PROJECT PLANNING

Center for Photogrammetric Training
Ferris State University

RCB

CONSIDERATIONS IN PLANNING

- What products will be prepared
  - scales
  - accuracies
- Meetings with client important in understanding client's needs

GENERAL PLANNING CATEGORIES

- Planning aerial photography
- Planning ground control
- Selecting instruments and procedures to achieve desired results
- Estimating costs and delivery schedules

GROUND CONTROL FOR PHOTOGRAMMETRY

- Photogrammetric control - point whose position is known in object space and whose image can be positively identified on photography
- Provides means for orienting or relating photographs to ground

PHOTOGRAMMETRIC CONTROL

- Must satisfy 2 requirements:
  - Must be sharp, well defined, and positively identified on all photos
  - Must lie in favorable locations
- Normally conducted after photography acquired to satisfy requirements
- Ensure control does not fall in shadowed areas on some photos

PHOTOGRAMMETRIC CONTROL

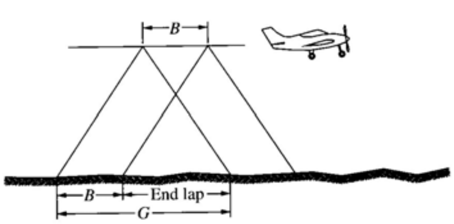
- HORIZONTAL CONTROL
  - Images must be very sharp and well defined horizontally
  - Samples: intersections of sidewalks, manhole covers, intersection of roads …
- VERTICAL CONTROL
  - Well defined vertically
  - Samples: small flat or slightly crowned areas with some feature nearby

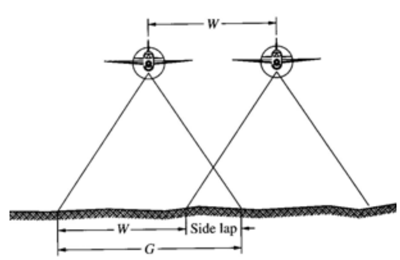
FLIGHT PLANNING

- Flight map
  - Shows where photos are to be taken
- Specifications – how the photos will be taken
  - Camera and film requirements
  - Scale
  - Flying height
  - End and side lap
  - Tilt and crab tolerances

END LAP AND SIDE LAP

- End lap – overlapping successive photos
- Side lap – overlapping adjacent flight strips





END LAP AND SIDE LAP

- Percent end lap:

$$PE = \frac{G - B}{G} \times 100$$

  - Normally taken as 60%

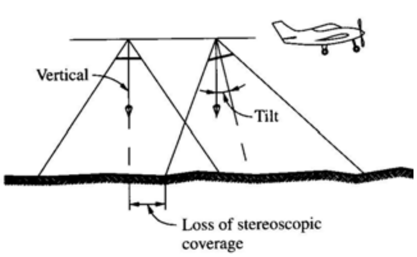
- Percent side lap:

$$PS = \frac{G - W}{G} \times 100$$

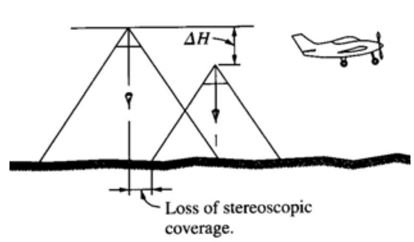
  - Normally about 30%
  - Excessive drift most common cause for gaps in coverage

LOSS OF STEREOSCOPIC COVERAGE

- Due to tilt

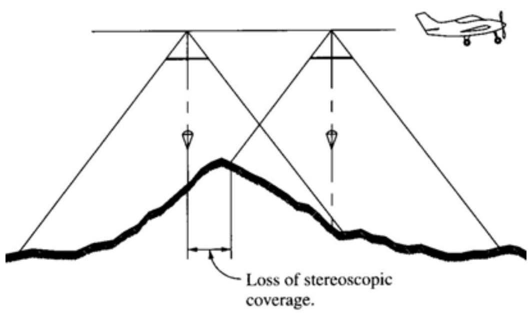


- Due to unequal flying heights



LOSS OF STEREOSCOPIC COVERAGE

- Due to terrain variations



END LAP AND SIDE LAP

- Example (18-1): Air base of a stereopair is 1400 m and flying height above average ground is 2440 m. Camera has a 152.4 mm focal length and 23-cm format. What is the percent end lap?

