**Topic Series 10**

# Remote Sensing Mission Planning

## I. Purpose/Requirements of Imagery

Most forest resource managers will contract for aerial photography and even though the contractor will be doing the calcualations, the manager should be able to estimate contract costs and requirements. Flight planning calculations are also important to verify that the contract price is reasonable and the low-bid contractor has not made a mathematical error and won't be able to complete the contract. There is also the factor of **INFORMATION CONTENT** OF THE RESULTING IMAGERY.

The objective of any flight mission is **to maximize the information content of the imagery with a minimum investment!!** How can we accomplish this objective in flight planning?

**First**, you must determine the specific objectives for the flight; that is, the information needs of the people who will be using the imagery and how - **who and how?** Wildlife habitat? logging road layout? stand mapping? site evaluation?

**Second**, you must determine the specific product that is desired. Your job will be to collate the needs of the intented users and set up the flight to acquire data that will mediate between demands that may be conflicting and acquire the data that, while not meeting 100% of everyone's needs, will serve for everyone's purpose. Sometimes this may be impossible, and a second flight will be required; for example, winter (leaf-off) imagery should be used for updating the transportation system and laying out logging roads, but stand mapping and habitat evaluation may require leaf-on.

**Thirdly**, given the information needs of the users and the desired photographic product, you must select the most appropriate combination of film, filter, season, scale, and time of day that will maximize the desired information output?

**You can control (i.e. specify):**

**season**
**time of day**
**scale**
**film-filter combination**
**stereo overlap - end and side lap (min/max acceptable percentages)**
**tilt, tip, crab - (minimum acceptable)**
**allowable vertical limits - (percentage within true vertical; 3%)**

**You cannot control:** camera calibration, aircraft performance, altitude, etc.

## II. Factors Affecting Time, Cost, and Quality

**Season**

**Climatic Season:**

You obviously cannot control the weather, but you can control the timing of the flight to specify the "windows" in which they should fly; EXAMPLE -- Fall, Winter, or Spring. You have to give them a window with strict specs on what you will accept in the way of **month/week, time of day, percentage cloud cover and other flight specs** such as the amount of photo tilt, crab, etc.

**USUALLY,** the "best" flying weather in the South is in late September/early October, or April/May - generally 24 hrs. after the passage of a strong high pressure front. It usually takes 24 hrs after passage to clear out the residual scud, and then another 48 - 72 hrs before it warms enough to generate enough **HAZE** to be a problem - so, lets say 30 - 60 hours after a front. Late May through September is generally a good window - unless it is a low altitude flight to avoid "cottonball" clouds and reduce the effects of haze.

**Phenological Development**

Another **TEMPORAL** factor is the stage of phenological development by latitudinal zones. If you have 1000 river miles of the Mississippi to fly, you can calculate about 2.0 - 2.5 weeks difference between Natchez and Cairo, IL, and another 2 weeks between Natchez and the mouth of the River. The northern end will be well into defoliation by late September, but the lower end is only partially defoliated, even in late October.

So, to RECAP, the first attribute over which we have control is **SEASON** - Another example of critical timing is ... EVALUATION OF WOOD DUCK BROOD HABITAT. First, an analysis of how you define various habitat qualities. For brood habitat, **what are the site attributes** that determine quality ?? Most obvious is presence of **WATER** - preferably ponded, but could be running.

**Den Trees** - cavity nesters; But most important is the primary **FOOD** source for young ducklings!! **WHAT is the primary food?** INVERTEBRATES. And where do you find invertebrates in profusion?? On and around stems and foliage of floating and emergent aquatic plants. When can you detect aquatics? **LATE SPRING around here.** Try for late MAY - have a good bloom, but can still see den trees/water before full leafout.

**Another example of timing:** DISCRIMINATION OF BOTTOMLAND HARDWOOD SPECIES. YOU GENERALLY HAVE ONLY TWO (2) WINDOWS -

1. in the Spring, just after full leaf expansion - but before full chlorophyll content. In the summer, everything looks about the same --- only subtle differences.

