.99	36.00	92.27	58.49	26.58

	#25	#26	#27
%	3.65	2.70	4.05
4	15.90	31.90	37.79
5	12.79	30.00	41.04
6	29.14	35.00	43.08
7	32.76	31.00	37.58

7.6 Accuracy Assessment Techniques

Both researchers and potential users of remotely-sensed data require procedures to assess the accuracy of classifications derived from remote-sensing sources. This need has been recognized by the remote sensing community and has been addressed on numerous occasions, including a national working conference, "Landsat Classification Accuracy" (Mead and Szajgin, 1981, 1982).

A broad spectrum of statistical sampling techniques has been proposed to test mapping accuracies. Most assume that a contingency table (Figure 7.13) has been produced from a random sample of individual pixels or clusters compared to "known" cover conditions. Previously, classification accuracy was computed as the ratio of the sum of the diagonal elements to the total sum of elements (Figure 7.14). Although simple to compute, this technique has been shown to over-estimate the true accuracy of the classification. To compensate for this random inflation of accuracy, the Kappa Coefficient of Agreement has been suggested as a standard as a measure of classification accuracy (Figure 7.15). The kappa or KHAT index will range from 0, no reduction in error, to 1, complete reduction of error, compared to the error from a completely random classifier (Figure7.16). Several small computer programs have been written to allow for the ease of computing the Kappa statistic.

For research purposes, complete enumeration of the test population, to facilitate a pixel-by-pixel comparison, has also been proposed. The use of complete enumeration, in the form of photo-interpreted cover-type maps, to evaluate the accuracy of Landsat classifications were compared with assessments made directly from the aerial photography. A computerized, geographic information system was utilized to compare the Landsat classifications with the cover-type maps on a pixel-by-pixel basis. Error maps of pixels which were similarly mis-classified by a variety of algorithms contained a larger number of errors than were verified from the aerial photography. For two test sites, only 67 and 52 percent of the pixels which were originally considered to be in error were substantiated as being in error. Discrepancies between the two results were determined to be primarily caused by definitional differences between the cover-type maps and the Landsat classifications, especially with regard to minimum-type size. Since Landsat classifications are typically compared with existing cover-type maps in an effort to replace photo-interpretation techniques or to provide an updating procedure, managers should be aware of the basic differences and limitations associated with these direct comparisons.

Confusion Table Format

7.13

	LANDSAT CLASSIFICATION						
COVER TYPE (Map)	Red [1] Pine	Jack Pine	Pine Mixtures	Swamp Conifers	Other [3]	**Total** [5]	***Percent Correct*** [8]
Red Pine [2]	_____ [4]						
Jack Pine		_____					
Pine Mixtures			_____				
Swamp Conifers				_____			
Other					_____		
Total [6]						[ ] [7]	
Percent Correct [9]							[ ] [10]

1 - columns correspond to classes, as determined from the Landsat classification, and show which cover type classes they actually represent

2 - rows correspond to classes, as determined from the cover type map, and show into which Landsat classes it was placed

3 - includes hardwoods and all non-forest categories

4 - values along the diagonal represent correctly classified pixels

5 - the total count for a class from the cover type map

6 - the total number of pixels for a particular Landsat class

7 - the total number of pixels for the entire sample

8 - the accuracy for a single class, considering omission errors only, ratio of the number of correct classifications for that row to the row total (expressed as a percent)

9 - the accuracy for a single class, considering commission errors only, ratio of the number of correct classifications for that column to the column total (expressed as a percent)

10 - overall classification accuracy, ratio of the sum of diagonal values to the total number of sample points (expressed as a percent)

Landsat Classification Performance

7.14

LANDSAT CLASSIFICATION

TYPE MAP	Red Pine	Jack Pine	Pine Mixes	Hard-woods	Grass	Water	Other	Total	*Percent Correct*
R. Pine	**66**	21	0	7	7	1	1	**103**	***64.1***
J. Pine	2	**22**	0	0	0	0	2	**26**	***84.6***
Mixtures	5	0	**5**	3	0	0	1	**14**	***35.7***
Hwds.	1	8	0	**166**	1	0	0	**176**	***94.3***
Grass	1	13	21	7	**61**	0	5	**108**	***56.5***
Water	0	0	0	0	0	**29**	0	**29**	***100***
Other	0	0	0	0	0	0	**16**	**16**	***100***
Total	**75**	**64**	**26**	**186**	**69**	**30**	**25**	**475**	
Percent Correct	***88.0***	***34.4***	***19.2***	***89.2***	***88.4***	***96.7***	***64.0***		***76.8***

Kappa Coefficient of Agreement

7.15

$$\hat{K} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} x_{i+}x_{+i}}{N^2 - \sum_{i=1}^{r} x_{i+}x_{+i}}$$

Where + represents summation over the index.

For computational purposes, the following form is often used:

$$\hat{K} = \frac{\theta_1 - \theta_2}{1 - \theta_2}$$

where $\theta_1 = \sum_{i=1}^{r} \frac{x_{ii}}{N}$ and $\theta_2 = \sum_{i=1}^{r} \frac{x_{i+}x_{+i}}{N^2}$

Summary of Landsat Classification Performance

7.16

Wexford County test site

Rank	Classification scheme	Kappa
1	April, visual interpretation	0.744
2	June, maximum likelihood	0.700
3	February, minimum distance	0.686
4	February, maximum likelihood	0.682
5	February, unsupervised clustering	0.678

Crawford County test site

Rank	Classification scheme	Kappa
1	June, maximum likelihood	0.623
2	February, maximum likelihood	0.563
3	February, minimum distance	0.562
4	February, unsupervised clustering	0.561
5	April, visual interpretation	0.549

Glossary

absolute altitude—Altitude above the actual surface of a planet or natural satellite, either land or water.

absolute orientation—The scaling, leveling, and orientation to ground control (in a photogrammetric instrument) of a relatively oriented stereoscopic model or group of models.

absorbed light—Light rays that are neither reflected nor transmitted when directed toward opaque or transparent materials.

absorption—The thermodynamically irreversible transformation of radiant energy into heat.

absorption band—A range of wavelengths (or frequencies) in the electromagnetic spectrum within which radiant energy is absorbed by a substance.

accomodation—The faculty of the human eye to adjust itself to give sharp images for different object distances. The ability of the eyes to bring two images into superimposition for stereoscopic viewing.

accuracy—The closeness of results of observations, computations, or estimates to the true values or to values which are accepted as being true.

achromatic—Devoid of hue, or transmitting light without showing its constituent colors.

actinic light—A part of the spectrum that causes chemical changes to take place in light sensitive photographic emulsions. The light that creates images on light sensitive material.

active—Denotes a source of radiation external to the surface or object.

active microwave—A system or a sensor that provides its own source of EMR in the microwave region (1mm to 1m), to detect and/or locate objects, measure altitude and to acquire imagery of the terrain. Examples are synthetic and real apperture radar, radar scatterometer and radar altimeter.

active system—A system having its own source of EMR as, for example, a radar .

acuity, visual—A measure of the human eye's ability to separate details in viewing an object.

acutance—An objective measure of the ability of a photographic system to show a sharp edge between contiguous areas of low and high illuminance.

adaption—The faculty of the human eye to adjust its sensitivity to varying intensities of illumination.

additive color process—A method for creating essentially all colors through the addition of light of the 3 additive color primaries (blue, green, and red) in various proportions.

adjustment—The determination and application of corrections to observations, for the purpose of reducing errors or removing internal inconsistencies in derived results.

aerial—Of or pertaining to operations in or from the air or atmosphere.

aerial camera—A camera specially designed for aerial use.

aerial film—A specially designed roll film supplied in many lengths and widths to fit aerial cameras.

aerial photograph—Any photograph taken from the air. Sometimes called aerial photo or air photograph.

aerial photograph, oblique—A photograph taken with the camera axis directed between the horizontal and the vertical. High oblique—An oblique photograph in which the apparent horizon is shown. Low oblique—An oblique photograph in which the horizon is not shown.

aerial photograph, vertical—An aerial photograph made with the optical axis of the camera approximately perpendicular to the Earth's surface and with the film as nearly horizontal as is practicable.

aerial photographs, composite—Aerial photographs made with a camera having one principal lens and two or more surrounding and oblique lenses symmetrically placed. The several resulting photographs may be rectified in printing to permit assembly as verticals with the same scale.

aerial photographs, overlapping—Two or more aerial photographs to which a portion of the total area projected thereon is common. Such photographs are used for stereoscopic studies and for making mosaics.

aerial photography—The art, science, or process of taking aerial photographs.

aerial reconnaissance—The securing of information by aerial photography or by visual observation from the air.

aerial survey—A survey using aerial photographs as part of the surveying operation; also, the taking of aerial photographs for surveying purposes.

aerospace—Of or pertaining to both the Earth's atmosphere and space.

air base—An imaginary line connecting the points in space at which successive photos in a flight strip were taken; specifically, the length of such a line.

airborne (device)—Any device transported by an aircraft.

air speed—The speed of an aircraft relative to the surrounding atmosphere.

algorithm—A statement of the steps to be followed in the solution of a problem. An algorithm may be in the form of a word description, an explanatory note, or a labeled diagram or flowchart. It usually refers to the coded instructions used by a computer to complete some operation.

altimeter—An instrument which indicates the vertical distance above a specified datum plane; when unmodified, usually means an aneroid barometer which utilizes relative pressure of the atmosphere.

altitude—Height above a datum; the datum is usually mean sea level.

altitude, absolute—Height above the surface of the Earth as distinguised from altitude, height above sea level. It is sometimes referred to as radar or radio altitude.

analytical phototriangulation—A phototriangulation procedure in which the spatial solution is obtained by computational routines. When performed with aerial photographs, the procedure is referred to as analytical aerotriangulation.

angle of drift—The angular difference between the true heading of an aircraft and its ground track.

angle of field—A property of a lens. The angle subtended by lines that pass through the center of the lens and locate the diameter of the maximum image area within the specified definition of the lens. Also called angular field.

angle of incidence—The angle at which EMR strikes a surface as measured from the normal to the surface at the point of incidence (limits 0 to 90 degrees).

angle of reflection—The angle which EMR reflected from a surface makes that is perpendicular (normal) to the surface.

angle of refraction—The angle made by the refracted ray with the incident ray when a ray of light passes through a transparent substance. The refracted ray is bent at an angle from the line of the incident ray.

angle of sun.—The angle of the sun above the horizon. Not only the quantity of light (lumens) being reflected to the aerial camera, but also the spectral quality of the light are influenced by sun-angle. Also called sun elevation, sun elevation angle.

