FOTOGRAMETRIA APLICADA AL DISEÑO Y CONSERVACION DE OBRAS DE INGENIERIA CIVIL

DR. BENGT ADOLFSSON
MARZO DE 1979

Seminar program

Monday: 03-26 — Introduction
Photogrammetry in a location stage of design
- photography
- topographic maps
- photo interpretation
- orthophotography
- remote sensing

Tuesday: 03-27 — Photogrammetry in preliminary design
- photography
- block (strip) triangulation
- evaluation of photos
- map specifications

Wednesday: 03-28 Photogrammetry in final design and constr.

- photography
- cross-sections, profiles
- digital terrain model
- photogrammetry and field surveying
- data processing

Thursday: 03-29 Terrestrial photogrammetry

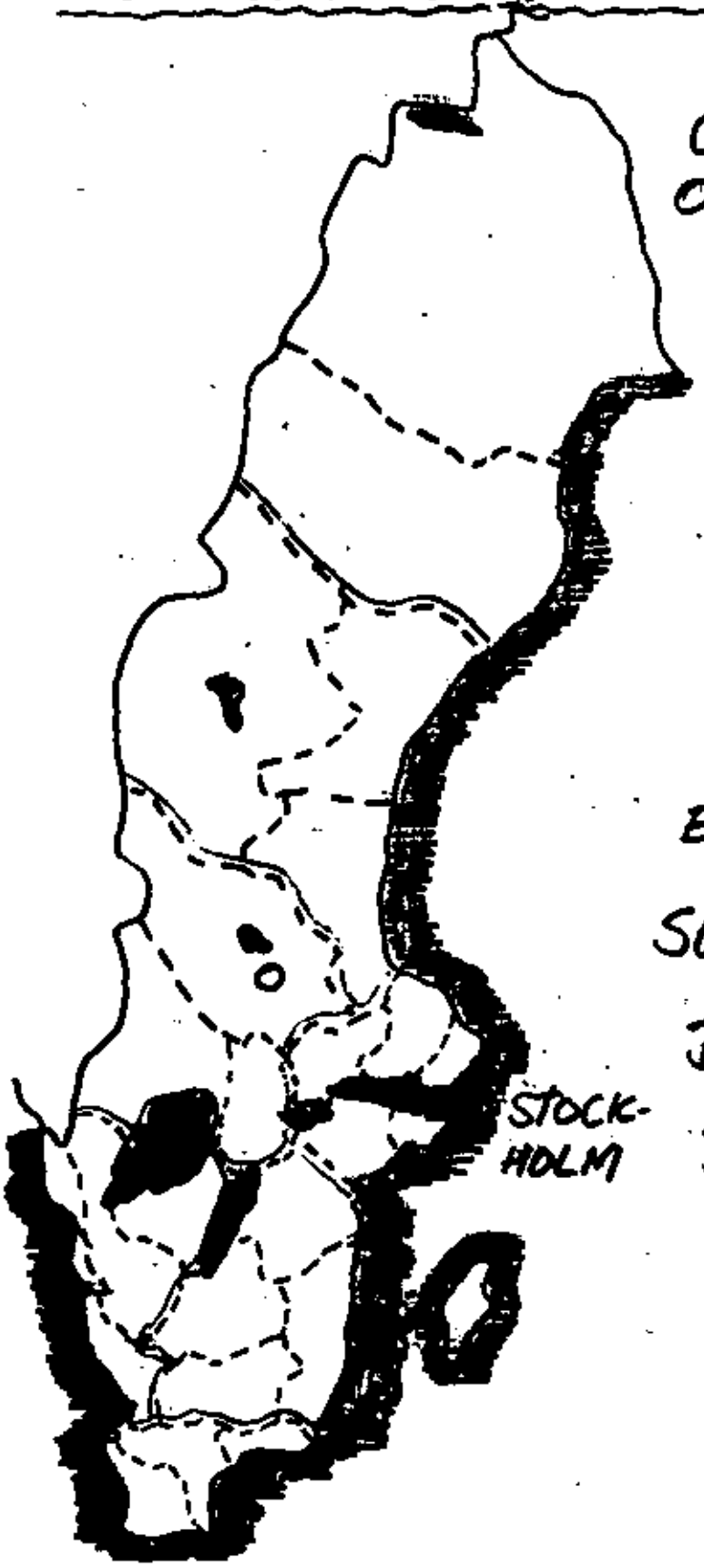
- principles
- cameras, instruments
- orthophotography
- applications
  - architecture
  - volumes
  - deformation

Friday: Field surveying and setting out methods
03-30

- electro-optical tacheometry
- field data collection
- self-instructing course in basic field survey

General remarks on the development of photogrammetric and geodetic instruments

the National Road Administration



central office Sthlm

24 regions

design
maintenance

7 districts

construction

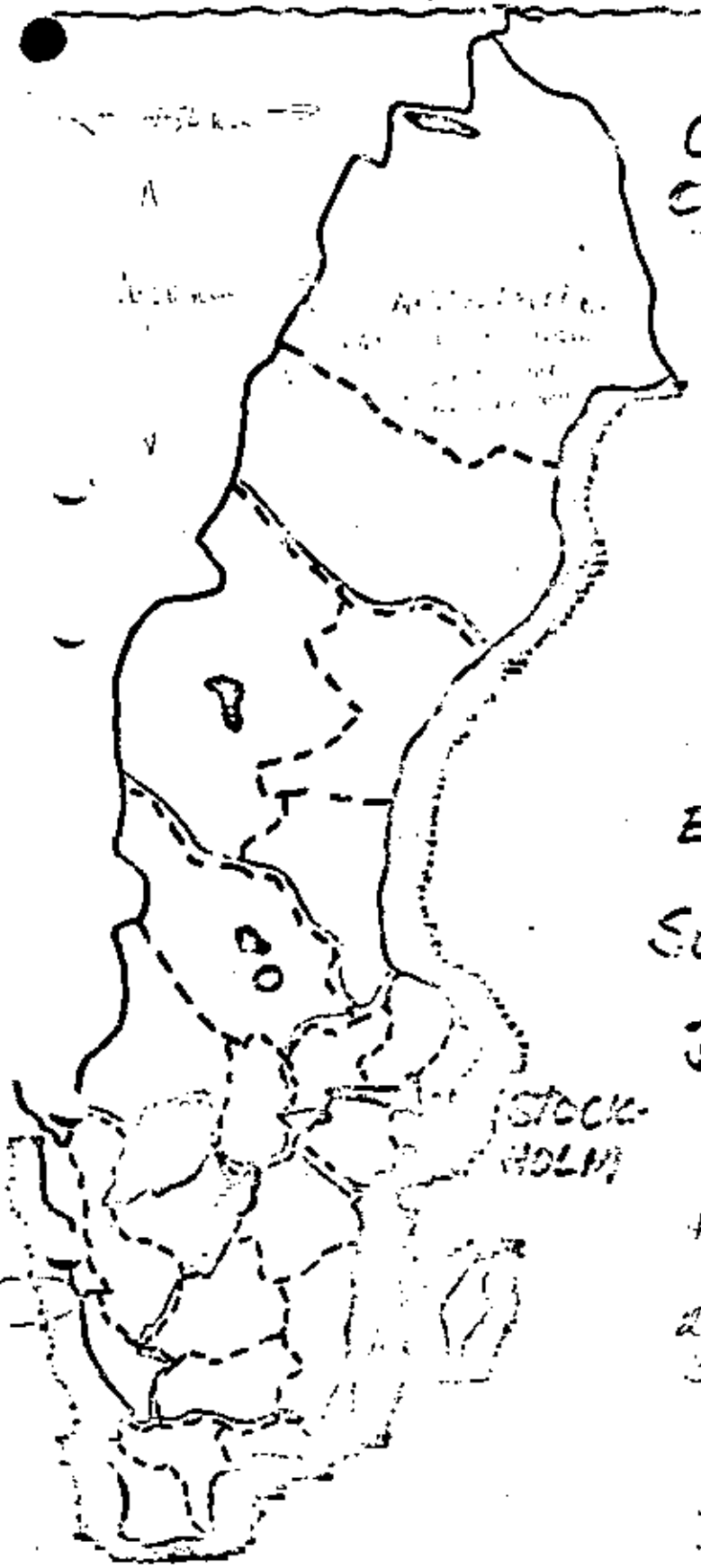
Employees 11000

State roads 100000 km

Bridges 10700

Budget ~~9100~~ 5000 mill. SW Kr

the National Road Administration



central office Sthlm

24 regions
design
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7 districts
construction

Employees . 11000

State roads 100000 km

bridges 10700

budget 3400 mill. SEK
+ un employment ?

Highway engineering has constantly to be developed to meet new or extended requirements on

- environment
- traffic safety
- community planning
- aestetics
- traffic costs
- construction costs

Need for constant development of techniques

Highway engineering has constantly to be developed to meet new or extended requirements on

- environment
- traffic safety
- community planning
- aesthetics
- traffic costs
- construction costs

many techniques have to be used e.g.

- field surveying
- photogrammetry
- aerial photointerpretation
- data processing
- automatic plotting

many techniques have to be used e.g.

- field surveying
- photogrammetry
- aerial photointerpretation
- data processing
- automatic plotting

Why photogrammetry?

+

- high density of information
- over-all and detailed information
- multiple use of photographs
- adaptable to various accuracy requirements
- efficient map production
- 3D design
- data acquisition at wish and at the needed occasion
- high production rates
- aid for presentation of plan

Why photogrammetry?

- vegetation
- weather dependent
- ground control
- high initial costs

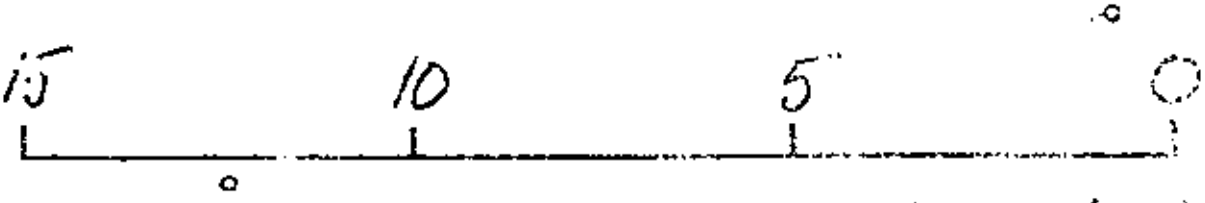
planning procedure

route location

prel design

final design

planning procedure



years before construction

route location

- [illegible] of the primary network
- community planning
- [illegible] analysis of topography and geology
- [illegible] areas
- [illegible] areas unsuitable for road construction
- [illegible] in corridor

preliminary design

- more detailed investigation
- [illegible]
- [illegible] and/or [illegible] on [illegible] conditions
- [illegible] in a narrow corridor with [illegible]

final design

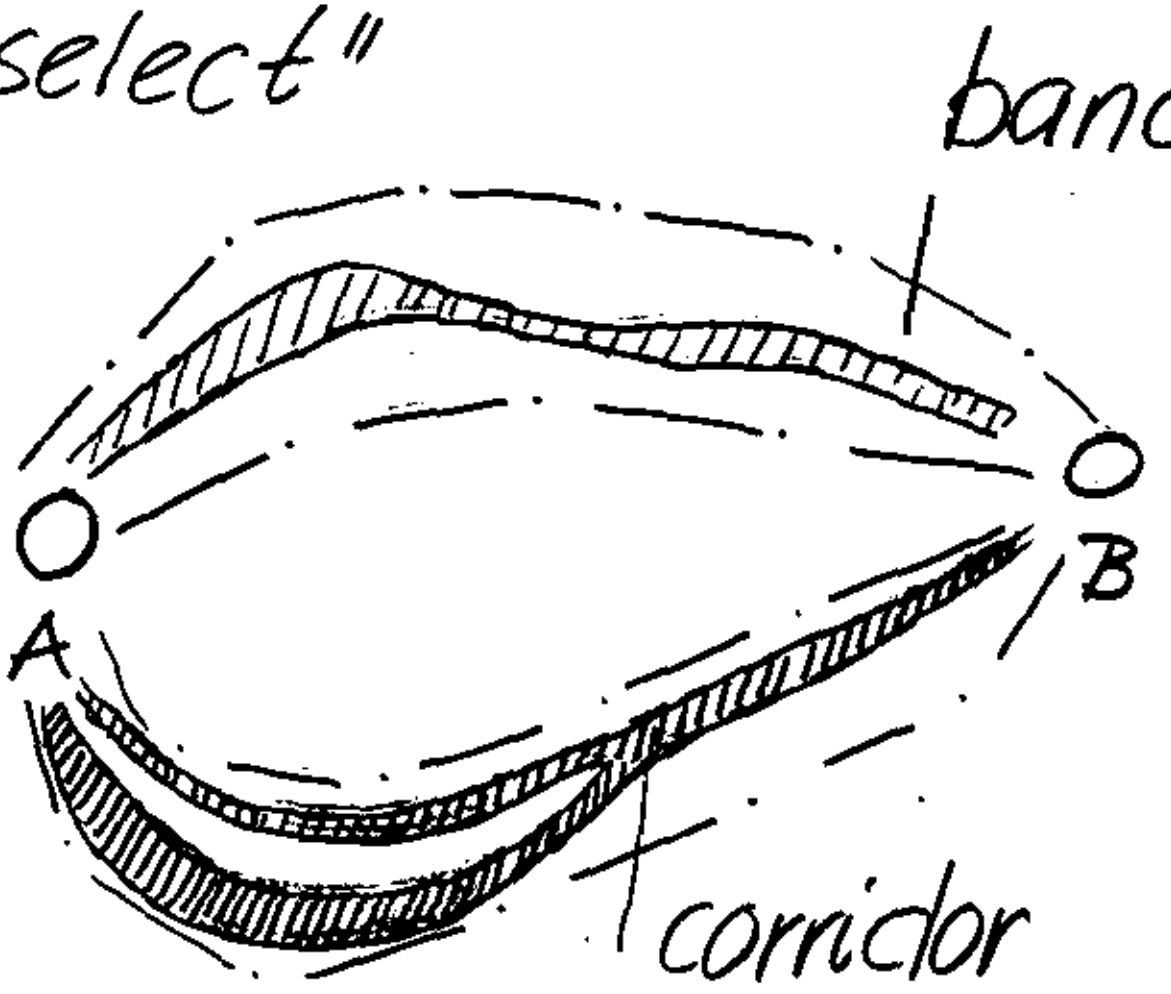
- [illegible]
- [illegible]
- [illegible]
- [illegible]

don't go into detailed investigation too soon!

route location

"search"

"select"



location factors

route independent

topography

soils

geology

land use

population distribution

travel demand

route dependent

user costs

construction costs

maintenance costs

aesthetics

safety

design geometr

location

- photography
- topographic maps
- photo interpretation
- orthophotography
- remote sensing