2. probably the best time is in the Fall; Mid-September to late October, depending upon your location and **amount of antecedent precipitation.** At any rate, it is the period **just before the onset of senescence! There is a noticeable chlorophyll shift** which varies with species: red oaks vs. white oaks, versus hickory, versus sweetgum. Around here you can begin to notice it in the uplands about mid-Sept. assume that normal dry spell late in the growing season. **UNFORTUNATELY, crown color/shade** will rarely be the **SOLE** discriminating attribute - crown density, crown shape, all play a role in I.D. There is too much genetic variation in a species for precise color measurement.

**Time of Day**

In arid land archaeology, for example, early morning or late afternoon shots produce images with long shadows - highly desirable when minor topographic relief is a critical indicator of cultural artifacts. Time of day is critical when you want good light on the forest floor or interpretation of understory vegetation. Thus, you want the sun as high in the sky as possible; preferrably between 10 a.m. and 2 p.m..

**Scale**

It is obvious that scale is crucial in capturing the required information. At a scale of 1/24,000, the average eye can perceive objects with dimensions of about 4 feet with magnification. The ability is perceive an object is dependent upon **System Resolution** - the resultant of lens and film resolution expressed in **LINE PAIRS PER MILLIMETER.** The scale or rather, the flying height, is also important in Topographic Mapping. Every instrument utilized if topographic mapping has an inherent precision factor called the **C-FACTOR** -

**C-Factor = (H-h) / contour interval**

For example, if a Kelch Plotter has a C-factor of 1800 and it was used to produce a topo maps with a 5-ft. interval from photos of scale 1/36,000 (f = 6"), is the map within the realm of accuracy predicated by the C-factor??

**First** 1/S = f/(H-h)
(H-h) = (f)(scale)
= 0.5(36000)
= 18,000 ft.
Therefore **1800 = 18,000'/(contour interval)**
**c.i. = 18,000/1800**
**= 10 ft.**

**AND IT DOES NOT WORK FOR A 5 FT. INTERVAL. O.K. for 10.5, 11 ft.**, but **nothing less than 10 ft.**

**Film/Filter Combination**

Film is usually discussed in conjunction with **FILTER**. The types of film we have previously discussed are:

| | |
|---|---|
| **CIR** | - color infrared |
| **B&WIR** | - black and white infrared |
| **PAN** | - panchromatice (black and white) |
| **COLOR** | - color (ektachrome,etc.) |

**It may be necessary to use more than one camera for a job to capture all the information you need!!** For example, use an RC-10 camera (9" format) with CIR film and a Wratten 15 filter for hardwood discrimination, but use a concurrent Hassleblad (70mm format) with a B&WIR film and Wratten 89B filter for land/water contact in wetlands.

When we progress out of the photographic area of the spectrum, we use **SENSORS, usually multispectral** - which replace both film and filter and capture data on an electronic medium.

