27 PHOTOGRAMMETRY

Asterisks (*) indicate problems that have partial answers given in Appendix G.

27.1 Describe the difference between vertical, low oblique, and high oblique aerial photos.

From Section 27.4, Paragraph 1:
Aerial photographs exposed with single-lens frame cameras are classified as vertical (taken with the camera axis aimed vertically downward, or as nearly vertical as possible) and oblique (made with the camera axis intentionally inclined at an angle between the horizontal and vertical). Oblique photographs are further classified as high if the horizon shows on the picture, and low if it does not.

27.2 Discuss the advantages of softcopy stereoplotters over optical stereoplotters.

From Section 27.14.4, Paragraph 5:
Softcopy photogrammetry systems are efficient, as well as versatile. Not only are they capable of producing maps, cross sections, digital elevation models, and other digital topographic files, but they can also be employed for a variety of image interpretation problems and they can support the production of mosaics and orthophotos (see Section 27.15). Also, digital maps produced by softcopy systems are created in a computer environment and are therefore in formats compatible for CADD applications and for in the databases of Geographic Information Systems. Softcopy systems have the added advantage that their major item of hardware is a computer rather than an expensive single-purpose stereoplotter, so it can be used for many other tasks in addition to stereoplotting.

27.3 Define the terms (a) metric photogrammetry and (b) interpretative photogrammetry.

(a) From Section 27.1, Paragraph 4:
Metrical photogrammetry is accomplished in different ways depending upon project requirements and the type of equipment available. Simple analyses and computations can be made by making measurements on paper prints of aerial photos using engineer's scales, and assuming that the photos are "truly vertical," i.e., the camera axis coincided with a plumb line at the time of photography. These methods produce results of lower order, but they are suitable for a variety of applications. Other more advanced techniques, including analog, analytical, and softcopy methods, do not assume vertical photos and provide more accurate determinations of the spatial locations of objects. The analog procedure relies on precise optical and mechanical devices to create models of the terrain that can be measured and mapped. The analytical method is based upon precise measurements of the photographic positions of the images of objects of interest, followed by a mathematical solution for their locations. Softcopy instruments utilize digital images in computerized procedures that are highly automated.

(b) From Section 27.1, Paragraph 2:

Interpretative photogrammetry involves recognizing objects from their photographic images and judging their significance. Critical factors considered in identifying objects are the shapes, sizes, patterns, shadows, tones, and textures of their images. This area of photogrammetry was traditionally called photographic interpretation because initially it relied on aerial photos. More recently, other sensing and imaging devices such as multispectral scanners, thermal scanners, radiometers, and side-looking airborne radar have been developed which aid greatly in interpretation. These instruments sense energy in wavelengths beyond those which the human eye can see, or standard photographic films can record. They are often carried in aircraft as remote as satellites; hence the term, remote sensing, is now generally applied to the interpretative area of photogrammetry.

27.4 Describe briefly how a digital camera operates.

From Section 27.3, Paragraph 6:
A new type of camera is now used for obtaining images in digital form. Instead of film, these cameras employ an array of solid state detectors, which are placed in the focal plane. The most common type of detector is the charge-coupled device (CCD). The array is composed of tiny detectors arranged in contiguous rows and columns, as shown in Figure 27.3. Each detector senses the energy received from its corresponding ground scene and this constitutes one "picture element" (pixel) within the overall image. The principle of operation of CCDs is fundamentally quite simple. At any specific pixel location, the CCD element is exposed to incident light energy which builds up an electric charge proportional to the intensity of the incoming light. The electric charge is amplified, converted from analog to digital form and stored in a file together with its row and column location within the array. Currently, the sizes of the individual CCD elements being manufactured are in the range of from about 5 to 15 micrometers square with arrays consisting of from 500 rows and columns (250,000 pixels) for inexpensive cameras, to more than 4,000 rows and columns. Obviously, significant storage and data handling capabilities are necessary in acquiring and processing digital images.

27.5 The distance between two points on a vertical photograph is *ab* and the corresponding ground distance is *AB*. For the following data, compute the average photographic scale along the line ab.

(a)* *ab* = 2.41 in.; *AB* = 4820 ft. 4820/2.41 = 1/2000 in./ft.

(b) *ab* = 5.47 in.; *AB* = 13,128 ft. 13,128 / 5.47 = 1/2400 in./ft.