angstrom (Å)—Unit of linear measurement equal to 10^{-10} m. In SI = 0.1 nanometers.

annotated photograph—A photograph on which planimetric, hypsographic, geologic, cultural, hydrographic, or vegetation information has been added to identify, classify, outline, clarify, or describe features that would not otherwise be apparent in examination of an unmarked photograph.

annotation—Any marking on illustrative material for the purpose of clarification, such as numbers, letters, symbols, and signs.

annual (thermal) wave—Annual cycle of heating and cooling of the upper 3-5m of soils, in response to the yearly progression of the seasons. Below this point, constant annual temperatures, at any given depth, may be observed. See diurnal wave.

antenna—The device that radiates EMR from a transmitter and receives EMR from other antennae or other sources.

aperture—The opening in a lens diaphragm through which light passes.

apparent horizon—In general, the apparent or visible junction of earth and sky, as seen from any specific position. Also called the apparent, visible, or local horizon.

astigmatism—An aberration affecting the sharpness of images for objects off the axis in which rays passing through different meridians of the lens come to a focus in different planes. Thus, an extra-axial point object is imaged as two mutually perpendicular short lines located at different distances from the lens.

attitude—The angular orientation of a camera, or of the photograph taken with that camera, with respect to some external reference system. The angular orientation of an aerial or space vehicle with respect to a reference system.

axis, optical—In a lens element, the straight line which passes through the centers of curvature of lens surfaces. Also called principal axis. In an optical system, the line formed by the coinciding principal axes of the series of optical elements.

axis of tilt—The line along which a tilted photo intersects the plane of an imaginary vertical photo taken with the same camera from the same point, and along which the tilted photo has the same scale as would the vertical photo.

azimuth—The direction of a line given as an angle measured clockwise from a reference direction, usually north. Direction at right angles to the antenna beam. In side-looking radar, the direction parallel to ground track.

band—A selection or range of wavelengths or frequencies.

bar scale—A graduated line on a map, plan, photograph, or mosaic, by means of which actual ground distances may be determined. Also called graphic scale.

base direction—The direction of the vertical plane containing the air base, which might be expressed as bearing or an azimuth.

base, photo—The distance between the principal points of two adjacent prints of a series of vertical aerial photographs.

bayonet mount—A device used to facilitate changing camera parts. Each part has prongs that fits into the mount and locks them into place.

bearing—Direction of a line measured as an acute angle from a reference meridian.

benchmark—A standard reference location or value used for calibration purposes. A point used in surveying or mapping, usually giving altitude (elevation above mean sea level or some other reference).

blackbody—An ideal emitter which radiates energy at the maximum possible rate per unit area at each wavelength for any given temperature.

blackbody radiation—The electromagnetic radiation emitted by an ideal black body; it is the theoretical maximum amount of radiant energy of all wavelengths which can be emitted by an object at a given temperature.

blow-up—Photographic slang meaning to enlarge or an enlargement.

bolometer—An instrument that measures the intensity of radiant energy by employing a thermally sensitive electrical resistor.

boresight camera—A camera mounted with its optical axis parallel to the axis of a sensor, such as an infrared spectrometer or radar, to photograph the area being sensed, thus providing location data.

brightness—The attribute of visual perception in accordance with which an area appears to emit more or less light.

brightness range—The ratio of the apparent brightness of highlights to the deepest shadow in the actual scene as measured from the camera station.

brilliance—The degree of intensity of a color.

cadastral map—A map showing the boundaries of subdivisions of land, usually with the bearings and lengths thereof and the areas of individual tracts, for purposes of describing and recording ownership. A cadastral map may also show culture, drainage, and other features relating to the value and use of land.

cadastral survey—A survey relating to land boundaries and subdivisions, made to create units suitable for transfer or to define the limitations of title.

calibrated focal length—The act or process of determining certain specific measurements in a camera or other instrument or device by a comparison with a standard, for use in correcting or compensating errors or for purposes of record.

calibration—The act or process of comparing certain specific measurements in an instrument with a standard.

camera—A lightproof chamber or box in which the image of an exterior object is projected upon a sensitized plate or film, through an opening usually equipped with a lens or lenses, shutter, and variable aperture.

camera, aerial—A camera specially designed for aerial use.

camera axis—In a single-lens camera, the photography perpendicular. In a multiple-lens camera, the photography perpendicular of the central perspective unit or the photography perpendicular of the transformed photograph.

camera calibration—The determination of the calibrated focal length, the location of the principal point with respect to the fiducial marks, the point of symmetry, the resolution of the lens, the degree of flatness of the focal plane, and the lens distortion effective in the focal plane of the camera and referred to the particular calibrated focal length.

camera, continuous-strip—A camera in which a continuous-strip exposure is made by rolling the film continuously past a narrow slit opening at a speed of the aircraft.

camera, ground—A camera designed for terrestrial use. Also called terrestrial camera.

camera magazine—The removable part of a camera in which the unexposed and exposed portions of film are contained.

camera, mapping—A camera specially designed for the production of photographs to be used in surveying. The prefixes mapping and surveying indicate that a camera is equipped with means for maintaining and indicating the interior orientation of the photographs with sufficient accuracy for surveying purposes. A mapping camera may be either an aerial mapping camera or a terrestrial mapping camera.

camera, metric—A specially constructed and calibrated camera used to obtain geometrically accurate photographs for use in photogrammetric instruments.

camera, multiband—A camera that exposes different areas of one film or more than one film, through one lens and a beam splitter, or two or more lenses equipped with different filters, to provide two or more photographs in different spectral bands.

camera, multiple-assembly—An assembly of two or more cameras mounted so as to maintain a fixed angle between their respective optical axes.

camera, multiple-lens—A camera with two or more lenses, the axes of the lenses being systematically arranged at a fixed angle to cover a wide field by simultaneous exposures in all chambers. In most such cameras the oblique lenses are arranged symmetrically around a central lens.

camera, panoramic—A camera with a very wide angle of view, up to horizon to horizon, usually equipped with a moving (sweeping) lens.

camera, photogrammetric—A general term applicable to cameras used in any of the several branches of photogrammetry.

camera port—The opening in the body or hull of a remote sensor platform through which the camera is operated.

camera, stereometric—A combination of two cameras mounted with parallel optical axes on a short, rigid base; used in terrestrial photogrammetry for taking photographs in stereoscopic pairs.

camera, surveying—A camera specifically designed for obtaining photographs to be used in surveying. The camera is equipped with a mechanism to maintain and to indicate the interior orientation of the photographs with sufficient accuracy for surveying purposes.

camera, terrestrial—A camera designed for use on the ground.

camera, trimetrogon—An assembly of three cameras equipped with wide-angle Metrogon lenses, in which one of the cameras is vertical and the other two are 60-degree obliques.

Cartesian coordinates—A coordinate system in which the locations of points in space are expressed by reference to three planes, called coordinate planes, no two of which are parallel.

cartography—Map and chart construction.

cartridge, film—A light-tight container which must be loaded with film in the dark but may be placed in the camera during daylight or under artificial light.

cassette—A container for roll film which may be loaded in the darkroom and used subsequently for daylight loading of the camera. A container to hold magnetic tape.

ceiling—The height above the earth's surface of the lowest layer of clouds or obstruction phenomena that is reported as broken, overcast, or obscuration and not classified as thin or partial. The maximum altitude at which an aircraft can fly.

cell, photoelectric—A device by which light is transformed into electrical energy. It can be used to activate a camera shutter or other device, or to measure the intensity of light.

center line—A line drawn from the center point of a vertical photo through the transposed center point from an overlapping photo.

center, photograph—The center of a photograph as indicated by the images of the fiducial marks of the camera. In a perfectly adjusted camera the photograph center and the principal point are identical.

center point—The point at the exact center of a photo, corresponding in position to the optical axis of the camera; it is sometimes referred to as the optical center, or principal point.

change detection—a process of comparing two or more images to determine differences.

chart—A map specifically designed for use in navigation.

chroma—The color dimension on the Munsell scales that correlates most closely with saturation.

classification—The process of assigning individual pixels to categories on the basis of spectral-reflectance characteristics.

closure or closing error—The amount by which a quantity obtained by a series of related measurements differs from the true or fixed value of the same quantity.

cluster—A homogenous group of units which vary "like" one another. "Likeness" is usually determined by the association, similarity, or distance among the measurement patterns associated with the units.

cluster analysis—Statistical analysis of observed units or values to show the likely groupings for unsupervised classification or to indicate confidence for supervised classification.

coated lens—A lens whose air-glass surfaces have been coated with a transparent film of such thickness and index of refraction as to minimize the light loss due to reflection.

color—That property of an object which is dependent on the wavelength of the light it reflects or, in the case of a luminescent body, the wavelength of light that it emits. White light is a balanced mixture of all the visible spectral colors.

color balance—The proper intensities of colors in a color print, positive transparency, or negative, that give a correct reproduction of the gray scale.

color composite—A color picture produced by assigning one of the primary colors to each of three spectral band images.

color infrared (film)—A three layer color film sensitized to green, red and near-infrared. Conventional color film is sensitive to blue, green and red.

color photography—Photography in which either the direct-positive or the negative-positive color process is used.

color sensitivity—The sensitivity of a photographic emulsion to light of various wavelengths.

compilation—The production of a new map from existing maps, aerial photographs, surveys, new data, or other sources.

composite photograph—A photograph made by assembling the separate photographs, made by the several lenses of a multiple-lens camera in simultaneous exposure, into the equivalent of a photograph taken with a single wide-angle lens.

computer compatible tape (CCT)—The magnetic tape upon which the digital data from multispectral scanner images are recorded.

contact print—A print made from a negative or a diapositive in direct contact with sensitized material.

contact size—A print, either positive or negative, of the same size as the negative or positive from which it was made.

contour—On land, an imaginary line on a surface connecting points of equal elevation; also, the line representing this feature on a map or chart (properly called contour line).

contour interval—The difference in elevation between adjacent contours.

contrast—The difference between highlights and shadows. The ratio of reflecting power between the highlights and shadows of a print determines the contrast.

contrast filter—A color filter so chosen as to make a colored subject stand out very sharply from surrounding objects.

contrast stretching—The process of increasing the contrast of images by digital or optical processing.

control—A system of points with established positions or elevations, or both, which are used as fixed references in positioning and correlating map features. Control is generally classified in four orders (with first order denoting highest quality) according to the precision of the methods and instruments used in establishing it, and the accuracy of the resultant positions and elevations. Often called basic control.