## III. Flight Planning Specifications

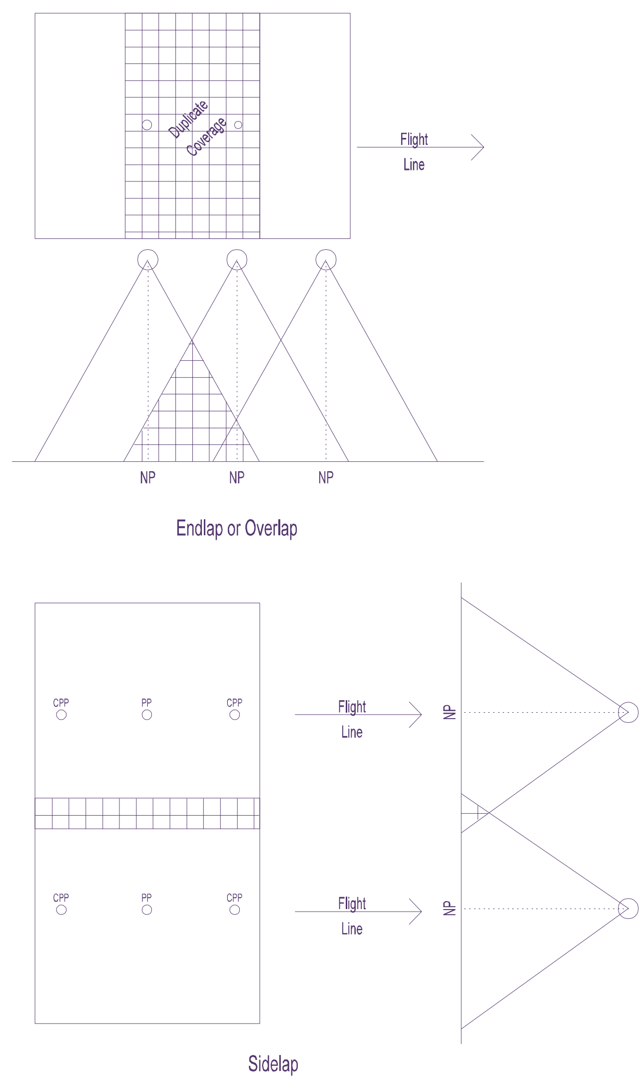
When the flight parameters have been selected, it is then required that calculation of number of flight lines and flight line spacing, in addition to image number and spacing be accomplished. The calculation of line and image spacing is determined much as you would determine cruise line spacing - however, in photogrammetry the image format and scale are determinants rather than plot size and cruise percentage.

See Figure 1O-1 below

**Overlap (also endlap, forward lap)** - the percentage of one image that is duplicated in coverage by the adjacent images **along the flight line.** It is normally 60% to assure complete stereo-coverage, but it could be higher in mountainous terrain.

**Sidelap** - the percentage duplicate coverage by images from **adjacent flight lines.** Normally 20 - 30%, depending upon terrain dissection. Rarely less than 15%.

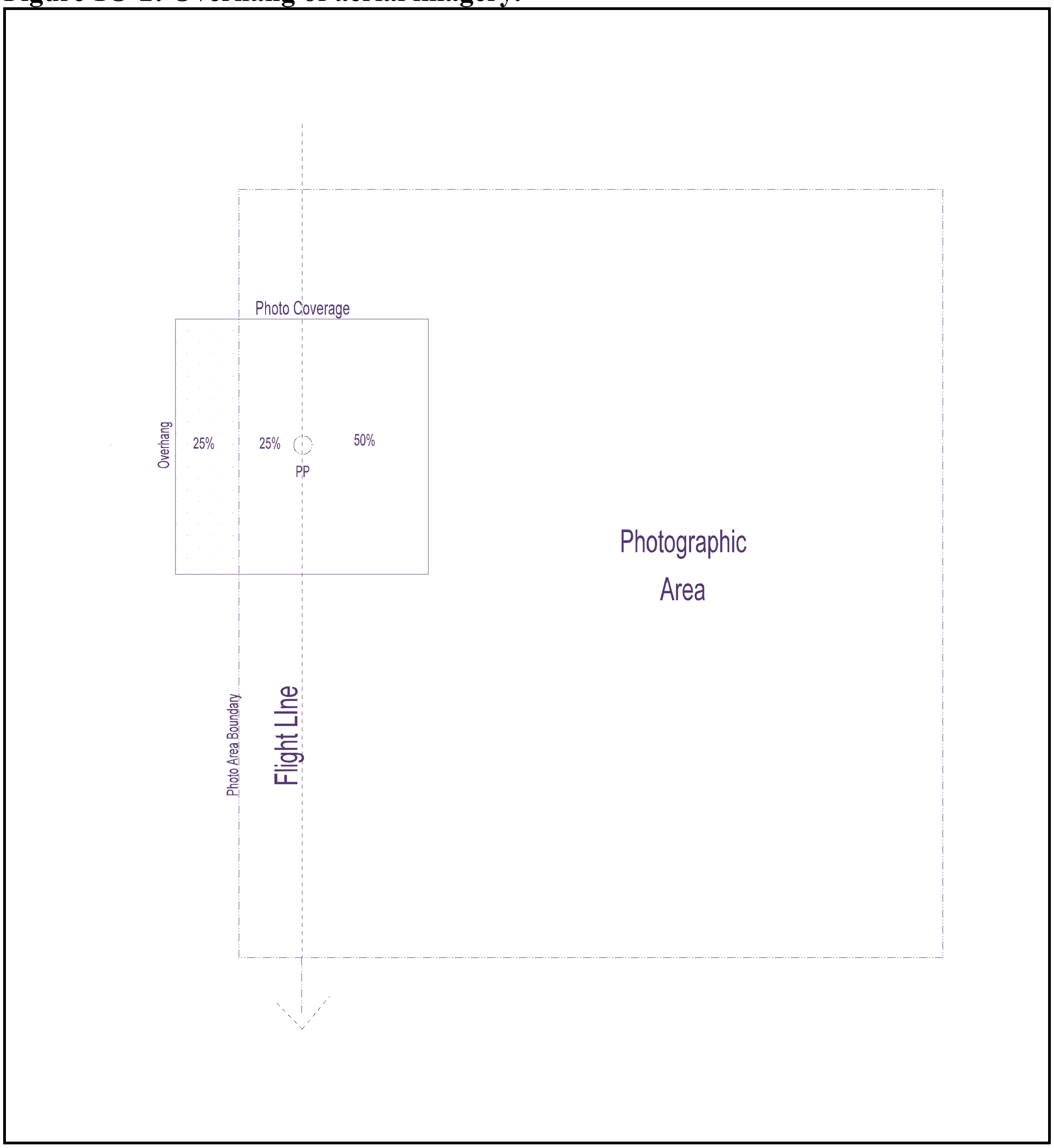
**Figure 1O-1 Relationship between endlap and sidelap of aerial imagery.**



