Topic Series 01

Introduction to Spatial Technologies

I. Photogrammetry

Photogrammetry is the science, art, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy, and other phenomena. Originally photogrammetry consisted of analyzing photographs, but now includes analysis of recorded acoustical energy pattern and magnetic phenomena. Photographic records still play a major role. Included within the definition of photogrammetry are two distinct areas:

1. Metric photogrammetry - making precise measurements from photos and other image media to determine relative locations of points, distances, scales, angles, areas, volumes, elevations, and the sizes and shapes of objects.

2. Interpretative photogrammetry - recognizing and identifying objects on aerial imagery and judging their significance.

Metric photogrammetry consists of making precise measurements from photos and other information sources to determine, in general, the relative locations of points. This enables finding distances, angles, areas, volumes, elevations, and the sizes and shapes of objects. The most common application of metric photogrammetry is the preparation of planimetric and topographic maps from photographs. The photographs are most often aerial (taken from an airborne vehicle), but terrestrial photos (taken from earth-based cameras) are also used.

Interpretative photogrammetry deals principally in recognizing and identifying objects and judging their significance through careful and systematic analysis. It includes branches of photographic interpretation and remote sensing. Photographic interpretation involves the study of photographic images, while remote sensing, which is a newer branch of interpretative photogrammetry, includes not only the analysis of photography but also the use of data gathered from a wide variety of sensing instruments, including multispectral cameras, infrared sensors, thermal scanners, and side-looking airborne radar. Remote sensing instruments, which are often carried in vehicles as remote as orbiting satellites, are capable of providing quantitative as well as qualitative information about objects. At the present time, with our recognition of the importance of preserving our environment and natural resources, photographic interpretation and remote sensing are both being employed extensively as tools in management and planning.

II. History and Development of Photogrammetry

Interesting History Concerning Photo-Intrepretation

Interpretative photogrammetry, commonly referred to as photo-interpretation (PI), is concerned with recognizing, identifying, and judging the significance of objects on remotely acquired imagery. In the 1962, military photo interpreters identified wood containers (approximately 120 ft in length) on cargo ships in the harbor of Havana Cuba**,** new roads with wide turn radii leading from the harbor to deep, circular holes in the ground, and large storage tanks near the holes. The U.S. immediately told Cuba to remove the long range missiles from Cuba or there would be war. Question; how did the photo interpreter induce there were missiles on the ships although no missiles were ever seen or identified directly?

Recent History

In the middle of July 1990, American KH-11 satellites passing over the Middle East began transmitting disturbing imagery of the border between Kuwait and Iraq. Where the optical system of the satellites had previously shown empty desert, it now showed an Iraqi division equipped with modern T-72 Russian tanks. The following day, the transmission showed evidence of a strong Iraqi force of 300 tanks and 10,000 men, plus a division of the Republican Guard. By the third day, image analysts estimated a force of 35,000 troops poised on the border.

Among the analysts were Colonel (Ret.) Lang who had extensive experience in the Middle East; also concerned was a Charles Allen, a National Intelligence Officer for Warning, who was convinced that Saddam Hussein was preparing to attack Kuwait. He, Allen, warned the National Security Council on August 1st., but the staff of NSC and the Intelligence Community (an oxymoron?) concluded that Saddam was bluffing. The satellites had done their jobs, the image analysts had done a good job, but the bureaucracy had fumbled the ball. This makes an excellent point! Remotely sensed data is just that - data, it does not provide information per se. It takes a human in the loop to convert data to information. We knew the potential of satellites or gathering military information from early in the Space Age. Despite their great potential, early satellites were far from perfect ... they returned their data by parachutes, sometime days or even weeks after the fact. Both the 1967 Six-Day War (Israel) and the Soviet invasion of Czechoslovakia were over long before we acquired imagery; after the '73 Yom Kippur War (Israel) a CIA analyst said, "we had wonderful coverage but we didn't get the images until the war was over." However, in 1976, the U. S. intelligence community gained a tremendous technological advantage with the launch of KH-11 (Keyhole #11); the KH 11 could return imagery almost immediately, and they have relatively long lives, a resolution (on a clear day) of 6 inches). The KH's transmit to ground stations at the rate of one image per 5 seconds; most images are simply stored, but others are viewed immediately. I believe that they are orbital-moveable, and can be positioned to cover "hot spots!" Current uses - monitoring Soviet arms reductions, drug trafficking, possible nuclear sites in the Middle East and North Korea.