control, geodetic—Control which takes into account the size and shape of the earth; implies a reference spheroid representing the geoid and horizontal—and vertical-control datums.

control, ground—Control obtained by ground surveys as distinguished from control obtained by photogrammetric methods; may be for horizontal or vertical control, or both. Ground (in-situ) observations to aid in interpretation of remote sensor data.

control, horizontal—Control with horizontal positions only. The positions may be referred to the geographic parallels and meridians or to other lines of reference, such as plane coordinate axes.

control, photogrammetric—Control, established by photogrammetric methods as distinguished from control established by ground methods. Also called minor control.

control point—Any station in a horizontal and/or vertical control system that is identified on a photograph and used for correlating the data shown on that photograph.

control strip—A strip of aerial photographs taken to aid planning and accomplishing later aerial photography, or to serve as control in assembling other strips. A strip of film used for control of exposure, development, or both.

control, vertical—Control with elevations only; usually referred to mean sea level.

convergence of evidence—The bringing together of several types of information in order that a conclusion may be drawn in the light of all available data. In remote sensing, often implies increase in scale to obtain more information about a smaller area.

coordinate systems, State plane—A series of grid coordinate systems prepared by the U.S. Coast and Geodetic Survey for the entire United States, with a separate system for each State. Each State system consists of one or more zones. The grid coordinates for each zone are based on, and mathematically adjusted to, a map projection. The Lambert conformal conic projection with two standard parallels is used for zones of predominant east-west extent and

limited north-south extent. The transverse Mercator projection is used for zones of predominant north-south extent and limited east-west extent.

coordinates—Linear or angular quantities which designate the position of a point in a given reference or grid system.

coordinate, geographic—A system of spherical coordinates for describing the positions of points on the earth. The declinations and polar bearings in this system are the latitudes and longitudes respectively.

coordinates, grid—A plane-rectangular coordinate system based on and mathematically adjusted to a map projection in order that geographic positions (latitudes and longitudes) may be readily transformed into plane coordinates and the computations relating to them made by the ordinary methods of plane surveying.

coordinates, photograph—A system of coordinates, either rectangular or polar, describing the position of a point on a photograph.

coordinates, plane-rectangular—A system of coordinates in a horizontal plane, used to describe the positions of points with respect to an arbitrary origin by means of two distances perpendicular to each other. A plane-rectangular coordinate system is used in mapping areas so small that the errors introduced by substituting a plane for the curved surface of the earth will be within the required accuracy.

coordinates, space—A three-dimensional system of rectangular coordinates in which the x- and y-coordinates lie in a reference plane tangent to the earth at a selected point and the z-coordinate is perpendicular to that plane. Used in the extension of horizontal and vertical control through a series of overlapping vertical photographs from an initial point of tangency of the reference plane. The use of the term "space coordinates," should be strictly limited to a three-dimensional rectangular coordinate system which has not been adjusted to the vertical and horizontal control data.

coordinates, spherical—A system of polar coordinates in which the origin is the center of a sphere and the points all lie on the surface sphere. The polar axis of such a system cuts the sphere at its two poles. In photogrammetry, spherical coordinates are useful in defining the relative orientation of perspective rays or axes and make it possible to state and solve, in simple forms, many related problems.

corresponding images—A point or line in one system of points or lines homologous to a point or line in another system. Corresponding image points (sometimes incorrectly called conjugate points) are the images of the same object point on two or more photographs.

course—The direction in which a pilot attempts to fly an aircraft; the line drawn on a chart or map as the intended track. The direction of a course is always measured in degrees from the true meridian, and the true course is always meant unless it is otherwise qualified (e.g., as a magnetic or compass course).

coverage—The ground area represented on aerial photographs, photomosaics or maps.

coverage, stereoscopic—Aerial photographs taken with sufficient overlap to permit complete stereoscopic examination.

crab—The condition caused by failure to orient the camera so that the axis perpendicular to the long dimension of the film is parallel to the track of the airplane. This is indicated in vertical photography by the sides of the photographs not being parallel to the principal-point base line. Any turning of an airplane which causes its longitudinal axis to vary from the track of the plane.

crop—To trim or cut off parts of the picture. Usually accomplished by masking the image area during printing.

crown closure—A photo measure or estimate of the density of a forest stand. As seen on the vertical photograph, crown closure is the percentage of ground are occupied by tree crowns.

crown diameter, visible—The apparent diameter of a tree crown image on a vertical aerial photograph.

culture—A term applied to all the works of humans that are shown on a map.

data—The plural of datum. Numerical or quantitative notations.

data collection (device)—Any device designed for the collection of usually digital data.

datum—Any numerical or geometrical quantity or set of such quantities that can serve as a reference or a base for measurement of other quantities. For a group of statistical references, the plural form is data; as geographic data for a list of latitudes and longitudes. Refers to a direction, level, or position from which angles, heights, depths, speeds, or distances are conventionally measured.

datum, horizontal-control—The position on the spheroid of reference assigned to the horizontal control (triangulation and traverse) of an area and defined by (1) the position (latitude and longitude) of one selected station in the area, and (2) the azimuth from the selected station to an adjoining station. The horizontal-control datum may extend over a continent or be limited to a small area. A datum for a small area is usually called local datum and is given a proper name.

datum, horizontal plane—A plane perpendicular to the direction of gravity; any plane tangent to the geoid or parallel to such a plane.

datum, vertical-control—Any level surface (as, for example, mean sea level) taken as a surface of reference from which to reckon elevations; also called the datum level. Although a level surface is not a plane, the vertical-control datum is frequently referred to as the datum plane.

definition—The degree of sharpness, that is, distinctness of small detail in the picture image, negative, or print.

delineation—The visual selection and distinguishing of mapworthy features on various possible source materials by outlining the features on the source material, or on a map manuscript (as when operating a stereoscopic plotting instrument); also, a preliminary step in compilation. The delineation of features on a photograph.

density slicing—The process of converting the continuous gray tone of an image into a series of density intervals, or slices, each corresponding to a specific digital range.

details (mapping)—The small items or particulars of information (shown on a map by lines, symbols, and lettering) which, when considered as a whole, furnish the comprehensive representation of the physical and cultural features of the earth's surface. The greater the omission of details, the more generalized the map.

develop—To subject to the action of chemical agents for the purpose of bringing to view the invisible or latent image produced by the action of light on a sensitized surface; also, to produce or render visible in this way.

diaphragm—The physical element of an optical system which regulates the quantity of light traversing the system. The quantity of light determines the brightness of the image without affecting the size of the image.

diapositive—A positive image on a transparent medium such as glass or film; a transparency. The term originally was used primarily for a transparent positive on a glass plate used in a plotting instrument, a projector, or a comparator, but now is frequently used for any positive transparency.

diazo—Refers to a series of UV sensitive salts which when processed in ammonia vapors yield a specific dye in inverse proportion to the amount of UV exposure. A positive reproduction of a black-and-white transparency is produced when exposed in contact with a diazo film where the diazo film is exposed in direct proportion to the transparency of the black-and-white film.

digital data—Of or relating to data in the form of numerical digits; a readout in numerical digits; data displayed, recorded, or stored in binary notation.

digitize—To use numeric values to represent data.

digitization—The process of converting an image recorded originally on photographic material into numeric format.

direct positive—The positive image obtained by exposure in the camera with subsequent chemical treatment to develop and "reverse" the tones of the image.

displacement—Any shift in the position of an image on a photograph which does not alter the perspective characteristics of the photograph (i.e., shift due to tilt of the photograph, scale change in the photograph, and relief of the objects photographed).

display—The graphic presentation of the output data of a device or system as, for example, on a radar scope. The cathode ray tube is a widely used display device for the output of "electronic" sensors.

diurnal (thermal) wave— The daily temperature rise of surficial materials under the heating of the sun. In soils, this thermal change is restricted to about the first 30 cm; below this point relatively constant daily temperatures exist at any given depth. See **annual wave.**

drift—The horizontal displacement of an aircraft, caused by the force of wind, from the track it would have followed in still air. Sometimes used to indicate a special condition of crab wherein the photographer has continued to make exposures oriented to the predetermined line of flight while the airplane has drifted from that line.

electromagnetic energy—see electromagnetic radiation, the preferred term.

electromagnetic radiation (EMR)—Energy propagated through space or through material media in the form of advancing oscillations of in-phase, plane-polarized electric and magnetic fields. The term radiation, alone, is used commonly for this type of energy, although it actually has a broader meaning. Also called electromagnetic energy.

electromagnetic spectrum—The ordered array of known electromagnetic radiations extending from the shortest cosmic ray, through gamma rays and X-rays, across ultraviolet, visible, infrared and microwave radiation, and extending into the wavelengths of radio energy.

elevation—Vertical distance from the datum, usually mean sea level, to a point or object on the earth's surface. Not to be confused with altitude, which refers to points or objects above the earth's surface.

emissivity—The ability of a material, in comparison to that of a blackbody, to emit radiant energy. It is the ratio of the exitance of a real object at some temperature divided by the exitance of a theoretical blackbody at the same temperature.

emittance—The obsolete term for the radiant flux per unit area emitted by an object. See **exitance**, the preferred term.

emulsion—A suspension of a light-sensitive silver salt (especially silver chloride or silver bromide) in a colloidal medium (usually gelatin), which is used for coating photographic films, plates, and papers.

end lap—The overlap of aerial or space photographs or images along (foreward) the flightline or track of the platform.

enhancement, image—The process of altering the appearance of an image for the purpose of extraction of additional information. It may be accomplished by digital or photographic (optical) methods.

environment—The complex of physical, chemical and biotic factors that act upon an organism or an ecological community. An external condition or the sum of such conditions, in which a piece of equipment or a system operates (e.g. temperature environment). These environments are usually typified by a range of values, and may be either natural or artificial.

equator—In a system of polar or spherical coordinates, the great circle of a sphere which is perpendicular to the polar axis.

exitance—The radiant flux per unit area (Wm^{-2}) emitted by an object. Replaces the obsolete term **emittance**.

exposure—The total quantity of light received per unit area on a sensitized plate or film; may be expressed as the product of the light intensity and the exposure time, in units of (for example) meter-candle-seconds or watts per square meter. The act of exposing a light-sensitive material to a light source.

exposure interval—The time interval between the taking of successive photographs.

exposure time—The time during which a light-sensitive material is subjected to the action of light.

eyepiece—In an optical device, the lens group which is nearest the eye and with which the image formed by the preceding elements is viewed.