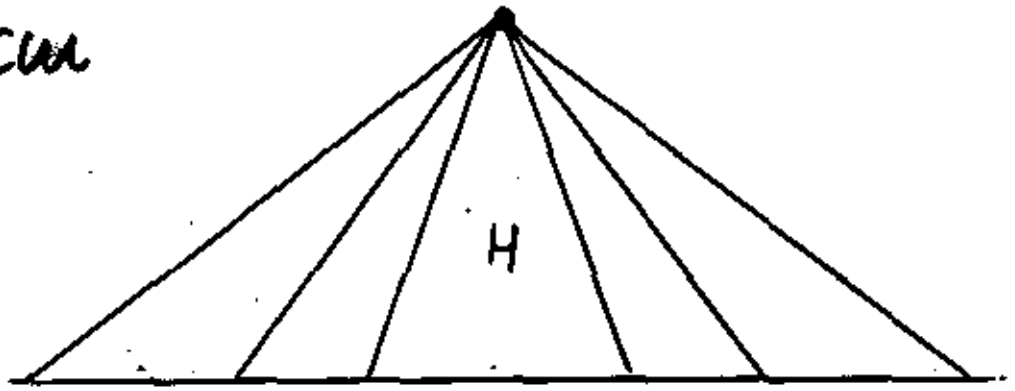
route location

data acquisition

- aerial photography
  - metric camera
  - non-metric — " —
- remote sensing

metric cameras

23×23 cm



normal angle c = 304 mm — 0.75 H

wide angle c = 152 mm — 1.5 H

super-wide angle c = 88 mm — 2.5 H

route location

evaluation

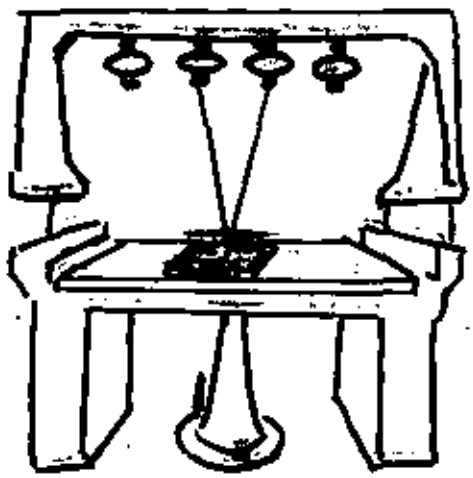
topographic maps	1:5000 – 1:50000
orthophoto plans	1:5000 – 1:20000
stereoscopic viewing	1:15000 – 1:30000

route location

instruments used for stereoscopic studies

mirror stereoscope

Balplex Plotter



route location

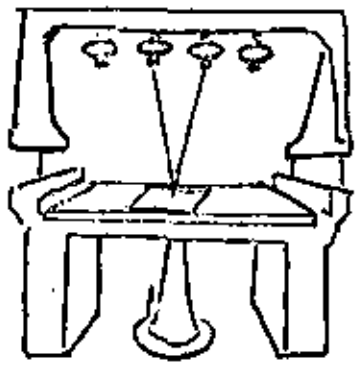
instruments used for stereoscopic studies

- mirror stereoscope

Scanning topography and aerial photographs ship stereoscopes

- Balplex Plotter

- together with Orthophoto Map
- 1 [illegible]



- lack of new instruments for easy 3D-studies in scaled models

route location

topographic maps	1:50000
	1:10000
	1:5000
aerial photography	1:30000
	1:20000

Sweden

route location

topographic maps

1:50000

1:10000

1:5000

- cadastral maps

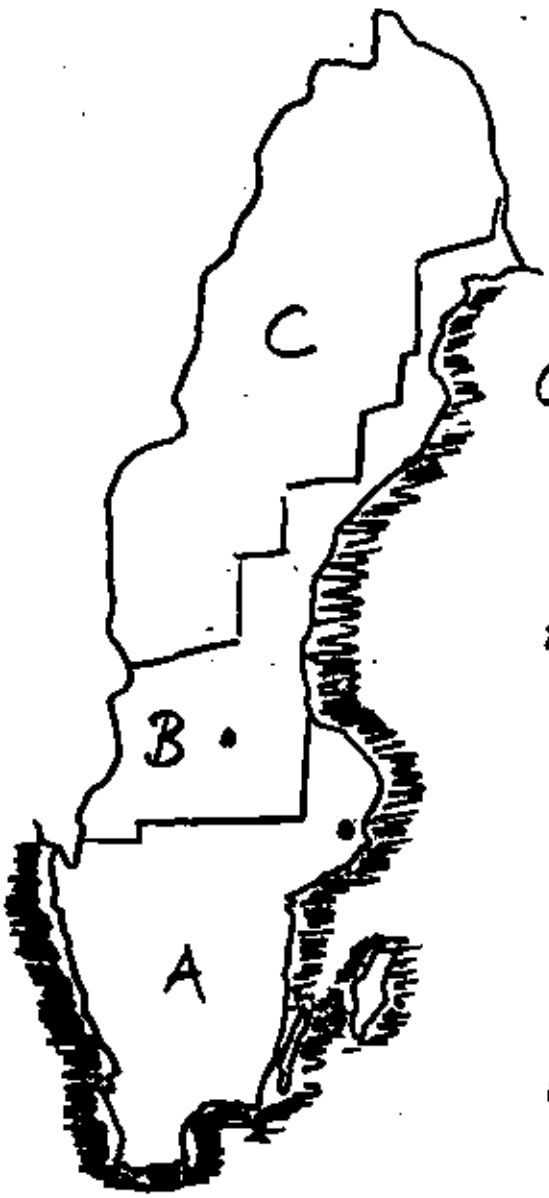
- aerial photography

1:30000

1:20000

- The land use map is based on ...

rephotography plan



aera	altitude m	interval years
A	3000/4600	5
B	3000	10
	9200	5
C	4600	10
	9200	5

aerial photointerpretation

stage	result	photo-scale
route location	unsuitable areas for highway construction	1:30000 1:20000
preliminary design	soil conditions	1:10000
final design		
construction maintenance	coarse material	1:30000 1:20000 1:10000

in Sweden

aerial photointerpretation

stage	result	photo-scale
route location	unsuitable areas for highway construction	1:30000 1:20000
preliminary design	soil conditions	1:10000
final design		
construction maintenance	coarse materials	1:[illegible] 1:[illegible] 1:[illegible]

interpreters

design engineer or specialist?

we have given a basic training to the engineers

the detailed interpretation are made by specialists

([illegible])

aerial photointerpretation

working procedure

inventory	geological maps literature previous results
interpre-tation	rock outcrop moraine coarse sediments fine sediments organic deposits
field check	
compilation of data	soil map 1:10000 1:50000

aerial photointerpretation

working procedure

literature

- geological maps
- literature
- previous results

interpretation

- rock outcrop
- 75% moraine
- ⊕ coarse sediments
- fine sediments
- organic deposits

field check

interpretation

- soil map 1:10 000
- 1:50 000

Aerial photointerpretation

1) knowledge of soil conditions, problems early
2) expensive and time-consuming borings can be limited
3) ... made by a group of specialists

aerial photointerpretation

instrument used

mirror
stereoscope

Stereo Facet
Plotter

Sweden

aerial photointerpretation

instrument used.

OMI, Italy

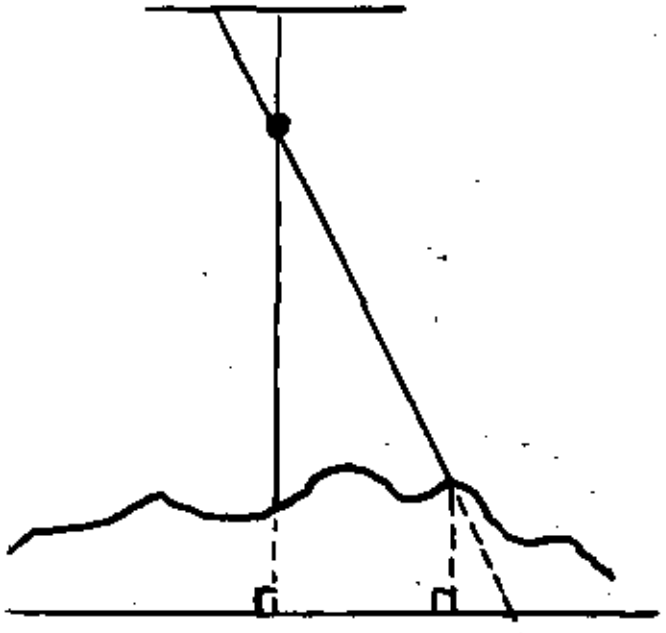
compensates:

conformal distortions (scale difference)

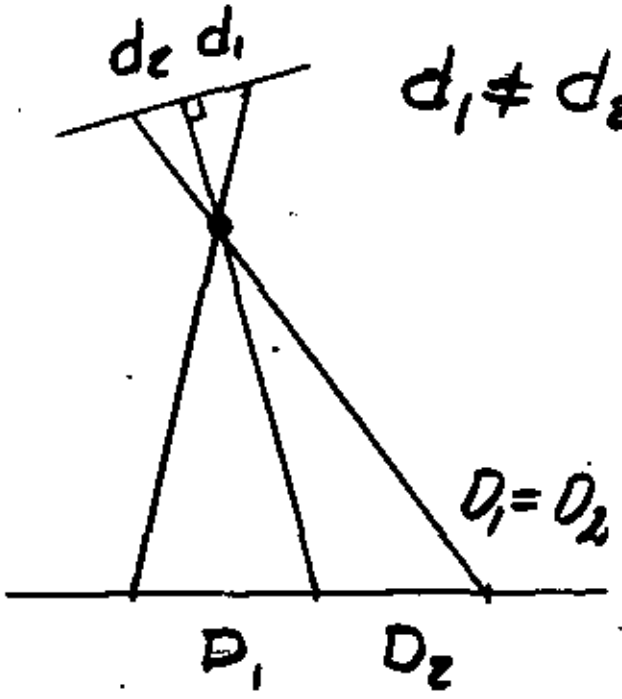
perspective -"- (inclination between sheet and photograph)

affine -"- (inclination of facet in orthogonal projection)

orthogonal projection (map) ≠ central projection (photo)



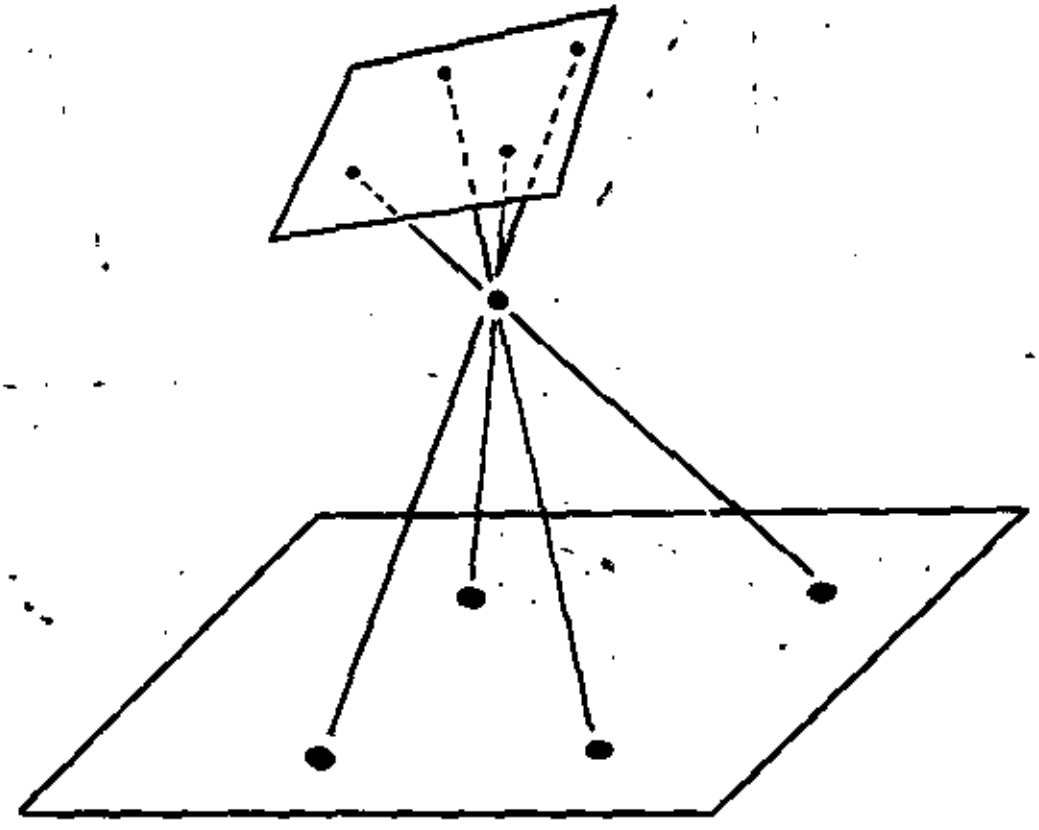
topography



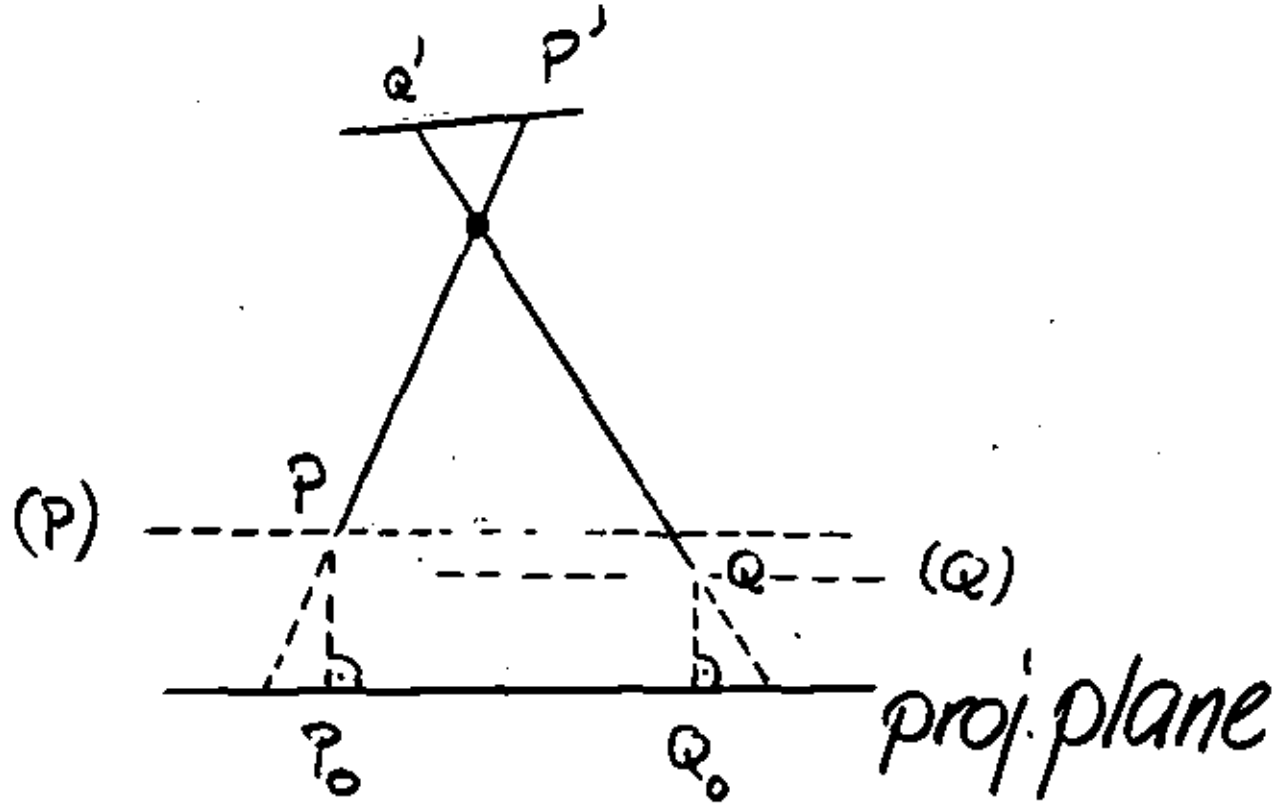
tilt of photo

Rectification

≥ 4 given points



principle of orthophotos



∴ height information necessary

idean 1930

Ortophoto — orthophotoscope 1953-57

explorman 1964 - Zeiss-Jena

normalvinkelkamera = bra...

jfr med vidvinkel

men vidvinkelkamera = ger högre höjdnoggrannhet

normalvinkel för ortokarta

supervidvinkel är högre

... snabbare än line mapping

nackdelar

irrelevanta objekt (bilar etc)

bildutjämning nödvändig

höjdskillnadsförskjutning

... 60% längdöverlappning ... med ...