**Overhang** - that percentage of an image that falls **outside of the nominal target area.** A safety factor to assure complete coverage of the boundaries - normally 15 - 25%.

**Safety Images** -normally two extra images are taken **at each end of each line.** Typically they are spaced at 0.5 and 1.5 photo distances out from the boundary. I disagree: I belive they should be spaced at 1.0 and 2.0 distances out from the boundary, so that the first photo (in the target area) has the boundary near the PP and the upper half of the 1st photo can be viewed stereoscopically with the next in-area photo.

**Figure 1O-2: Overhang of aerial imagery.**



WHY ALL THE "SAFETY" FACTORS?? - **FILM IS CHEAPER THAN FLIGHT TIME SO MAKE SURE YOU HAVE GOTTEN COMPLETE COVERAGE THE FIRST TRIP.** It is too expensive to return for a few shots, or one line.

**Drift** - a steady cross-wind can cause the pilot to "drift" off course; if this creates gaps in coverage, or even a reduction in sidelap below the accepted minimum, it is NOT acceptable - this so be so stated in the contract.

**Crab** - caused by gusty cross-winds that literally cause the plane to "twist" on its axis on the flight line -

**Tilt** - the acceptable degree of tilt from the vertical should be stated; the amount will depend upon your purpose. If the imagery is to be used only for interpretation, 3 -7 deg. may be allowable; if, however, you intend to transfer mapping units from the imagery to a base map, only 2 - 3 degrees should be allowed.