END LAP AND SIDE LAP

- Solution:
  - Average scale: $S_{Avg} = \frac{f}{H'} = \frac{152.4\,\text{mm}}{(2440\,\text{m})(1000\,\text{mm/m})} = \frac{1}{16{,}000}$
  - Ground coverage: $G = \left(\frac{23\,\text{cm}}{1/16{,}000}\right)\left(\frac{1\,\text{m}}{100\,\text{cm}}\right) = 3680\ \text{m}$
  - Percent end lap: $PE = \frac{3680\,\text{m} - 1400\,\text{m}}{3680\,\text{m}} \times 100 = 62\%$

END LAP AND SIDE LAP

- Example (18-2): Assume spacing between adjacent flight lines is 2500 m in the previous example. What is the percent side lap?

- Solution:

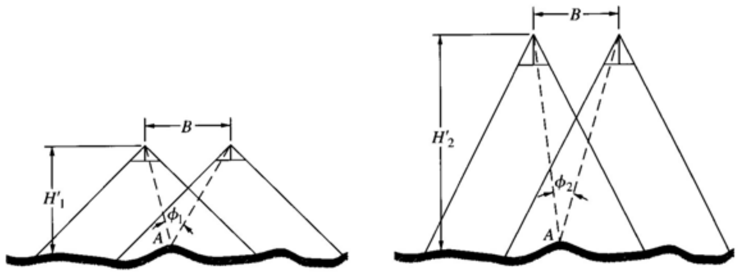
$$PS = \frac{3680\,\text{m} - 2500\,\text{m}}{3680\,\text{m}} \times 100 = 32\%$$

PURPOSE OF PHOTOGRAPHY

- Metric qualities vs. pictorial qualities
- For topographic mapping & other quantitative operations
  - Prefer wide or super-wide-angle camera
    - Large B/H' ratio
  - Larger B/H' – greater parallactic angles between intersecting light rays
  - Errors
    - Increase with increasing flying height
    - Decrease with increasing x parallax

PURPOSE OF PHOTOGRAPHY

- Parallactic angles increase with increasing B/H' ratios



PURPOSE OF PHOTOGRAPHY

- For mosaics – relief displacement, tilt displacement & scale variation degrade pictorial qualities
  - Minimized by decreasing B/H' ratio
  - Increase flying height reduces scale but can use longer focal length camera

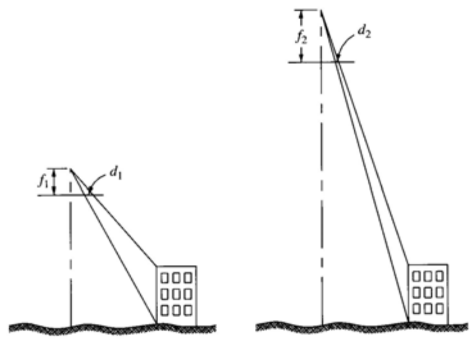
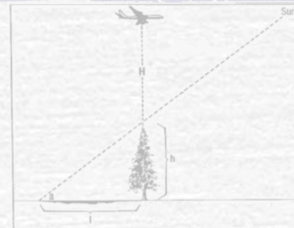


PHOTO SCALE

- For topographic mapping – dictated by required scale of map and accuracy
- Example: Using aerial photos to study centerline markings. Actual width of painted centerline is 100 mm (4"). A high-resolution (80 line pair per millimeter) film used. What is minimum photo scale required?

PHOTO SCALE



- Solution:
  - Smallest object size:

$$d = \frac{1}{80}\,\text{mm} = 0.0125\ \text{mm}$$

  - Minimum scale

$$S_{Min} = \frac{0.0125\,\text{mm}}{100\,\text{mm}} = \frac{1}{8{,}000}$$

PHOTO SCALE

- 5-6 times enlargement ratios common
- Example (18-4): A map will be compiled at a scale of 1:6,000. What is the photo scale if a 5 times enlargement will be used?
- Solution

$$S_p = \frac{S_{Map}}{5} = \frac{1/6000}{5} = \frac{1}{30{,}000}$$

PHOTO SCALE

- Optimal scale important
  - If larger than necessary – uneconomical
  - If too small – reduces usefulness or may make it unsatisfactory
- Assume point to be plotted correctly within 1/30" with accuracy of 2'
  - Required map scale: $S_M = \frac{0.0333''}{2'} = \frac{1''}{60'}$ or $1:720$
  - If 5 times enlargement: $S_p = \frac{S_M}{5} = \frac{1''}{300'}$ or $1:3600$