(c) *ab* = 56.48 mm; *AB* = 169.440 m. 169,440 / 0.05648 = 1:3,000,00

27.6 On a vertical photograph of flat terrain, section corners appear a distance d apart. If the camera focal length is f compute flying height above average ground in feet for the following data:

(a) d = 2.800 in.; f = 3 ½ in. H = 3.5(5280/2.80) = 6,000 ft.

(b) d = 50.800 mm; f = 152.4 mm H= 152.4(5280/50.8) = 15,840 ft.

27.7 On a vertical photograph of flat terrain, the scaled distance between two points is ab. Find the average photographic scale along *ab* if the measured length between the same line is *AB* on a map plotted at a scale of S_{map} for the following data.

(a) *ab* = 1.86 in.; *AB* = 4.46 in.; S_{map} = 1:8000
AB = (4.46/12) 8000 = 2973 ft.
S = 2973/1.86 = 1 in./ 1599 ft.

(b) *ab* = 41.53 mm; *AB* = 6.23 mm; S_{map} = 1:20,000
AB = (0.00623)20,000 = 124.6 m
S = 124.6/0.04153 = 1:3000

27.8 What are the average scales of vertical photographs for the following data, given flying height above sea level, *H*, camera focal length, *f*, and average ground elevation *h*?

(a)* H = 7300 ft.; f = 152.4 mm; h = 1240 ft.

$$S = \frac{f}{H - h_A} = \frac{\frac{152.4}{25.4}}{7300 - 1240} = 1\ in./1010ft$$

(b) H = 5500 ft.; f = 8.25 in.; h = 920 ft.
S = 8.25 / (5500 – 920) = 1 in. / 555 ft.

(c) H = 3524 m.; f = 88.9 mm; h = 590 m.
S = 0.0889 / (3524 – 590) = 1:33,000

27.9 The length of a football field from goal post to goal post scales 49.15 mm on a vertical photograph. Find the approximate dimensions (in meters) of a large rectangular building that also appears on this photo and whose sides measure 21.5 mm by 14.0 mm. (Hint: Football goal post are 120 yards apart.)

120 yds = 360 ft = 109.728 m.
0.04915 / 109.728 = 1:2232.5
0.0215 (2232.5) = 47.999 m.
0.0068 (2232.5) = 31.255 m.

27.10* Compute the area in acres of a triangular parcel of land whose sides measure 48.78 mm, 84.05 mm, and 69.36 mm on a vertical photograph taken from 6050 ft above average ground with a 152.4 mm focal length camera.

S = [(152.4 / 25.4) / 12] / 6050 = 39.69816 ft/mm
a = 48.78 (39.69816) = 1936.48 ft
b = 84.05 (39.69816) = 3336.63 ft
c = 69.36 (39.69816) = 2653.46 ft
s = 2446.499 / 2 = 1223.250
area = sqrt[s(s-a)(s-b)(s-c)] = 2,665,548 ft^2 = 69.19 ac.

27.11 Calculate the flight height above average terrain that is required to obtain vertical photographs at an average scale of *S* if the camera focal length is *f* for the following data:

(a) S = 1:5000; f = 152.4 mm
H = 0.5 (5000) = 2500 ft.

(b) S = 1:10,000; f = 88.9 mm
H = 0.0889(39.37/12) (10,000) = 2916.7 ft

27.12 Determine the horizontal distance between two points *A* and *B* whose elevations above datum are h_A = 1560 ft. and h_B = 1425 ft. and whose images *a* and *b* on a vertical photograph have photo coordinates x_a = 2.95 in., y_a = 2.32 in., x_b = -1.64 in., and y_b = -2.66 in. The camera focal length was 152.4 mm and the flying height above datum 7500 ft.

S_A = 6/(7500 – 1560) = 1 in. / 990 ft
X_A = 2.95(990) = 2920.50 ft. Y_A = 2.32 (990) = 2296.80 ft.
S_B = 6 / (7500 – 1425) = 1 in. / 1012.50 ft.
X_B = -1.64 (1012.50) = −1660.50 ft. Y_B = −2.66 (1012.50) = −2693.25 ft.
Distance = $\sqrt{(-1660.5-2920.50)^2+(-2693.25-2296.80)^2} = 6773.93$ ft.

27.13* Similar to Problem 27.12, except that the camera focal length was 3-1/2 in., the flying height above datum 4075 ft, and elevations h_A and h_b 983 ft and 1079 ft, respectively. Photo coordinates of images a and b were x_a = 108.81 mm., y_a = −73.73 mm., x_b = −87.05 mm., and y_b = 52.14 mm.