**Tip** -

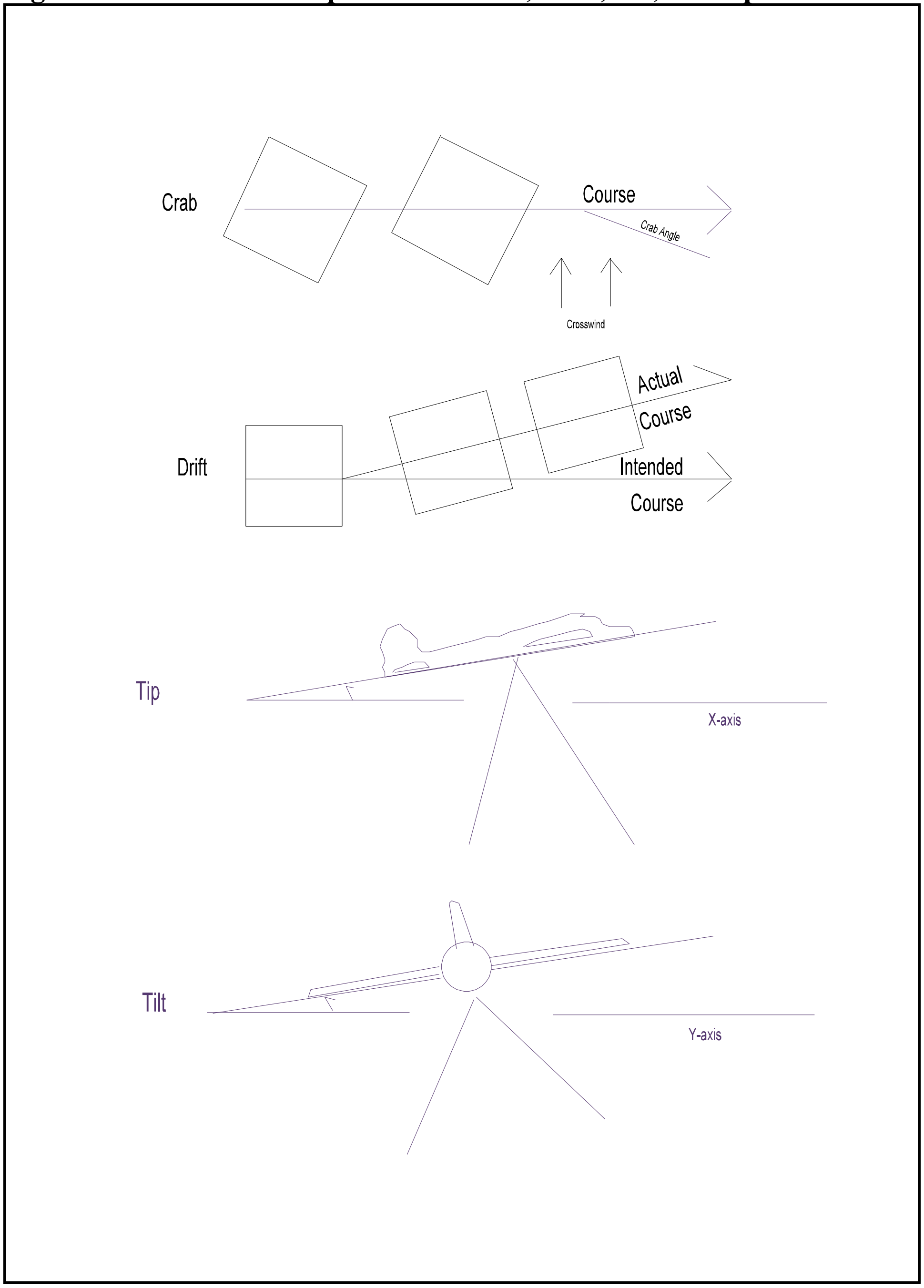
**Image Product -**

Format of imagery - 9 x 9, 12 x 12, etc.

Number of copies

Imagery media - paper prints, positive transparencies, negatives

**Figure 1O-3: Relationship between drift, crab, tilt, and tip of aerial imagery.**



## IV. Flight Planning Computations

In a step-wise progression, the setup for a flight plan is:

1. state flight specs; OL, SL, OH, scale, film/filter

2. square out the target area; i.e. minimum rectangle to cover desired area

3. calculate the latitude/longitude of the target area corners

4. calculate the number of lines and line lengths (images)

5. plot the lines on a base map - either 7.5 min or 1/100,000 quad sheets or even an aeronautical chart. In the absence of maps, small scale aerial imagery has sometimes been used.