C-FACTOR

- Empirical measure of contouring accuracy of a stereoplotter
- Defined as:

$$C - \text{factor} = \frac{H'}{CI}$$

- Sometimes C-factor stretched for economical purposes

SOME C-FACTOR VALUES

Instrument	C-Factor Commercial	C-Factor Government
Analytical Plotter	3000	2500
Zeiss Planimat	2400	2100
Wild A10	2400	2100
Wild AG1	2000	1800
Wild A8	2000	1800
Kern PG2	2000	1800
Kelsh	1500	1200

COMPATIBLE MAP SCALES & CONTOUR INTERVALS FOR AVERAGE TERRAIN

Imperial Units		SI Units	
S_{Map}	CI	S_{Map}	CI
1”=50’	1’	1:500	0.5 m
1”=100’	2’	1:1000	1 m
1”=200’	5’	1:2000	2 m
1”=500’	10’	1:5000	5 m
1”=1000’	20’	1:10000	10 m

PHOTO SCALE

- Example: A topographic map has a scale of 1”=200’ with a 5’ contour interval is to be compiled on a stereoplotter having a nominal 6” focal principal distance. Determine the flying height for the photography if the maximum values for the C-factor and enlargement ratio are 1500 and 5 respectively.

PHOTO SCALE

- Solution:
  - Using C-factor and contour interval

$$H' = (C - factor)(CI) = 1500(5') = 7{,}500'$$

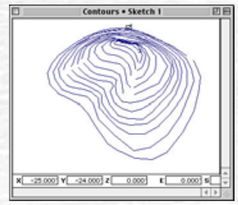
  - Using enlargement ratio

$$S_p = \frac{S_M}{5} = \frac{1''/200'}{2} = \frac{1''}{1000'}$$

$$\frac{f}{H'} = \frac{1''}{1000'} \Rightarrow H' = \frac{6''}{1''/1000'} = 6{,}000'$$

  - The lower flying height controls = 6,000’

PHOTO SCALE

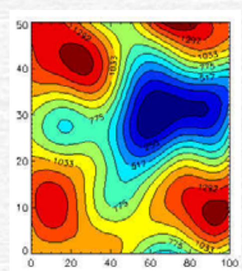


- If contours not being used, spot elevations taken over model
  - Rule of thumb: Ratio of flying height above ground to the accuracy to which spot elevations can be reliably read is ~ 5000
  - Example: if spot heights are to be accurate to ½ m, then

$$H' = \frac{1}{2}\,\text{m}\,(5000) = 2500\ \text{m}$$

COMPUTED PHOTO SCALE

- C-factor should be used only under following conditions (Thorpe)
  - 6” focal length camera
  - Instrument in good calibration
  - Good experienced operator
  - Full vertical ground control
  - Sharp, clear diapositives
  - Smooth-sloped terrain
  - Terrain unobscured by vegetation
- CPS – Computed Photo Scale - alternative



COMPUTED PHOTO SCALE

- Defined as:

$$CPS = CI \times CF \times CA \times FL \times AN \times IN \times OP \times \frac{20 - MB}{20} \times 2$$

- CI = contour interval, in feet
- CF = C-factor of instrument
- CA = camera's maximum radial distortion
  - 1.0 if distortion less than 5 μm
  - 0.95 for distortions between 5 and 10 μm
  - 0.90 for distortions greater than 10 μm

COMPUTED PHOTO SCALE

$$CPS = CI \times CF \times CA \times FL \times AN \times IN \times OP \times \frac{20 - MB}{20} \times 2$$

- FL = focal length
  - 1.1 if f = 3 ½"
  - 1.0 if f = 6"
  - 0.75 if f = 8 ¼"
  - 0.5 if f = 12"
- IN = instrument condition
  - 1.0 for excellent calibration
  - 0.9 for average calibration
- MB = maximum number of models bridged