However, as indicated earlier, the data is just data until it is transformed into "information" by a skilled interpreter. The people who analyze satellite imagery are trained to extract the maximum amount of information. They use PI Keys - volumes that contain satellite views of everything from submarines, cruiser, to aircraft to missile silos to SCUD missile launchers. For example, the surrogates of an ICBM site is modern roads with a wide turn radius that end in a secured area. Interpreters always examine an object in relation to its environment, to it surroundings. This is often called surrogate analysis. You may never actually see the object in question, but by an analysis of surrounding objects, you can deduce the nature of the object, just as in the ICBM missile site.

Much has been said about reading license plates from "spy" satellites just what is the reality? The resolution - the smallest object that can be discriminated - of a satellite can be calculated as follows: Wavelength x Altitude/camera aperture. Given the Low Earth obitual nature, about 200 miles, and a wavelength on the visible part of the electromagnetic spectrum, say slighter greater than a millionth of a foot: = a figure just a bit greater than 1; then given an aperture (mirror) about 8 ft, we should be able to see an object with a dimension of 1/8 of a foot, 1.5 inches. So, maybe we can detect an E from a B on a license plate given that the letters are normal - about 2.5 inches high.

One point here needs emphasis - maximizing information! In an civilian remote sensing mission, THE OBJECT TO IS MAXIMIZE THE INFORMATION CONTENT OF THE DATA WHILE MINIMIZING TO COST PER UNIT OF INFORMATION! The beauty of high quality remotely sensed data is that is can be used and reused by different experts; the silviculturist will be able to gain information that will assist him; the harvesting man will see his thing, the wildlifer, the recreationist, etc. But back to recent developments: the Gulf War.

KH-lls played a major role here, but it was the startling array and combination of both old and "NEW" remote sensing technology exhibited by the military that decided the war. The Defense Mapping Agency produced 12,000 individual products, more than 100 million map sheets, and over 600 digital map products; these map products (PHOTOGRAMMETRY) plus the NAVSTAR constellation of satellites and the handheld GPS receivers gave the U.S. troops a decided edge in maneuvering troops, and vehicles through the roadless desert; this capability also gave the Air Force the ability to do their pin-point bombing, assisted by radar sensors, thermal sensors and laser guidance on the bombs. They used every remote sensing technology that we will cover in this course, plus a few new ones. The NOAA weather satellites also provided invaluable information on sandstorms, etc;

So, how did all this started? What was the beginning of the"SPACE AGE?" Was it the launch of SPUTNIK by the Russians in 1957? Or was it Werner Von Braun and his group of rocket scientists in Germany in 1943? Or was it much earlier than this? Perhaps several thousand years ago when the Chinese invented black powder rockets? I believe that each of these events added impetus to our current space age technology. But one thing we cannot overlook is the early groundwork that was done to introduce the science of PHOTOGRAMMETRY.

Development of Photogrammetry

Developments leading to the present-day science of photogrammetry occurred long before the invention of photography. As early as 350 B. C. Aristotle had referred to the process of projecting images optically. The actual practice of photogrammetry could not occur, of course, until a practical photographic process was developed. This occurred in 1839, when Louis Daguerre of Paris announced his direct photographic process. In his process the exposure was made on metal plates which had been light-sensitized with a coating of silver iodide. This is essentially the photographic process in use today.

A year after Daguerre's invention, Arago, a geodesist with the French Academy of Science, demonstrated the use of photographs in topographic surveying. The first actual experiments in using photogrammetry for topographic mapping occurred in 1849 under the direction of Colonel Laussedat's experiments were the use of kites and balloons for taking aerial photographs. Due to difficulties encountered in obtaining aerial photographs, he curtailed this area of research and concentrated his efforts on mapping with terrestrial photographs. In 1859, Colonel Laussedat presented an accounting of his successes in mapping using photographs. His pioneering work and dedication to this subject earned him the title "Father of Photogrammetry."