S_A = 3.5 / (4075 – 983) = 1 in. / 883.4 ft.
X_A = (108.81 / 25.4) (883.4) = 3784.48 ft.
Y_A = (-73.73 / 25.4) (883.4) = -2564.38 ft.
S_B = 3.5 / (4075 - 1079) = 1 in. / 856 ft.
X_B = (-87.05 / 25.4) (856) = -2933.65 ft.
Y_B = (52.14 / 25.4) (856) = 1757.16 ft.
Distance = 7988 ft.

27.14 On the photograph of Problem 27.12, the image *c* of a third point *C* appears. Its elevation h_C = 1365 ft. and its photo coordinates are x_c = 3.20 in. and y_c = −2.66 in. Compute the horizontal angles in triangle *ABC*.

S_C = 6 / (7500 – 1365) = 1 in. / 1022.50 ft.
X_C = 3.20 (1022.50) = 3272 ft. Y_C = −2.66 (1022.50) = −2719.85 ft.
Angle A = 46°33'39" Angle B = 47°45'22" Angle C = 85°40'59"

27.15 On the photograph of Problem 27.12, the image *d* of a third point *D* appears. Its elevation is h_D = 1195 ft. and its photo coordinates are x_d = 2.72 in. and y_d = 3.09 in. Calculate the area, in acres, of triangle *ABD*.

S_D = 6 / (7500 – 1195) = 1 in. / 1050.83 ft.
X_D = 2.72 (1050.83) = 2855.45 ft.
Y_D = 3.09 (1050.83) = 3248.48 ft.

Dist._{AB} = 6773.93 ft. Dist._{BD} = 7463.11 ft. Dist._{DA} = 953.90 ft.
s = 7595.47
area = sqrt [s(s-a)(s-b)(s-c)] = 2,342,120 ft^2 = 53.77 ac.

27.16 Determine the height of a radio tower, which appears on a vertical photograph for the following conditions of flying height above the tower base H, distance on the photograph from principal point to tower base r_d and distance from principal point to tower top r_t

(a)* H = 2425 ft.; r_b = 3.18 in.; r_t = 3.34 in.

$$d = \frac{rh}{H} \qquad h = \frac{dH}{r} \qquad h = \frac{(3.34 - 3.18)2425}{3.34} = 116.17\text{ ft.}$$

(b) H = 6600 ft.; r_b =96.28 mm; r_t = 97.67 mm.

$$h = \frac{(97.67 - 96.28)6600}{97.67} = 93.92\text{ ft}$$

27.17 On a vertical photograph, images a and b of ground points A and B have photographic coordinates x_a = 3.27 in., y_a = 2.28 in., x_b = −1.95 in. and y_b = −2.50 in. The horizontal distance between *A* and *B* is 5350 ft, and the elevations of *A* and *B* above datum are 652 ft and 785 ft, respectively. Using Equation (27.9), calculate the flying height above datum for a camera having a focal length of 152.4 mm.

$$L^2 = \left[\frac{(H-h_b)x_b - (H-h_a)x_a}{f}\right]^2 + \left[\frac{(H-h_b)y_b - (H-h_a)y_a}{f}\right]^2$$

$$5350^2 = \left[\frac{-1.95(H-785) - 3.27(H-652)}{6}\right]^2 + \left[\frac{-2.50(H-785) - 2.28(H-652)}{6}\right]^2$$

$$0 = 1.39158H^2 - 1978.12614H - 27{,}919{,}387.625897$$

H = 5246 ft. = **5250 ft**

27.18 Similar to Problem 27.17, except x_a = -52.53 mm, y_a = 69.67 mm, x_b = 26.30 mm, y_b =

-59.29 mm line length *AB* = 4695 ft. and elevations of points *A* and *B* are 925 and 875 ft, respectively.

$$4695^2 = \left[\frac{26.30(H-875)+52.53(H-925)}{152.4}\right]^2 + \left[\frac{-59.29(H-875)-69.67(H-925)}{152.4}\right]^2$$

$$0 = 0.9835997H^2 - 1777.81255H - 21{,}239{,}688.082$$

H = 5638 ft = **5640 ft**

27.19* An air base of 3205 ft exists for a pair of overlapping vertical photographs taken at a flying height of 5500 ft above MSL with a camera having a focal length of 152.4 mm. Photo coordinates of points *A* and *B* on the left photograph are x_a = 40.50 mm, y_a = 42.80 mm, x_b = 23.59 mm, and y_b = -59.15 mm. The x photo coordinates on the right photograph are x_a = -60.68 mm and x_b = -70.29 mm. Using the parallax equations, calculate horizontal length *AB*.