f-number—A representation of the speed of a lens, defined by focal length divided by diameter.

factor, filter—The amount that film exposure must be increased to off-set the reduction in light resulting from the use of a filter. A filter absorbs part of the light passing through it; therefore, less light reaches the film. The lens diaphragm must be opened wider or the shutter longer for correct exposure of the film. A filter factor of 2 means that the normal exposure must be double.

false-color, image—A color image in which the dye color is not the same as scene color. Infrared Ektachrome film produces false color images since the infrared exposure is represented as red, the red exposure as green, and the green exposure as blue.

far infrared—A term for the longer wavelengths of the infrared region, from 15 μm to 1 mm, the generally accepted shorter wavelength limit of the microwave part of the EM spectrum. This spectral region is severely limited in remote sensing because the atmosphere transmits very little radiation between 15 μm and the millimeter regions.

fiducial marks—Index marks (usually 4), rigidly connected with the camera lens through the camera body, which form images on the negative. The marks are adjusted so that the intersection of lines drawn between opposite fiducial marks define the principal point.

field-of-view—The solid angle through which an instrument is sensitive to radiation. Due to various effects, diffraction, etc., the edges are not sharp. In practice they are defined as the "half-power" points, i.e., the angle outwards from the optical axis, at which the energy sensed by the radiometer drops to half its on-axis value.

film—The sensitized material and its base, which is exposed in a camera.

film cassette—A reloadable film container, usually used for perforated roll film, which may be installed in or removed from the camera magazine in daylight or under artificial illumination.

film speed—That property of film which determines how much exposure must be allowed for a given light source in order to secure a negative of correct density and contrast.

filter—Any material which, by absorption or reflection, selectively modifies the radiation transmitted through an optical system. Such a filter may operate by polarization, scattering, etc., and may also be electronic. The filter usually is interposed between the film and the scene being photographed, but it may form part of the film itself.

filter factor—A number indicating the exposure increase necessary when using a filter, as compared to the exposure necessary under the same conditions without the filter.

filtering—The decomposition of a signal into its harmonic components. The separation of a wanted component of a time series from any unwanted residue (noise).

fix—To render a developed photographic image permanent by removing the unaffected light-sensitive material. To establish the position of a point of observation by a surveying procedure. Also, the point thus established.

flatness—Lack of contrast in print or negative, generally due to flat, even lighting, overexposure, or incorrect concentration of developer.

flicker method—The alternate projection of corresponding photographic images onto a tracing-table, platen or projection screen, or into the optical train of a photogrammetric instrument.

flight altitude—The vertical distance above a given datum, usually mean sea level, of an aircraft in flight or during a specified portion of a flight. In aerial photography, when the datum is mean ground level of the area being photographed, this distance is called flight height or sometimes absolute altitude.

flight attitude—The spatial orientation of an aircraft, rocket, satellite, spacecraft, or other vehicle in flight.

flight characteristics—A characteristic exhibited by an aircraft, rocket, spacecraft, or other vehicle during flight, such as a tendency to stall or yaw, an ability to remain stable at certain speeds.

flight (flightline) map—The map on which are indicated the desired lines of flight and/or the positions of exposure stations previous to the taking of air photographs, or the map on which are plotted, after photography, selected air stations and the groundtracks joining them.

flight strip—A succession of overlapping aerial photographs taken along a single course.

flightpath—The path made or followed in the air or in space by an aircraft, rocket, etc.; the continuous series of positions occupied by a flying body; more strictly, the path of the center of gravity of the flying body, referred to the Earth or other fixed reference.

floating mark—A mark seen as occupying a position in the three-dimensional space formed by the stereoscopic fusion of a pair of photographs and used as a reference mark in examining or measuring the stereoscopic model. Index mark—A real mark (such as a cross or dot) lying in the plane or the object space of a photograph and used singly as a reference mark in certain types of monocular instruments, or as one of a pair to form a floating mark.

focal length—The distance measured along the optical axis from the optical center of the lens to the plane of critical focus of a very distant object.

focal length-calibrated—An adjusted value of the equivalent focal length, computed to equalize the positive and negative values of distortion over the entire field used in the aerial camera. Also stated as the distance along the lens axis from the interior perspective center to the image plane; the interior center of the perspective being selected so as to equalize the positive and negative values of lens distortion over the field. The calibrated focal length is used when determining the setting of diapositives in plotting instruments and in photogrammetric computations based on linear measurements on the negative, such as those made with a precision comparator.

focal length, equivalent—Same as focal length but measured to the plane of best average definition throughout the angular field of the lens-calibrated focal length; an adjusted value of the focal length which distributes the effect of lens distortion throughout the entire area of the photograph. It usually minimizes the effect of distortion for the purpose of determining the best principal distance setting for stereoplotters.

focal plane—The plane (perpendicular to the axis of the lens) in which images of points in the object field of the lens are focused.

focus—To make the camera adjustments necessary to have the focal plane of the lens and film or ground-glass coincide. The point at which the rays from a point source of light reunite and cross after passing through a camera lens. In practice, the plane in which a sharp image of any scene is formed.

focus, fixed—A focus that cannot be adjusted, as in an ordinary box camera. Aerial cameras, with few exceptions, are focused at infinity and must be flown at an altitude greater than the hyperfocal distance. Fixed-focus head cameras are normally focused at the hyperfocal distance, thus permitting all objects from infinity to one-half the hyper-focal distance to be sharply defined.

fog—A fault photographic negative seen as a veil over the whole negative, as darkened patches, or as an obscuring of shadows (light areas in the negative). It may be due to light reaching the negative accidentally (light fog), or to an error in compounding or using solutions (chemical or dichroic fog), or to gradual degeneration of the film or developer with age.

form line—An approximate, or uncontrolled contour line.

frame—Any individual member of a continuous sequence of photographs. One complete television picture consisting of two fields of interlaced scanning lines.

frequency—Number of oscillations or wavelengths that pass a point per unit time.

full aperture—The maximum opening of a lens or lens diaphragm.

generation—The number of reproduction steps in which a negative or positive photographic copy is separated from the original. The original is the first generation, any positive made from that negative is a second generation copy.

geodesy—The science which deals mathematically with the size and shape of the earth, and the earth's external gravity field, and with surveys of such precision that overall size and shape of the earth must be taken into consideration.

geodetic coordinates—Quantities which define the position of a point on the spheroid of reference with respect to the planes of the geodetic equator and of a reference meridian.

geodetic datum—A datum consisting of five quantities, the latitude and longitude and elevation above the reference spheroid of an initial point, a line from this point, and two constants which define the reference spheroid.

geoid—The figure of the earth; the mean sea level conceived as extended continuously through all the continents.

geometric accuracy—Four types: Geographic—the ability to locate a point using standard latitude and longitude coordinates; Positional—the ability to locate a point in an image by using a map; Scene registration—the ability to superimpose the same point in two images of a scene taken at the same time (different spactral bands); Temporal registration—the ability to superimpose a point in two images of the same scene taken at different times (same or different spectral bands).

geometric correction—The removal of sensor, platform, or scene induced geometric errors such that the data conform to a desired projection. This involves the creation of a new digital image by resampling the input digital image.

geostationary (satellite)—A satellite so placed into orbit above the Earth that it rotates with the Earth and thus remains fixed over the same area.

gray body—A radiating surface whose radiation has essentially the same spectral energy distribution as that of a blackbody at the same temperature, but whose emissive power is less.

gray scale—A monochrome strip of shades ranging from white to black with intermediate shades of gray. The scale is placed in a setup for a color photograph and serves as a means of balancing the separation negatives and positive dye images.

grid line—One of the lines in a grid system; a line used to divide a map into squares. East-west lines in a grid system are x-lines, and north-south lines are y-lines.

ground-based (device)—A piece of equipment or mechanism situated on the ground (usually used in conjunction or support of an aerial or a space mission).

ground-check—The process of collecting or providing information concerning the actual state of the ground usually at the time of a remote sensing overflight.

ground control—Accurate data on the horizontal and/or vertical positions of identifiable ground points.

ground data—Supporting data collected on the ground, and information derived therefrom, as an aid to the interpretation of remotely-recorded surveys, such as airborne imagery.

ground information—Information derived from ground data and surveys to support interpretation of remotely sensed data.

ground resolution—The area of the earth's surface encompassed by the IFOV of a radiometer at a given flight altitude above terrain:

$$D = H' \beta$$

where

D = diameter of the ground area viewed
H' = flying height above the terrain
β = IFOV of the system (expressed in radians)

ground speed—The rate of motion of an aircraft or space vehicle along its track with relation to the ground; The resultant of the heading and air speed of an aircraft and the direction and velocity of the wind.

ground support—Services and information provided to an aerial or space mission from the ground.

ground survey—A survey made by ground methods, as distinguished from an aerial survey.

hard copy—Information recorded on a sheet (map, picture, chart, graphics, etc.) in such a manner that it may be stored or transported.

heading—Azimuth of the longitudinal axis of an aircraft.

heat-sensing (device)—An instrument used to detect and sense heat.

high oblique—An oblique photo which shows the horizon line.

high-oblique photograph—An oblique photograph in which the apparent horizon is included within the field of view.

horizon—In general, the apparent or visible junction of earth and sky, as seen from any specific position. Also called the apparent, visible, local, or sensible horizon.

horizon photograph—A photograph of the horizon, taken simultaneously with a vertical photograph and used to determine the relative tilt between adjacent photographs.

horizontal-control datum—The position on the spheroid of reference assigned to the horizontal control (triangulation and traverse) of an area and defined by (1) the position (latitude and

longitude) of one selected station in the area, and (2) the azimuth from the selected station to an adjoining station. The horizontal-control datum may extend over a continent or be limited to a small area. A datum for a small area is usually called a local datum and is given a proper name.

hue—The attribute of a color by virtue of which it differs from gray of the same brilliance, and which allows it to be classed as red, yellow, green, blue, or intermediate shades of these colors.

humidity—Degree of wetness, especially of the atmosphere. Relative humidity—Ratio of water vapor present, at a given temperature, to the greatest amount possible at the temperature. Absolute humidity—The weight of water vapor contained in a given volume of air, in grains per cubic foot or grams per cubic meter. Specific humidity—The weight of water vapor per unit weight of the moist air.

image—The representation of an object produced by the optical, electro-optical, optical mechanical, or electronic recordation of reflected or emitted EMR. The term is generally used when the EMR from a scene is not directly recorded on film. See **imagery.**

image compression—An operation which preserves all or most of the information in the image and which reduces the amount of memory needed to store an image or the time needed to transmit an image.