Topographic mapping using photogrammetry was introduced to North America in 1886 by Captain Deville, the Surveyor General of Canada. He found Laussedat's principles extremely convenient for mapping the rugged mountains of Western Canada. The U. S. Coast and Geodetic Survey (now the National Geodetic Survey), adopted photogrammetry in 1894 for mapping along the border between Canada and the Alaska Territory.

Meanwhile new developments in instrumentation, including improvements in cameras and films, continued to nurture the growth of photogrammetry. In 1861 a three-color photographic process was developed, and roll film was perfected in 1891. In 1909 Dr. Carl Pulfrich of Germany began to experiment with stereo pairs of photographs. His work formed much of the foundation for the development of many instrumental photogrammetric mapping techniques in used today.

The invention of the airplane by the Wright Brothers in 1902 provided the great impetus for the emergence of modern aerial photogrammetry. Until that time almost all photogrammetric work was, for the lack of a practical means of obtaining aerial photos, limited to terrestrial photography. The airplanes was first used in 1913 for obtaining photographs for mapping purposes. Aerial photos were used extensively during World War I, primarily in reconnaissance. In the period between the two World Wars, aerial photogrammetry for topographic mapping progressed to the point of mass production of maps. During this period many private firms and governmental agencies in North America and in Europe became engaged in photogrammetric work.

During World War II photogrammetric techniques were used extensively to meet the great new demand for maps. Air maps interpretation were also employed more widely than ever before in reconnaissance and intelligence. Out of this war-accelerated mapping program came many new developments in instruments and techniques.

Contributions in instrumentation and techniques during the past 35 years have been too numerous to itemize. All the contributions taken collectively, however, have made photogrammetry so accurate, efficient, and advantageous that at the present time, except for mapping small parcels, very little topographic mapping is done by other means. Although topographic mapping constitutes the major use of photogrammetry, it is also being employed in many other fields.

History of Photogrammetry in Forestry

1917 - WWI	Mapped a national forest in the west; first use in forestry.
1920 - Canada	Mapping of spruce budworm infestation.
1923 - Germany	All theories on inventory procedures were developed.
1929 - Canada	German theories on inventory were tried in Canada.
1940 - Oregon	First aerial timber cruise performed.
1941 - Pennsylvania	U.S. Government used aerial photos to inventory timber in anthrocite region
1943 - Maine	Brown Company made a timber appraisal in Vermont, NH, and Maine.
1945-46 - Harvard	Stephen Spurr gave short courses in aerial photos and initiated new interest.

III. Map vs. Aerial Photograph

An aerial photograph <u>cannot</u> be considered a map!

<u>Map</u>

1. map = two-dimensional scale representation of a portion of the earths surface.

2. all points appear as if they are viewed from above, straight down; i.e. <u>orthogonal projection</u>. (see Figure 1-1 below)

3. the scale is constant across the entire map and all points have been located, orthogonally, on the datum plane.