... som normalvinkel

Stereo-ortofoto

an orthophoto

differentially rectified photograph

an orthophoto mosaic

joined orthophotos

an orthophoto plan

orthophoto (mosaic) enhanced by planimetric details

an orthophoto contour map

orthophoto (mosaic)
with contours

an orthophoto map

orthophoto plan
with contours

orthophoto instruments

optical projection

Zeiss GZ-1

Wild Avioplan OR1

electronic image transfer

Gestalt Photomapper

on-line

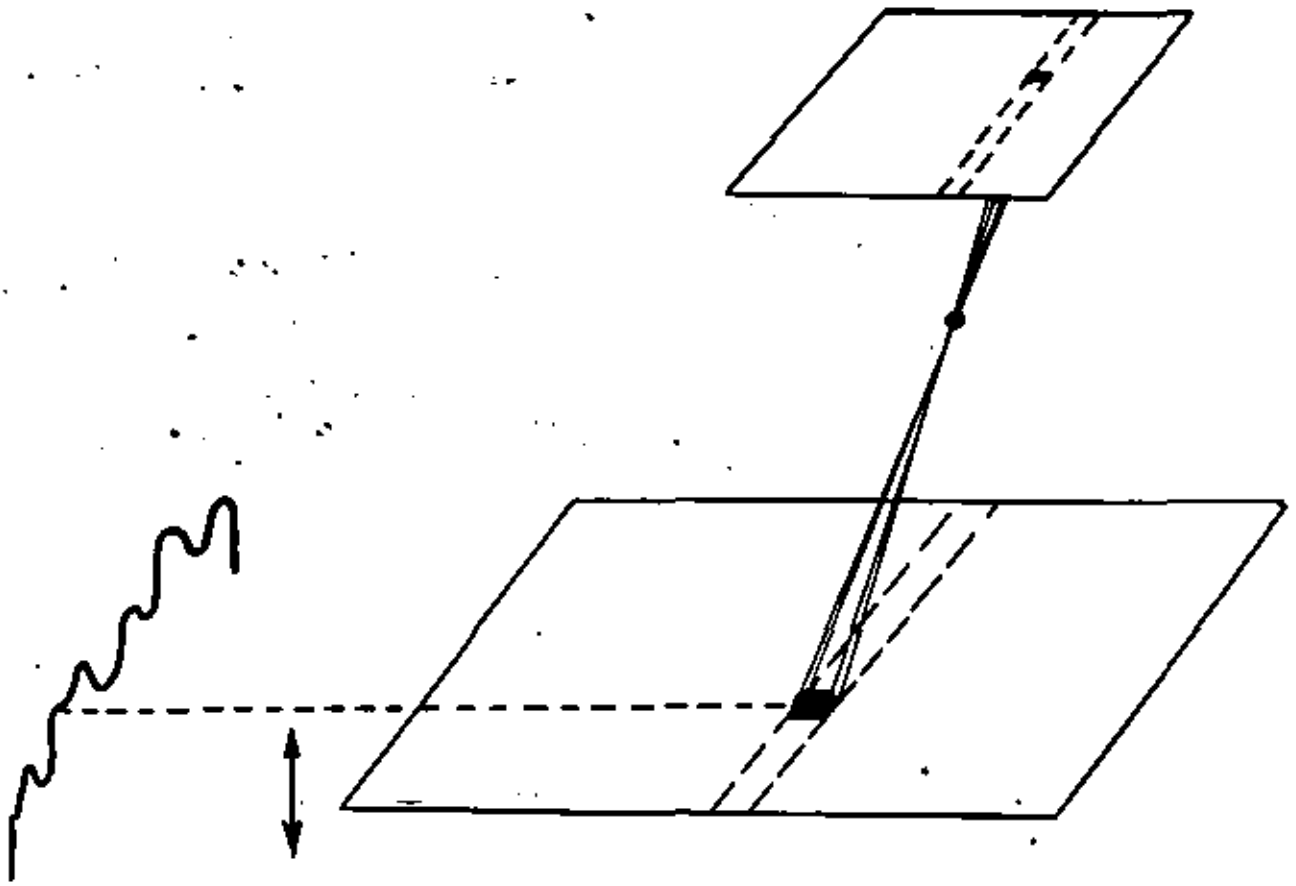
off-line

Ortho photo system

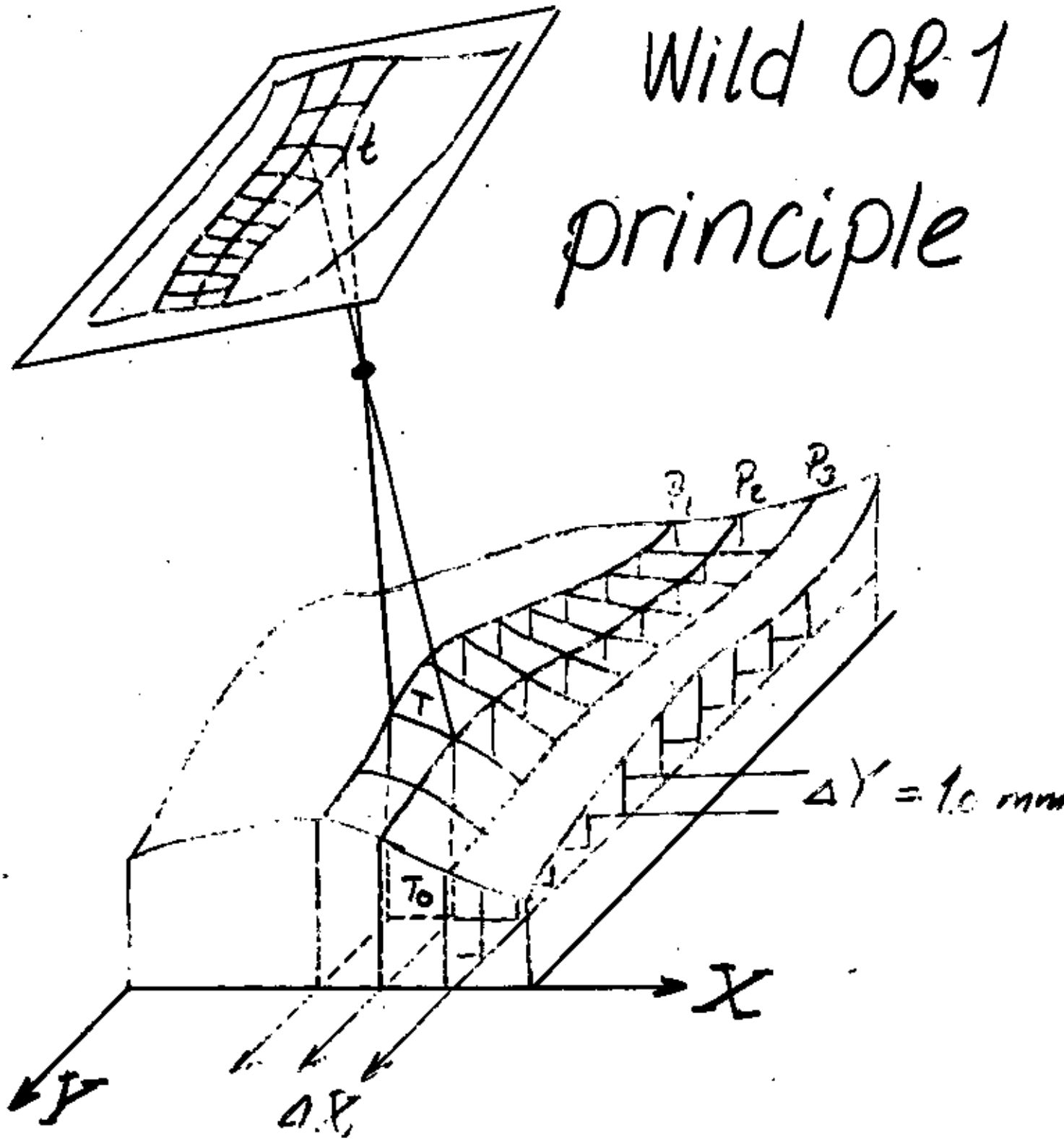
Gigas-Zeiss GZ 1

① profile measurement

② ortho-projection



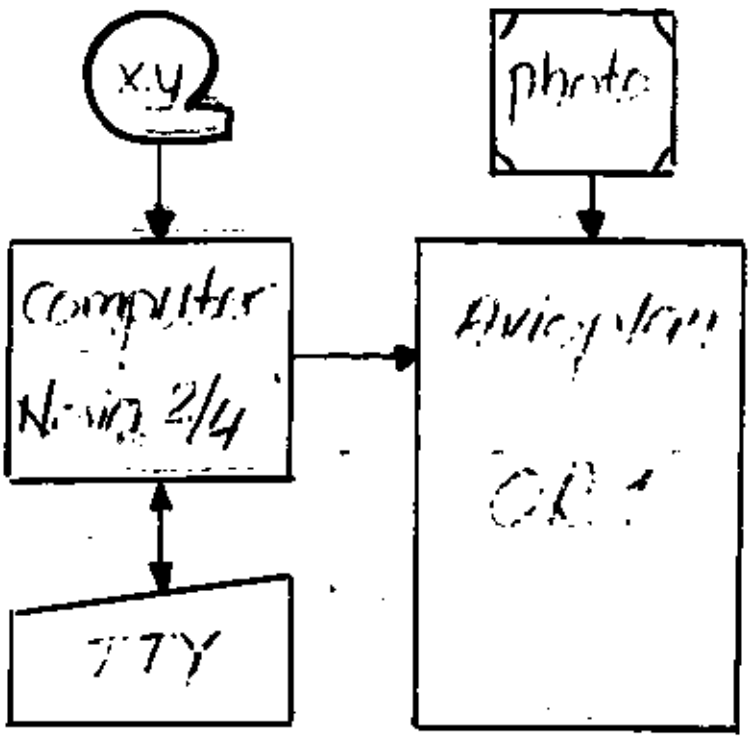
Wild OR1 principle

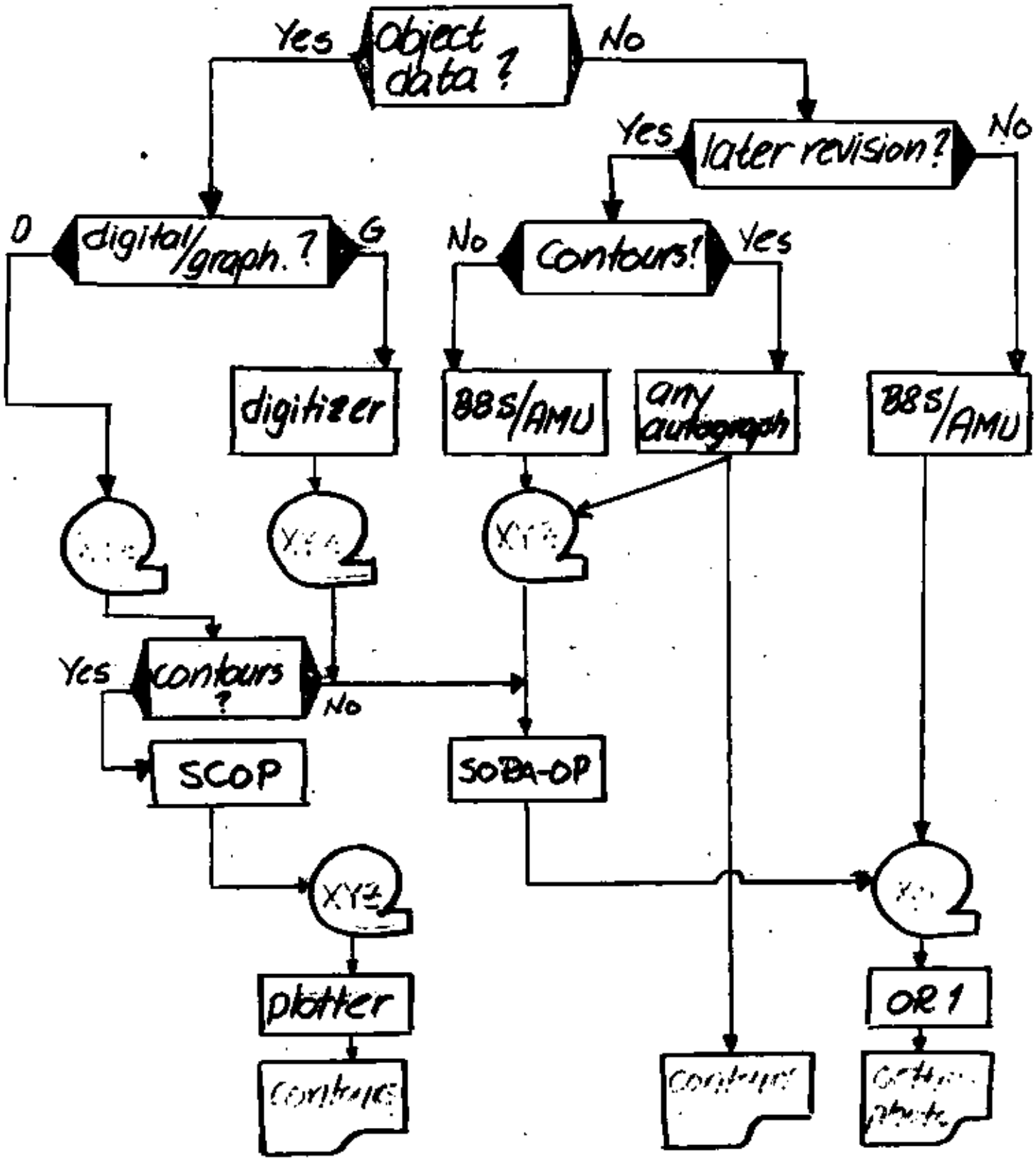


Wild OR 1

- off-line operation
- enlargements 0.25x → 15x
- slit masks 0.1 mm x (5-12) mm
- max. proj. speed 30 mm/sec
- day-light operation
- any-c-value
- flexible data acquisition
- unconventional projections