6. calculate the photo spacing and total number of photographs; including safety images

7. calculate flying time; ferry time plus time-on-target

8. develop flight constraints - tilt, crab, drift; acceptable scale variation; time of day (window); seasonal window, etc.

9. specify the products you want; paper prints (contacts); positive transparencies, negatives, or all three.

10. send out bids

11. **evaluate** bids in light of your estimates/constraints.

**Latitude/Longitude Determination**

Use a 7.5 minute quad sheet (scale of 1:24,000) to calculate the geographic location scales:

1. Measure the distance along the y-axis in 60'ths of an inch for a 2.5 minute change in latitude:

______ inches per 2.5 minutes on the y-axis translates to

_____ (round to 4 decimals) **seconds** per 1/60 in. change in latitude

2. Measure the distance along the x-axis in 60'ths of an inch for a 2.5 minute change in longitude:

______ inches per 2.5 minutes on the x-axis translates to

_____ (round to 4 decimals) **seconds** per 1/60 in. change in longitude.

Steps 1 and 2 produce the scale factors needed to compute lat/long of a given point

3. Measure the y-axis distance (in 60'ths of an inch) from a known latitude line to the desired point and multiply the distance by the latitude scale factor from step 1 above and convert answer to degrees, minutes, and decimals of minutes:

_____ inches north/south of the __°__._'N line translates to

_____ (round to 2 decimals) **minutes** of change in latitude

4. Measure the x-axis distance (in 60'ths of an inch) from a known longitude line to the desired point and multiply the distance by the longitude scale factor from step 2 above and convert answer to degrees, minutes, and decimals of minutes:

______ inches west/east of the __°__._'W line translates to

_____ (round to 2 decimals) **minutes** of change in longitude

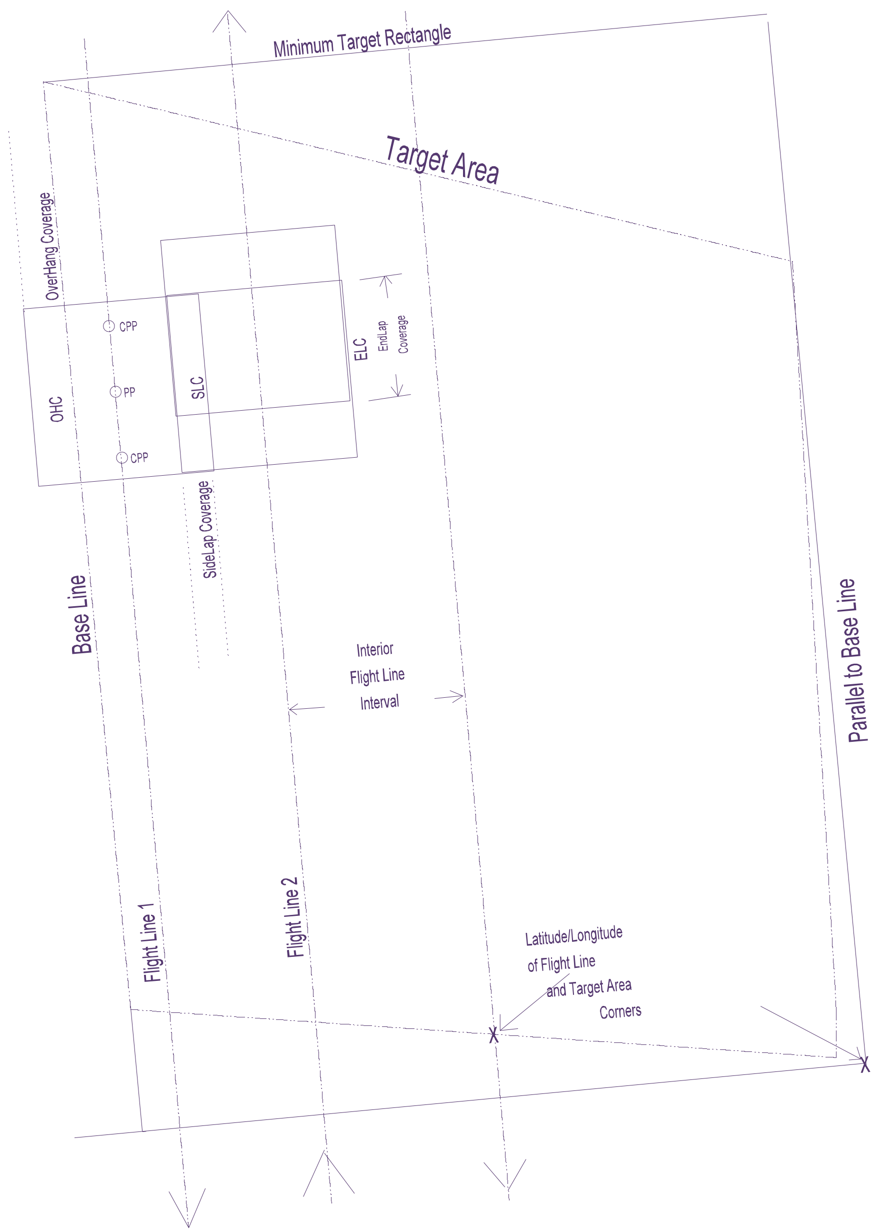
5. Add/Subtract the change in latitude between the known line and the point to the latitude of the known line: (remember 60 degrees = 1 minute; so convert excess minutes to degrees)