<u>Aerial Photo</u>

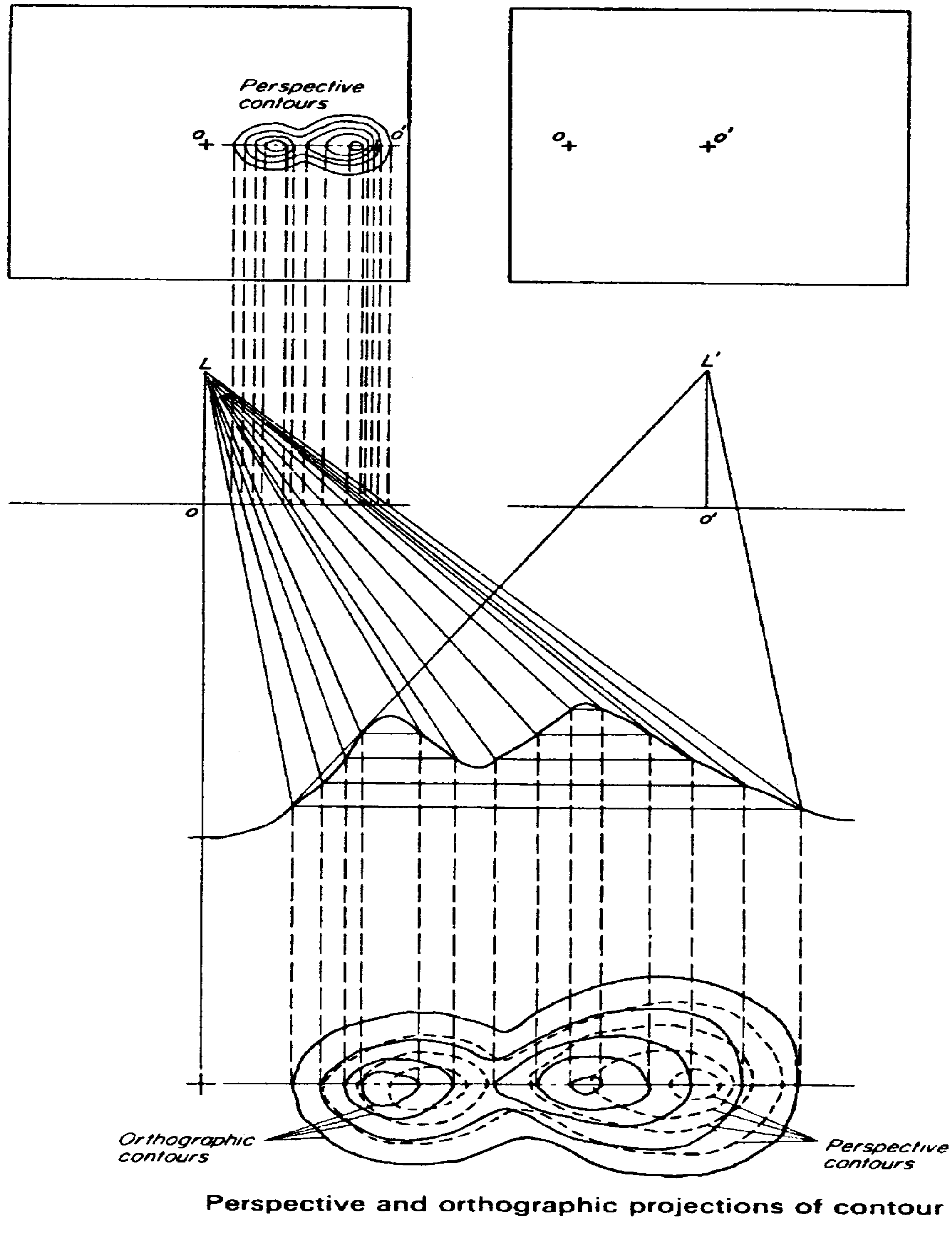
1. aerial photo = perspective or central projection. (see Figure 1-1 below)

2. a photo is a map for all points that are on the datum plane.

3. distortion results for all points not on the datum plane.

4. the scale is not constant across the entire photo.

Figure 1-1: Prespective and orthographic projections of contour lines



Perspective and orthographic projections of contour lines.

IV. Formats, Types, Scales, and Attributes of Remotely Sensed Images

1. Formats

A. Hardcopy
- 1. Size/format - enlargement
- 2. Media - contact print, positive transparency, negative

B. Digital - magnetic tape, CD Rom

2. Types

A. Geometry
- 1. Vertical - +/- 3 degrees from true vertical
- 2. Oblique - greater than 20 degrees from vertical
  - a. High - shows horizon
  - b. Low - no horizon

B. Film Types
- 1. Panchromatic - black and white
- 2. Modified Infrared - black and white
- 3. Ektachrome Color
- 4. Color Infrared - color reversal, camouflage detection
- 5. SLAR - side looking radar
- 6. LIDAR - scanning radar

3. Scale: *the ratio of map/image distance to the corresponding ground distance.*

A. Large vs Small Scale - a large scale photograph covers more ground area in more detail than small scale photograph.

Example: 1:10,000 is larger than 1:120,000; larger number

B. Lineal Scale Expressions

- 1. Representative Fraction
  - Characteristics of RF: RF = 1/S
    - a) unitless (i.e. has no unit of measure)
    - b) expressed as 1: x units or 1/x units
- 2. Equivalent scales
  - a. Feet per inch: ft/inch = denominator of RF divided by 12
  - b. Chains per inch: chains/inch = denominator of RF divided by 12 x 66
  - c. Miles per inch: miles/inch = denominator of RF divided by 12 x 5280