COMPUTED PHOTO SCALE

$$CPS = CI \times CF \times CA \times FL \times AN \times IN \times OP \times \frac{20 - MB}{20} \times 2$$

- AN = analytical triangulation
  - 1.0 for full ground control
  - 0.9 for simultaneous bundle adjustment with additional parameters
  - 0.85 for simultaneous bundle adjustment without additional parameters
  - 0.8 for independent model
  - 0.7 for polynomial adjustment
- OP = operator
  - 1.0 for excellent operator
  - 0.9 for average operator

COMPUTED PHOTO SCALE

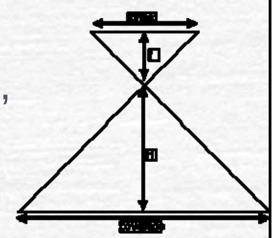
- Example: Area to be mapped with 2’ contour interval using a 6” focal length camera having a maximum radial distortion of 8μm, with mapping on a Kelsh plotter in average condition with an excellent operator, using analytics developed from a polynomial adjustment method, bridging over 3 models
- Solution

$$CPS = 2 \times 1500 \times 0.95 \times 1.0 \times 0.7 \times 0.9 \times 1.0 \times \frac{20 - 3}{20} \times 2$$

- Photo scale is 1:3052

Flying Height

- Given focal length & average scale, flying height computed from scale relationship
- For topographic mapping, flying height normally 500 – 10,000 m
- May have 2 different flying heights on project if elevations have substantial differences
  - Maintain uniform photo scale



Flying Height

- Example: Aerial photography is to be taken with an average scale of 1:6,000 with a 152.4 mm focal length camera. The average elevation is 425 meters above seal level. What is the required flying height above mean sea level?

Flying Height

- Solution:

$$S = \frac{f}{H - h_{avg}} \Rightarrow H = \frac{f}{S} + h_{avg}$$

$$H = \left(\frac{152.4\,mm}{1/6{,}000} \right) \left(\frac{1\,m}{1{,}000\,mm} \right) + 425\,m$$

$$= \underline{1{,}340\,m}$$

Flying Height

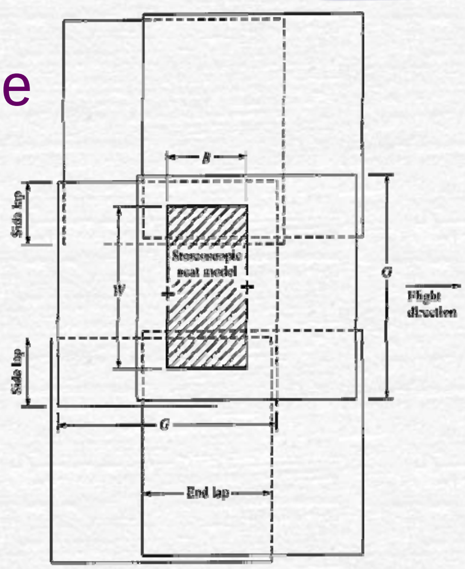
- Ground coverage/photo greater for high-altitude vs. low altitude
  - Fewer photos required
  - Very high altitude more expensive – special equipment
  - Problems at high altitude: decrease oxygen available, decrease pressure, extreme cold
  - > 3,000m oxygen supply necessary for flight crew
  - >10,000m pure oxygen under pressure required
    - Cabin pressurized, heaters required

Flying Height

- Most aerial photography uses single- or twin-engine aircraft
  - Supercharged single-engine – up to ~6km
  - Supercharged twin-engine – up to ~10 km
  - Higher altitudes require turbocharged or jet aircraft
- Proper flying height maintained by altimeter or GPS
  - Altimeter – elevation above mean sea level
  - Barometric instruments – affected by pressure
    - Check daily and adjust to base airport air pressure

Ground Coverage

- Stereoscopic neat model area determined once end lap and side lap known
- Area between adjacent principal points, extending sideways to middle of side lap
- Represents approximate mapping area of each stereopair



Ground Coverage

- Example: Aerial photo taken from flying height of 6,000 ft above average ground with camera having a 6” (152.4 mm) focal length and a 9” (23 cm) format. End lap will be 60% and side lap will be 30%. What is the ground covered by a single photograph and by the stereoscopic neat model?