image enhancement—The manipulation of image density to more easily see certain features of the image.

image, latent—The invisible image, recorded by light action upon the film or plate, which is made visible in development.

image motion—In aerial photography, the movement of the platform during the exposure which blurs and degrades the photographic image.

image-motion compensator—A device installed with certain aerial cameras to compensate for the forward motion of an aircraft while photographing ground objects. True image-motion compensation must be introduced after the camera is oriented to the flight track of the aircraft and the camera is fully stabilized.

image processing—Encompasses all the various operations which can be applied to photographic or image format data. These include, but are not limited to, image compression, image restoration, image enhancement, preprocessing, quantization, spatial filtering, and other image pattern recognition techniques.

image restoration—A process by which a degraded image is restored to its original condition. Image restoration is possible only to the extent that the degradation transform is mathematically invertible.

imagery —The products of image-forming instruments (analogous to photography). The term is generally used when the EMR from a scene was not directly recorded on film.

inch (in.)—Exactly 2.540 centimeters.

index map—A map of smaller scale on which are depicted the location (with accompanying designations) of specific data, such as larger-scale topographic quadrangles or geodetic control. A map showing the location and numbers of flight strips and photographs. Photo index—A mosaic (not an index map) made by assembling individual photographs, with accompanying designations, into their proper relative positions and copying the assembly photographically at a reduced scale.

infrared (IR)—Pertaining to or designating the portion of the EM spectrum with wavelengths beyond the red end of the visible spectrum from 0.7 to 14 μm. It is divided into three regions: near, middle, and thermal IR.

infrared film—A color or a black and white film which responds to photographic infrared radiation.

infrared, middle—Pertaining to or designating the portion of the EM spectrum with wavelengths from 1.35 to 5.0 μm.

infrared, near—Pertaining to or designating the portion of the EM spectrum with wavelengths from 0.7 to 1.35 μm.

infrared, photographic—Pertaining to or designating the portion of the EM spectrum with wavelengths from 0.7 to about 0.98 μm that can be sensed directly by photographic films. Photographic IR is a subset of the near IR spectral region.

infrared scanner—An optical-mechanical scanning device which operates in one or more spectral bands of the infrared EMR range.

infrared, thermal—Pertaining to or designating the portion of the EM spectrum with wavelengths from about 3.0 to 14 μm. The thermal IR region contains two useful bands: short-wavelength thermal (3.4 to 4.8 μm) and long-wavelength thermal (8.1 to 13.2 μm).

instantaneous field-of-view (IFOV)—The solid angle through which a detector is sensitive to radiation. For a radiometer, it is determined by the focal length of the instrument's optical system and the size of it's detector element. In a scanning radiometer, it is the solid angle subtended by the detector element when the scanning motion is stopped.

instrument—A device that measures, detects, or otherwise performs to provide information about quantities or conditions.

instrumentation—The installation and use of electronic, gyroscopic, and other instruments for the purpose of detecting, measuring, recording, telemetering, processing, or analyzing different values or quantities as encountered in the flight of a rocket or spacecraft. The assemblage of such instruments in an aircraft, rocket, spacecraft, other vehicle or place.

interface—A common boundary between two parts of a system, whether material or non-material. To join or work together, coordinate, either physically or mentally.

interpupillary distance—The distance between the pupils of the eyes of an individual. Also called eye base and interocular distance.

intervalometer—A timing device for automatically operating the shutter of a camera at any predetermined interval.

irradiance—The measure of radiant flux incident on a surface, expressed in Wm^{-2}.

key, photointerpretation—A device designed to aid in the rapid, accurate identification of an object and in judging its significance from its appearance in a picture.

knot—A nautical mile per hour, 1.1508 statute miles per hour.

latent image—An invisible image produced by the physical or chemical effect of light upon matter (usually silver halide or halides), which can be rendered visible by the subsequent chemical process of photographic development.

latitude—Angular distance north or south of the Equator measured along a meridian.

leader—A strip of film at the beginning of a roll of film which is used for loading the camera.

legend—A description, explanation, table of symbols, and other information, printed on a map or chart to provide a better understanding and interpretation of it. The title of a map or chart formerly was considered part of the legend, but this usage is obsolete.

lens—A piece, or combination of pieces (elements) of glass or other transparent material shaped to form all but the simplest cameras.

lens distortion—An aberration affecting the position of images off the axis in which objects at different angular distances from the axis undergo different magnifications.

lens element—One lens of a complex lens system. In a photographic lens, the terms front element and rear element are often used.

light—Visible radiation (about 0.4 to 0.7 um in wavelength) considered in terms of its luminous efficiency, i.e., evaluated in proportion to its ability to stimulate the sense of sight.

light, actinic—Light that is capable of causing photochemical change in a photographic emulsion. The wavelength of actinic light varies with the sensitivity of the material. Blue and violet are normally considered to be the most antinic of visible light rays because all commonly used photographic materials are highly sensitive to these colors.

line, center—A line extending from the true center point overlapping aerial photographs through each of the transposed center points.

line, flight—A line drawn on a map or chart to represent the track over which an aircraft has been flown or is to fly. The line connecting the principal points of vertical aerial photographs.

line, rhumb—A line which has constant bearing on the globe.

lithosphere—The solid part of the Earth or other spatial body. Distinguished from the atmosphere and the hydrosphere.

loran—An acronym for **lo**ng-**ra**nge **n**avigation; it is a low-frequency aid to navigation operating in the 90 to 110 kHz range.

low oblique—An oblique photo which does not show the horizon line; the term is restricted by some writers, however, to photos more nearly vertical than horizontal (camera axis less than 45 degrees from vertical).

magazine—A container for rolled film or photographic plates, attached to the camera body; those used with aerial cameras are equipped with automatic mechanisms that advance and position the photographic material for exposure.

magnetic declination—The angle between true (geographic) north and magnetic north (direction of the compass needle). The magnetic declination varies for different places and changes continuously, but very slowly, with respect to time.

magnification—The ratio of the size of an image to the size of the object, normally the ratio of a linear quantity in the image to a corresponding linear quantity in the object.

map—A representation in a plane surface, at an established scale, of the physical features of (natural, artificial, or both) a part or all of the earth's surface with the means of orientation indicated. Also, similar representation of certain features to satisfy specific requirements. Frequently the word "map" is preceded by an adjective which explains what type of information the map is designed primarily to present. Many types and scales of maps are made to serve numerous purposes.

map (verb)—To prepare a map or engage in a mapping operation.

map, base—A map showing certain fundamental information, used as a base upon which additional data of specialized nature are compiled. Also, a map containing all the information from which maps showing specialized information can be prepared: a source map.

map, cadastral—A map showing the boundaries of subdivisions of land, usually with the bearings and lengths thereof and the areas of individual tracts, for purposes of describing and recording ownership. A cadastral map may also show culture, drainage, and other features relating to the value and use of land.

map, contour—A topographic map which portrays relief by means of contour lines.

map grid—Two sets of parallel lines at right angles drawn on a plane surface and used as a rectangular coordinate system (a reference system) for plotting position and scaling distances and directions in surveying an mapping. A map grid may or may not be based on a map projection.

map, hydrographic—A map showing a portion of the waters of the earth, including shorelines, the topography along the shore and of the submerged portions, and as much of the topography of the surrounding country as is necessary for the purpose intended.

map, planimetric—A map presenting only the horizontal positions for the features represented: distinguished from a topographic map by the omission of elevation contours.

map projection—A systematic drawing of lines on a plane surface to represent the parallels of latitude and the meridians of longitude of the earth or a section of the earth.

map, special-purpose—Any map designed primarily to meet specific requirements. Usually the map information portrayed on a special-purpose map is emphasized by omitting or subordinating nonessential or less important information. A word or phrase is usually employed to describe the type of information which a special-purpose map is designed to present, i.e., route, tax, or index map.

map, topographic—A map which represents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form. A topographic map uses contours or comparable symbols to show mountains, valleys, and plains; and, in the case of hydrographic charts, symbols and numbers to show depths in bodies of water.

marginal information—The notations printed in the margins or borders of mosaics, plans, or especially, maps.

mean sea level (MSL)—The average level of the sea, as calculated from a large number of observations taken at equal intervals of time.

meteorology—The study of dealing with the phenomena of the atmosphere. This includes not only the physics, chemistry, and dynamics of the atmosphere, but is extended to include many of the direct effects of the atmosphere upon the earth's surface.

meter (m)—The basic unit of length of the metric system, defined as 1.650.763.73 wavelengths in vacuo of the unperturbed transition 2p 10—5d in krypton u. Effective 1 July 1959 in the U.S. customary system of measures, 1 yard = 0.9144 meter, exactly, or 1 meter = 0.094 yards = 39.37 inches. The standard inch is exactly 25.4 millimeters.

metric system—The international standard system of weights and measures. The meter, kilogram, and second are the fundamental units of measures of length, mass, and time, respectively. Officially referred to as the International System of Units (abbreviated SI).

microwave—EM radiation between 1 meter and 1 millimeter in wavelength or 0.3 to 300 GHz in frequency. The portion of the electromagnetic spectrum in the millimeter and centimeter wavelengths, bounded on the short wavelength side by the far infrared (at 1 mm) and on the long wavelength side by very high-frequency radio waves. Passive systems operating at these wavelengths sometimes are called microwave systems. Radar is an active microwave system. The exact limits of the microwave region are not defined.