$$p_a = x_a - x_{1a} = 40.50 - (-60.68) = 101.18\text{ mm.}$$

$$p_b = x_b - x_{1b} = 23.59 - (-70.29) = 93.88\text{ mm.}$$

$$X_A = \frac{B}{p_a}x_a = \frac{3205}{101.18}40.50 = 1282.89\text{ ft.}$$

$$X_B = \frac{B}{p_b}x_b = \frac{3205}{93.88}23.59 = 805.35\text{ ft.}$$

$$Y_A = \frac{B}{p_a}y_a = \frac{3205}{101.18}42.80 = 1355.74\text{ ft.}$$

$$Y_B = \frac{B}{p_a}y_b = \frac{3205}{93.88}(-59.15) = -2019.34\text{ ft.}$$

$$\text{Distance}_{AB} = \sqrt{(805.35-1282.89)^2 + (-2019.34-1355.74)^2} = 3408.70\text{ ft.}$$

27.20 Similar to Problem 27.19, except the air base is 7450 ft, the flying height above mean sea level is 15,520 ft, the *x* and *y* photo coordinates on the left photo are x_a = 37.98 mm, y_a = 50.45 mm, x_b = 24.60 mm, and y_b = -46.89 mm, and the *x* photo coordinates on the right photo are x_a = -52.17 mm and x_b = -63.88 mm.

$$p_a = x_a - x_a' = 37.98 - (-52.17) = 90.15\text{ mm.}$$

$$p_b = x_b - x_b' = 24.60 - (-63.88) = 88.48\text{ mm.}$$

$$X_A = \frac{B}{p_a}x_a = \frac{7450}{90.15}37.98 = 3138.67\text{ ft}$$

$$Y_A = \frac{B}{p_a}y_a = \frac{7450}{90.15}50.45 = 4169.19\text{ ft}$$

$$X_B = \frac{B}{p_b}x_b = \frac{7450}{88.48}24.60 = 2032.94\text{ ft}$$

$$Y_B = \frac{B}{p_b}y_b = \frac{7450}{88.48}(-46.89) = -3874.99\text{ ft}$$

$$\text{Distance}_{AB} = \sqrt{(3138.87 - 2032.94)^2 + (4169.19 + 3874.99)^2} = 8119.82\text{ ft}$$

27.21* Calculate the elevations of points *A* and *B* in Problem 27.19.

$$h_A = H - \frac{Bf}{p_a} = 5500 - \frac{3205(152.4)}{101.18} = 672.54 \text{ ft.}$$

$$h_B = H - \frac{Bf}{p_b} = 5500 - \frac{3205(152.4)}{93.88} = 297.17 \text{ ft.}$$

27.22 Compute the elevations of points *A* and *B* in Problem 27.20.

$$h_A = H - \frac{Bf}{p_a} = 15{,}520 - \frac{7450(152.4)}{90.15} = 2925.66 \text{ ft}$$

$$h_B = H - \frac{Bf}{p_b} = 15{,}520 - \frac{7450(152.4)}{88.48} = 2687.95 \text{ ft}$$

27.23 List and briefly describe the four different categories of stereoscopic plotting instruments.

From Section 27.14:
Stereoplotters can be classified into four different categories: (1) optical projection, (2) mechanical projection, (3) analytical, and (4) digital or "softcopy" systems.

27.24 Name the three stages in stereoplotter orientation, and briefly explain the objectives of each.

From Section 27.14, Paragraphs 5-7:
Interior orientation ensures that the projected light rays are geometrically correct, i.e., angles and of Figure 27.14(b), (i.e., the angles between the projected light rays and the axis of the projector lens), must be identical to corresponding angles and respectively, in Figure 27.14(a), (i.e., the angles between the incoming light rays and the camera axis). Preparing the diapositives to exacting specifications, and centering them carefully in the projectors accomplish this.

After the diapositives have been placed in the projectors and the lights turned on, corresponding light rays will not intersect to form a clear model because of tilts in the photographs and unequal flying heights. To achieve intersections of corresponding light rays, the projectors are moved linearly along the X, Y, and Z-axes and also rotated about these axes until they duplicate the relative tilts and flying heights that existed when the photographs were taken. This process is called relative orientation, and when accomplished, parallactic angle of Figure 27.14(b) for each corresponding pair of light rays will be identical to its corresponding parallactic angle of Figure 27.14(a), and a perfect three-dimensional model will be formed.