OR 1 basic configuration




Yes
object data ?
No
Yes
later revision?
No
D
digital/graph. ?
G
No
Contours!
Yes
digitizer
BBS/AMU
any autograph
BBS/AMU
Yes
contours ?
No
SCOP
SOBA-OP
plotter
OR 1

Wild OR1 production rate

- a double model (60%, 20%)
- 4x photo → orthophoto

	hours	
profiling	3.75	
contouring		8
ortho projection	0.75	0.75
	4.50	8.75

Gestalt Photo Mapper II

- computer-controlled
- auto-correlating

  9×8 mm patches
  with 2444 points each
- diff. rectification in < 1 sec

  analytical plotter
- electronic image transfer

GPM II

speed : ≈ 1.5 hours for one model

GPM Plotting System

Minicomputer
- DataGeneral Nova (40K)
- 10 MByte disk
- plotter (contours from DTM)

GPM II output

photographic

- orthophoto 20×25 cm
- stereomate
- contours

digital

- DTM on mag tape
  (≈ 700 000 points/model)

accuracy of ortho-photos

ISP Working Group 1972-76

distributed material

one stereomodel

1:10000 60%

Wild RC8 10 mm resc

camera calibration data

six targeted (XYZ)-points

paper prints

some aspects on orthophotograp

① flight planning
- long c-value
- double-models
- 3-5x enlargement
- 80-90% overlap

② photography
- correct exposure
- uniform contrast
- b/w (color)

③ data acquisition
- image profiles
- model profiles
- contours

WG II-4

test material

- 1 stereopair 1:10000 60%
  Wild RC8 (1 cm reseau) 15/23
- camera calibration data
- 6 targeted XYZ-control/poin

WG II-4

participants provided

- original orthophoto negatives from both photographs (1:2500)
- contour lines/drop lines
- recorded profiles

WG II-4

control data

XYZ for reseau points measured in A7 (+40 natural points)

XY for control points measured in mono-comparator

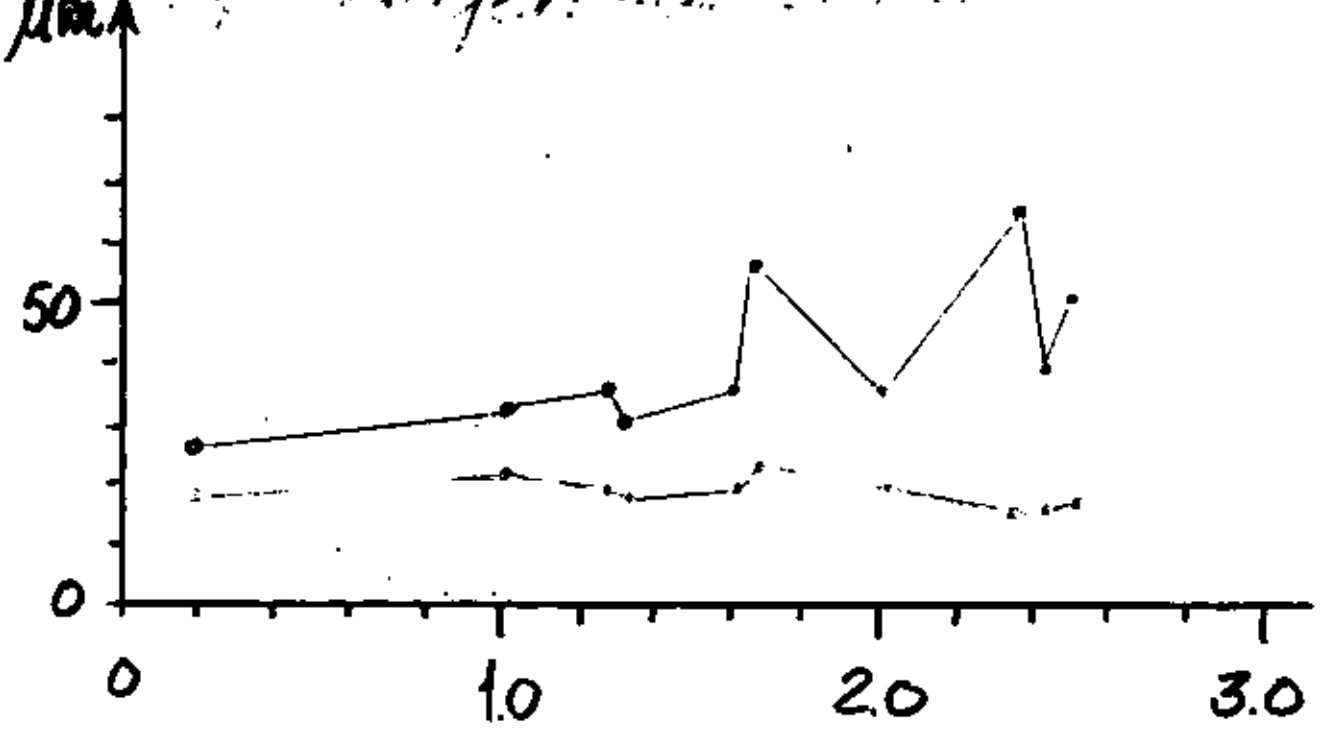
WG II-4

results

10 participants

s_r radial errors

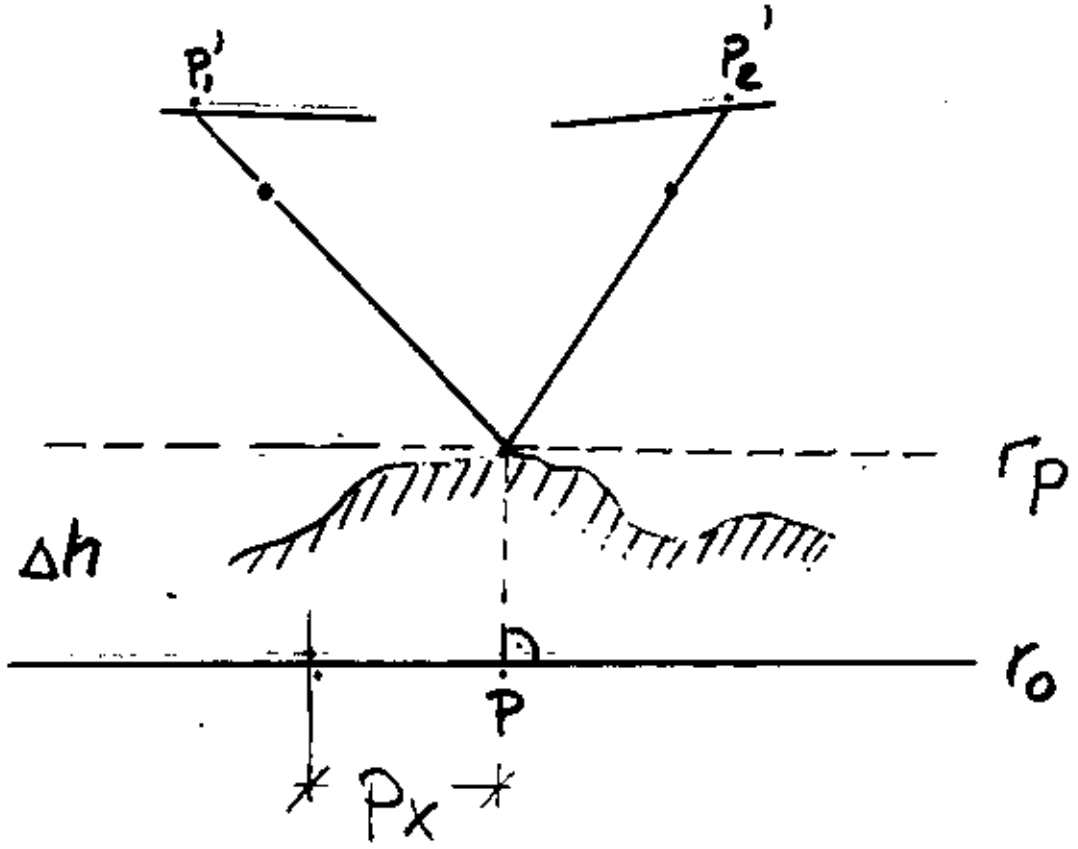
s_t tangential errors



orthophoto vs. conventional mapping

+	−
contains all info	non-relevant info
fast (5-10x)	interpretation by user
semi-automated process	radial displacement of vertical objects
	restricted vertical info

stereo-orthophotos



$P_x = \text{coust.} \cdot \Delta h$

oblique parallell projection

orthophotos in Sweden

① the National Land Survey
land use map 1:10000
GZ1 1968
OR1 1978

② communities
orthophotomaps 1:500

③ the National Road Adm.
trials with orthophotos
in 1:1000 and 1:2000

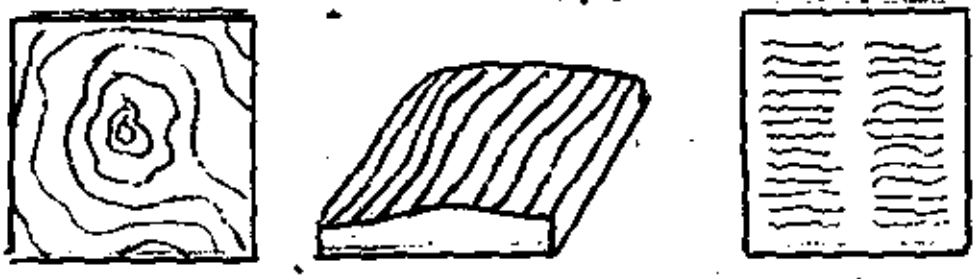
orthophotos in Sweden

the National Land Survey

a nation-wide DTM

50×50 m or 100×100

25% 25% 50%



contours stereo-models GE1-profiles

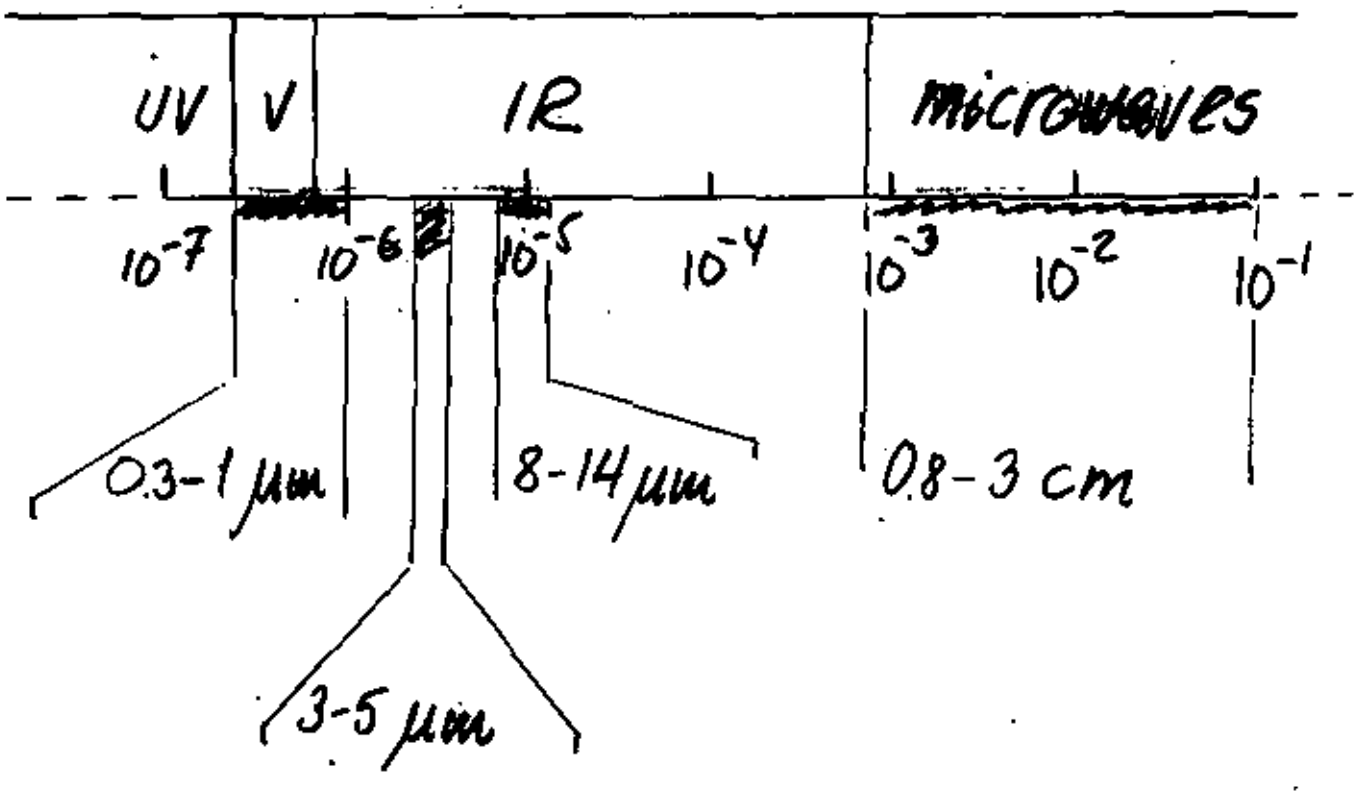
remote sensing

spectrum

UV = ultraviolet

V = visible

IR = infrared



Remote Sensing

spectrum, four windows, visible 0.4-0.7 near IR 0.7-1.0
middle IR 3-5, far IR 8-14
H_2O water vapor, CO_2 carbon dioxide

photography	visible - near IR	central projection	often multispectral
TV	visible - near IR	one scene at a time	
scanners	visible - IR		