Mie scattering—Scattering produced by atmospheric particulates having diameters about equal to the wavelengths of the interacting EMR.

mission—The dispatching of one or more aircraft to accomplish one particular task. A single flight of an aircraft engaged in photographic reconnaissance. A flight of one or more space vehicles to accomplish one or more objectives.

mosaic—An assemblage of overlapping aerial or space photographs or images whose edges have been matched to form a continuous pictorial representation of a portion of the earth's surface.

mosaic, controlled—A mosaic which is laid to ground control and in which prints are used which have been ratioed and rectified.

mosaic, semi-controlled—A mosaic composed of corrected or uncorrected prints laid to a common basis of orientation other than ground control.

mosaic strip—A mosaic consisting of one strip of photographs or images taken on a single flight.

mosaic, uncontrolled—A mosaic composed of uncorrected prints, the detail of which has been matched from print to print without ground control or other orientation.

mosaicking—The assembling of photographs or other images whose edges are cut and matched to form a continuous photographic representation of a portion of the earth's surface.

mottled—Covered with irregular spots; said of negatives, prints, or image texture.

mount, aerial camera—A device which supports a camera in an aircraft for vertical and/or oblique photography.

multiband system—A system for simultaneously observing the same target with several filtered bands, through which data can be recorded. Usually applied to cameras, may be used for scanning radiometers which utilize dispersant optics to split wavelength bands apart for viewing by several filtered detectors.

multi-lens camera—A camera having two or more lenses pointing at the same target which, when used with different film/filter combinations, produces multiband photographs. A camera having two or more lenses pointed at an angle to one another, and taking two or more overlapping pictures simultaneously.

multispectral—Generally used for acquisition of remote sensing data in two or more spectral bands.

multispectral (line) scanner—A remote sensing device which operates on the same principle as the infrared scanner except that it is capable of recording data in the ultraviolet and visible portions of the spectrum as well as the infrared.

nadir—That point on the celestial sphere vertically below the observer, or 180 degrees from the zenith. That point on the ground vertically beneath the perspective center of the camera lens.

nadir, ground—The point on the ground vertically beneath the perspective center of the camera lens.

nadir, photograph—That point at which a vertical line through the perspective center of the camera lens pierces the plane of the photograph.

nautical chart—A map especially designed for the mariner, on which are shown navigable waters and the adjacent or included land, if any, and on which are indicated depths of water, marine obstructions, aids to navigation, and other pertinent information.

nautical mile (knot)—A unit of distance used principally in navigation. For practical navigation it is usually considered the length of 1 minute of any great circle of the earth, the meridian being the great circle most commonly used. Because of various lengths of the nautical mile in use throughout the world, due to differences in definition and the assumed size and shape of the earth, the International Hydrographic Bureau in 1929 proposed a standard length of 1852 meters, which is known as the international nautical mile.

near infrared—Pertaining to or designating the portion of the EM spectrum with wavelengths from 0.7 to 1.35 μm. The term emphasizes the radiation reflected from plant materials, which peaks around 0.85 micrometers. It is also called solar infrared, as it is only available for use during the daylight hours.

negative—A photographic image on film, plate, or paper, in which the tones are reversed. A film, plate, or paper containing such a reversed image.

negative, color—A photographic image on film, plate, or paper, in which the colors appear as the complements of those in nature. A film, plate, or paper containing such an image.

oblique—Any position, or direction that is slanted, inclined, or not perpendicular.

oblique photograph—A photograph taken with the camera axis intentionally directed between the horizontal and the vertical. A high-oblique photograph is one in which the apparent horizon is included within the field of view, whereas a low-oblique photograph does not include the apparent horizon within the field of view.

optical axis—In a lens element, the straight line which passes through the centers of curvature of the lens surfaces. Also called principal axis. In an optical system, the line formed by the coinciding principal axes of the series of optical elements.

orbit—The path of a body or particle under the influence of a gravitational or other force. For instance, the orbit of a celestial body is its path relative to another body around which it revolves. To go around the earth or other body in an orbit.

orientation—Direction or arrangement with respect to other detail. The direction in which the photograph is turned with respect to observer, map, etc. A single photo is best oriented for study when turned so that the shadows are cast toward the observer.

origin—The reference position from which angles or distances are reckoned.

orthophotographic projection—Projection by parallel rays onto a plane at right angles to the rays.

orthophoto map—A photomap made from an assembly of orthophotographs. It may incorporate special cartographic treatment, photographic edge enhancement, color separation, or a combination of these.

orthophoto mosaic—An assembly of orthophotographs forming a uniform scale mosaic.

orthophoto scope—A photomechanical device, used in conjunction with a double-projection anaglyphic instrument, for producing orthophotographs.

over exposure—The result of too much light being permitted to act on a light-sensitive material, with either too great a lens aperture or too slow a shutter speed or both.

overlap—The area common to two successive photos along (foreward) the same flight strip; the amount of overlap is expressed as a percentage of photo area.

overlapping pair—Two photographs taken at different exposure stations in such a manner that a portion of one photograph shows the same terrain as shown on a portion of the other photograph.

panchromatic—Used for films that are sensitive to broad band (e.g., entire visible part of spectrum) EMR, and for broadband photographs.

passive—Applied to EMR emitted from an object or surface; also used for reflected natural EMR.

passive system—A sensing system that detects or measures radiation reflected or emitted by the target.

pattern—In a photo image, the regularity and characteristic placement of tones or textures. The relations between any more-or-less independent parameters of a response; e.g., the pattern in the frequency domain of the response from an object.

pattern recognition—Concerned with, but not limited to, problems of: pattern discrimination, pattern classification, feature selection, the pattern identification, cluster identification, feature extraction, filtering, enhancement, and pattern segmentation.

perpendicular, photograph—The perpendicular from the interior perspective center to the plane of the photograph.

perspective—Representation, on a plane or curved surface, or natural objects as they appear to the eye. The appearance of such objects to the eye.

photo base—Air base reduced to photo scale; measured as the mean distance between center points and transposed center points on a stereopair of photos.

photogeology—The interpretation of the geology of an area from an analysis of landforms, drainage, tones, and vegetation distribution on aerial photographs.

photogrammetric survey—A method of surveying that uses either ground photographs or aerial photographs.

photogrammetry—The art or science of obtaining reliable measurements by means of photography.

photograph—A picture formed by the action of light on a base material coated with a sensitized solution which is chemically treated to fix the image points at the desired density. Usually now taken to mean the direct action of EMR on the sensitized material.

photograph axes—The preferred term is fiducial axes.

photograph center—The center of a photograph as indicated by the images of the fiducial mark or marks of the camera. In a perfectly adjusted camera, the photograph center and the principal point ar identical.

photograph, composite—A photograph made by assembling the separate photographs made by each lens of a multiple lens camera in a simultaneous exposure into the equivalent of a photograph taken with a single wide-angle lens.

photograph horizon—A photograph of the horizon taken simultaneously with another photograph for the purpose of obtaining an indication of the orientation of the other photograph at the instant of exposure.

photograph perpendicular—The perpendicular from the interior perspective center to the plane of the photograph.

photographic interpretation—The act of examining photographic images for the purpose of identifying objects and judging their significance.

photographic interpreter (PI)—An individual specially trained or skilled in photographic interpretation. Photointerpreter, photo interpreter, and image interpreter are other widely used terms.

photography—The art of process of producing images or sensitized material through the action of light. The term photography is sometimes incorrectly used in place of photographs, however, the distinction between the process and the product is a valuable one and should be observed.

photomap—A single photo, composite, or mosaic showing coordinates and marginal information: normally reproduced in quantity.

photosensitive—A term used to describe substances whose chemical composition is altered by the action of light.

phototopography—The science of surveying in which the detail is plotted entirely from photographs taken at suitable ground stations.

phototriangulation— The process of the extension of horizontal and/or vertical control whereby the measurements of angles and/or distance on overlapping photographs are related into a spatial solution using the perspective principles of the photographs.

pitch—A rotation of an aircraft about the horizontal axis normal to its longitudinal axis so as to cause a nose-up or nose-down attitude. A rotation of the camera or of the photograph-coordinate system about either the photograph axis or the exterior Y; tip or longitudinal tilt.

pixel—A contraction of a picture element. In Landsat, an integrated radiance mapping unit.

Planck's Law—A mathmatical expression for the variation of monochromatic radiant flux as a function of wavelength for a blackbody at a given temperature.

planimetric map—A map which presents only the horizontal positions for features represented.

polarization—The direction of the electric vector in an EM wave. Waves may be plane-polarized, or linearly polarized, in which case the electric vector is in the same direction at all points in the wave. They may also be circularly or elliptically polarized, in which case the direction of the electric vector at some point changes with time (circular) or both direction and amplitude change in a relative manner (elleptical).

polarizing filter—A filter which passes light waves vibrating in one polarization direction only. Used over camera lenses to cut down or remove rays of any or all other polarization direction(s) when they may constitute objectionable reflections from glass, water, or other highly reflecting surfaces.

positive—A photographic image having approximately the same rendition of light and shade as the original subject. A film, plate, or paper containing such an image.

positive, direct—A positive image obtained directly without the use of a negative.

precision—A quality associated with the refinement of instruments and measurements, indicated by the degree of uniformity or identity of repeated measurements.

precision camera—An indefinite term sometimes applied to any camera used for photogrammetric purposes. May be construed as meaning a camera that can be calibrated.

preprocessing—Commonly used to describe corrections and processing done to image data before information extraction. Includes geometric and radiometric correction, mosaicking, resampling, and formatting.

primary color—Any one of three colors—red, yellow, or blue—used for producing an extensive range of colors by additive mixtures.

principal plane—The vertical plane through the internal perspective center containing the photograph perpendicular of a tilted photograph.

processing—The operations necessary to produce negatives, diapositives, or prints from exposed film, plates, or papers. The manipulation of data by means of computer or other device.

projection, map—A systematic drawing of lines on a plane surface to represent the parallels of latitude and the meridians of longitude of the earth or a section of the earth. A map projection is frequently referred to as a projection but the complete term should be used unless the context clearly indicates the meaning.

pseudoscopic view—A reversal of the normal stereoscopic effect, causing valleys to appear as ridges and ridges as valleys.

radar—Acronym for radio detection and ranging. A method, system, or technique, including equipment components, for using beam, reflected, and timed EMR to detect, locate, and (or) track objects, to measure altitude and to acquire a terrain image. In remote sensing of the earth's or a planetary surface, it is used for measuring, and often, mapping the scattering properties of the surface.

radial—A line or direction from the radial center of a photograph to any other point on the photograph.

radial triangulation—The aerotriangulation procedure, either graphical or analytical, in which directions form the radial center, or approximate radial center, of each overlapping photograph are used for horizontal-control extension by the successive intersection and resection of these direction lines. A radial triangulation also is correctly called a radial plot or a minor-control plot. If made by analytical methods, it is called an analytical radial triangulation. A radial triangulation is assumed to be graphical unless prefixed by the word analytical. A graphical triangulation is usually laid out directly onto ground control plotted on a map, map projection, or map grid; but it may be first laid out independently of such control and later adjusted to it as a unit. In the latter case, the scale and azimuth of the radial triangulation unit are not known until it is adjusted to the ground control. The radial center for near-vertical photographs may be the principal-point, the nadir point, or the isocenter. A radial triangulation is assumed to be made with principal points as radial centers unless the definitive term designates otherwise (as, for example, nadir-point triangulation or nadir-point plot, the isocenter triangulation or isocenter plot. The adjective radial is not necessary in these four terms). The adjective analytical is required to designate that the triangulation is by analytical and not graphical methods (e.g., analytical nadir-point triangulation).

radiance—The accepted term for radiant flux in power units (e.g. watts) and not for flux density per solid angle (e.g. watts/cm^{2}sr) as often found in publications.

radiant temperature—Concentration of the radiant flux from a material. Radiant temperature is the product of the kinetic temperature multiplied by the emissivity to the one-fourth power.

radiation—The emission and propagation of energy through space or through a material medium in the form of waves; e.g., the emission and propagation of EM waves, or of sound and elastic waves. The process of emitting radiant energy.

