Photogrammetry
2^{nd} Year- Civil

- Flight Planning

By D. Kamal M. Ahmed

ملاحظات

- محاضراتي تغطي الابواب التاليه من الكتاب: الثاني و الثالث و الرابع
- الاسبوع الثاني من الترم عملي في الفصول
- هذه المحاضرات ليس المقصود منها ان تغطي كل المعلومات المطلوبه و الطالب مسئول عن إضافه ملاحظات وشرح و كل ما يضيفه المحاضر خلال المحاضرات
- يغلق باب قاعة المحاضره عند بدئها و يفتح بعد عشر دقائق فقط و لايسمح بالدخول بعدها
- سيعقد قبل امتحان منتصف الترم و قد يعقد خلال المحاضره او لطالب منفردا
- غير مسموح بالحضور في فصل غير الفصل المسجل فية الطالب

Basic concepts and Units

- Stereoscopic = 3D
- Air base: the distance between exposure stations, points where photos are taken.
- H: flying height above datum, h is height of point above datum or elevation of a point, H-h: above ground
- Uppercase letters refer to ground space, while lowercase letters refer to photo space: A is a point in “reality” or in ground system, while a is a point on a photograph.
- <u>Standard film cameras are of 9X9” frame size and 6” focal length</u>
- I ft = 12 inch, 1 yard = 3 ft, 1 mile = 5280 ft
- I inch = 2.54 cm
- 1 m = 3.2808333 ft cm, 1 km = 0.6213699 mile

Symbols used

- G: Length of a side of ground area covered by a photograph
- R: End lap (overlap)
- P: Side lap
- S: distance between adjacent strips
- f: focal length of the camera
- L: exposure station
- H: flying height above DATUM
- h: Elevation above datum,
- H-h: flying height above ground
- B: air base, b: photographic base
- N_s : Adjusted number of strips in a block.

Summary of equations

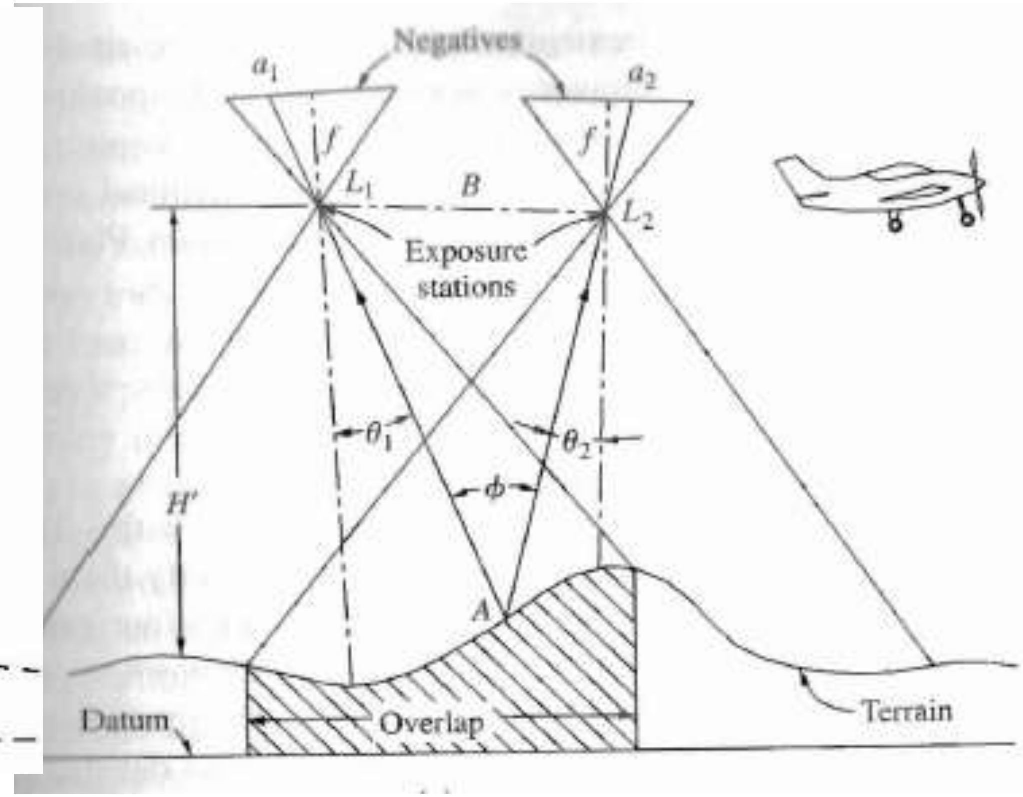
- G^2 = area of photograph x $S.N^2$
- Overlap R = {(G-B)/G} x 100
- Sidelap P = {(G-S)/G} x 100
- Lateral advance per strip (S) = [1-(P/100)] *G
- Linear advance per photo (B) = [1- (R/100)] * G
- number of strips ={(l_2 - 0.4G)/S} +1
- adjusted distance between strips = (l_2 - 0.4G)/N_s

The basic idea? الفكره الاساسيه

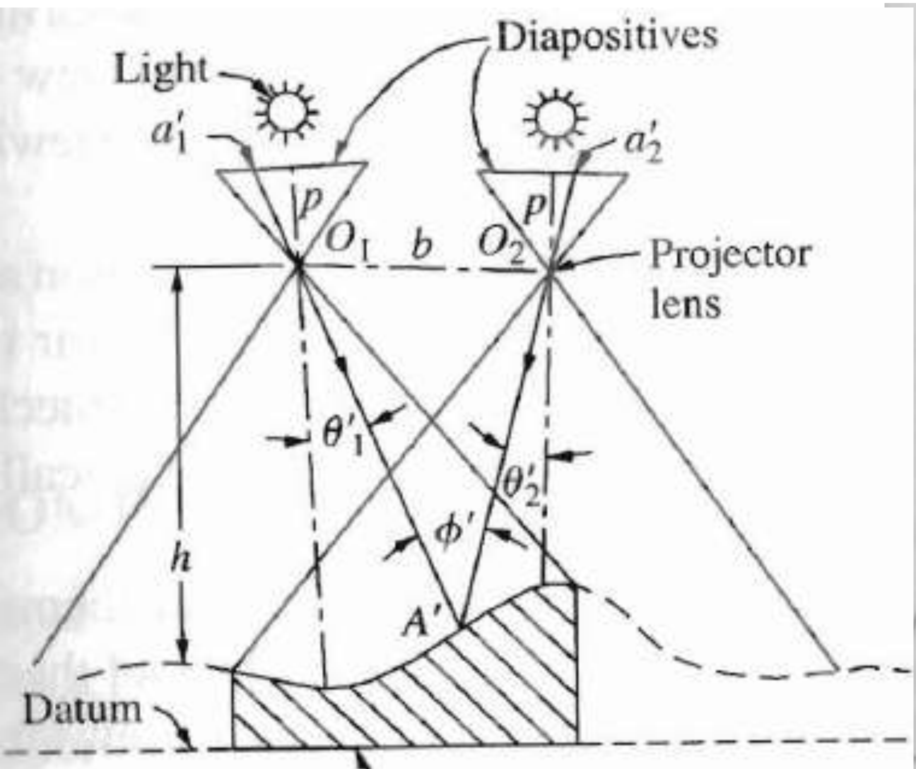
- تلتقط صور من الارض او الجو ثم نوجد العلاقه الفراغيه بين الصوره و الواقع
- ننشئ محاور علي الصوره و نقيس س و ص بدقه عاليه
- نطبق معادلات للحصول علي اللحداثيات الارضيه من احداثيات الصوره المقاسه
- تستخدم الاحداثيات الارضيه لكافة التطبيقات المساحيه مثل انتاج خرائط و عمل مقاطع و توليد اسطح و حساب كميات
- قد تلتقط الصور من الارض او الجو من طائرات او اقمار صناعيه

للقياس الدقيق او لتفسير الصور

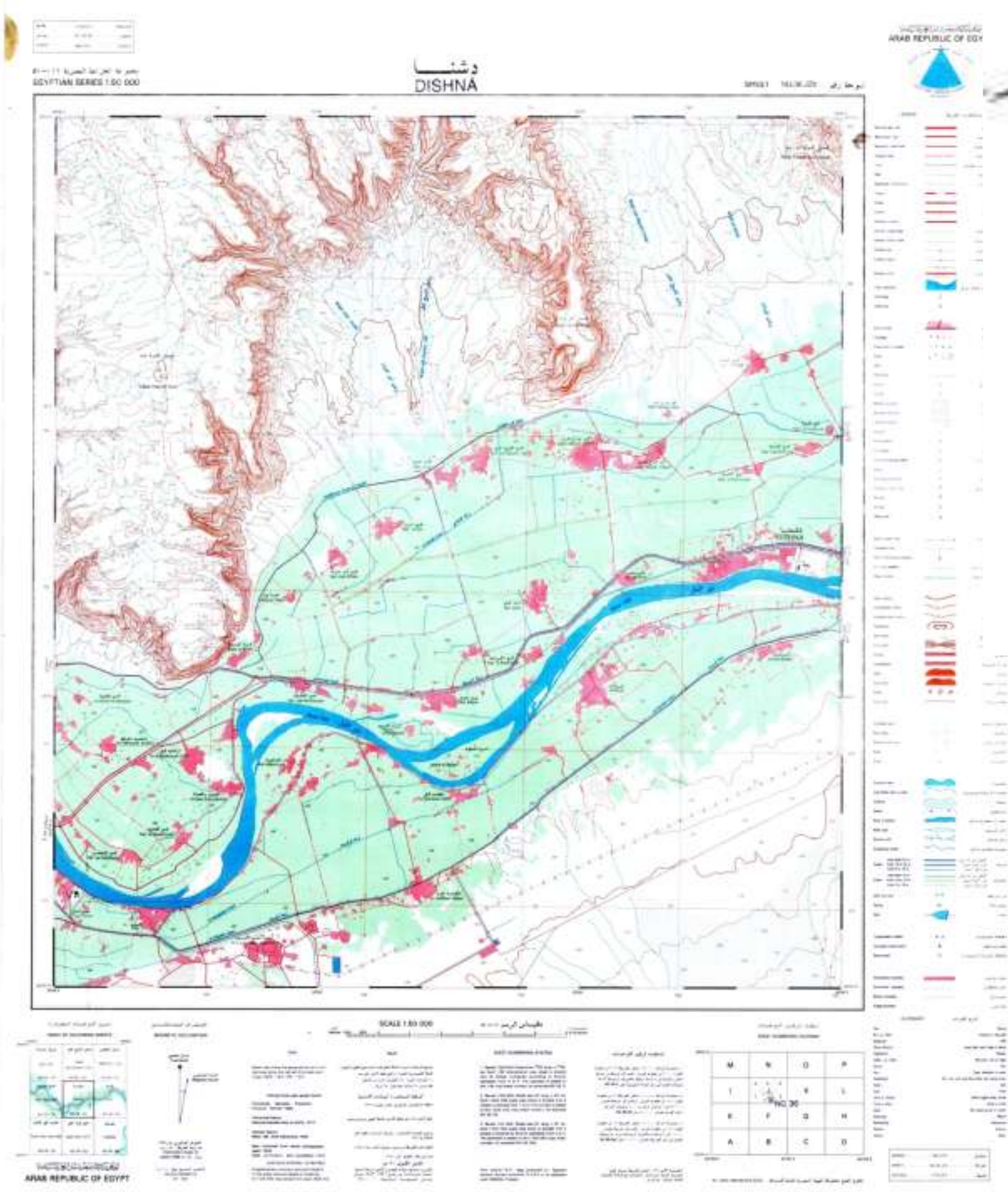
ما هي العلاقه بين الفوتجرامتري و الاستشعار من بعد؟؟



تؤخذ صور متداخله من طائرات



ثم نولد نموذج ثلاثي الابعاد و نقيسه



الشبكة

توضح الشرطات السوداء الشبكة الجغرافية بالتربيع الخطوط الحمراء الشبكة الكيلومترية الحمراء . وتقع نقطة الأصل على بعد ٥٠٠ كيلومترا جنوبا ، ٥٠٠ كيلومترا غربا من تقاطع خط عرض ٣٠° شمالا وخط طول ٣١° شرقا