Ground Coverage

- Scale is: $S = \frac{f}{H'} = \frac{6''}{6{,}000'} = \frac{1''}{1{,}000'} \text{ or } 1:12{,}000$
- Dimension of G for single photo:

$$G = \frac{\text{format}}{S} = \frac{9''}{1''/1{,}000'} = 9{,}000'$$

- Area in acres covered on ground by single photo:

$$A = \frac{G^2}{43{,}560\,\text{ft}^2/\text{acre}} = 1{,}900\,\text{acres}$$

Ground Coverage

- Dimension of rectangular stereoscopic neat model

$$B = 0.4(9{,}000') = 3{,}600'$$

$$W = 0.7(9{,}000') = 6{,}300'$$

- Area of neat model

$$A = \frac{(3{,}600')(6{,}300')}{43{,}560\ \text{ft}^2/\text{acre}} = 520\,\text{acres}$$

6” focal length

Ground Coverage for Photo

Photo Scale	Photo Scale, in/ft.	Flying Height, ft	G, ft	W (0.7 G), ft	B (0.4 G), ft	Acres/ photo	Acres/ neat model
1:1,800	1/150	900	1,400	940	540	42	12
1:2,400	1/200	1,200	1,800	1,300	720	74	21
1:3,600	1/300	1,800	2,700	1,900	1,100	170	47
1:4,800	1/400	2,400	3,600	2,500	1,400	300	83
1:6,000	1/500	3,000	4,500	3,200	1,800	460	130
1:7,200	1/600	3,600	5,400	3,800	2,200	670	190
1:8,400	1/700	4,200	6,300	4,400	2,500	910	260
1:9,600	1/800	4,800	7,200	5,000	2,900	1,200	330
1:10,800	1/900	5,400	8,100	5,700	3,200	1,500	420
1:12,000	1/1,000	6,000	9,000	6,300	3,600	1,900	520

152 mm focal length

Ground Coverage for Photo

Photo Scale	Photo Scale, in/ft.	Flying Height, m	G, m	W (0.7 G), m	B (0.4 G), m	Hectares/ photo	Hectares/ neat model
1:1,000	1/83	152	230	160	92	5.3	1.5
1:2,000	1/167	304	460	320	180	21	5.9
1:3,000	1/250	456	690	480	280	48	13
1:4,000	1/333	608	920	640	370	85	24
1:5,000	1/417	760	1,200	800	460	130	37
1:6,000	1/500	912	1,400	970	550	190	53
1:7,000	1/583	1,060	1,600	1,100	640	260	73
1:8,000	1/667	1,220	1,800	1,300	740	340	95
1:9,000	1/750	1,370	2,100	1,400	830	430	120
1:10,000	1/833	1,520	2,300	1,600	920	530	150

Weather Conditions

- Important consideration
- Ideal: free from clouds (if less than 10% - may be satisfactory)
  - Number varies with time of year and locality
  - Overcast conditions may be favorable in certain conditions
    - Example: large-scale photos for topographic mapping over built-up areas, forests, steep canyons, or other features – clear, sunny days may cast troublesome shadows

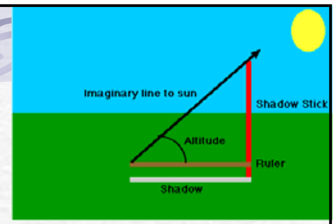
Weather Conditions

- Cloudless day may be unsuitable
  - Atmospheric haze, smog, dust, smoke, high winds, or air turbulence
  - Best day to photograph over industrial areas susceptible to smog, dust, smoke: after heavy rains or during moving cold fronts which clear the air

Season of Year

- Limiting factor
  - Ground cover conditions
  - Sun's altitude
- For topo mapping – deciduous trees bare
  - Twice a year for most localities
  - Oak trees tend to hold leaves until spring ∴ best between budding and leafing out
- Normally photos not taken when snow-covered
  - Obscures ground
  - Causes difficulties in interpretation and stereoviewing
- Sometimes, want leave on (forestry interpretation) and sometimes light snow may make ground surface more identifiable in tree-covered areas