3. Metric conversions:
1 inch = 2.54 cm
1 meter = 100 cm = 100/2.54 = 39.37 inches
1 kilometer = 1000 meters

C. Area Scale Expressions

1. Acres per square inch
acres/sq. inch = $(\text{RF divided by } 12)^2/43560$ sq.ft/ac
= $(\text{RF divided by } 12 \times 66)^2/10 \text{ chns}^2$

2. Square chains per acre = 10

3. Metric conversions
1 hectare = 10,000 sq. meters = $(100)^2$ sq. meters
= $(100\text{m} \times 100\text{cm} /2.54 /12)^2/43{,}560$ = 2.471053815 acres

1 sq. m = $(100\text{cm}/2.54/12)^2 /43{,}560$ = 0.0002471053815 acres

4. Season of Year

A. Winter vs. Summer - vegetation/leaf differences

5. Film Sensitivity

A. Visible Spectrum
UV, Violet, Blue, Green, Yellow, Orange, Red, Infrared
0.4 - 0.7 microns in wavelength
radio and tv are 10 to 8 power microns

See Figure 1-2 below

B. File sensitivity

See Figure 1-3 below
See Figure 1-4 below

C. Filter modification

Figure 1-2: Wedge spectrogram of eye sensitivity within visible spectrum

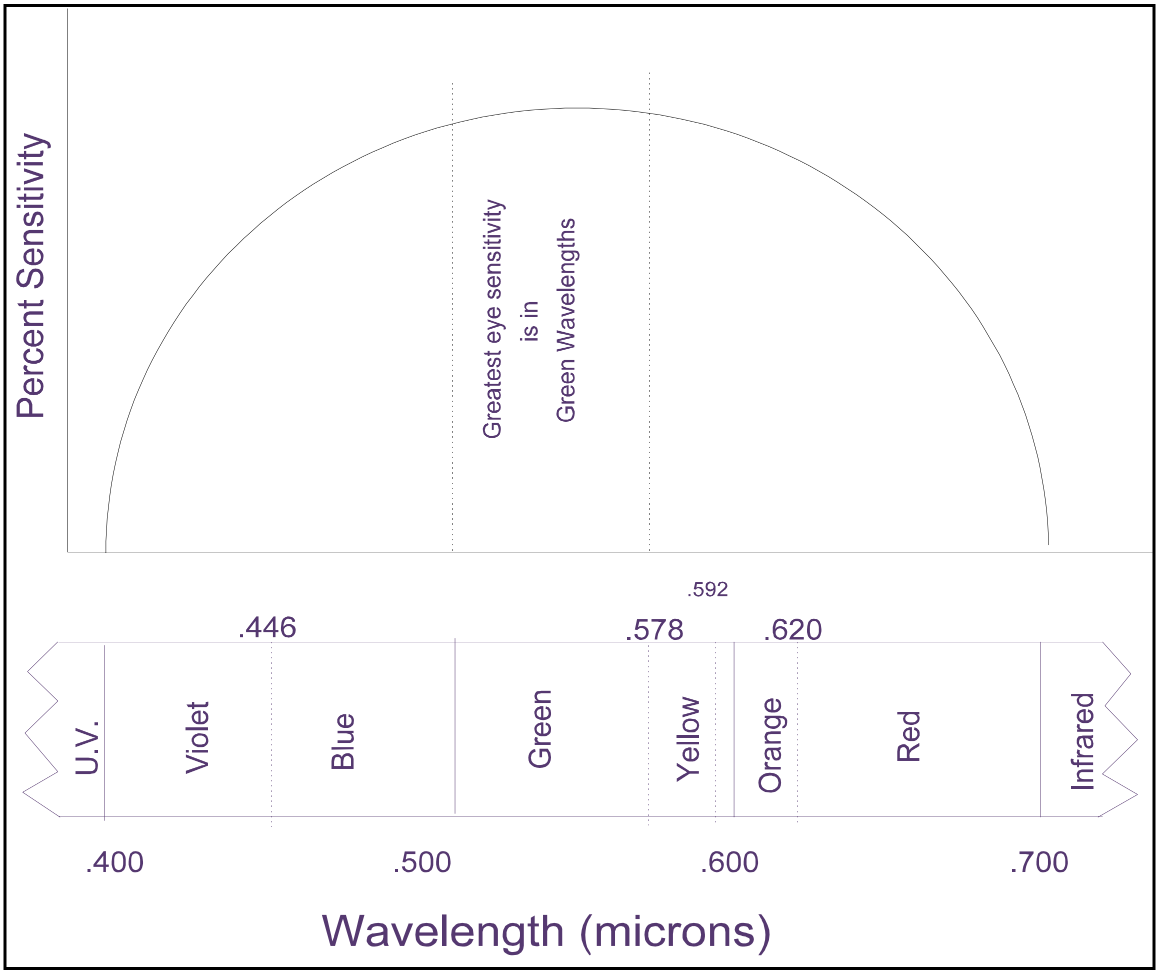

Percent Sensitivity
Greatest eye sensitivity
is in
Green Wavelengths
.592
.446
.578
.620
U.V.
Violet
Blue
Green
Yellow
Orange
Red
Infrared
.400
.500
.600
.700
Wavelength (microns)

Figure 1-3: Typical spectro-photometric curves for hardwoods vs. softwoods.

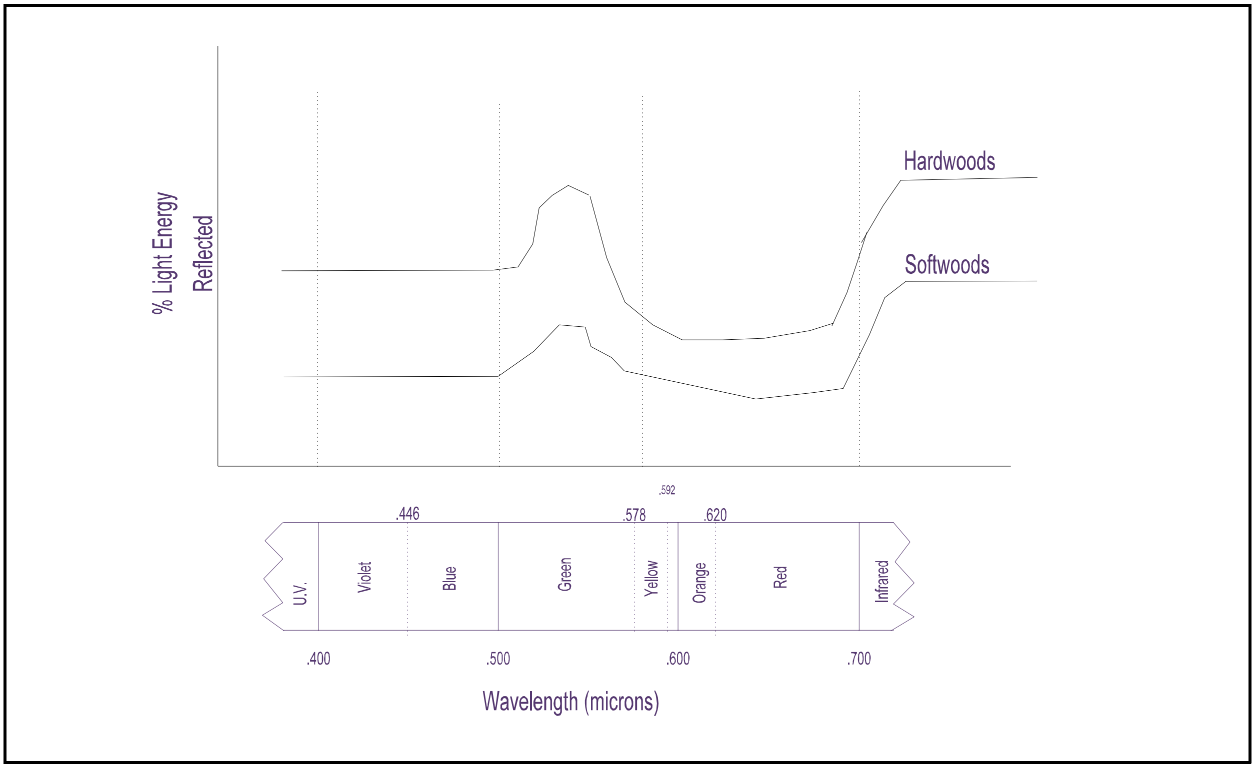


Figure 1-4: Spectrogram of Infrared film sensitivity and foliage reflectance