المسقط المستخدم و البيانات الأساسية

مسقط مركاتور المستعرض مجسم هلمرت ١٩٠٦

نقطة الزهرة ... هي نقطة الأساس للشبكة الجيوديسية في مصر

مستوى المقارنة الرأسية : متوسط منسوب سطح البحر الاسكندرية ١٩٠٦

أنتجت هذه الخريطة من صور جوية أخذت عام ١٩٨٨

تمت المراجعة الحقلية عام ١٩٩٠

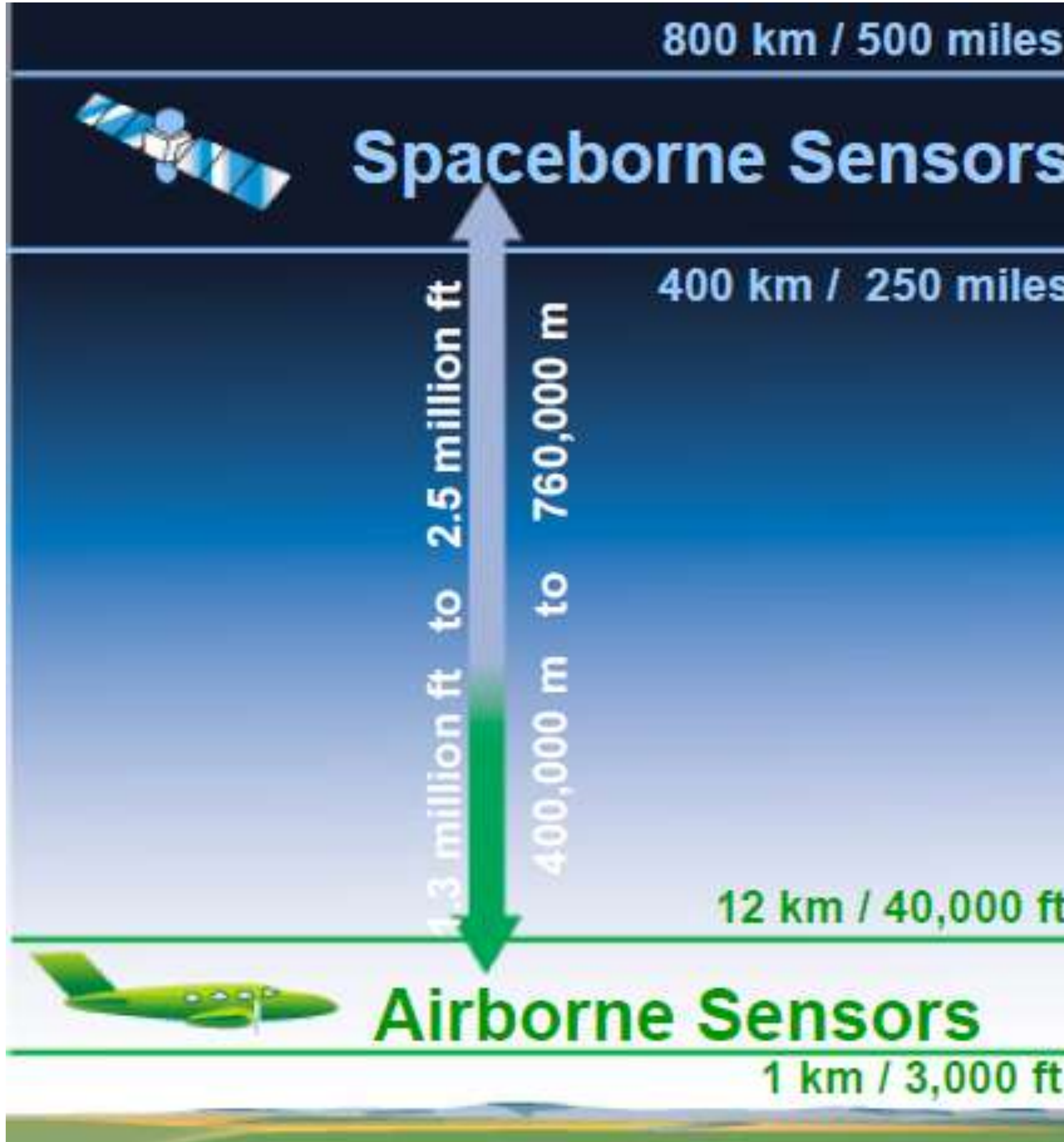
الفاصل الكنتورى ٢٠ مترا

الكنتورات الإضافية ونقاط الارتفاع و الأعماق الرأسية أساسها أعمال مرئية تمت بين عامي ١٩٣٢ ، ١٩٥٣ بمقياس ١ : ٢٥٠٠٠

PSR President of The American Society for Photogrammetry and Remote Sensing, 2002

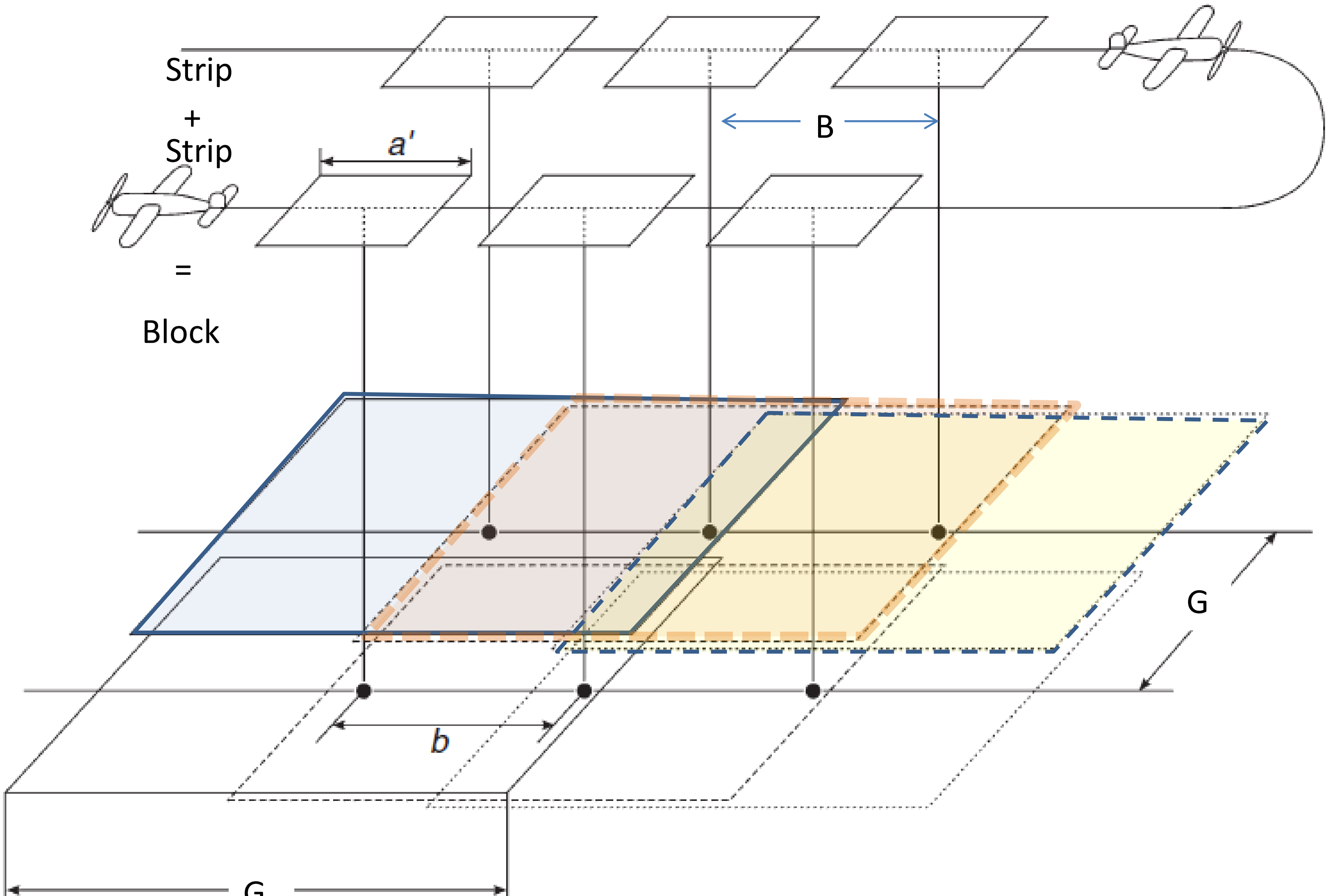
Washington-USA and British Columbia-Canada

Airborne and Spaceborne Imagery



Why Flight Planning?

- To ensure coverage of the area to be mapped at the required scale with no gaps, and provide stereo models by an efficient design.
- The product of a flight plan is basically a map,
- A flight plan will determine the spacing between successive photographs, locations of flight lines, and start and end locations of each flight line.



By D. Kamal M. Ahmed

Factors Affecting Flight Mission

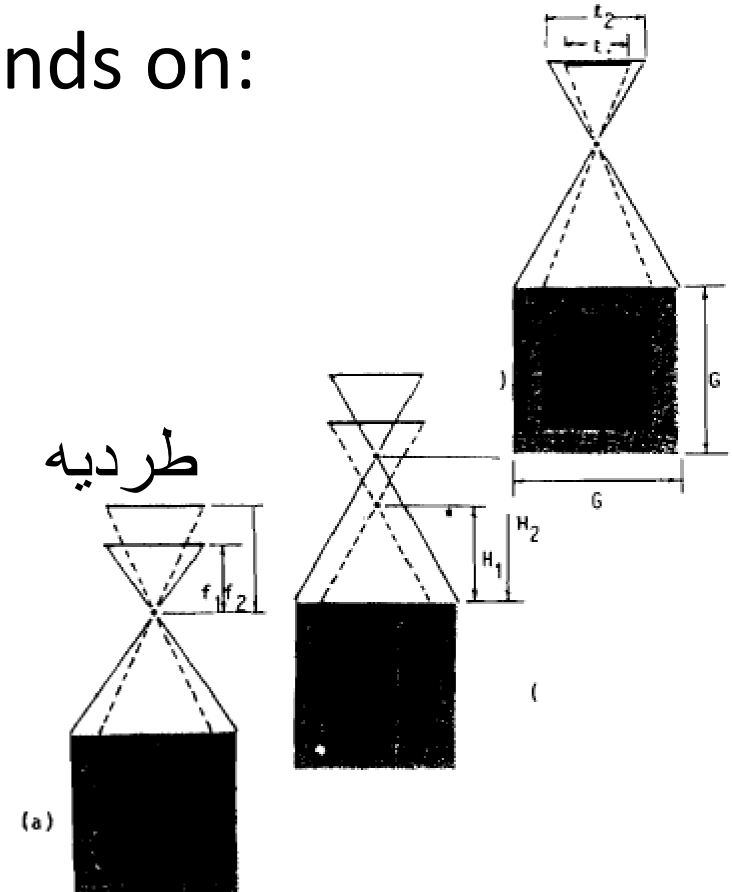
1- Ground Coverage (G x G) المنطقه المغطاه

How much of the ground will show in a single photograph? Depends on:

– format (photo) size. طرديه

– Flying height above ground طرديه

– Camera focal length. عكسيه



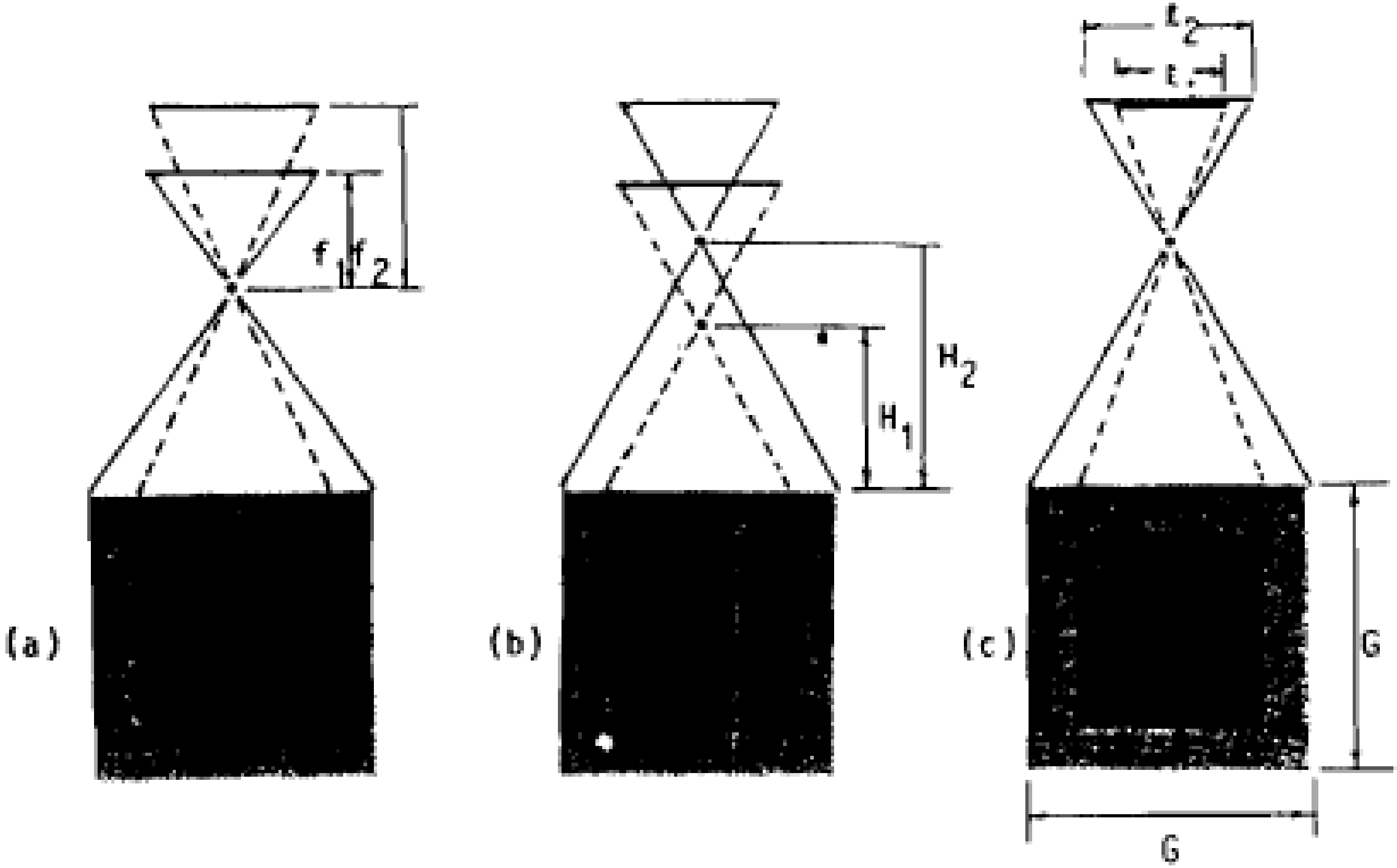


Figure (2-1) Change in ground coverage (GxG) due to variation of (a) focal length; (b) flying height; and (c) format size