active passive sensors

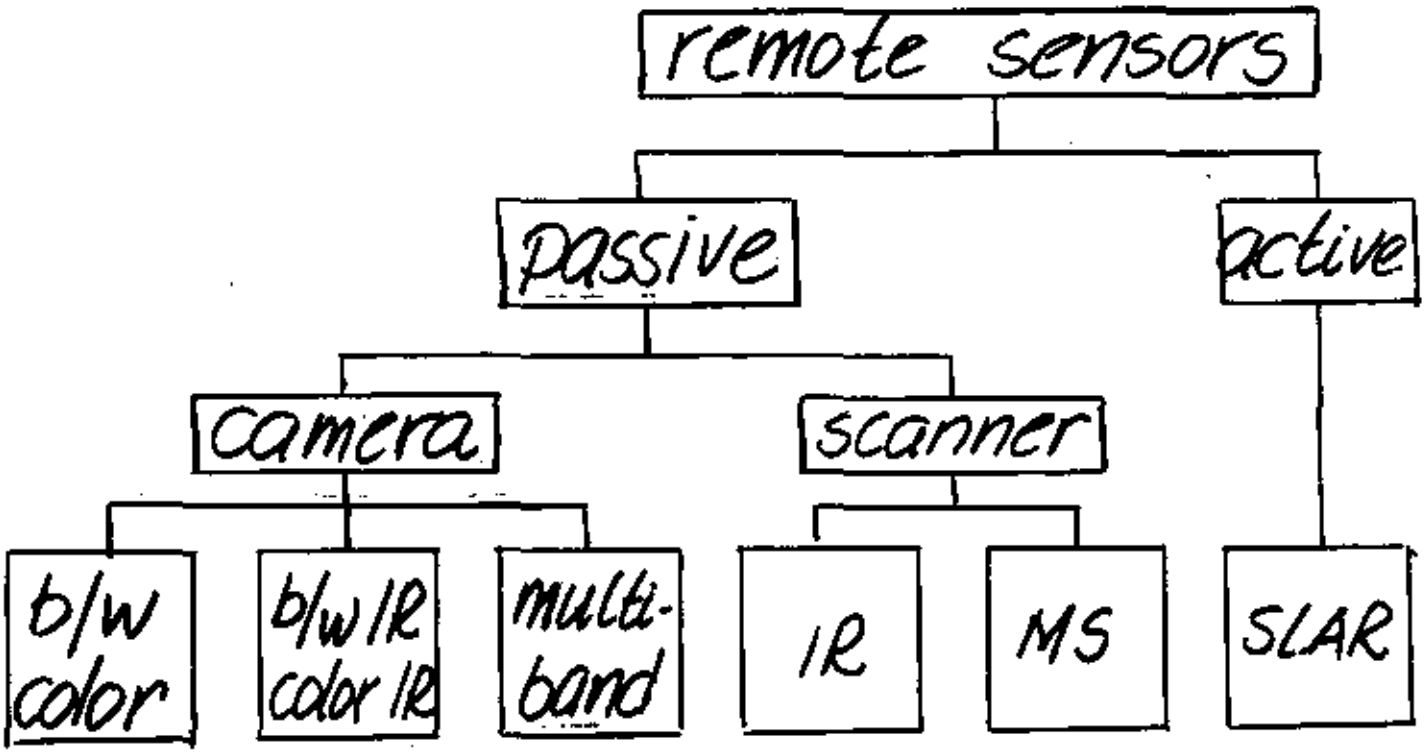
Resolution: Landsat scanner 0.08 mrad
Airborne — " — 2.5 mrad

Satellites	SKYLAB	Landsat 1	Landsat 2	Landsat 3
Yr	1973	1972	1975	1978
	manned			
Sensors RBV		3 (3 bands)	3 (3 bands)	2 (1 band)
		same area		different area
pixel		80 m		
MSS				

Data are collected & receiving ... on mag tape.
Bulk processing ... pictures ...
... processing ...

Major characteristics: large areas ...
multispectral
digital data
repetitive coverage

Interpretation
visual
digital


remote sensors
passive
active
camera
scanner
b/w
color
b/w IR
color IR
multi-
band
IR
MS
SLAR

remote sensors

active — SLAR

passive — camera
TV
scanner (MSS)

platforms — aircraft
satellites

satellites

	LANDSAT1	LANDSAT2	LANDSAT3
year	1972	1975	1978
sensors			
RBV	3 (3 bands)	3 (3 bands)	2 (1 band)
MSS	0.5-0.6 μm	0.5-0.6	0.5-0.6
	0.6-0.7	0.6-0.7	0.6-0.7
	0.7-0.8	0.7-0.8	0.7-0.8
	0.8-1.1	0.8-1.1	0.8-1.1
			10.4-12.6

LANDSAT - scenes

area 185 × 185 km^2

time interval 18 days

pixel 80 × 80 m (40 × 40)

interpretation

visual

digital

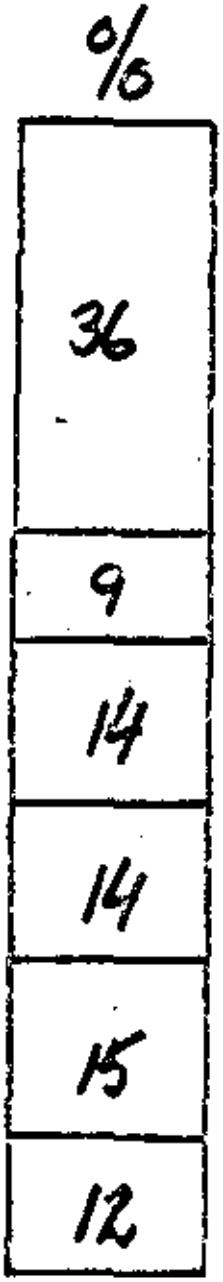
centro de educación continua
división de estudios superiores
facultad de ingeniería, unam

FOTOGRAMETRIA EN EL DISEÑO Y CONSTRUCCION DE OBRAS DE INGENIERIA CIVIL

ACTIVITIES IN FINAL DESIGN

ING. BULMARO CABRERA RUIZ

activities in final design



office work

miscellaneous

soil investigation

levelling

setting out

traverse measurement

Wednesday

final design

new aerial photography (1:5000)

second order traverse

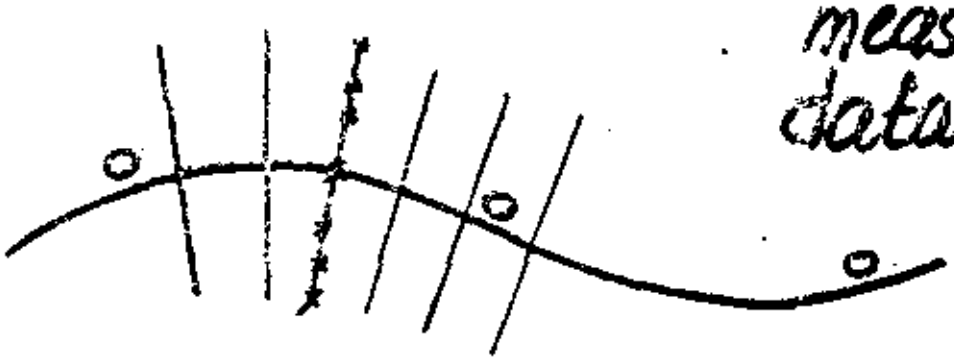
products

large-scale maps (1:500 or 1:1000)

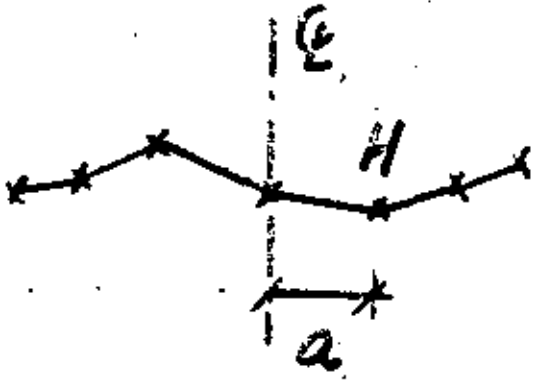
numerical measurements

- longitudinal profiles
- cross profiles
- digital terrain model (DTM)

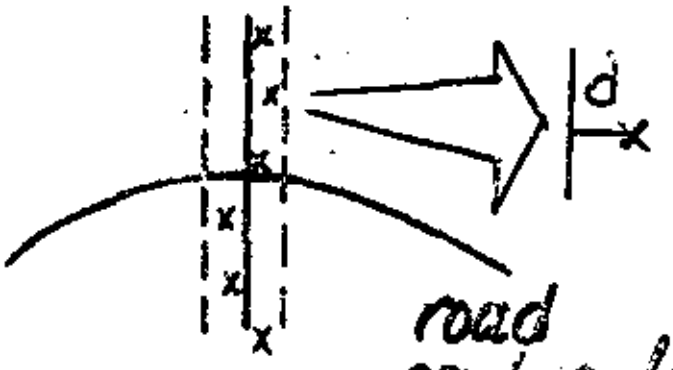
Profile measurement



measured data: xyz (model)



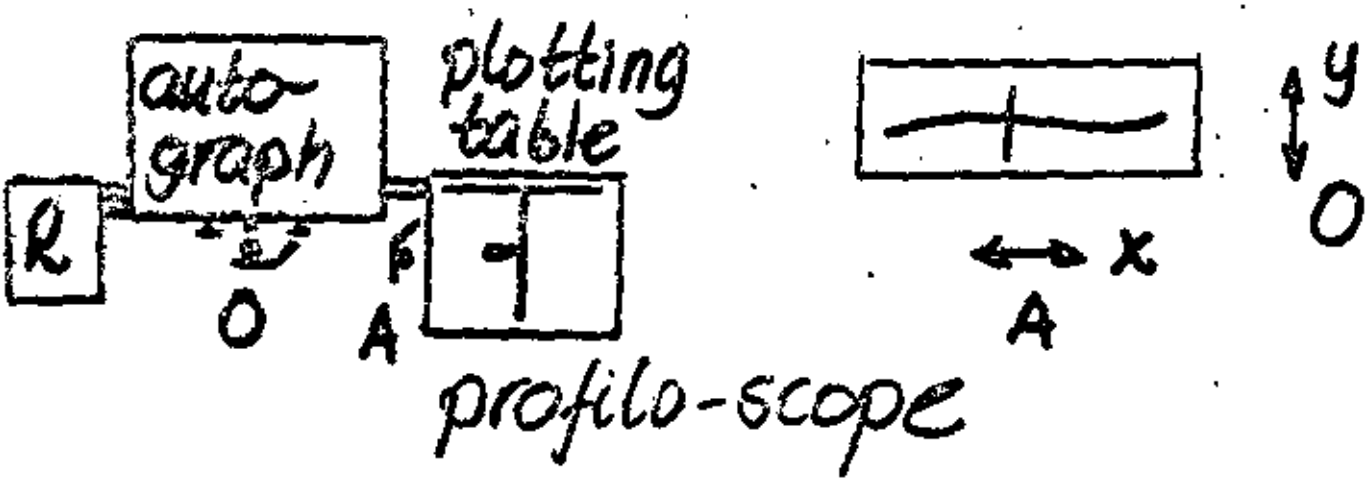
result: a, H



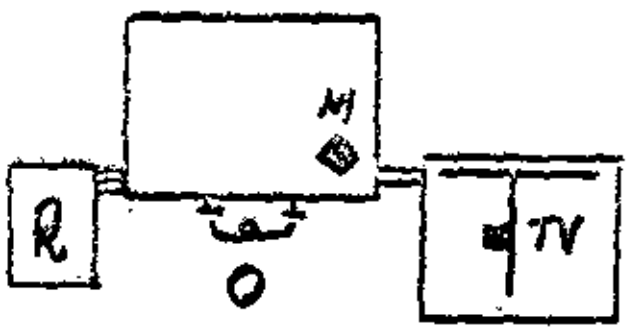
check: $\frac{\Sigma d}{n}$

$\sqrt{\frac{\Sigma d^2}{n}}$

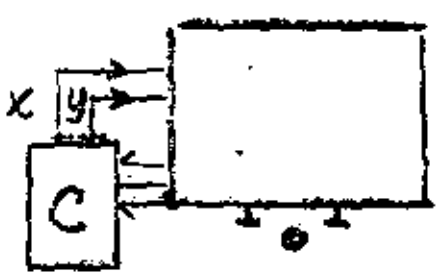
operation



profilo-scope



TV-camera
monitor



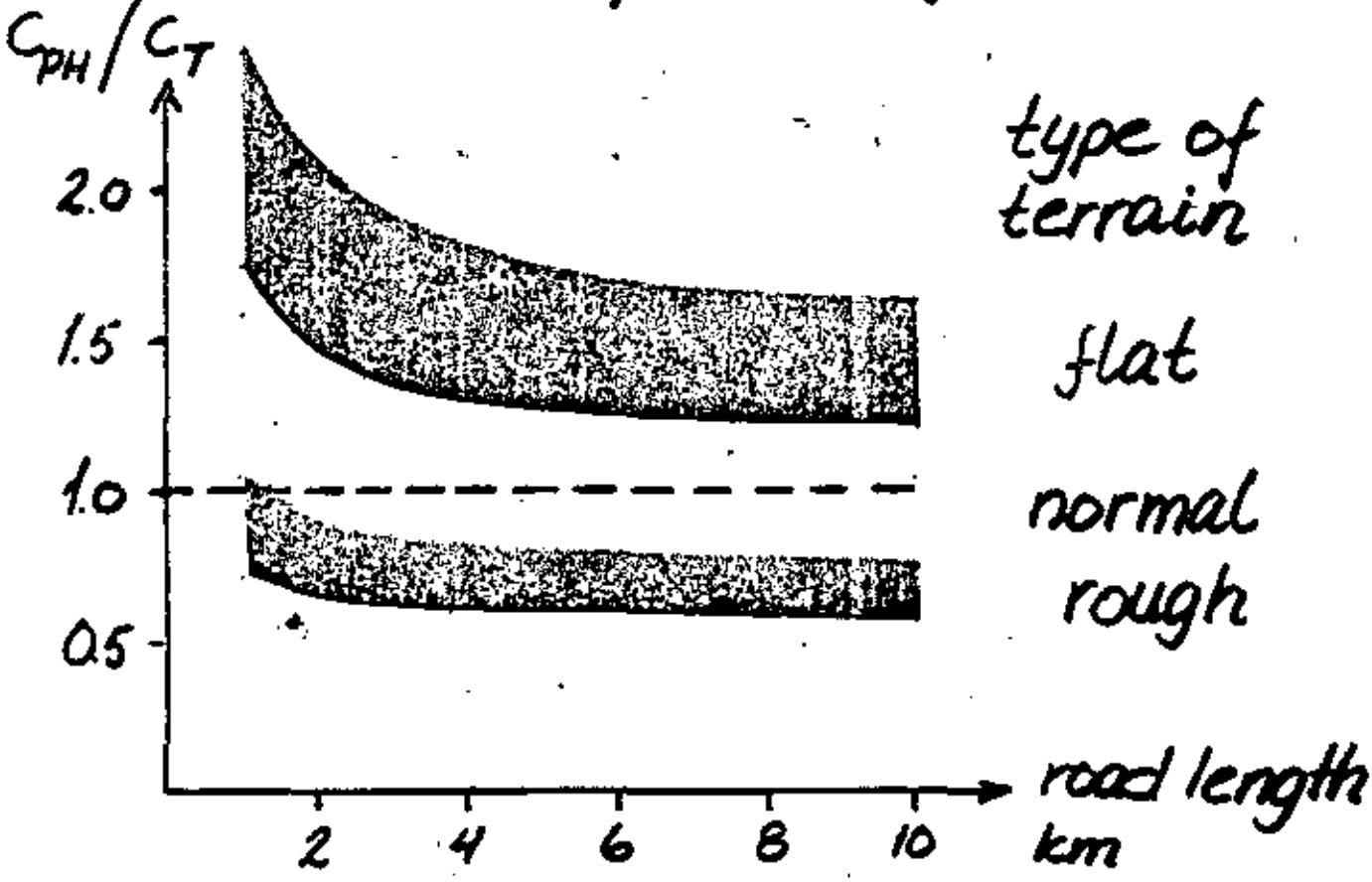
computer
controlled

photogrammetric cross-sectioning

+ fast measurement
  homogeneous quality
  less blunders
- season dependent
  systematic errors

cross profile measurement

economic aspects, final design



C_{PH} = costs, photogrammetric meas.