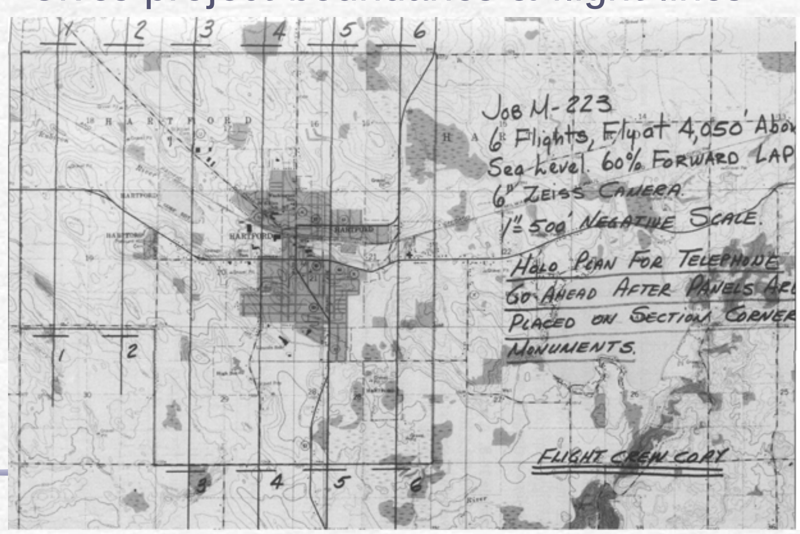
Season of Year



- Sun's altitude important
  - Low sun angle – long shadows which can obscure detail
  - Generally ~30° acceptable
    - Some areas in northern US – sun never rises above 30° during winter months
    - Aerial photography avoided if possible
- Shadows sometimes beneficial
  - Aid in identifying object like tree species
  - Help in identifying fenceposts, power poles

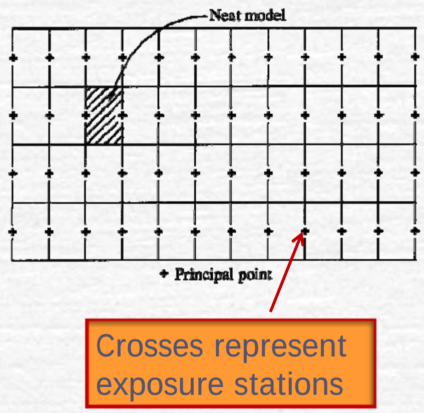
Flight Map

- Gives project boundaries & flight lines



Flight Map

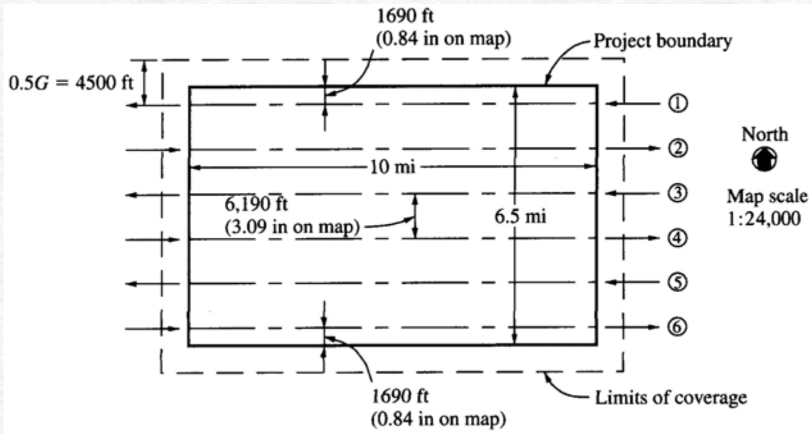
- Flight planning templates useful
  - Determine best & most economical photographic coverage for mapping
    - Especially good for small areas
  - Transparent plastic sheets at scales corresponding to scales of flight map
  - Superimposed over map and oriented in position to yield best coverage with fewest neat models



Flight Map Example

- Project are is 10 mi (16 km) long E/W and 6.5 mi (10.5 km) wide in N-S direction. Photography at scale of 1:12,000 with 60% end lap and 30% side lap required. A 6” (152.4 mm) focal length camera with 9” (23 cm) format will be used. Prepare flight map on a base map whose scale is 1:24,000 and compute the total number of photographs required for the project.