- To increase ground coverage, you increase flying height, decrease focal length, or increase the size of the photograph.
- If a single photograph covers a square of side G on the ground, then;
- The area on the ground G^2 covered by one photograph at a scale 1 : S.N

$$G^2 = \text{area of photograph} \times S.N^2$$

- For example: ground coverage G X G or G^2 of a 9 X 9” photograph taken at a scale of 1: 25,000 is

(9X9) X (25,000X25,000) /144 = 364,050,000 ft^2

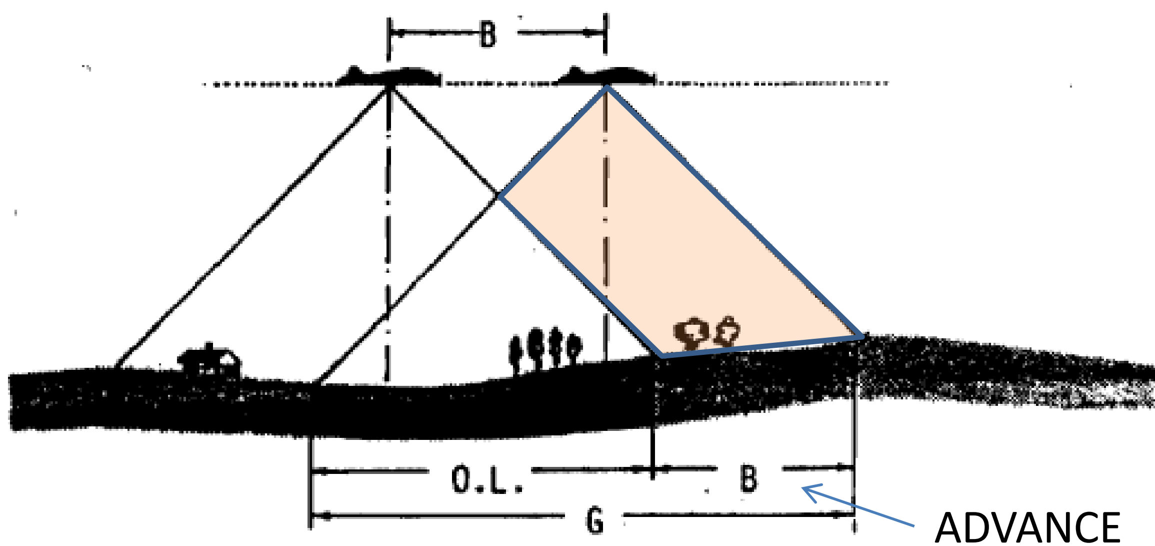
(1 ft = 12 inch   القدم = 12 بوصه)

Factors Affecting Flight Mission

2- Overlap (R%) and Sidelap (P%)

التداخل الامامي و الجانبي

- A reasonable size photogrammetric project usually include several photographs.
- A pair of overlapping photographs make a stereo pair and provide a stereo model



By D. Kamal M. Ahmed

Figure (2-3) overlap between successive aerial photographs

- Stereo pairs taken at the same flight lineخط طيران make a “STRIP” شريحه
- More than one strip make a “BLOCK”.
- Overlap (endlap) is needed to provide stereoscopic coverage while the sidelap is needed to ensure that no gaps exist between strips.

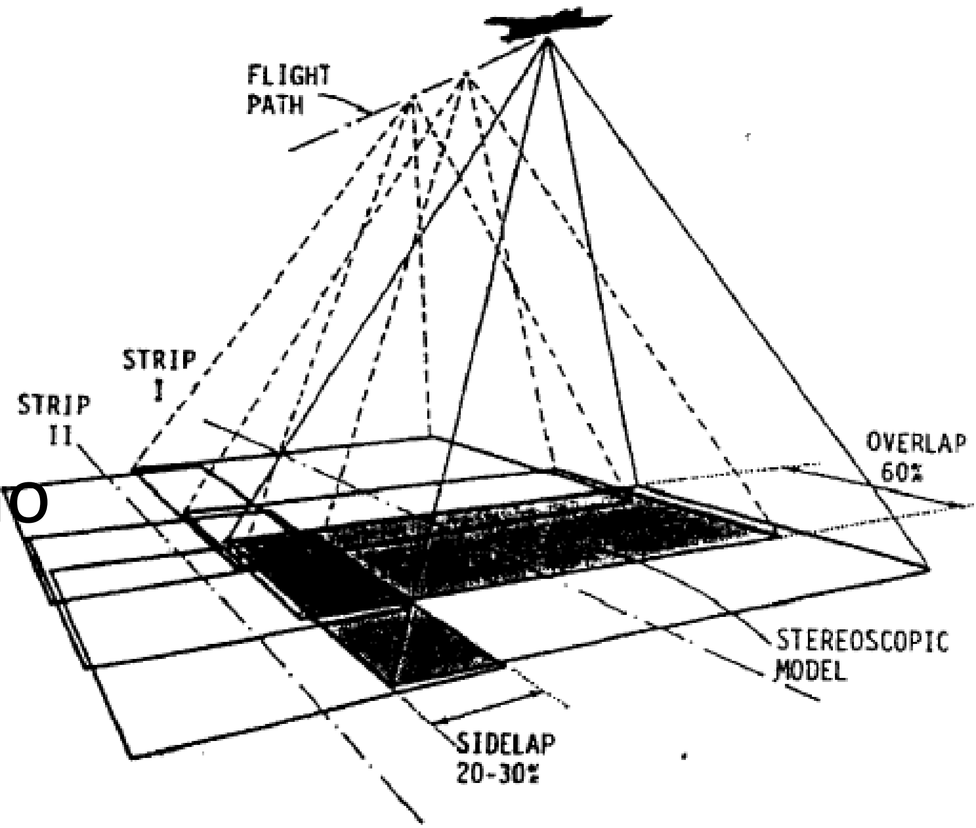
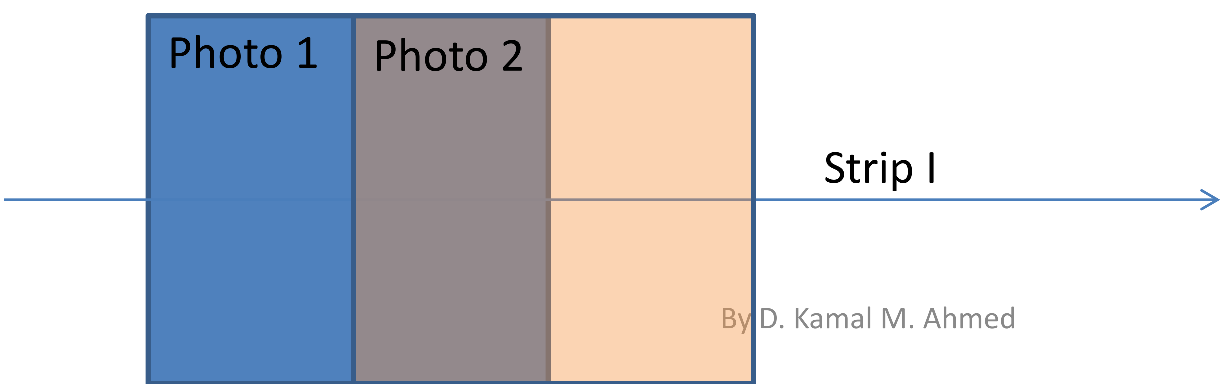


Figure (2-2) Overlap and sidelap between successive photographs and adjacent strips

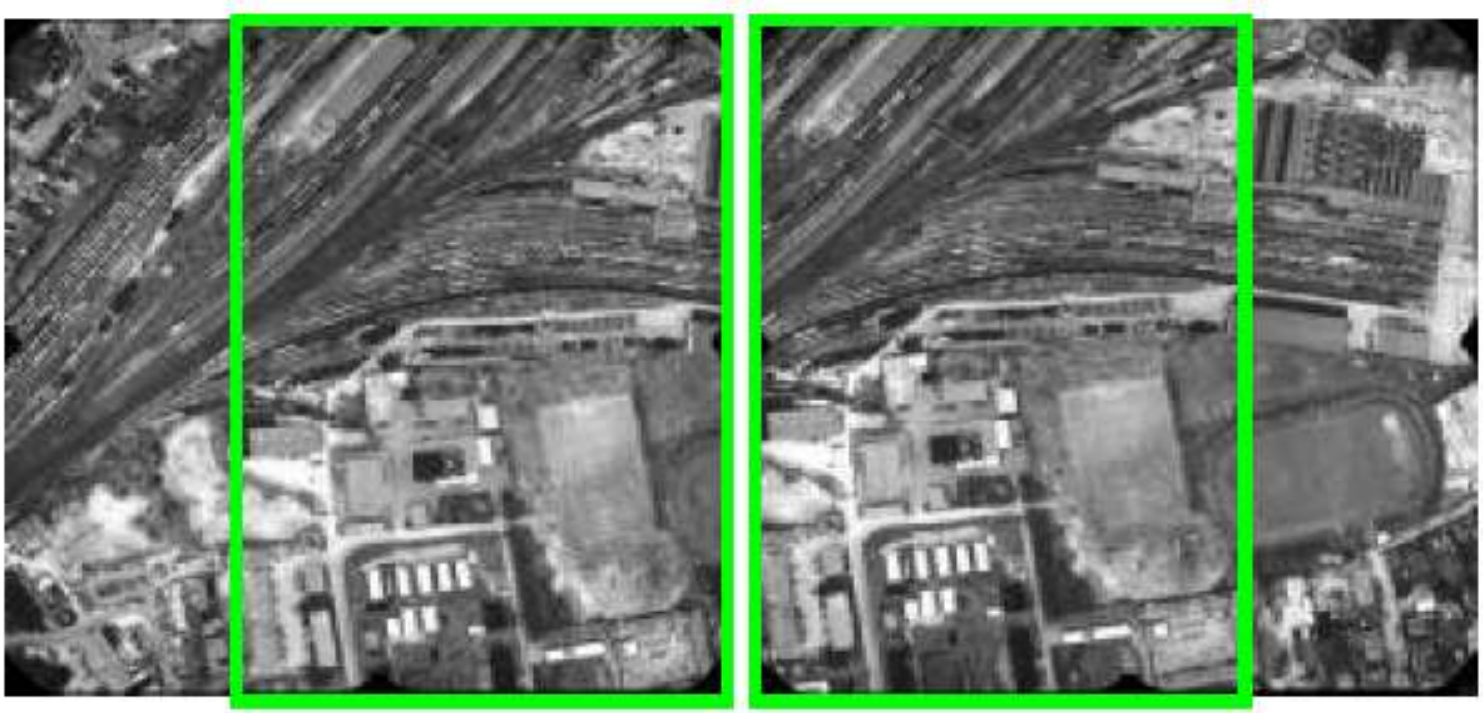
Overlap (endlap) (P%)

- To ensure stereo coverage
- At least 50% of the area photographed is shown in both photographs to provide stereoscopic coverage of the entire strip with no gaps in the direction of flight.
- For example, photos 1 and 2 in strip I are covered as shown in the following figure.
- Now, what happens if photo 3 overlaps with photo 2 with more or less than 50%?



Usually, the overlap is more than 50 % to ensure that the entire area is covered in stereo, minimum of 60 % is most common as shown below.

The overlap can be as much as 90% to provide triple coverage if needed.



Computation of overlap (R%)

- In the figure below, if:

G: is the length of a side of the square on ground covered by the photograph;

B: is the air base, the distance between the successive photos; then the overlap percent of G is:

$$\text{Overlap } R = \{(G-B)/G\} \times 100$$

Note that B cannot be larger than G

- For example, if the area on ground covered be a single photograph is 15,000 X 15,000 ft, and the air base was 9,000 ft, calculate the overlap.