C_T = -"- terrestrial measurement

cross profile measurement

economic aspects,
results of a study

type of costs
- aerial photography
- geodetic control
- stereo measurement
- data processing

type of terrain	cross profile interval	no. of points per profile
flat	20 m	5
normal	20	10
rough	10	20

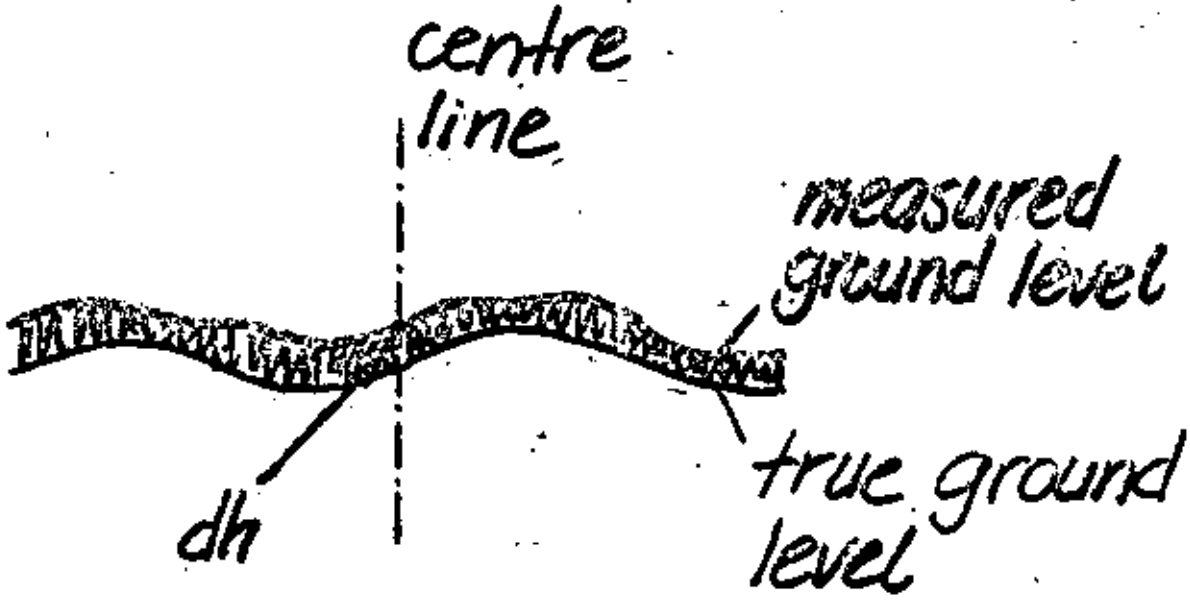
cross profile measurement

systematic errors

photos: distortion
refraction
earth curvature

instrument
orientation
vegetation

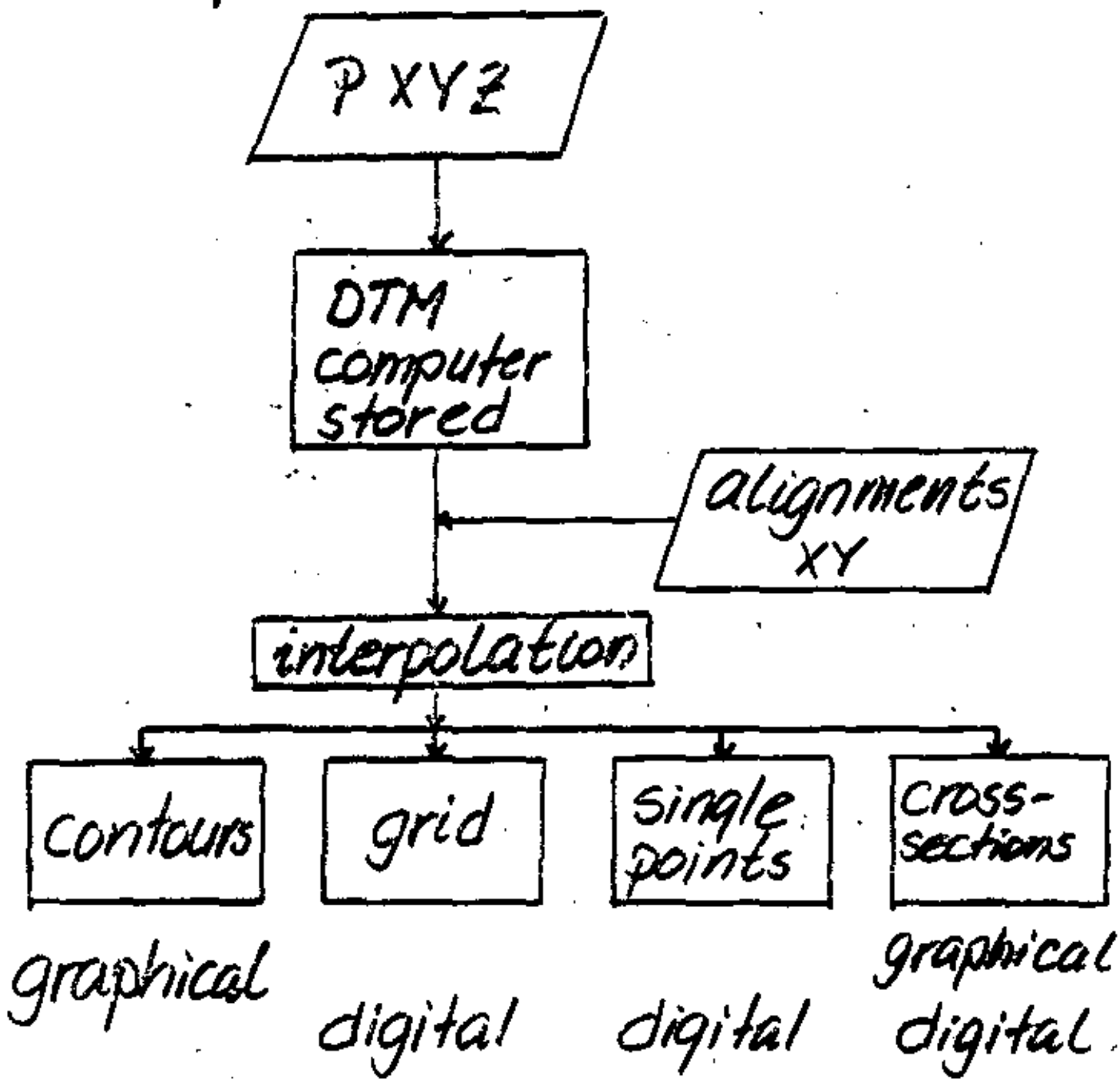
reduction of errors due to vegetation



dh from levelling in the field and applied to the whole cross profile

Digital Terrain Model (DTM)

concept



Digital Ground Model (DGM)

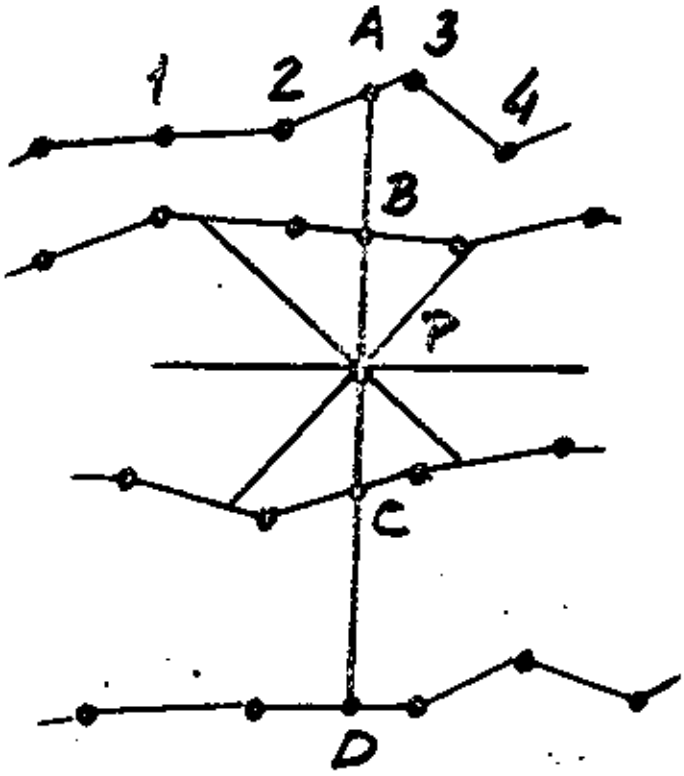
- ground surface
- max. 7 layers

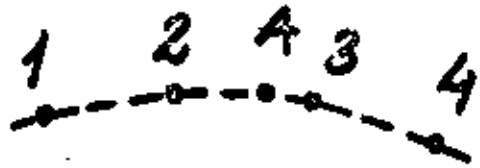
primary data

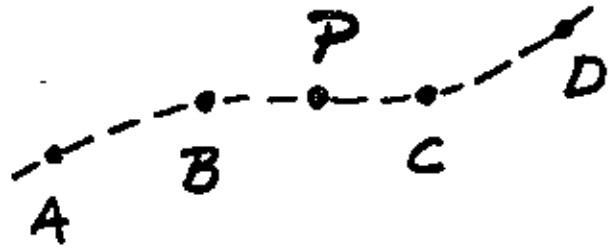
- terrain lines

- break lines

DGM interpolation







1) shortest "5D intersection"

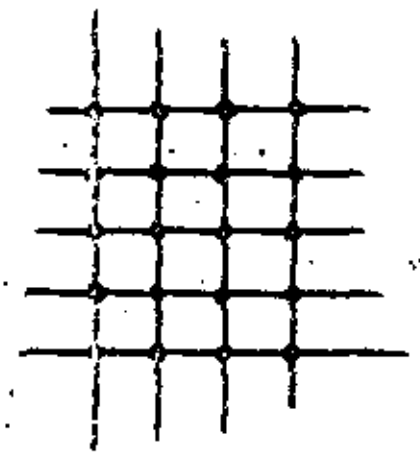
2) A, B, C, D with 1st, 2nd or 3rd degree interpolation

3) P from A, B, C, D in the same way

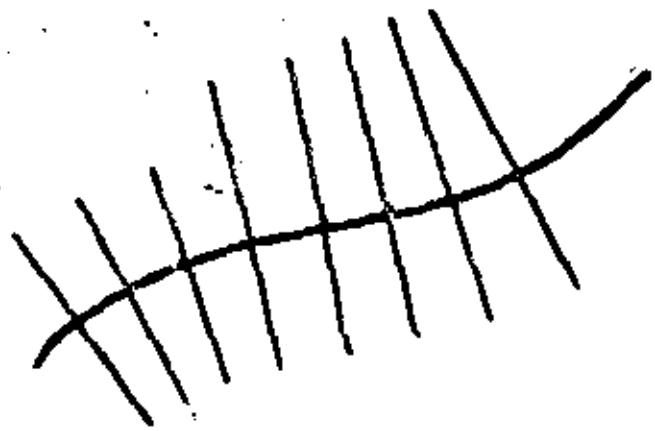
DGM

secondary data

regular grid



cross profiles



data acquisition

photogrammetry
geodesy
cartography
instruments
methods

photogrammetric instruments for DTM

type	info	operation	small scale	large scale
stereocomp.	x'y' x"y"	manual	−	−
analogue instr.	xyz	manual semi-automatic	+	+
analytical plotter	xyz XYZ	semi-automatic	+	+
correlator	xyz	automatic	+	−

interpolation

procedures

- linear
- bilinear
- 2nd degree functions
- other functions

interpolation

principles

A) I regular grid from primary data

II heights from grid

B) I interrelations eg. triangular facets

II heights within facets

C) heights from primary data

methods

manual
computer assisted
computer controlled

selection	automated recording
random points	—
break lines ("strings")	—
contours	Δs Δt Δx Δy
parallell profiles	Δs Δt Δx Δy Δz
regular grid	(Δx) (Δy)
cross-sections	(Δs) (Δt)