Rayleigh scattering—Scattering by particles small in size compared with the wavelengths being scattered, e.g., scattering of blue light by the atmosphere.

reconnaissance—A general examination or survey of the main features, or certain specific features, of a region, usually as a preliminary to a more detailed survey.

reconnaissance photography—Aerial photography taken primarily for purposes other than making maps, charts, or mosaics.

rectification—The process of projecting a tilted or oblique photograph onto a horizontal reference plane, the angular relation between the photography and the plane being determined by ground reconnaissance. Transformation is the special process of rectifying the oblique images from a multiple-lens camera to equivalent vertical images by projection onto a plane that is perpendicular to the camera axis. In this case, the projection is onto a plane determined by the angular relations of the camera axis and not necessarily onto a horizontal plane.

reference spheroid—A spheroid determined by revolving an ellipse about its shorter (polar) axis and used as a base for geodetic surveys of a large section of the earth (such as the Clarke Spheroid of 1866, which is used for geodetic surveys in the United States). The spheroid of reference is a theoretical figure whose dimensions closely approach the dimensions of the geoid; the exact dimensions are determined by various considerations of the section of the earth's surface concerned.

reflectance—The ratio of the radiant energy reflected by a body to that incident upon it.

reflection—EMR neither absorbed nor transmitted is reflected. Reflection may be diffuse, when the incident radiation is scattered upon being reflected from the surface, or specular, when all or most angles of reflection equal the angle of incidence.

refraction—The bending of EMR rays when they pass from one medium to another having a different index of refraction or dielectric coefficient. EMR rays also bend in media that have continuous variations in their indices of refraction or dielectric coefficients.

registration (image)—The process of superimposing two or more images or photographs so that equivalent geographic points coincide. Registration may be done digitally or photographically.

r**elative humidity**—Ratio of water vapor present, at a given temperature, to the greatest amount possible at that temperature.

relative tilt—The tilt of a photograph with reference to an arbitrary plane, not necessarily a horizontal plane, such as that of the preceding or subsequent photograph in a strip. Also defined as the angle between the photograph perpendicular and a reference direction, such as the photograph perpendicular of the preceding or subsequent photograph in a strip.

remote sensing—In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g., the utilization at a distance (as from

aircraft, spacecraft, or ship) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers, radiometers, scanners, and radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, and scintillation counters. The practice of data collection in the wavelengths from ultraviolet to radio regions. This restricted sense is the practical outgrowth from airborne photography.

rendezvous—To assemble or cause to assemble at a certain place and time.

representative fraction (R.F.)—The relation between map or photo distance and ground distance, expressed as a fraction (1/25,000) or often as a ratio (1:25,000) (1 inch on map = 25,000 inches on ground).

reproduction—The processes involved in printing copies from an original drawing. The principal processes are photography, lithography, (or engraving), and printing. Also, a printed copy of an original drawing, made by any of the processes of reproduction.

resolution—The ability of an entire remote sensor system, including lens, antennae, display, exposure, processing, and other factors, to render a sharply defined image. It may be expressed as line pairs per millimeter or meters, or in many other manners. In radar, resolution usually applies to the effective beamwidth and range measurement width, often defined as the half-power points. For infrared line scanners the resolution may be expressed as the instantaneous field-of-view. Resolution also may be expressed in terms of temperature or other physical property being measured. If expressed in size of object, or distances on the ground, the distance is termed ground resolution.

resolution cell—The element on the ground distinguishable on the image, usually consisting of the half-power beamwidth distance by the half-power pulse duration. As some systems use other discrimination techniques, however, different definitions may apply.

resolution target—Regularly spaced pairs of light and dark bars that are used to evaluate the resolution of images or photographs.

resolving power—A mathematical expression of lens definition, usually stated as the maximum number of line pairs per millimeter that can be resolved (that is, seen as separate lines) in an image.

return beam vidicon (RBV)—A modified vidicon television camera tube, in which the output signal is derived from the depleted electron beam reflected from the tube target.

rhumb line—A line (curved) on the surface of the earth, crossing all meridians at a constant angle. Also called a loxodromic curve. On a Mercator projection, the rhumb line is represented by a straight line.

roll—A rotation of an aircraft about its longitudinal axis so as to cause a wing-up or wing-down

attitude. A rotation of a camera or a photograph-coordinate system about either the photograph x axis or the exterior X axis.

satellite—An attendant body that revolves about another body. A man-made object that revolves about a spacial body.

scale—The full range of tones of which a photographic paper is capable of reproducing is called the scale of the paper, it is also termed dynamic range. The ratio of a distance on a photograph or map to its corresponding distance on the ground. Scale may be expressed as a ratio, 1:24,000; a representative fraction, 1/24,000; or an equivalence, 1 in. = 2,000 ft.

scale, graphic—A graduated line on the margin of a map, chart, mosaic, etc., by means of which scaled distances may be measured in terms of actual ground distances. Also called bar scale.

scale, gray—A term used to describe the various tonal graduations on a photographic medium, cathode ray tube, or other display medium or device.

scale height—A measure of the relationship between density and temperature at any point in an atmosphere; the thickness of a homogeneous atmosphere which would give the observed temperature or pressure.

scale, tree crown—A simple measuring device printed on a transparent templet for measuring diameters of tree crowns and dimensions of other small objects. It may be designed in the form of a micrometer wedge or with small circular dots of graduated sizes.

scanner—Any device that scans, and by this means produces an image. A radar set incorporating a rotatable antenna, or radiator element, motor drives, mounting, etc., for directing a searching radar beam through space and imparting target information to an indicator.

scanning—The sweep of a mirror, prism, antenna, or other element across the track (direction of flight); may be straight, circular, or other shape. The motion of the radar antenna assembly when searching for targets.

scanning radiometer—A radiometer, which by the use of a rotating or oscillating plane mirror, can scan a path normal to the movement of the radiometer. The mirror directs the incoming radiation to a detector, which converts it into an electrical signal. This signal is amplified to stimulate a device such as a tape recorder, or glow tube, or CRT that can be photographed to produce a picture. When the system is moved forward at velocity V and altitude H, a suitable V/H ratio may be established, so that consecutive scans are just touching. This is often called an IR-imager, but is only so restricted because of the optical materials used, all-reflective optics being as useful in the UV and visible regions. They may all be single or multiple-band.

scanning radiometer (microwave)—A scanning device which operates in the microwave region of EMR, or portions of it, by systematically breaking up an image into picture elements (or pixels) and reducing some attribute of each picture element.

scattering—The process by which small particles suspended in a medium of a different index of refraction diffuse a portion of the incident radiation in all directions. The process by which a

rough surface diffusely reflects EMR incident upon it.

scene—The area on the ground that is covered by an image or photograph.

sensitivity, color—The sensitivity of a photographic emulsion to light of various wavelengths.

sensor—Any device which gathers EMR or other energy and presents it in a form suitable for obtaining information about the environment. Passive sensors, such as thermal infrared and microwave, utilize EMR produced by the surface or object being sensed. Active sensors, such as radar, supply their own energy source. Aerial cameras use natural or artificially produced EMR external to the object or surface being sensed.

shadow—Obscurity within the area or space from which direct EMR from a source is excluded by an interposed opaque body. A no-return area extending in range from an object which is elevated above its surroundings. The object obstructs the beam, preventing illumination of the area behind it. Radar shadows are analogous to shadows caused by visible light.

shutter—The mechanism of a camera which, when set in motion, permits light to reach the sensitized surface of the film or plate for a predetermined length of time.

sidelap—The area common to two photos in adjacent flight strips; the amount is expressed as a percentage of the total photo area. Also called overlap.

sidelooking radar—An all weather, day/night remote sensor which is particularly effective in imaging large areas of terrain. It is an active sensor, as it generates its own energy which is transmitted and received to produce a photo-like picture of the ground. Also referred to as sidelooking airborne radar, abbr. SLAR.

signature—Any characteristic or series of characteristics by which a material may be recognized. Used in the sense of spectral signature.

signature analysis techniques—Techniques which use the variation in the spectral reflectance or emittance of objects as a method of identifying the objects.

slotted templet—A templet on which the radials are represented as slots cut in a sheet of cardboard, metal, or other material.

slotted templet triangulation—A graphic radial triangulation using slotted templets.

space coordinates—May refer to any general three-dimensional coordinate system used to define the position of a point in the object space, as distinguished from the image of the point on a photograph.

spacecraft—Devices, manned and unmanned, which are designed to be placed into an orbit about the earth or into a trajectory to another celestial body. Generally considered to be maneuverable, as contrasted to satellites, which are placed in “fixed” orbits.

spatial model—A term applied to the three-dimensional image seen by stereoscopic methods.

spectral band—An interval in the electromagnetic spectrum defined by two wavelengths or frequencies.

spectral colors—The continuous band of pure colors in the visible spectrum are divided, for convenience, into seven basic spectral colors: violet, indigo, blue, green, yellow, orange, and red.

spectral discrimination—The ability to differentiate between segments of spectrum.

spectral reflectance—The reflectance of electromagnetic energy at specified wavelength intervals.

spectrum—In physics, any series of energies arranged according to wavelength (or frequency). The series of images produced when a beam of radiant energy is subject to dispersion. A rainbow-colored band of light is formed when white light is passed through a prism or a diffraction grating. This band of colors results from the fact that the different wavelengths of light are bent in varying degrees by the dispersing medium and is evidence of the fact that white light is composed of colored light of various wavelengths.

speed, emulsion—A measure of the sensitivity of the emulsion. It determines the exposure required to produce the desired density of image.

speed, ground—The velocity of an aircraft along its track with relation to the ground; the resultant of the heading and air speed of an aircraft and the direction velocity of the wind.

speed, lens—The ratio of the equivalent focal length to the diameter of the entrance pupil at the maximum diaphragm opening.

spheroid of reference—See spheroid or ellipsoid under geoid.

State Plane Coordinate Systems—See coordinate systems, state plane.

stationary orbit—An orbit in which an equatorial satellite revolves about the primary at the same angular rate as the primary rotates on its axis. From the primary, the satellite thus appears to be stationary over a point on the primary.