Answer: overlap

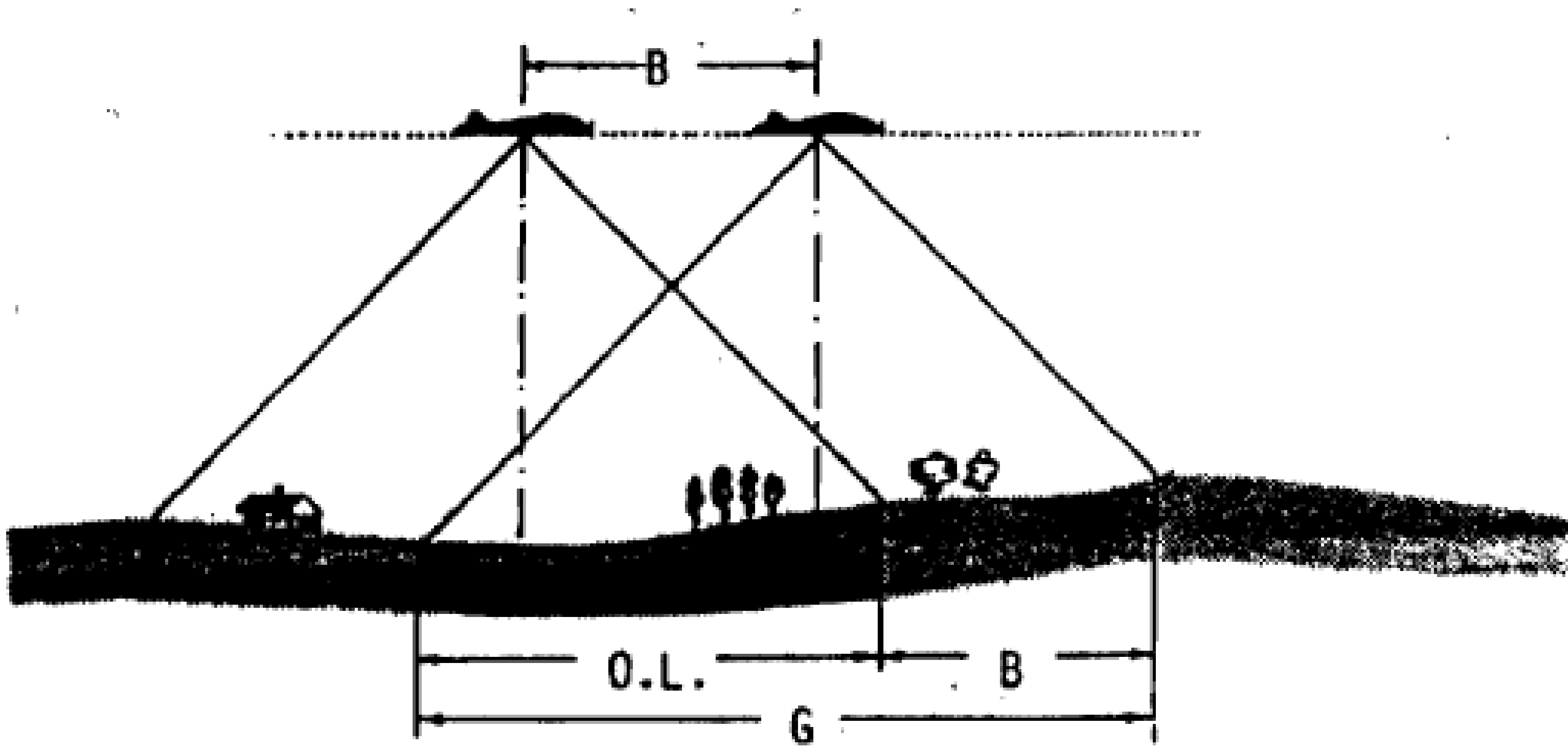


Figure (2-3) overlap between successive aerial photographs

Computation of Sidelap (P)

- In the figure below, if:

G: is the length of a side of the aqulre on ground covered by the photograph;

S: is the distance between adjacent strips; then the sidelap percent of G is:

Sidelap P = {(G-S)/G} x 100

- For example, if the area on ground covered be a single photograph is 15,000 X 15,000 ft, and the distance between two slides was 10,500 ft, calculate the sidelap.

Answer: sidelap (S.L) =

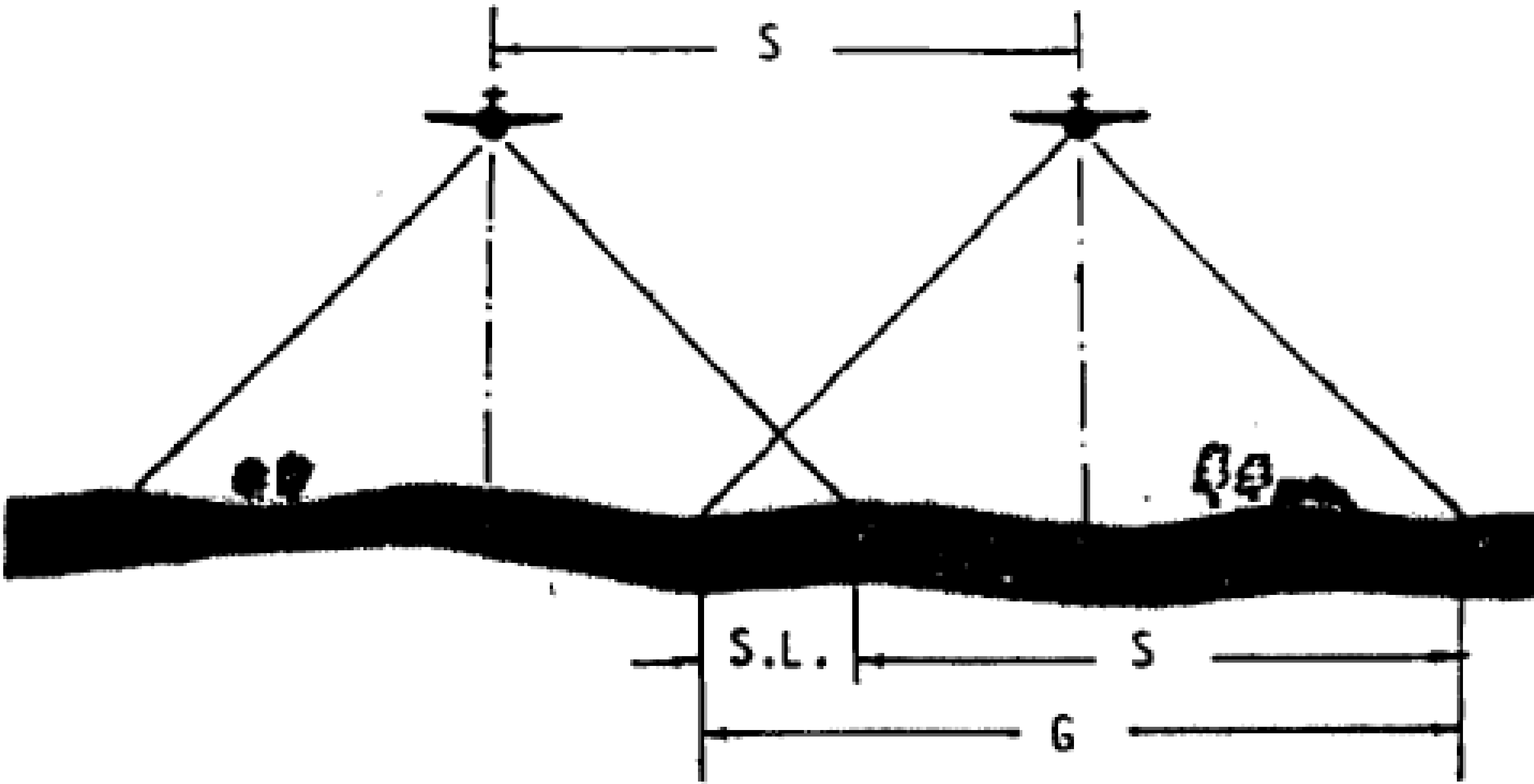
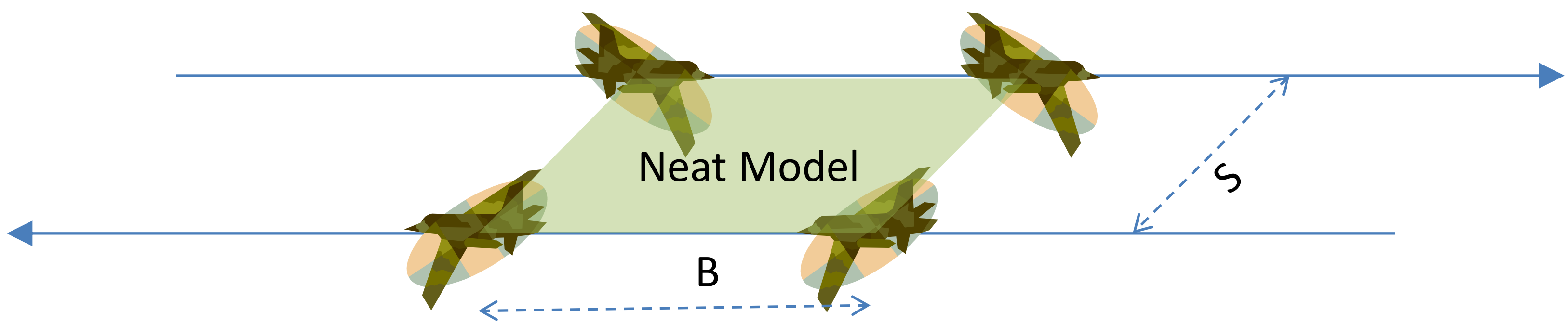


Figure (2-4) sidelap between adjacent strips

The Neat Model

- The neat model is the area on ground that corresponds to the area between the exposure stations of four photos for example.
- The length of the neat model is (B)
- The width of the neat model is (S)



Factors Affecting Flight Mission

3- Purpose

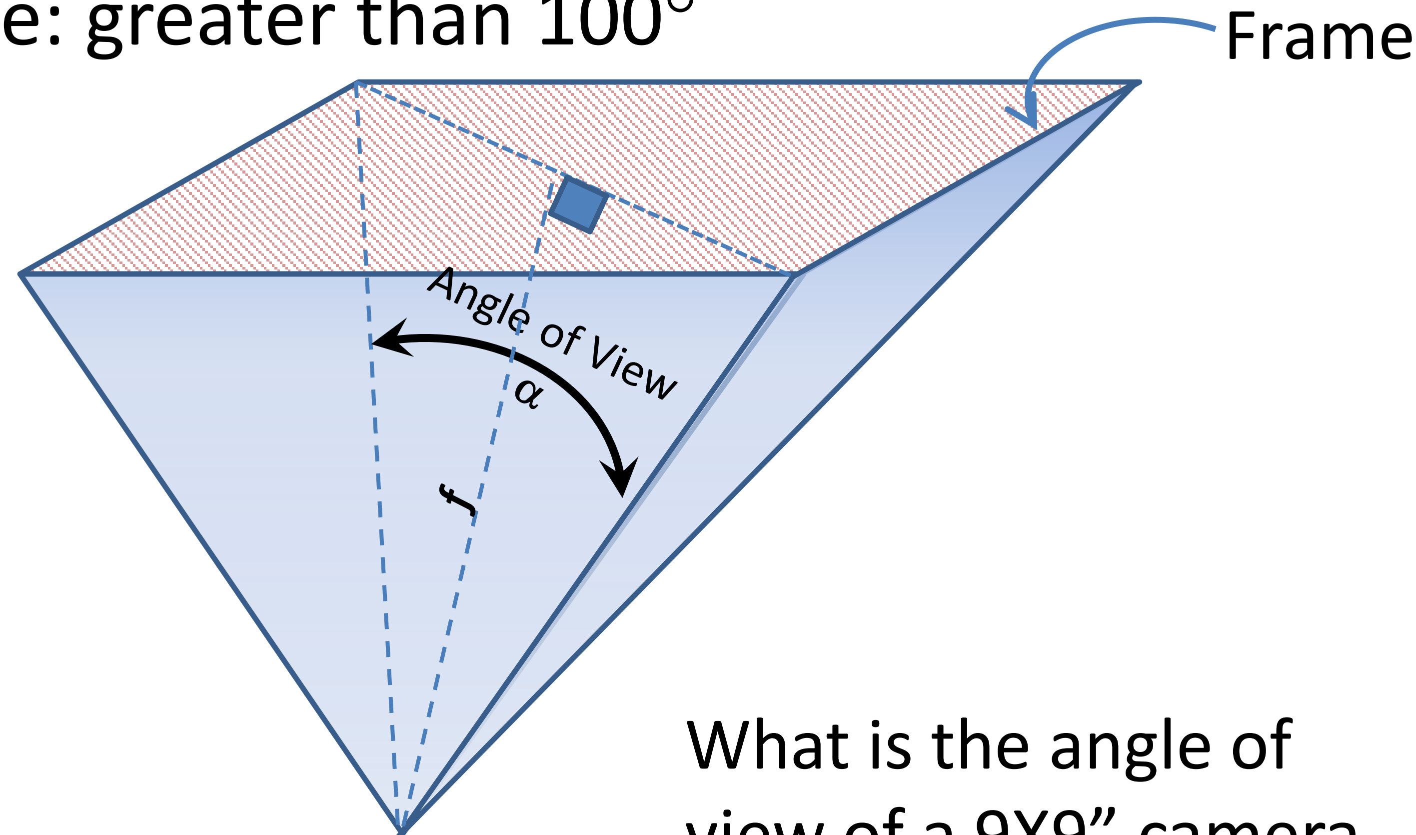
- The camera should be selected to serve the purpose of the survey best, one important factor is the angular field of view.
- Field of view of the camera is controlled by the focal length of the camera and the size of the frame. The most commonly used aerial camera is 6 inch focal length and 9 inch X 9 inch frame