results

Technical University
of Hannover, W. Germany 1979

aerial photography

test 1:4000
check 1:1800

instruments

Wild A10 / EK22
Zeiss Planimat / Ecomat II
-"- Planicart / POP8
OMI AP/C-3

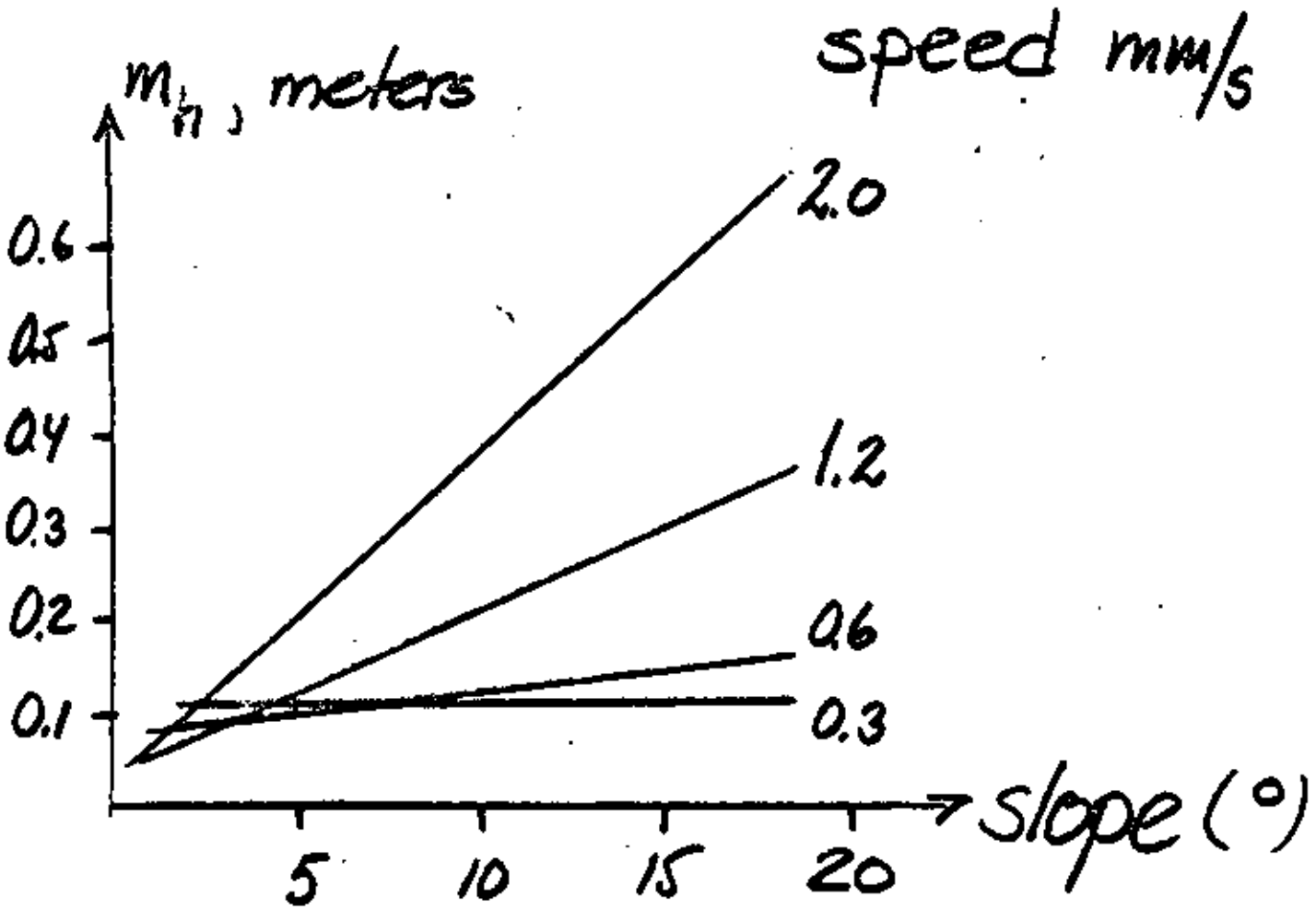
results

accuracy of measuring methods

random	0.07 m	(0.1‰H)
grid	0.07 m	
contours	0.13+0.4 tan α, m	

results

accuracy of continous profiling



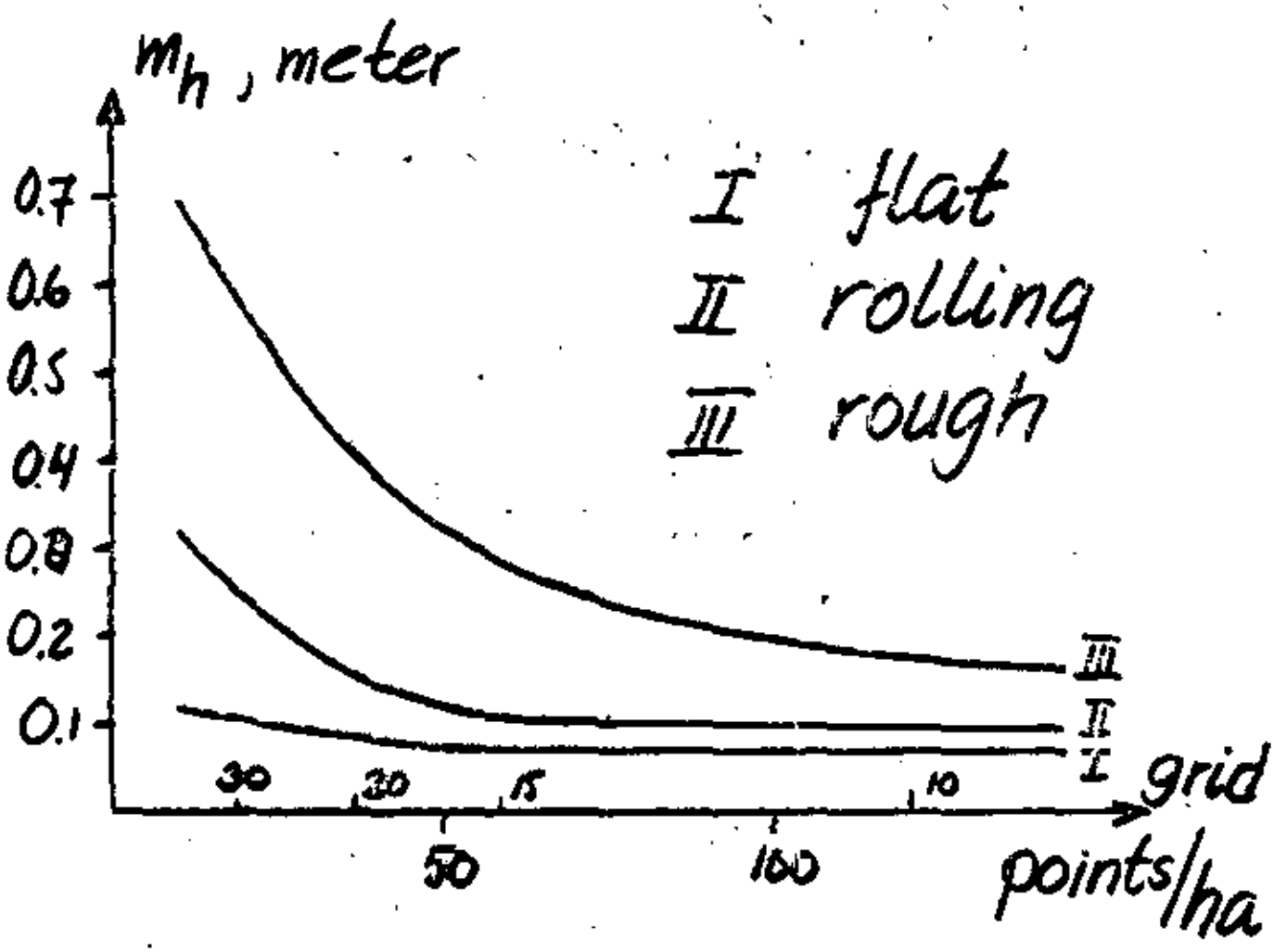
results

accuracy of measuring methods

random	0.07 m	(0.1‰H)
grid	0.07 m	
contours	0.13+0.4 tan α, m	

results

interpolated heights

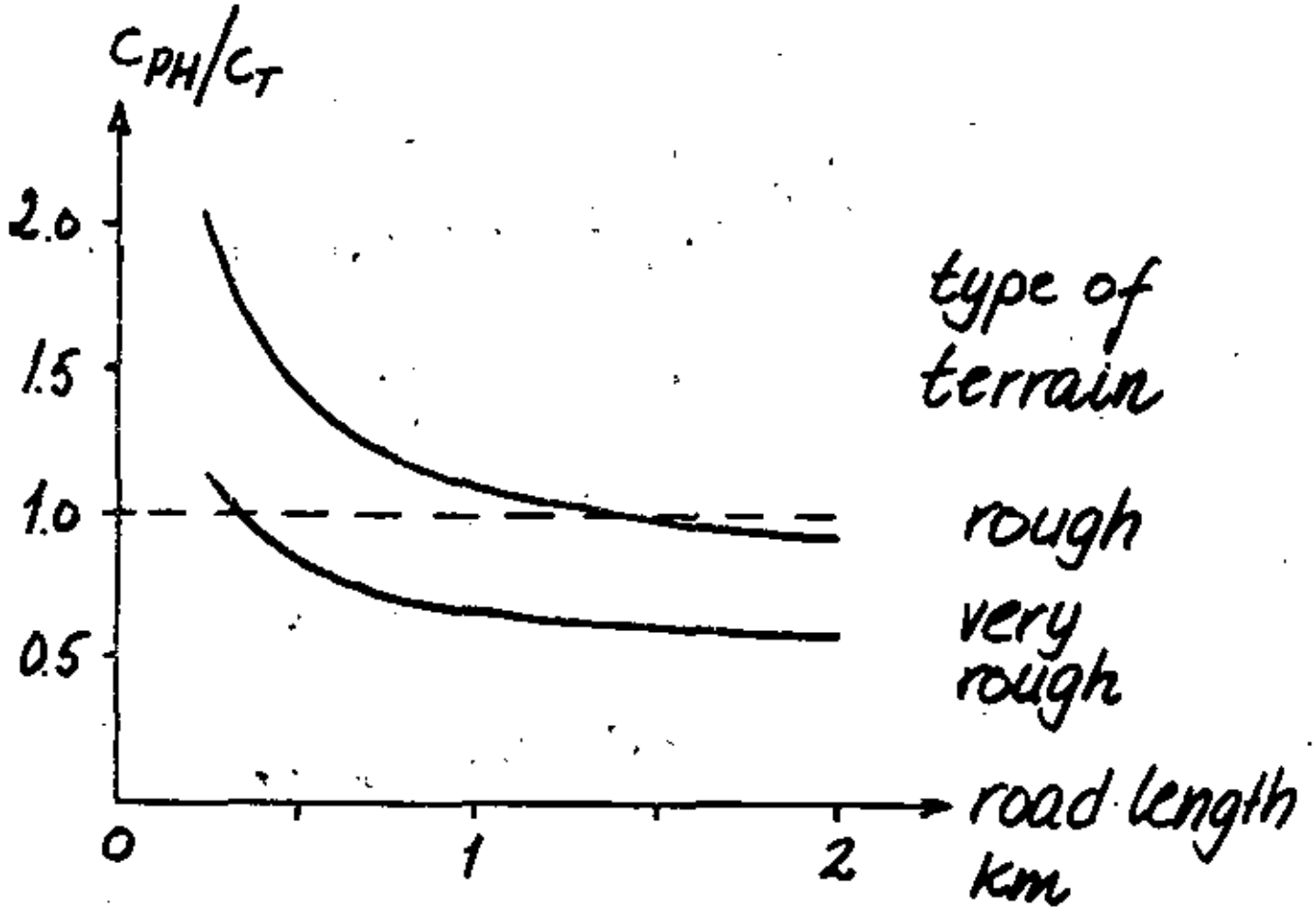


DTM results

- profiles
- cross-sections
- volumes
- contours
- perspectives

construction stage

cross profiles



c_{PH} = Costs, photogrammetric meas.

c_T = –"–, terrestrial measurement

DTM application

design

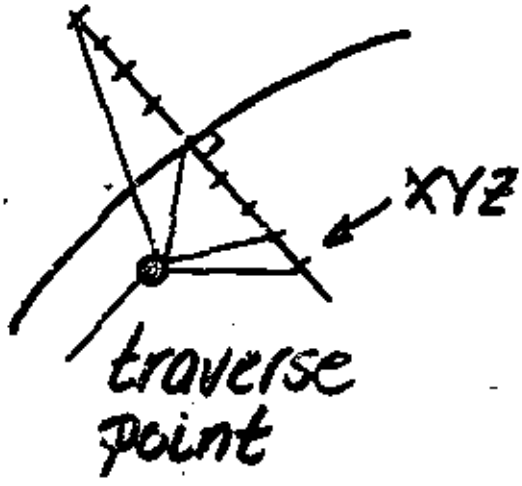
highways
interchanges
railways
power lines
air ports
residental areas
industrial areas