Latitude: _______________ North

6. Add/Subtract the change in longitude between the known line and the point to the longitude of the known line: (remember 60 degrees = 1 minute; so convert excess minutes to degrees)

Longitude: _______________ West

**Figure 1O-4: Flight planning for target photo area.**



## FLIGHT PLANNING FORMULAS

$1\ nautical\ mile = 6{,}076.11\,ft.$

$1\ statute\ mile = 1.1507784\ n.m.$

$PC = Photo\ Coverage = (photo\ width, inches)(photo\ scale, ft/inch)$

$SLC = SideLap\ Coverage = (1.0 - .SideLap\%)(PC) = INTERIOR\ LINE\ SPACING = ILS$

$ELC = EndLap\ Coverage = (1 - .End\%)(PC) = PHOTO\ SEPARATION$

$OHC = OverHang\ Coverage = (.OH\%)(PC)$

$$Total\ Flight\ Lines = \frac{(Target\ Area\ Width, ft.) + 2(.OverHang\%)(PC)}{(SLC)}$$

$$= (round\ at\ 0.5\ up/down)$$

$$Interior\ Flight\ Lines = \frac{(Width) - 2(.5 - .OverHang\%)(PC)}{SLC} - 1$$

$$= (round\ up\ to\ whole\ number)$$

$Check\ on\ Total\ Flight\ Lines = Interior\ Lines + 2$

$Line\ Space\ 1,N = (.5 - .OverHang\%)(PC)$

$$Interior\ Line\ Spacing = \frac{(Area\ Width) - 2(.5 - .OverHang\%)(PC)}{(Total\ Lines - 1)}$$

$$Interior\ Line\ Spacing = \frac{(Area\ Width) - 2(.5 - .OverHang\%)(PC)}{(Interior\ Lines + 1)}$$

$Interior\ Line\ Spacing \leq SLC$

$$Actual\ Photos\ per\ line = \frac{(Line\ Length, ft.)}{(ELC)} \quad (round\ up)$$

$Total\ Photos\ per\ line = (Actual\ Photos\ per\ line) + 4$

$Total\ Photos\ per\ job = \sum (Photos\ per\ line)$

$$Actual\ Side\% = \frac{(PC) - [\frac{(Width) - 2(.5 - .OverHang\%)(PC)}{Total\ Lines - 1}]}{(PC)}\ 100\% = \frac{(PC - ILS)}{PC} * 100\%$$