Angular Field of View (α)

Normal: up to 75°

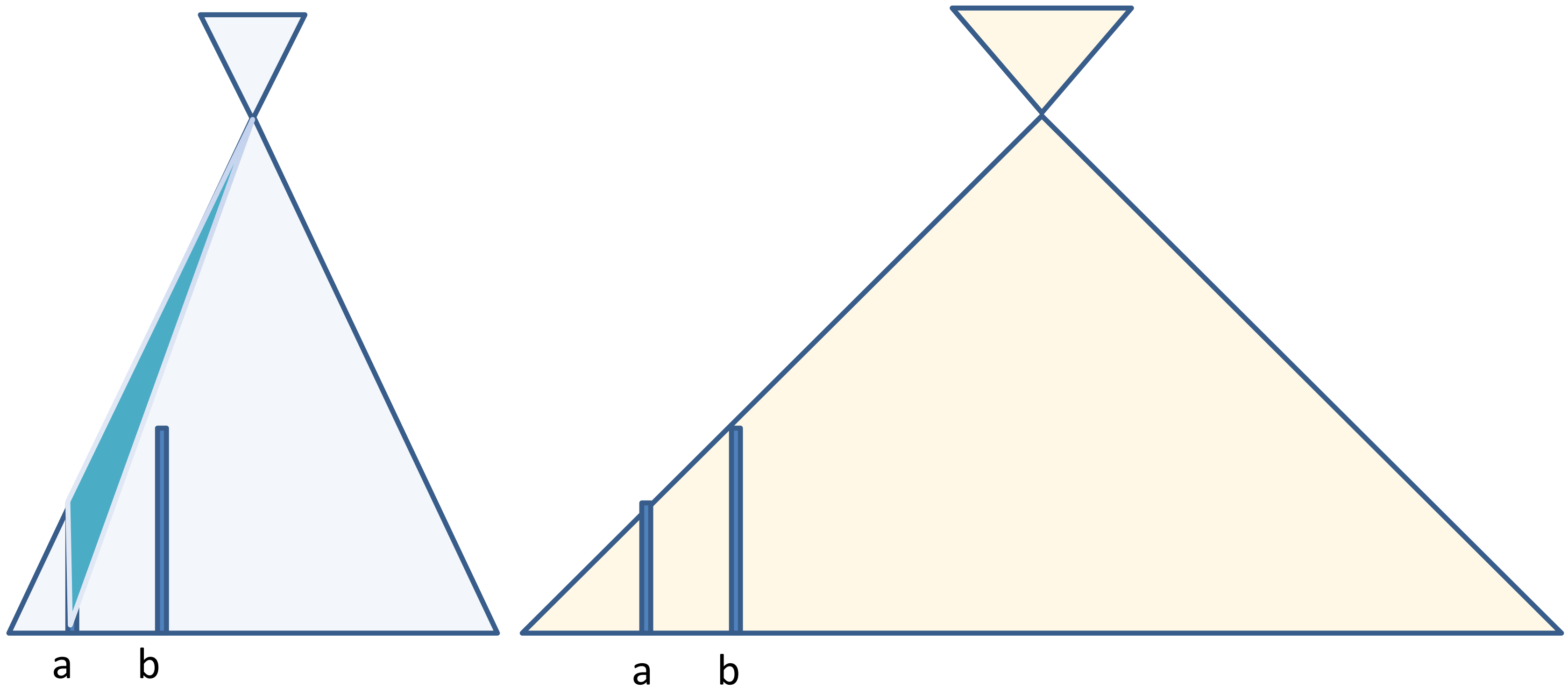
Wide: 75 to 100°

Super Wide: greater than 100°



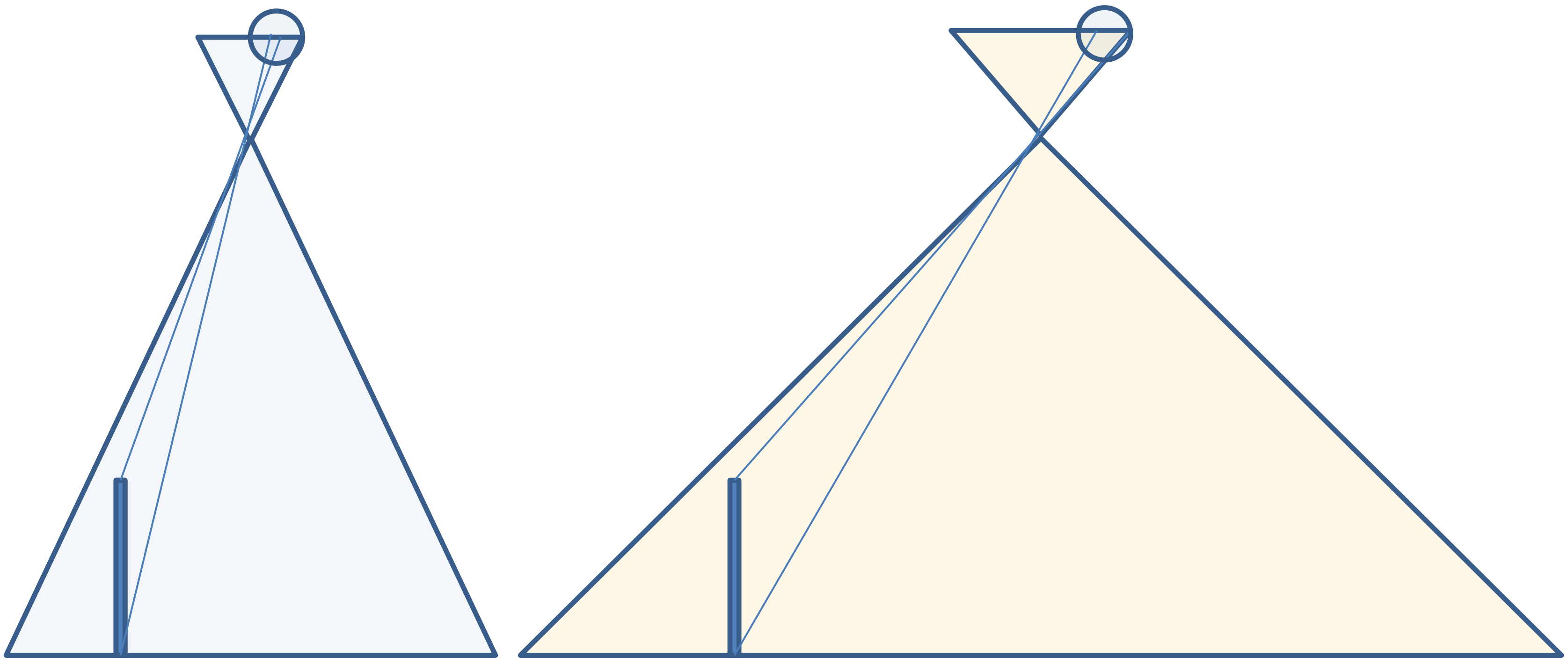
What is the angle of view of a 9X9” camera of focal length 6” ?

• Effect of the field of view:



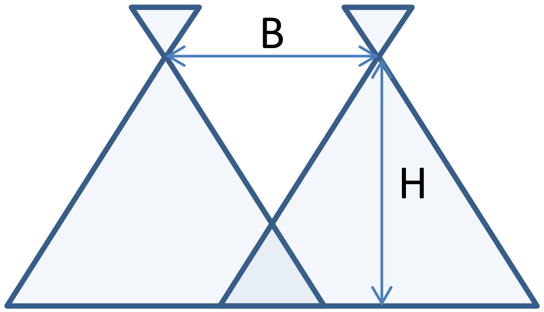
a) Normal field of view is more suitable if tall features such as buildings exist. Two tall buildings such as (a) and (b) at the edge of the ground coverage are shown above for cameras of different angle of view. A wider angle results in total disappearance of building a as shown to the right

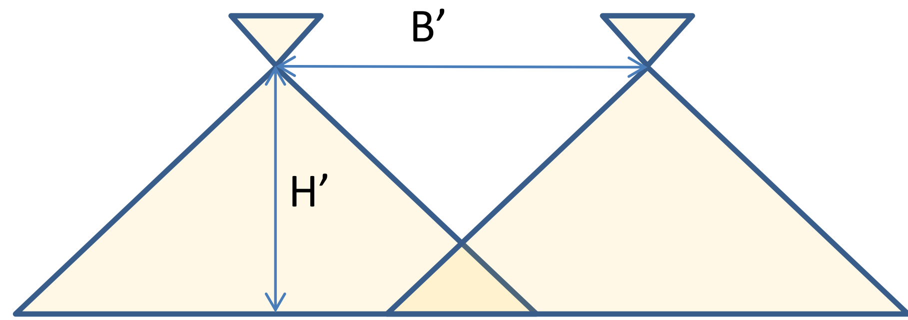
• **Effect of the field of view:**



b) Normal angle of view Will result in smaller relief displacement (shift on the photograph of a point because of its relief (height)

• Effect of the angle of view:





c) Normal angle of view results in a smaller base/height or (B/H) ratio, and a less accurate elevations when computed from photographs. This is because the intersection solution is worse as the intersection angle is reduced, WHY???

- **<u>Effect of the angle of view:</u>**

In summary

- For generating contours, you need better elevation values, you need a larger base to height ratio, you need a wider filed of view (topographic mapping)
- For interpretation or reconnaissance purposes, you need to see as much as you can, less features obscured by others and less effect of relief, you need a camera with smaller field of view

Factors Affecting Flight Mission

4- Scale

The scale of photographs is also determined according to purpose:

- for interpretation purposes, you need to see features bigger, you chose a larger scale
- for topographic mapping purposes, usually five times enlargement form photo to map scale is preferred. For example, Engineering maps at the scale of 1:500 are often produced from 1:3,000 scale aerial photography using an enlargement ratio of 6.

- Scale of a vertical photograph
  = focal length/ flying height
- The scale gets larger if
  – The flying height is reduced (the closer the camera to the ground, the larger the features appear on the photograph)
  – The focal length is increased

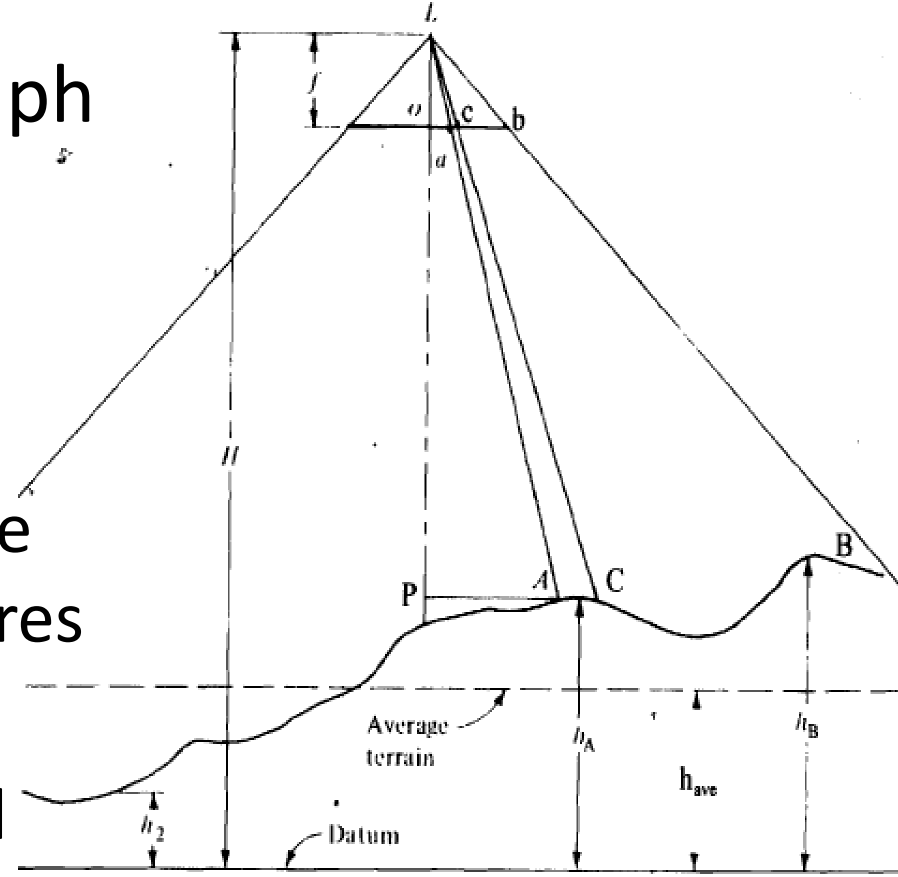


Figure (3-4) Scale of a vertical photograph over variable terrain

Severe changes in ground elevation (topography) result in variable scale and stereo coverage, and may result in gaps.