Stefan-Boltzmann law—One of the radiation laws; it states that the amount of emergy radiated per unit time from a unit surface area of an ideal black body is proportional to the fourth power of the absolute temperature of the black body.

stereo base—A line representing the distance and direction between complementary image points on a stereopair of photos correctly oriented and adjusted for comfortable stereoscopic vision under a given stereoscope, or with the unaided eyes.

stereogram—A stereopair of photos or drawings correctly oriented and permanently mounted for stereoscopic examination.

stereopair—A pair of photos which overlap in area and are suitable for stereoscopic examination.

stereophotogrammetry—Photogrammetry utilizing stereoscopic equipment and methods.

stereoscope—A binocular optical instrument for assisting the observer to view two properly oriented photographs or diagrams to obtain the mental impression of a three-dimensional model.

stereoscopic base—The length of the air base as represented on a photograph.

stereoscopic image—That mental impression of a three-dimensional object which results from stereoscopic vision.

stereoscopic model—The mental impression of a three-dimensional model which results from viewing two overlapping perspective views.

stereoscopic pair—Two photographs of the same area taken from different camera stations so as to afford stereoscopic vision; frequently called stereopair.

stereoscopic plotting instrument—An instrument for plotting a map or obtaining spatial solutions by observation of stereoscopic models formed by stereopairs of photographs.

stereoscopic vision—Binocular vision which enables the observer to view an object simultaneously from two different perspectives (as stations) to obtain the mental impression of a three-dimensional model.

stereoscopy—The science or art which deals with three-dimensional effects and the methods by which these effects are produced.

stereotriangulation—The use of stereoscopic plotting instruments to establish horizontal and (or) vertical control data by orientation of the stereoscopic pairs fo photographs in a continuous strip. Orientation of the initial model is by reference to ground control established by survey aperture.

stereo triplet—A series of three photos, the end members of which overlap sufficiently on the central one to provide complete stereoscopic coverage for the latter.

strip—Any number of photos taken along a photo flight line, usually at an approximately constant altitude.

strip radial triangulation—A direct radial triangulation in which the photographs are plotted in flight strips without reference to ground control and the strips are later adjusted together to the ground control.

subtractive color process—A method of creating essentially all colors through the subtraction of light of the 3 subtractive color primaries (cyan, magenta and yellow) in various proportions through use of a single white light source.

sun synchronous—An earth satellite orbit in which the orbit plane is near polar and the altitude such that the satellite passes over all places on earth having the same latitude twice daily at the same local sun time.

survey—The act or operation of making measurements for determining the relative positions on, above, or beneath the earth's surface; also, the results of such operations; also, an organization for making surveys.

surveying camera—See camera, surveying.

symbol—A diagram, design, letter, or abbreviation, placed on maps and charts, which (by convention, usage, or reference to a legend) is understood to stand for or represent a specific characteristic or object.

target—The distinctive marking or instrumentation of a ground point to aid in its identification on a photograph. In photogrammetry, target designates a material marking so arranged and placed on the ground as to form a distinctive pattern over a geodetic or other control-point marker on a property corner on line, or at the position of an identifying point above an underground facility or feature. In radar, an object returning a radar echo to the receiver.

telemetry—The science of measuring a quantity or quantities, transmitting the measured value to a distant station, and there interpreting, indicating, or recording the quantities measured.

telephoto lens—A lens comprising a positive front element and a negative rear element; the focal length of the combination is greater than the distance from the front lens surface to the focal plane.

terrain—An area of ground considered as to its extent and topography.

terrestrial photograph—A photograph taken by a camera located on the ground. Sometimes called a ground photograph, although this is not a preferred term.

texture—In remote sensing, pertaining to emitted or infrared radiation in the 4.5 to 13.5 wave length range; any sensible heat; of or pertaining to heat, as thermal capacity, emissivity or conductivity.

thermal infrared—Pertaining to or designating the portion of the EM spectrum with wavelengths from about 3.0 to 14 μm. The thermal IR region contains two useful bands: short-wavelength thermal (3.4 to 4.8 μm) and long-wavelength thermal (8.1 to 13.2 μm). The spectral limits represent the envelope of energy emitted by the earth, behaving as a greybody, with a surface temperature around 290 K (27 ^{o}C).

thermal capacity (heat capacity)—The ability of a material to store heat; product of density and specific heat at constant pressure (cal cm^{-3} $^{o}C^{-1}$).

thermal conductivity—The ability of material to conduct heat as a consequence of molecular motion. A measure of the rate at which heat will pass through a material (W m^{-1} K^{-1}).

thermal inertia—Sometimes referred to as the **thermal contact coefficient**, it is a measure of the rate of heat transfer and is the product of thermal conductivity and thermal capacity.

thermal radiation—The electromagnetic radiation emitted by a hot black-body, such as the

filament of lamp.

tilt—The angle between the optical axis of the camera and the plumb line for a given photo.

tilt displacement—Displacement of images, on a tilted photograph, radially outward or inward with respect to the isocenter, according as the images are, respectively, on the low or high side of the isometric parallel (the low side is the one tilted closer to the earth, or the object plane).

tilt, x- and y—Tilt expressed as resultant rotations about each of two stationary rectangular axes lying in a horizontal plane, and the x-tilt being the resultant rotation about the x-axis and the y-tilt the resultant rotation about the y-axis. In an aircraft, the x-axis is the longitudinal axis of the aircraft, lengthwise through the fuselage; the y-axis is the transverse axis, from wingtip to wingtip.

time, Greenwich mean—Mean solar time of the meridian of Greenwich, England, used by most navigators and adopted as the prime basis of standard time throughout the world.

tolerance—The allowable variation from a standard or from specified conditions.

tone—Each distinguishable shade variation from black to white.

topography—Features of the surface of the earth considered collectively as to form. A single feature (such as a mountain or valley) is called a topographic feature. Topography is subdivided into hypsography (relief features), hydrography (water and drainage features), and culture (man-made features).

track—The actual path of an aircraft above, or a ship on, the surface of the earth. The course is the path which is planned; the track is the path which is actually taken. The azimuth of this path generally is referred to the true meridian.

transmittance—The ratio of the radiant energy transmitted through a body to that incident upon it.

transparency—The light-transmitting capability of a material. A positive image upon glass or film, intended to be viewed by transmitted light, either black-and-white or in color; also called a diapositive.

tree height, visible—That part of the total height of a tree discernible on an aerial photograph, limited by the observer's stereoscopic acuity and by the point in a tapering tree crown where the crown diameter is too small to register as photo detail.

triangulation—An operation in surveying which consists of extending the survey from a measured base line by measuring the angles in a network of triangles at least one of which includes the base line as one of its sides.

triangulation, radial—A method of triangulation using overlapping aerial photographs. The center of each photograph serves as a station from which directions to points imaged are traced or measured and used to extend the triangulation. Also called a radial plot or minor control plot.

ultraviolet absorbing filter—A haze cutting filter used mainly in photography with color films to avoid expressive bluishness and loss of contrast in the pictures; usual designations are U.V.; Haze; Wratten 2A.

ultraviolet radiation—EMR of shorter wavelength than visible radiation but longer than X-rays; roughly, radiation in the wavelength interval between 10 and 4000A.

ultraviolet rays—Radiant energy in the ultraviolet portion of the EM spectrum.

uncontrolled mosaic—A mosaic made without correction for distortion of any type.

underexposure—The result of insufficient light being allowed to pass through the lens to produce all the tones of an image; or of sufficient light being allowed to pass for too short a period of time.

value (color)—Degree of lightness, one of the attributes, along with hue and saturation, that may be thought of as the dimensions of color.

vertical—Perpendicular, or at right angle to the plane of the horizon.

vertical photograph—An aerial photograph made with the camera axis vertical (or as nearly vertical as practical) in an aircraft.

video—In general, used to mean television, or used in the transmission or reception of the television image. Specifically, pertains to the bandwidth and spectrum position of the signal which results from television scanning and which is used to reproduce a picture.

view—The appearance to the eye, on a photograph, etc., of a scene or an aspect of something; and act of viewing or inspection.

vignette—The interference, by the lens mounting or other obstruction, with oblique rays, which causes a reduction in the effective diaphragm area. A process of regulating the distribution of light which reaches the print in such a way that the image obtained fades out toward the edges.

vignetting—A gradual reduction in density of parts of a photographic image caused by the stopping of some of the rays entering the lens. Thus, a lens mounting may interfere with the extreme oblique rays. An antivignetting filter is one that gradually decreases in density from the center toward the edges; it is used with aerial wide-angle lenses to produce a photograph of uniform density by cutting down the overexposure of the photograph center.

vignetting filter—A filter which gradually decreases in density from the center toward the edges. It is used in certain cases in photography or printing processes to produce a photograph of uniform density.

visibility—The greatest distance toward the horizon at which prominent objects (such as mountains, buildings, and towers) can be seen and identified by the unaided eye.

visible radiation—EMR of the wavelength interval to which the human eye is sensitive, the spectral interval from approximately 0.4 to 0.7 um.

vision, binocular—Simultaneous vision with both eyes.

wave—A disturbance which is propagated in a medium in such a manner that at any point in the medium the quantity serving as measure of disturbance is a function of time, while at any instant the displacement at a point is a function of the position of the point.

wavelength—Wavelength = velocity/frequency. In general, the mean distance between maximums (or minimums) of a roughly periodic pattern. Specifically, the least distance between particles moving in the same phase of oscillation in a wave disturbance. Optical and IR wavelengths are measured in nanometers (10-9m). Micrometers (10-6m) and Angstroms (19-19m).

white—An object is said to be white if it reflects all wavelengths of the visible spectrum equally. White light is a wavelength intensity distribution which creates a hueless sensation to the eye.

wing photograph—A photograph taken by one of the side or wing lenses of a multiple-lens camera.

x-axis—A horizontal axis in a system of rectangular coordinates; that line on which distances to the right or left (east or west) of the reference line are marked, especially on a map, chart, or graph.

X-ray—Nonnuclear EMR of very short wavelength, lying within the interval of 0.1 to 100A (between gamma rays and ultra-violet radiation).

y-axis—A vertical axis in a system of rectangular coordinates; that line on which distances above or below (north or south of) a reference line are marked, especially on a map, chart, or graph.

yaw—The rotation of an aircraft about its vertical axis so as to cause the aircraft's longitudinal axis to deviate from the flight line. Sometimes called crab. The rotation of a camera or a photograph coordinate system about either the photograph z axis or the exterior z axis.