The model is brought to required scale by making the rays of at least two, but preferably three, ground control points intersect at their positions plotted on a manuscript map prepared at the desired scale. It is leveled by adjusting the projectors so the counter reads the correct elevations for each of a minimum of three, but preferably four, corner ground control points when the floating mark is set on them. **Absolute orientation** is a term applied to the processes of scaling and leveling the model.

27.25 What advantages does a softcopy plotter have over an analytical plotter?

From Section 27.14.4, Paragraph 5:
Softcopy photogrammetry systems are efficient, as well as versatile. Not only are they capable of producing maps, cross sections, digital elevation models, and other digital topographic files, but they can also be employed for a variety of image interpretation problems and they can support the production of mosaics and orthophotos (see Section 27.15). Also, digital maps produced by softcopy systems are created in a computer environment and are therefore in formats compatible for CADD applications and for in the databases of Geographic Information Systems. Softcopy systems have the added advantage that their major item of hardware is a computer rather than an expensive single-purpose stereoplotter, so it can be used for many other tasks in addition to stereoplotting.

27.26 What kind of images do softcopy stereoplotters require? Describe two different ways they can be obtained.

From Section 27.14.4, Paragraph 1:
These systems utilize digital or "softcopy" images. The images can be acquired by using a digital camera of the type described in Section 27.3, but more often they are obtained by scanning the negatives of aerial photos taken with film cameras.

27.27 Compare an orthophoto with a conventional line and symbol map.
From Section 27.15, Paragraph 4:
Orthophotos combine the advantages of both aerial photos and line maps. Like photos, they show features by their actual images rather than as lines and symbols, thus making them more easily interpreted and understood. Like maps, orthophotos show the features in their true planimetric positions. Therefore true distances, angles, and areas can be scaled directly from them.

27.28 Discuss the advantages of orthophotos as compared to maps.
From Section 27.15, Paragraph 4:
Orthophotos combine the advantages of both aerial photos and line maps. Like photos, they show features by their actual images rather than as lines and symbols, thus making them more easily interpreted and understood. Like maps, orthophotos show the features in their true planimetric positions. Therefore true distances, angles, and areas can be scaled directly from them.

Aerial photography is to be taken of a tract of land that is X-mi square. Flying height will be H ft above average terrain, and the camera has focal length f. If the focal plane opening is 9 × 9 in. and minimum sidelap is 30%, how many flight lines will be needed to cover the tract for the data given in Problems 27.29 and 27.30?

27.29* X = 8; H = 4000; f = 152.4 mm
S = 6 / 4000 = 1 in. / 666.67 ft.
d_S = 9 * S (1 – 0.3) = 4200 ft.
# of Flight Lines = [8 (5280)]/4200 = 10.05 + 1 = 11 so choose 12

27.30 X = 30; H = 10,000; f = 3.5 in.
S = 6 / 10,000 = 1 in. / 2857.14 ft.
d_S = 9 * 2857.14 (1 -0.3) = 18,000ft.
# of Flight Lines = [30 (5280)] / 18000 = 8.8 + 1 = 10 so choose 11

Aerial photography was taken at a flying height H ft above average terrain. If the camera focal plane dimensions are 9 × 9 in. the focal length is *f* and the spacing between adjacent flight lines is X ft, what is the percent sidelap for the data given in Problems 27.31 and 27.32?

27.31* H = 4500; f = 152.4 mm; X = 4700
S = 6 / 4500 = 1 in. / 750 ft.
4700 = 9 * 750x x = 0.696 = 69.6 = 30.4% sidelap

27.32 H = 6800; f = 3.5 in.; X = 13,500
S = 3.5 / 6800 = 1 in. / 1942.857 ft.
13,500 = 9 * 1942.857x x = 0.772 = 22.8% sidelap

Photographs at a scale of S are required to cover an area X mi square. The camera has a focal length f and focal plane dimensions of 9 × 9 in. If endlap is 60% and sidelap 30%, how many photos will be required to cover the area for the data given in Problems 27.33 and 27.34?