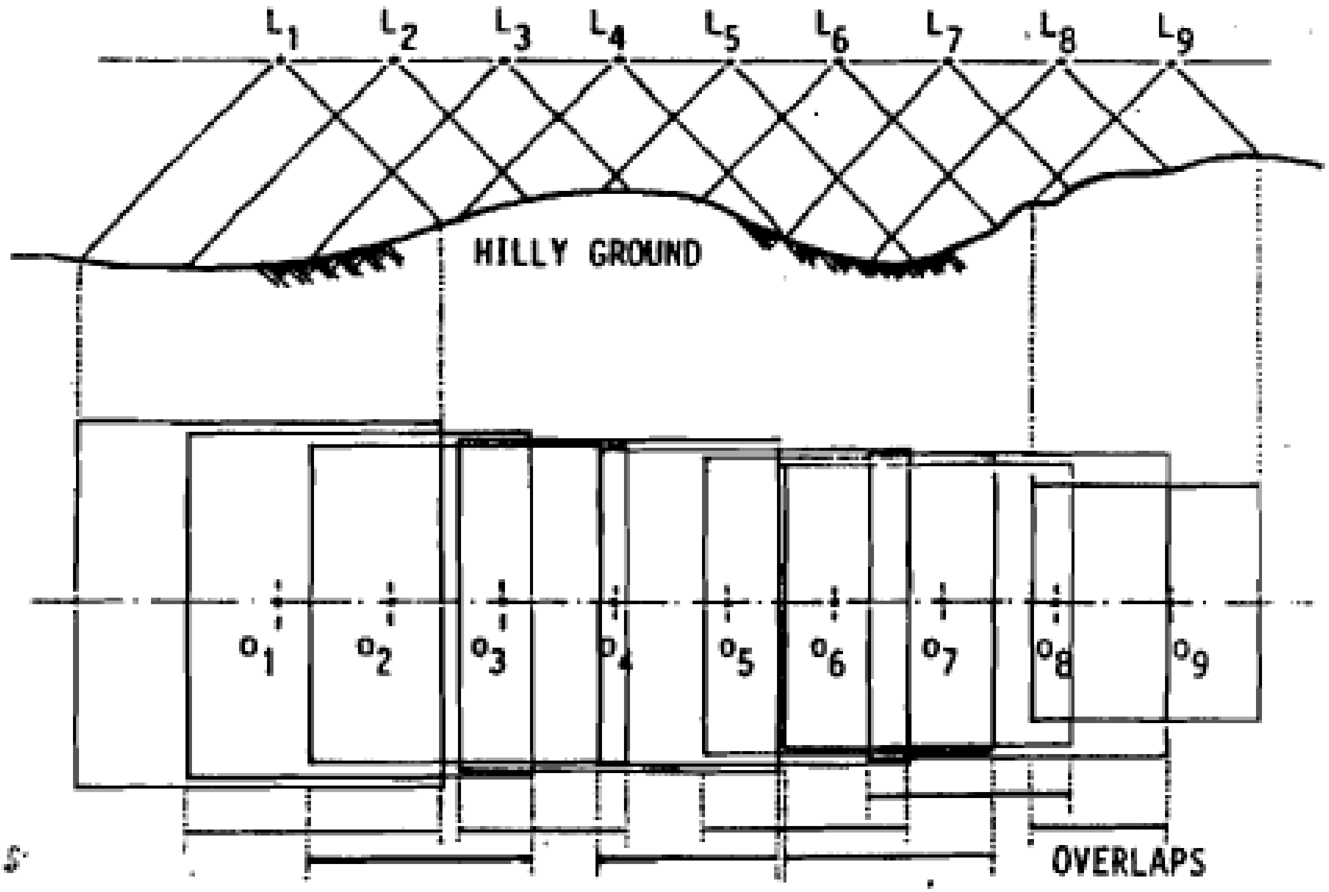
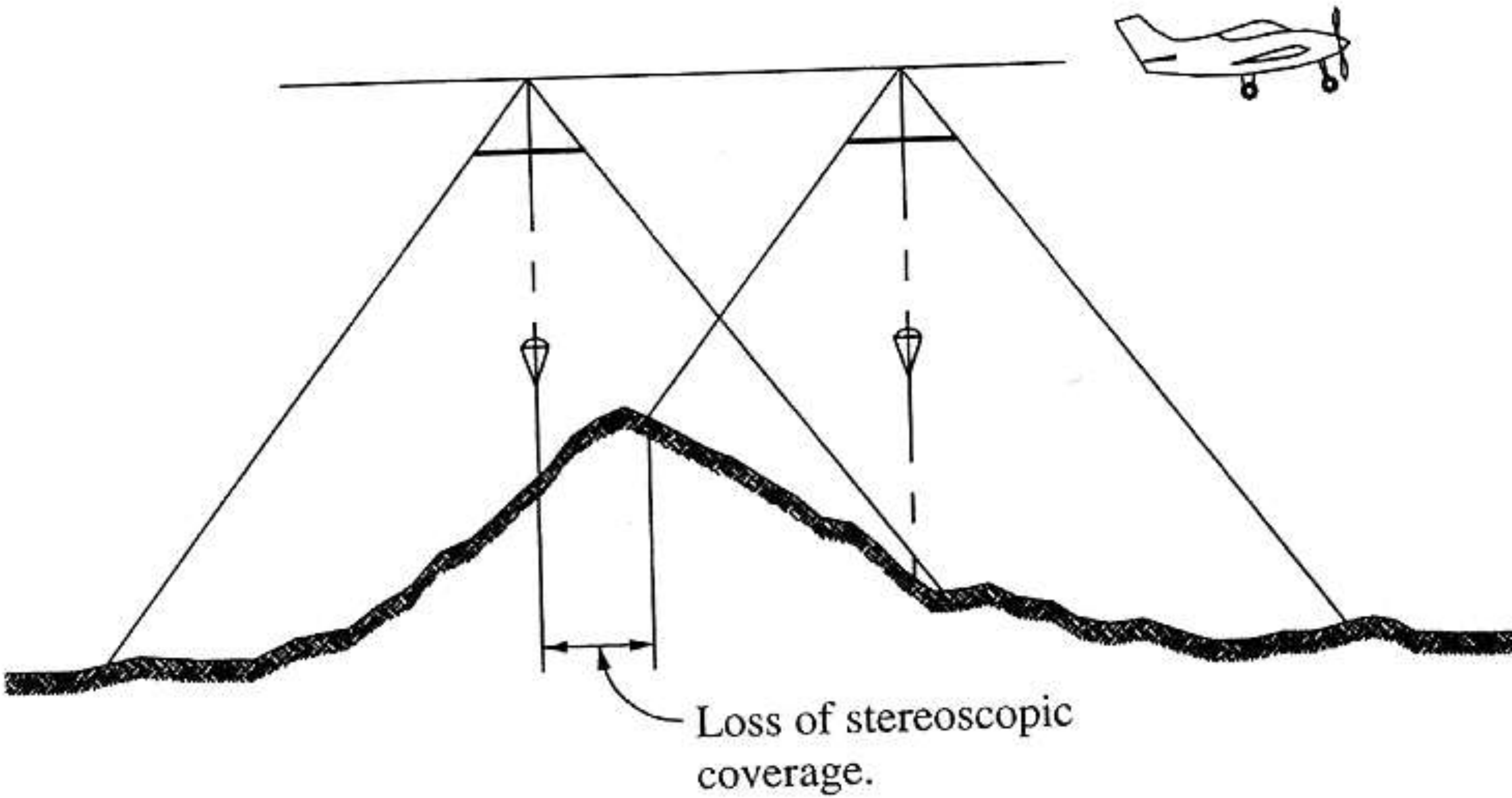


Figure (2-6) Effect of topography on scale and overlap

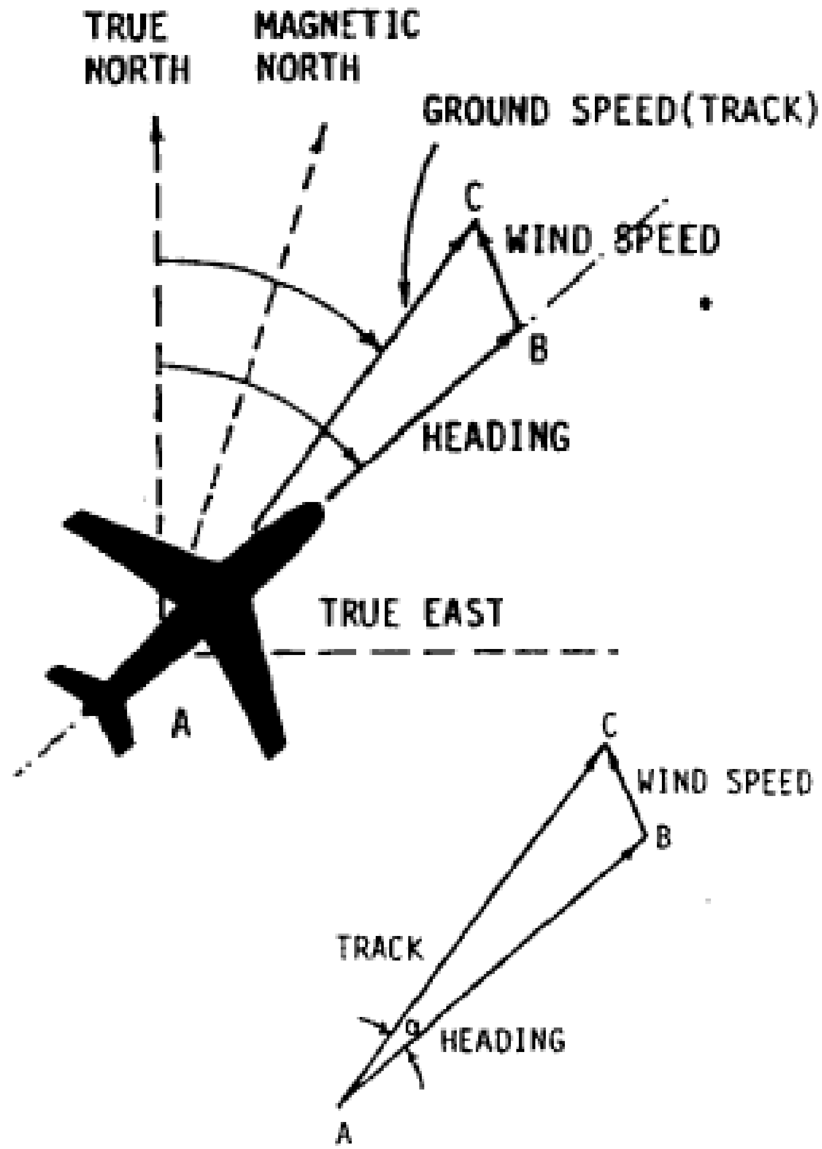


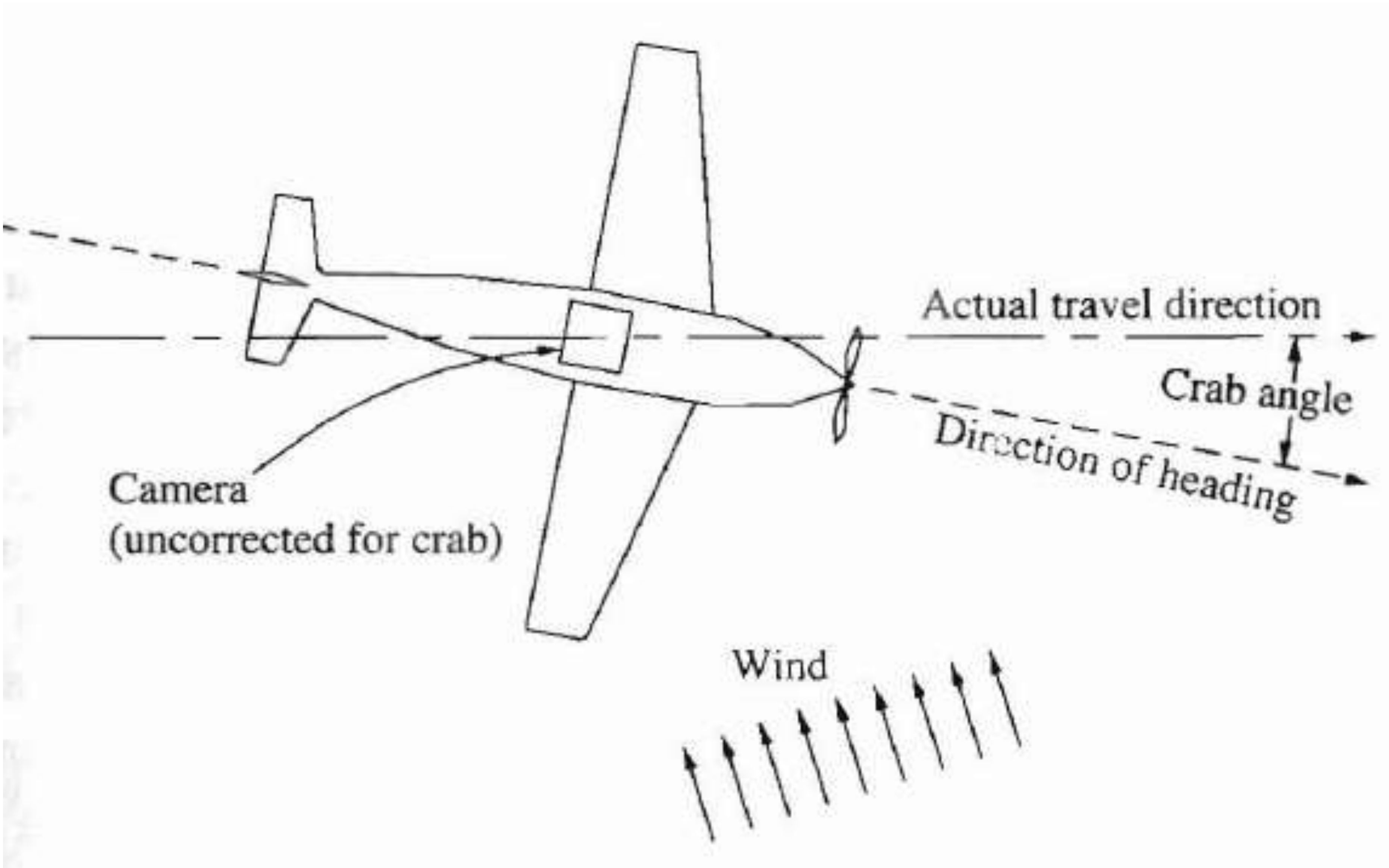
Failure to achieve stereoscopic coverage due to terrain variations.