$Photo\ Spacing,\ ft = ELC$

1st Photo = 2.0 spaces beyond target area boundary

$$Photo\ Spacing, sec = \frac{[Photo\ Spacing, ft]}{(speed, mph) * (5{,}280)/(3600)}$$

$$Time, hrs = \frac{(Line\ Length, miles) + (Lines - 1) * 5 + (Ferry\ Dist, miles)}{(plane\ speed, mph)}$$

*Image Blur*:

$$GD = 1.4666667\left(\frac{S}{F}\right) \qquad PD = \frac{GD * 12}{scale}$$

where $GD$ = ground distance, ft; $S$ = aircraft speed, mph; $F$ = shutter speed, secs

$PD$ = photo distance, inches; $scale$ = denominator of Photo RF

## VI. Flight Planning Example

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Given:    Photo Scale  1:15,840        Overlap  60%
          Focal Length 6 inches        Sidelap  25%
          Photo Format 9 x 9 inches    Overhang 30%
          Plane Speed = 150 knots = 150(1.15) = 172.5 mph

          Target Area = 5 x 10 miles = 26,400 x 52,800 ft.

1 nautical mile = 6076.11 ft    1 statute mile = 1.15 n.m.

Photo Scale    1 inch          = 1320 feet
PC = (9")*(1320)               = 11,880 ft.
ILS = SLC = (1-.25)*(11,880)   = 8,910 ft.
ELC = (1-.60)*(11,880)         = 4,752 ft.
OHC = (.30)*(11,880)           = 3,564 ft.

Total Flight Lines = [26,400 + 2(3,564)]/8,910
                   = 3.76 = 4 lines (round up/down at 0.5)

Interior Lines = {[26,400-2(0.5-0.3)(11,880)]/8,910} - 1
               = 2.42 - 1 = 1.42 = 2 interior (round up)

Linespace 1,N = (0.5-0.3)(11,880) = 2,376 ft.

Interior Line Spacing = [26,400-2(0.5-0.3)(11,880)]/(2 + 1)
                      = 21,648/3 = 7,216 ft.

Actual SideLap% = (11,880 - 7,216)/11,880 = 39.3%

Photo Spacing, ft. = ELC = 4,752 ft.

Number of Photos per Line = 52,800/4,752+4 = 11.11 = 16

Total Photos = 16/line * 4 lines = 64 total

Photo Spacing, sec. = ELC/[(speed,mph* 5,280ft/mile)/(3600)]
                    = 4,752 /[(172.5 * 5,280)/(3600)]
                    = 18.78 seconds

Time, hrs = [(lines * length,miles)+(lines-1)*5]/(speed,mph)
          = [(4 * 10)+(3 * 5)]/172.5 = .32 hrs
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## VII. Practice Problem - Flight Planning

Photo Scale = 1:24,000 <u>at average elevation</u>
Average Elevation = 350 ft.

Photo overlap = 60%
Photo sidelap = 25%
Photo overhang = 25%

Aircraft Speed = 160 knots
Camera = 6.0 inch focal length
Film format = 9 x 9 inches

Target area = 10 x 20 miles

1. Desired aircraft altitude = ___________ ft.

2. Target Area
   a. Target area width = ___________ ft.
   b. Target area length = ___________ ft.

3. Photo coverage = _________ by _________ ft.

4. Planned SideLap Distance or ILS = _________ ft.

5. EndLap Coverage Distance = _________ ft.

6. OverHang Coverage Distance = _________ ft.

7. Total Flight Lines = _______

8. Interior Flight Lines = _______

9. Line spacing, 1 & N = _______ ft.

10. Interior Line Spacing = _________ ft.

11. Actual SideLap Percent = _____%

12. Photo Spacing = _____ ft.

13. Photos per line = _____

14. Total Photos for job = _____

15. Photo spacing = _____ seconds

16. Name 4 factors you can control in contract photography:

______________________ ____________________________

______________________ ____________________________