27.33 S = 1:6000; X = 6; f = 152.4 mm
de = (9 / 12)(6000)(1 – 0.6) = 1800 ft.
ds = (9 / 12)(6000)(1 – 0.3) = 3150 ft.
# of Flight Lines = 6(5280) / 3150 = 10.057 +1 = 11 so choose 12
# of Photos per Line = 6(5280) / 1800 + 2 + 2 + 1 = 22.6 = 23
Total # of photos = 12 * 23 = 276 photos

27.34 S = 1:14,400; X = 40; f = 3.5 in.
de = (9/12)(14,400)(1 – 0.6) = 4320 ft.
ds = (9/12)(14,400)(1 – 0.3) = 7560 ft.
# of Flight Lines = 40(5280) / 7560 = 27.9 +1 = 28
# of Photos per Line = 40(5280) / 4320 + 2 + 2 + 1 = 53.9 = 54
Total # of photos = 28 * 54 = 1566 photos

27.35 Describe a system that employs GNSS and which can reduce or eliminate ground control surveys in photogrammetry?

From Section 27.16, Paragraph 3:
Currently GPS is being used for real-time positioning of the camera at the instant each photograph is exposed. The kinematic GPS surveying procedure is being employed (see Chapter 15), which requires two GPS receivers. One unit is stationed at a ground control point; the other is placed within the aircraft carrying the camera. The integer ambiguity problem is resolved using on-the-fly techniques (see Section 15.2). During the flight, camera positions are continuously determined at time intervals of a few seconds using the GPS units and precise timing of each photo exposure is also recorded. From this information, the precise location of each exposure station, in the ground coordinate

system, can be calculated. Many projects have been completed using these methods and they have produced highly accurate results, especially when supplemented with only a few ground control points. It is now possible to complete photogrammetric projects with only a few ground photo control points used for checking purposes.

27.36 To what wavelengths of electromagnetic energy is the human eye sensitive? What wavelengths produce the colors blue, green, and red?

From Section 27.20, Paragraph 4:
Within the wavelengths of visible light, the human eye is able to distinguish different colors. The primary colors (blue, green, and red) consist of wavelengths in the ranges of 0.4–0.5, 0.5–0.6, and respectively. All other hues are combinations of the primary colors. To the human eye, an object appears a certain color because it reflects energy of wavelengths producing that color. If an object reflects all wavelengths of energy in the visible range, it will appear white, and if it absorbs all wavelengths, it will be black. If an object absorbs all green and red energy but reflects blue, that object will appear blue.

27.37 Discuss the uses and advantages of satellite imagery.
From Section 27.20:
Satellite imagery is unique because it affords a practical means of monitoring our entire planet on a regular basis. Images of this type have been applied for land-use mapping; measuring and monitoring various agricultural crops; mapping soils; detecting diseased crops and trees; locating forest fires; studying wildlife; mapping the effects of natural disasters such as tornadoes, floods, and earthquakes; analyzing population growth and distribution; determining the locations and extent of oil spills; monitoring water quality and detecting the presence of pollutants; and accomplishing numerous other tasks over large areas for the benefit of humankind.

Problems 27.38 through 27.42 involve using WolfPack with images 5 and 6 on the CD that accompany this book. The ground coordinates of the paneled points are listed in the file "ground.crd." The coordinates of the fiducials are listed in the file "camera.fid." To do these problems, digitize the eight fiducials and paneled points 21002, 4, 41, GYM, WIL1A, WIL1B, and RD on both images. After digitizing the points, perform an interior orientation to compute photo coordinates for the points on images 5 and 6. The focal length of the camera is 153.742 mm.

Responses will be affected by the quality of the observations. Approximate values for the problem are supplied herewith.

27.38 Using photo coordinates for points 4 and GYM on image 5, determine the scale of the photo.

Photo Coordinates:	4: (–1.187, 70.338) mm
	GYM:(78.889, –14.642) mm
Ground Coordinates:	4: (745143.093, 128206.079) m.
	GYM: (745413.425, 127875.820) m.
ab = 116.771 mm	AB = 426.791 m.

S = 0.116771 / 426.791 = 1:3655

27.39 Using photo coordinates for points 4 and GYM on image 5, determine the flying height of the camera at the time of exposure.

H = 938 m. or -220 m.

27.40 Using photo coordinates for points 4 and GYM on image 5 and 6, determine the ground coordinates of points WIL1A and WIL1B using Eq. (27.12) and Eq. (27.13).

Distance = 423.354 m.

27.41 Using the exterior orientation option in WolfPack, determine the exterior orientation elements for image 5.

Responses will be affected by the quality of the observations.

27.42 Using the exterior orientation option in WolfPack, determine the exterior orientation elements for image 6.

Responses will be affected by the quality of the observations.