Factors Affecting Flight Mission

5- Wind Effect

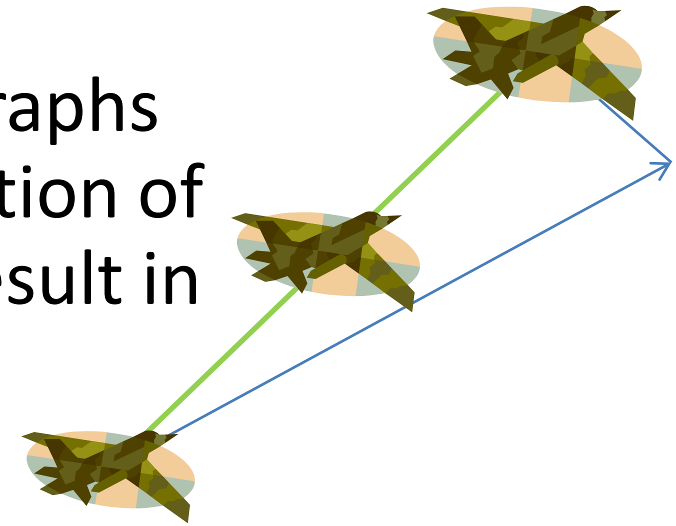
- The intension was that the plane travels from A to B, but the wind pushes in a NW direction as shown in the figure, the plane will travel along the resultant vector AB + BC , that is AC.
- Then, the plane will travel from A to C not to be, but will be oriented in the direction of AB.

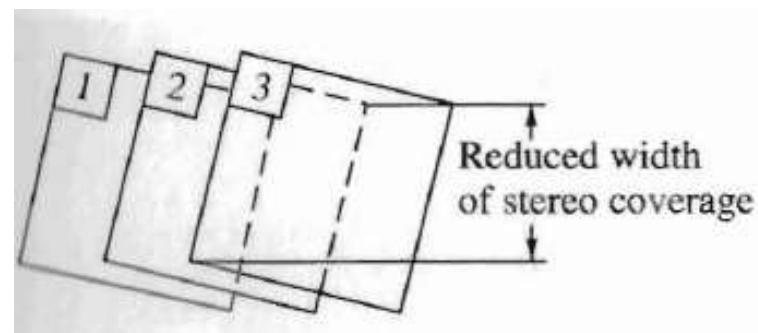


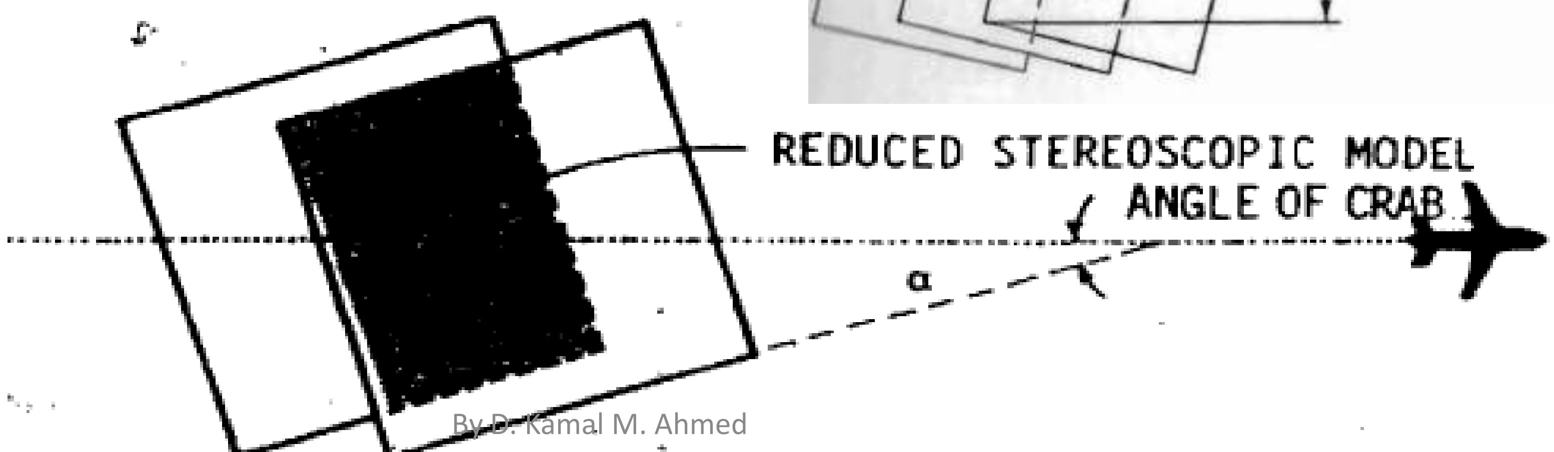

Actual travel direction
Crab angle
Direction of heading
Camera
(uncorrected for crab)
Wind

- The plane will travel as shown to the right.
- The problem is that the photographs will not be oriented in the direction of flight as intended, which may result in loss of stereoscopic coverage.
- The solution is simple, the

camera is rotated by the angle of crab

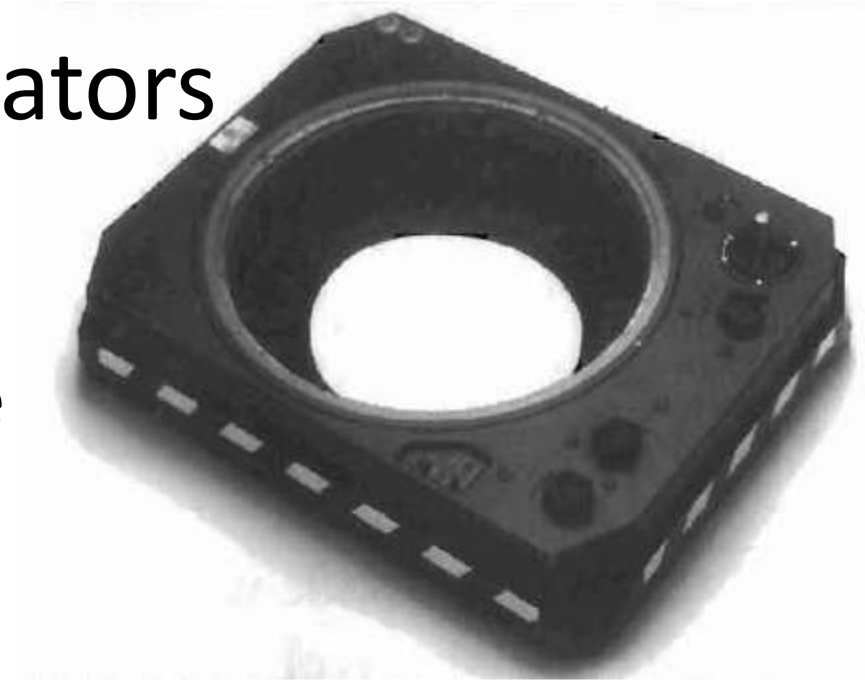






Gyro stabilizers and Motion Compensators

- Camera mounts may contain a gyroscope to sense and record the three tilts of the aircraft (roll, pitch, yaw) and keep the camera properly oriented.
- Image motion compensators reduce the effect of movement as the picture is taken, how????



Leica Gyro – stabilized aerial camera mount

Design of Flight Map

- A flight map is a map (or a photograph in absence of a map) to guide the mission, it should show, to scale:

1. Boundaries of the area to be covered (photographed): *usually extended by about 30% G at each of the sides*
2. Direction of flight lines (strips) *: usually selected in the direction of long side of the area covered*
3. Location of each exposure station: *determined according to the length of the strip and endlap*.

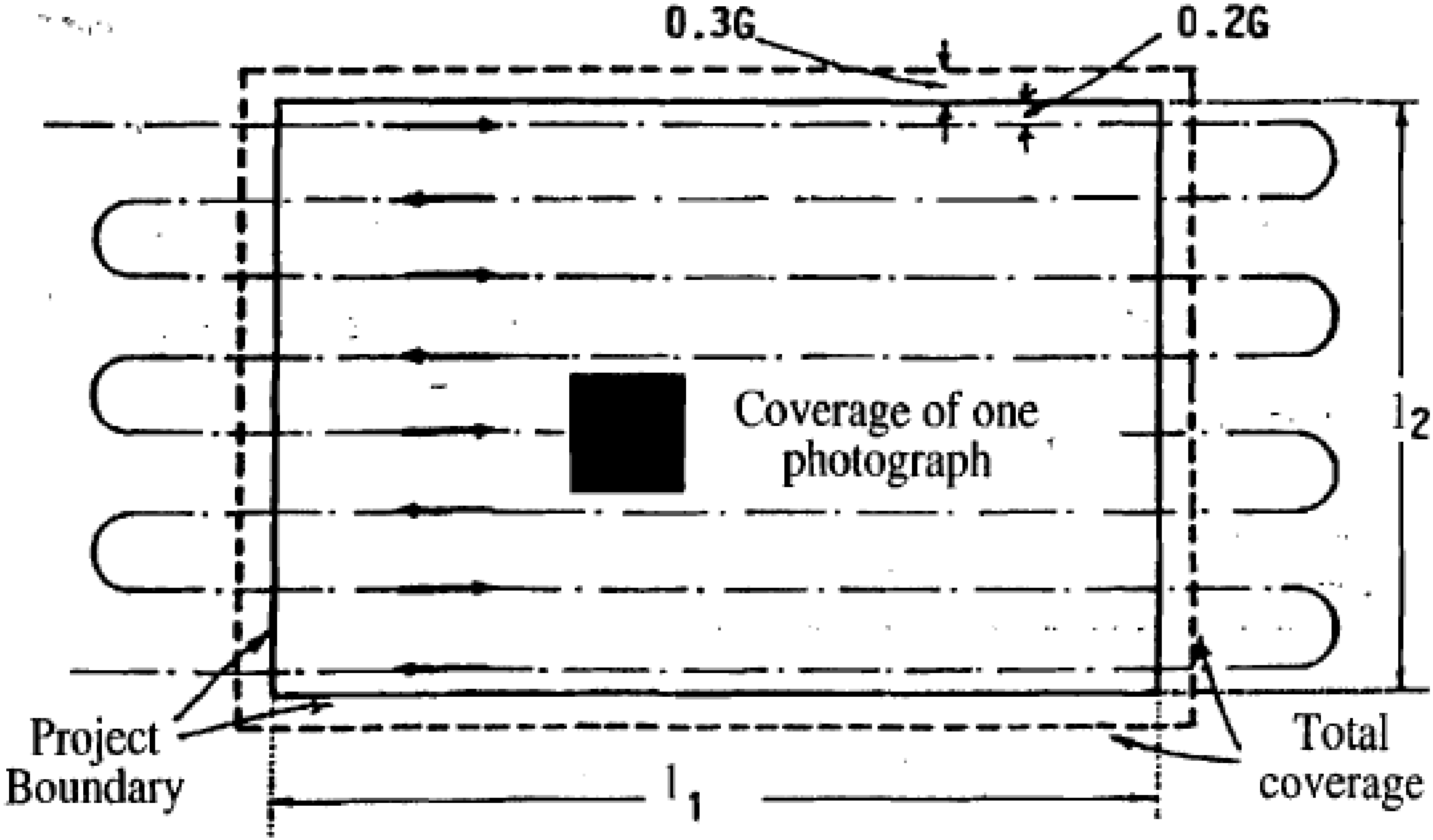


Figure (2-9) Design elements of a flight map for an area (l_1 x l_2)


1
2
3
4
5
6
H A R T F O R D
HARTFORD
Job M-223
6 Flights, Fly at 4,050' Above
Sea Level. 60% FORWARD LAP
6" ZEISS CAMERA.
1" = 500' NEGATIVE SCALE.
HOLD PLAN FOR TELEPHONE
GO AHEAD AFTER PANELS ARE
PLACED ON SECTION CORNER
MONUMENTS.
FLIGHT CREW COPY

Design of Flight Map

- Flight plan is shown on a map to show flying lines (location, start, and end), and the location at which each photograph is to be taken (location of exposure station).
- Given the dimensions of ground coverage and the percent of end and side lap (R and P %), you should be able to compute the number of strips and the number of photographs to be taken.