Flight Map Example



Flight Map Example

1. East-West flight lines selected to reduce number of flight lines
2. Dimension of ground coverage/photo

$$G = \frac{\text{format}}{S} = \frac{9''}{1''/1{,}000'} = 9{,}000' \, (2800\,\text{m})$$

3. Lateral advance per strip (30% side lap)

$$W = 0.7\,G = (0.7)(9{,}000') = 6{,}300' \, (1{,}900\,\text{m})$$

Flight Map Example

4. Number of flight lines – align first & last flight line with north & south project boundaries. Dist of 1st & last flight lines inside project boundaries

$$0.5\,G - 0.3\,G = 0.2\,G = (0.2)(9{,}000') = 1{,}800'\ (550\,m)$$

number of spaces between flight lines

$$\frac{(6.5\,mi)(5{,}280\,ft/mi) - 2(1{,}800')}{6{,}300'} = 4.9 \Rightarrow 5\ (\text{round up})$$

number of flight lines = No. spaces + 1 = 6

Flight Map Example

5. Adjust percent side lap & flight line spacing

$$2\left(0.5 - \frac{PS}{100}\right)G + (\text{no. spaces})\left(1 - \frac{PS}{100}\right)G = \text{total width}$$

$$2\left(0.5 - \frac{PS}{100}\right)9{,}000' + (5)\left(1 - \frac{PS}{100}\right)9{,}000' = (6.5\,mi)(5{,}280\,ft/mi)$$

$$2\left(0.5 - \frac{PS}{100}\right) + (5)\left(1 - \frac{PS}{100}\right)G = 3.813$$

$$PS = 31.2\%$$

$$W_a = \left(1 - \frac{31.2}{100}\right)G = 6{,}190'\ (1{,}890\,m)$$

Flight Map Example

6. Linear advance per photo (60% end lap)

$$B = 0.4G = (0.4)(9{,}000') = 3{,}600'\ (1{,}100\,m)$$

7. No photos per strip (2 extra beyond project boundaries to ensure complete stereoscopic coverage)

$$\text{No. photos / strip} = \frac{(10\,mi)(5{,}280\ ft/mi)}{3{,}600'} + 1 + 2 + 2 = 19.7 \Rightarrow 20$$

Flight Map Example

8. Total number of photos:

$$(20\ \text{photos / strip})(6\ \text{strips}) = 120\ \text{photos}$$

8. Spacing of flight lines on map:

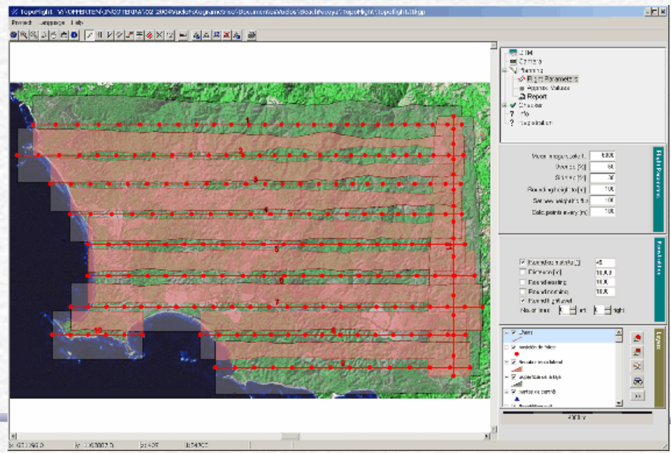
$$W_M = W_a S = (6{,}190\,ft/strip)\left(\frac{1''}{2{,}000'}\right) = 3.09''\ (78.6\,mm)$$

Draw flight lines at 3.09” spacing with 1st & last inside project boundaries by

$$\left[\left(\frac{0.5 - 31.2}{100}\right)9{,}000'\right]\left(\frac{1''}{2{,}000'}\right) = 0.84''$$

Flight Map

- Today – prepared on computer



Specifications

- Projects often contain specific specs
- Technical specs may include
  - General – discusses who will perform the work: general and sub-contracts
    - Experience/qualifications
    - Area to be covered
  - Scale – may designate negative scale
    - Criteria for variance (i.e. 5%) due to tilt/flight altitude

Specifications

- Cont.
  - End lap/side lap – specify amount and acceptable variations
  - Tilt – usually specify maximum amount acceptable, average tilt for entire project, and tilt differences between adjacent photos.
  - Crab – specify amount (i.e. 3º) above which flight/photos can be rejected