Design of Flight Map

Calculations

- Assuming that the area that needs to be mapped is $l_1 X l_2$, then;
- Lateral advance per strip (S) is the neat side distance covered by each strip, not counting the area that is repeated in the adjacent strip. The new ground covered in each strip in lateral direction (perpendicular to the direction of the strip)
- Lateral advance per strip (S) =

$$S = [1-(P/100)] *G$$

Where G is the side of a square covered by each photo.

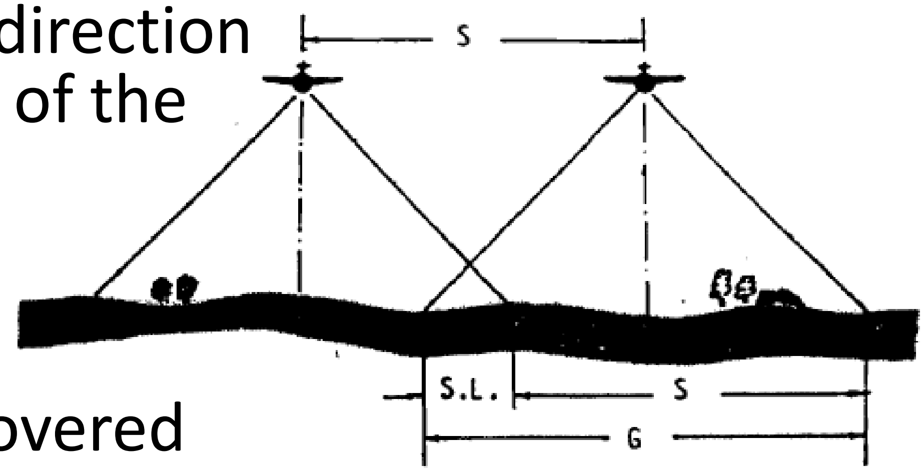


Figure (2-4) sidelap between adjacent strips

- Then, the number of strips $=\{(l_2 - 0.4G)/S\} + 1$

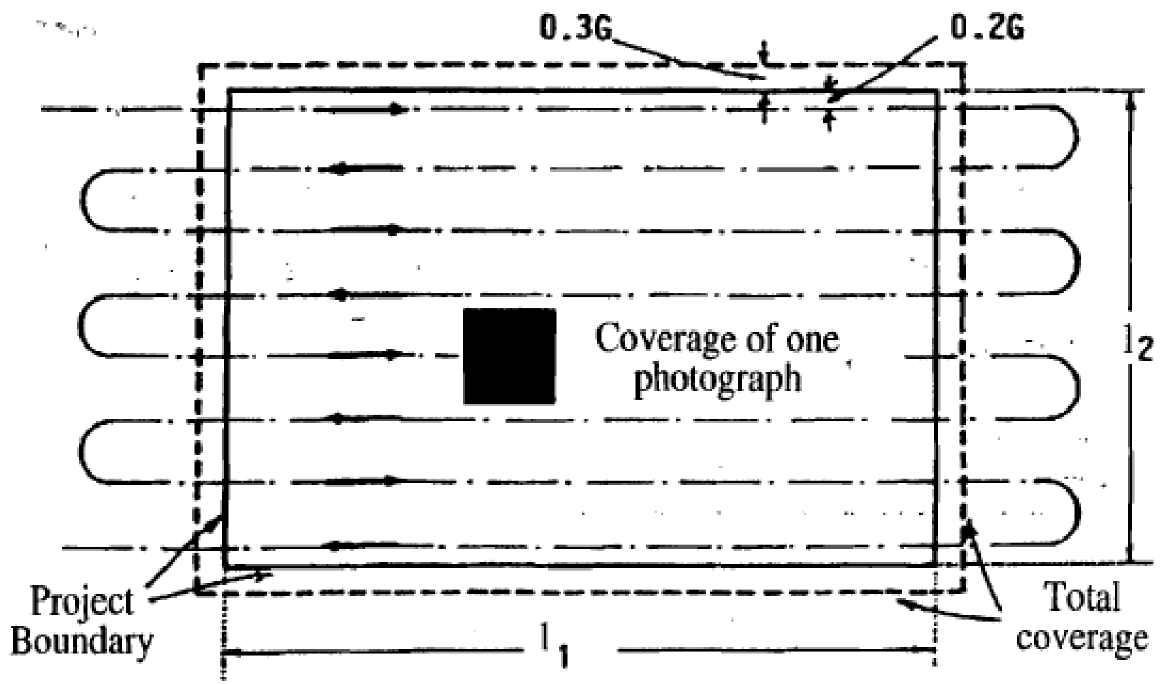


Figure (2-9) Design elements of a flight map for an area (l_1 x l_2)

- The value 0.2 may be different in problems
- This number should be rounded UP to N_s
- you then compute the adjusted distance between strips

$$= (l_2 - 0.4G)/ N_s$$

- Now to calculate the number od photos per strip, you divide the length of a strip by the Linear advance per photo (B), which is also the air base, where

$$\text{Linear advance } B = [1- (R/100)] * G$$

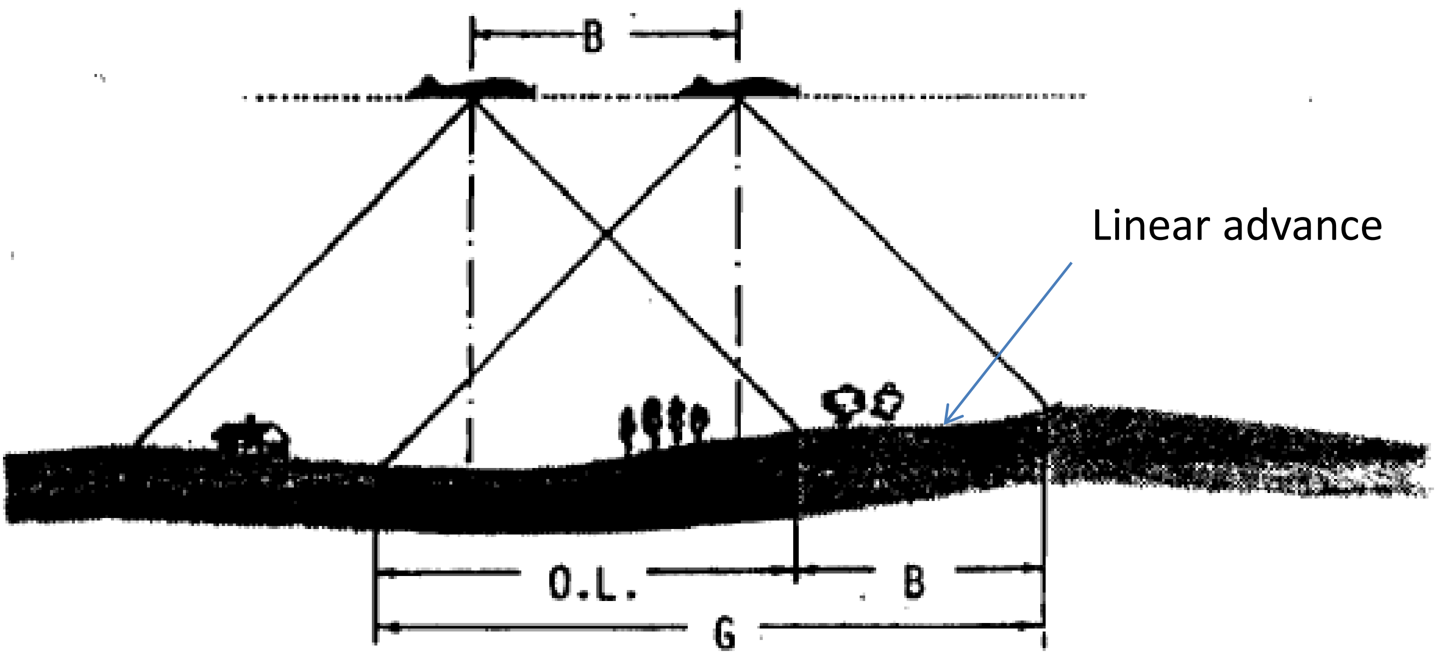
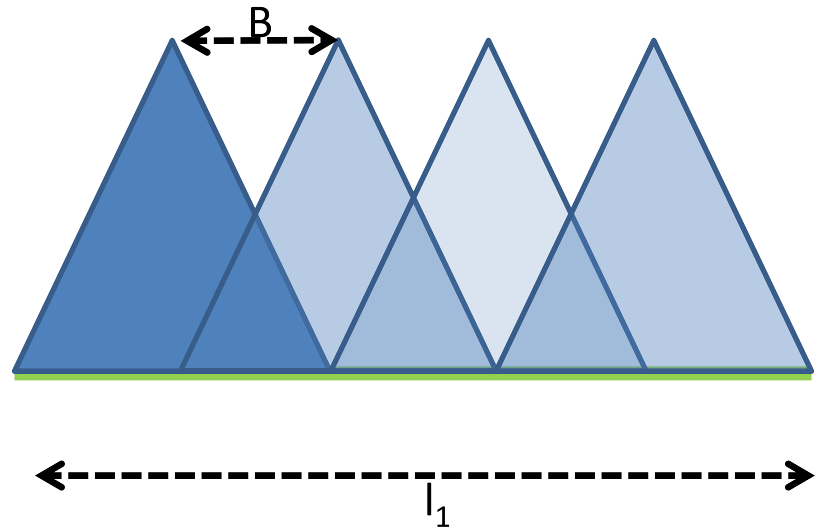


Figure (2-3) overlap between successive aerial photographs

- In the figure to the right, assume that you have 4 pyramids , the distance l_1 is 4 meters, and the distance B is 1 meter, the number of pyramids = 4/ 1 = 4



- Same logic applies to the strip

  To cover the length l_1 , you need (l_1 /B) photos. To ensure that the width is covered, the plane usually continues flying and take two extra photos before it turns around and outside of the boundaries to be covered. Thus,

  Number of photos in a strip = (l_1 /B) + 4

Design of Flight Map

- Example 2-1

Calculate the total number of photographs needed to be taken by a standard camera to map an area that is 12 X 8.5 miles, the average scale of the photographs is 1:15,000, overlap and sidelap are 60% and 25% respectively.

Answer:

$G = 9 \times 15{,}000/12 = 11{,}250$ ft

- Lateral advance per strip (distance between strips)

Number of strips :

Adjusted S

Adjusted sidelap

Linear advance per photo B =

Number of photos per strip

Total number of photos in the project :

Airborne GPS

- Airborne GPS is used to measure the location of the camera at the instant of exposure. This gives the photogrammetrist XL, YL, and ZL. GPS can also be used to derive the orientation angles by using multiple antennas. Unfortunately, the derived angular relationships only have a precision of about 1’ of arc while photogrammetrists need to obtain these values to better than 10” of arc.
- To compute the position of the camera during the project, two geodetic GPS receivers are commonly employed. One is placed over a point whose location is known and the other is mounted on the aircraft. Carrier phase data are collected by both receivers during the flight with sampling rates generally at either 0.5 or 1 second. Generally, on-the-fly integer ambiguity resolution techniques are employed.

By D. Kamal M. Ahmed

ADVANTAGES OF AIRBORNE GPS

- **The main limitation of photogrammetry is the need to obtain ground control to fix the exterior orientation elements (three rotations of the photo around the three axes, and three coordinates of exposure station L) . The necessity of obtaining ground control is costly and time-consuming.**
- **GPS gives the photogrammetrist the opportunity to minimize (or even eliminate) the amount of ground control and still maintain the accuracy needed for a mapping project.**

Flight Planning for Airborne GPS

When planning for an airborne GPS project, special consideration must be taken into account for the addition of the GPS receivers that will be used to record the location of the camera. The first issue is the form of initialization of the receiver to fix the integer ambiguities. Next, when planning the flight lines, the potential loss of lock on the satellites has to be accounted for. Depending on the location of the airborne receiver, wide banking turns by the pilot may result is a loss of the GPS signal. Banking angles of 25° or less are recommended which results in longer flight lines

- The location of the base receiver must also be considered during the planning. Will it be at the airport or near the job site? The longer the distance between the base receiver and the rover on the plane the more uncertain will be the positioning results.
- When planning, try to find those times when the satellite coverage consists of 6 or more satellites with minimum change in coverage
- Also plan for a PDOP that is less than 6 to ensure optimal geometry. Additionally, one might have to arrive at a compromise between favorable sun angle and favorable satellite availability.
- Make sure that the GPS receiver has enough memory to store the satellite data.
- There may also be some consideration on the amount of sidelap and overlap when the camera is locked down during the flight. This will be important when a combined GPS-INS system is used.
- Finally, a flight management system should be used to pre-calculate the exposure station locations during the flight

GPS-Aided Navigation

- One of the exciting applications of airborne-GPS is its utilization of in flight navigation.
- The ability to precisely locate the exposure station and activate the shutter at a predetermined interval along the flight line is beneficial for centering the photography over a geographic region.