open mining

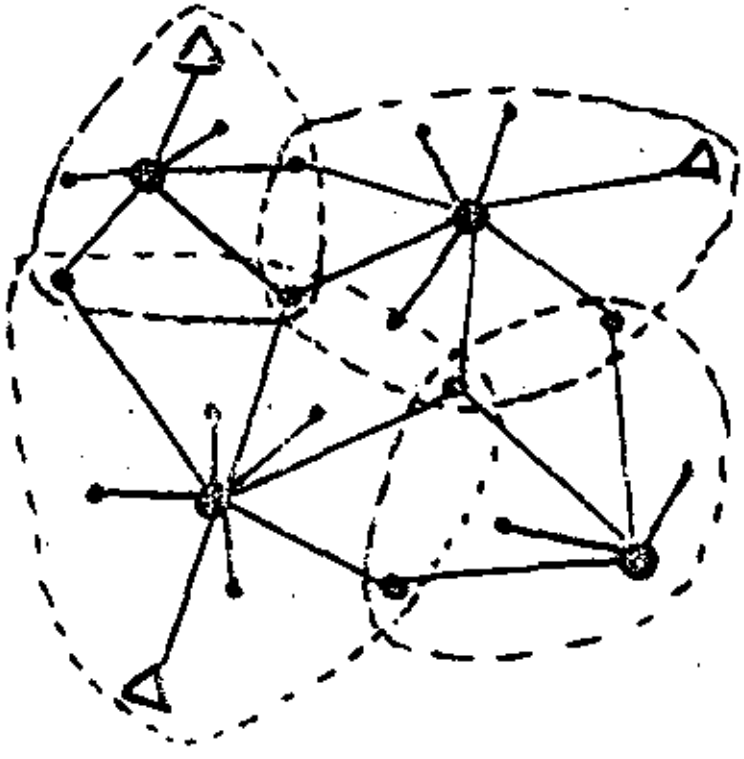
orthophoto-production

combination of photogrammetric and terrestrial surveys

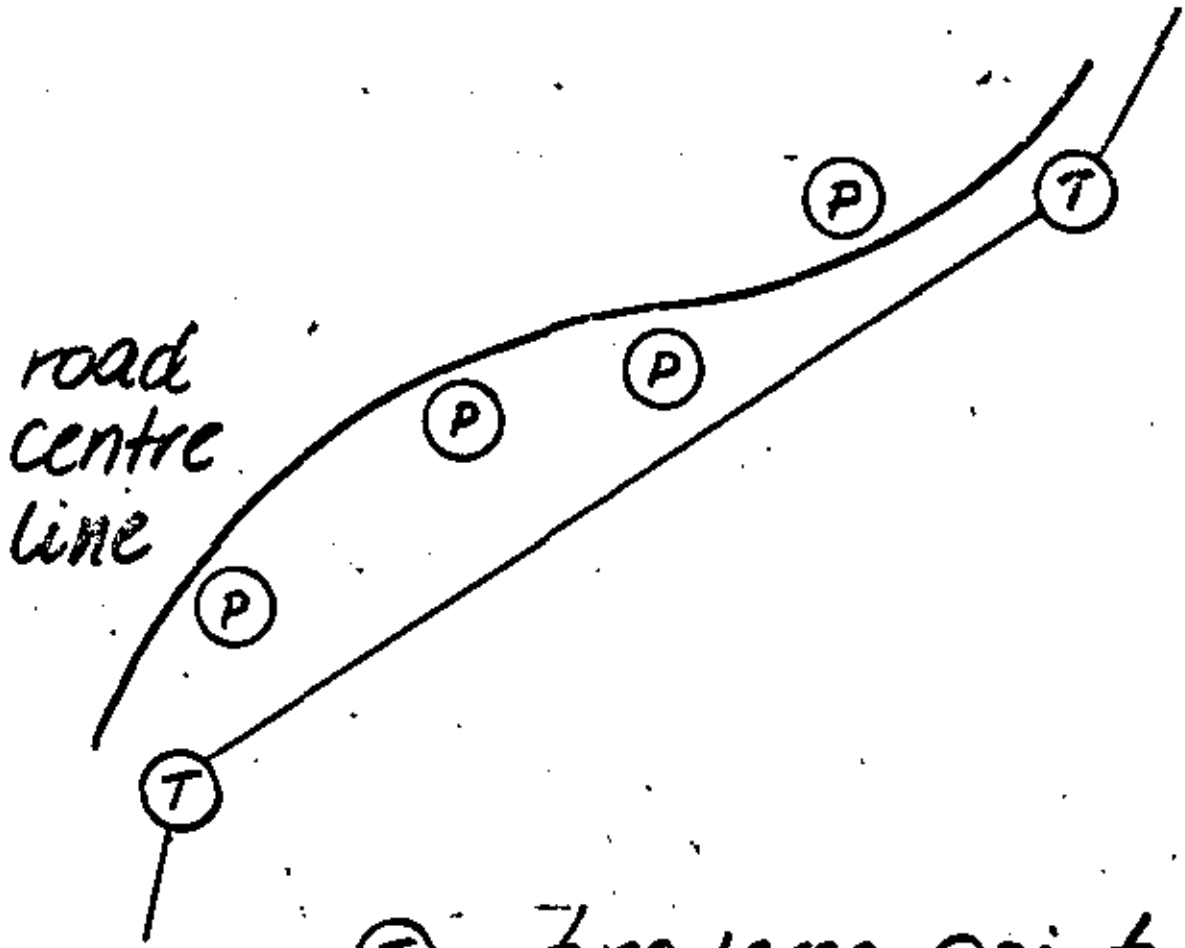
polar
cross profiling



terrestrial
blocks



photogrammetry and setting out



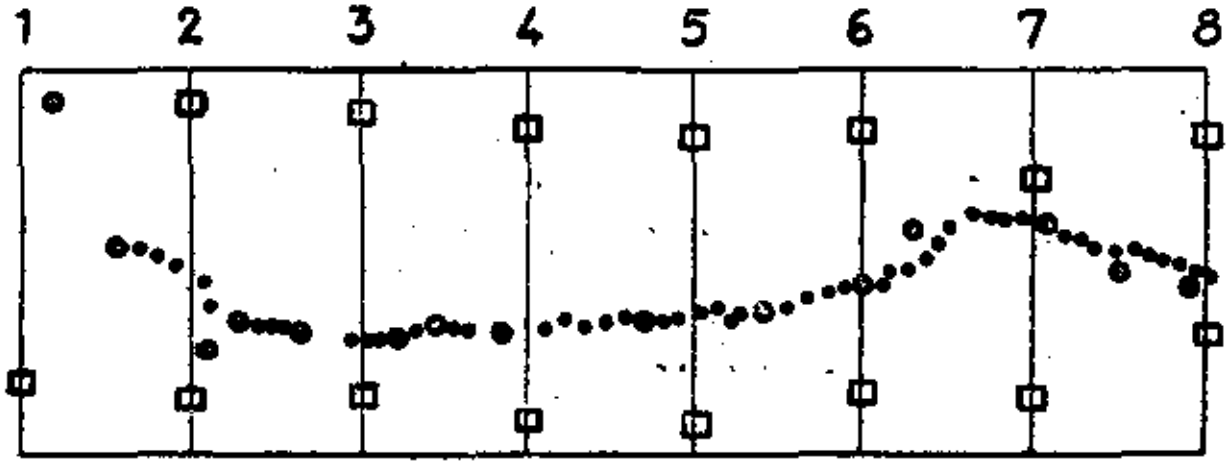
(T) = traverse point

(P) = point with coordinates determined by photogrammetry

test area

Rv 32 Tranås—Sommen

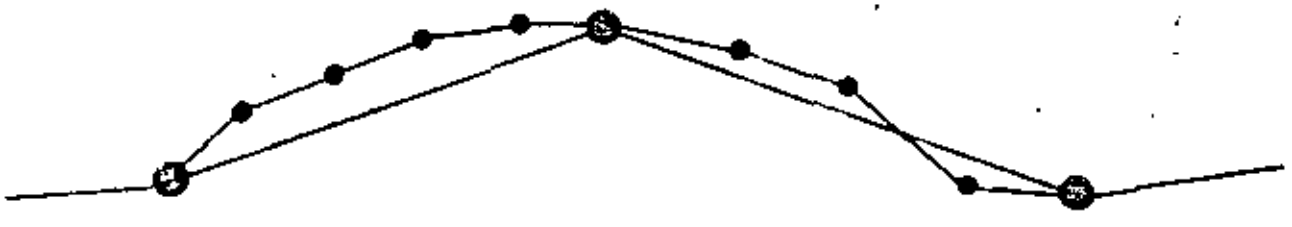
flying height: 15000 m (1:10 000)



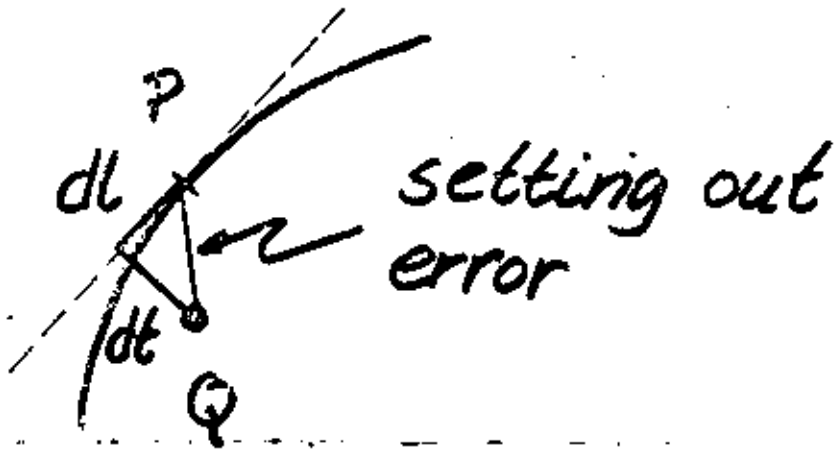
• - XYZ-control

□ - Z-control

• - photogrammetric point



photogrammetry and setting out



dl = longitudinal error

dt = transverse error

photogrammetry and setting out

results of a study

	No. of points	root mean square values, m			
		dx	dy	dl	dt
"photo" stations	51	0.04	0.05		
road centre points	320			0.07	(0.05)

photo scale 1:10000
autograph Wild A10

data processing

large computers

SAAB D22

UNIVAC 1100

desk top calculators

HP9820 HP97

HP9825

pocket calculators

HP45 HP25 HP65

HP67

data processing

computer programs

data handling	design presentation
surveying	earthworks
road alignment	photogrammetry
ground data	production planning
road cross sections	bridges
setting out	geotechnique

terrestrial photogrammetry

principles

- photography
- control points
- evaluation
- +/—
- accuracy

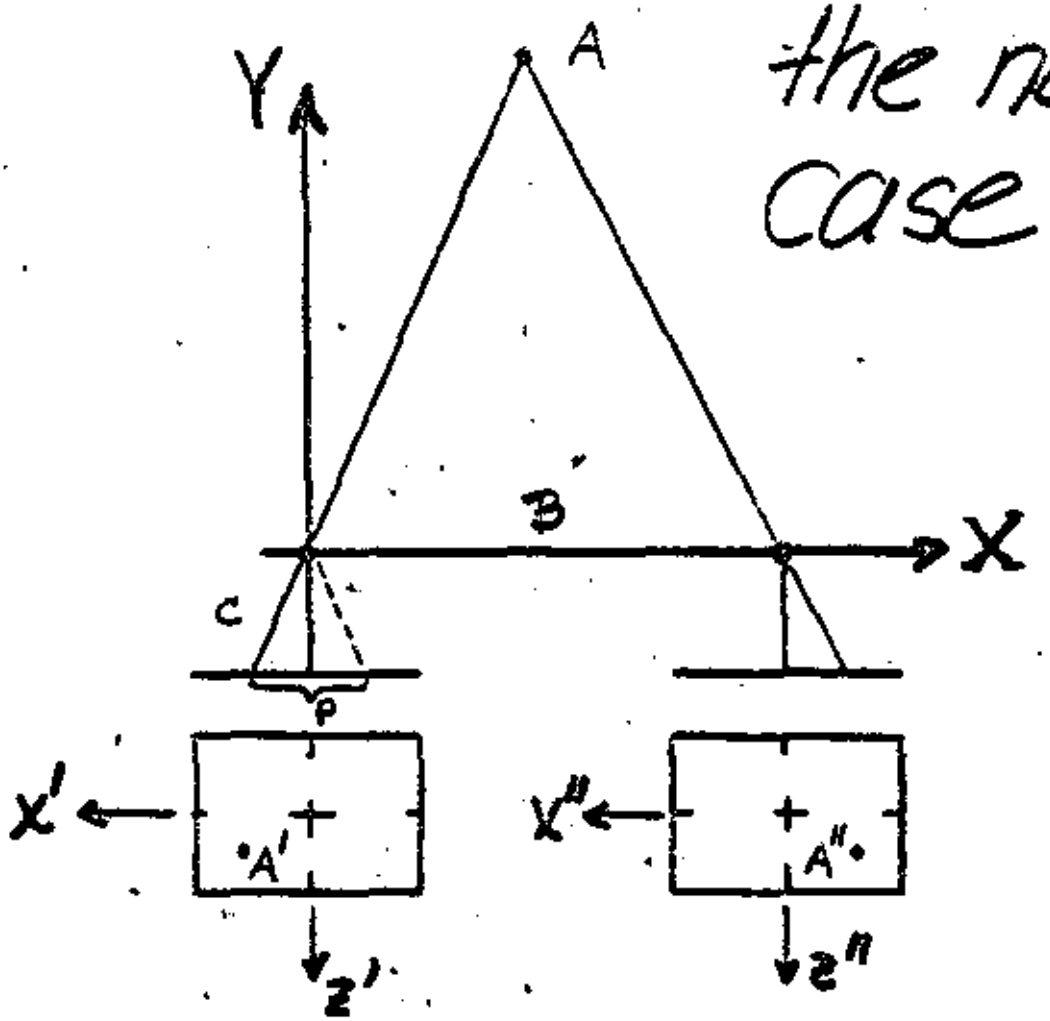
planning

application

- engineering
- deformation
- documentation

Thursday

the normal case



$$\frac{Y}{B} = \frac{C}{P}; \qquad Y = \frac{BC}{P}$$

$$X = \frac{Y}{C} x'$$

$$Z = \frac{Y}{C} z'$$

photography

- camera
  - metric
  - non-metric
    - single
    - stereo
- emulsion base
  - glass plates
  - cut sheet film
  - roll film

photography

normal case

fixed base

free base

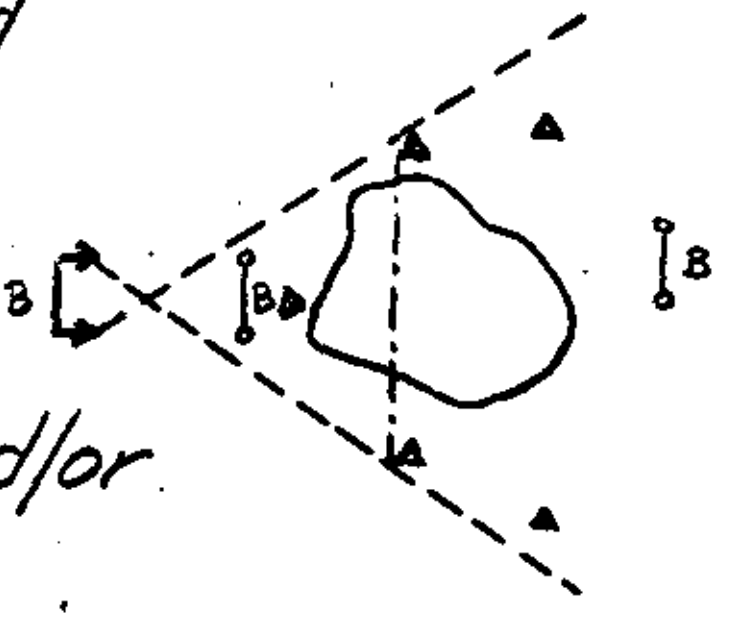
tilted base

convergent

control points

well distributed
(XYZ)

use B-bars



use vertical and/or
horizontal
straight lines

terrestrial photogr. block adj.
simultaneous geod./photogr. adj.

evaluation

graphical
- "normal case" - plotters
- universal plotters
- analytical plotters

numerical
- plotters
- comparators

photographic
- rectification
- orthophotography

characteristics of terrestrial photogrammetry

+

flexible to requirements on accuracy

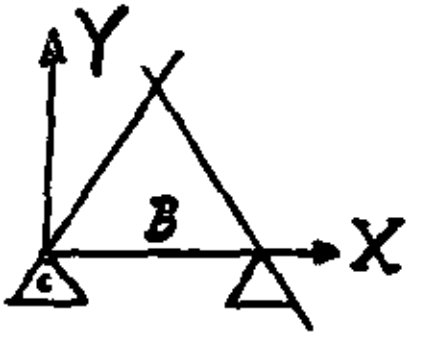
fast recording

-

special requirements on plotters

many models for complete coverage

accuracy



$$Y = \frac{Bc}{P}$$

$$dY = \frac{Y^2}{Bc} dp$$

"thumb rules"

$dp = 10\ \mu m$

gives $dY = 10\ mm$

for $c = 10\ cm$

$B = 10\ dm$

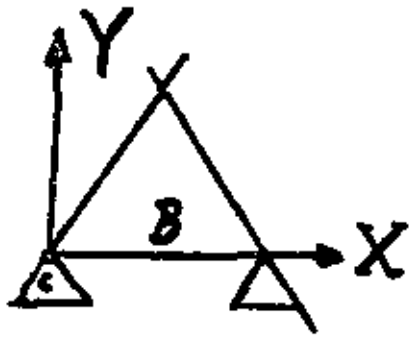
$Y = 10\ m$

planning

decisive factors

- available camera(s)
- — " — evaluation instr.
- analog/analytic evaluation
- graphical/numerical/photographic products
- size of object
- moving/non-moving object
- movable object
- single or repeated photogr.
- accuracy requirements
- economy

accuracy



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planning

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- single or repeated photogr.
- accuracy requirements
- economy

application of close-range photogrammetry

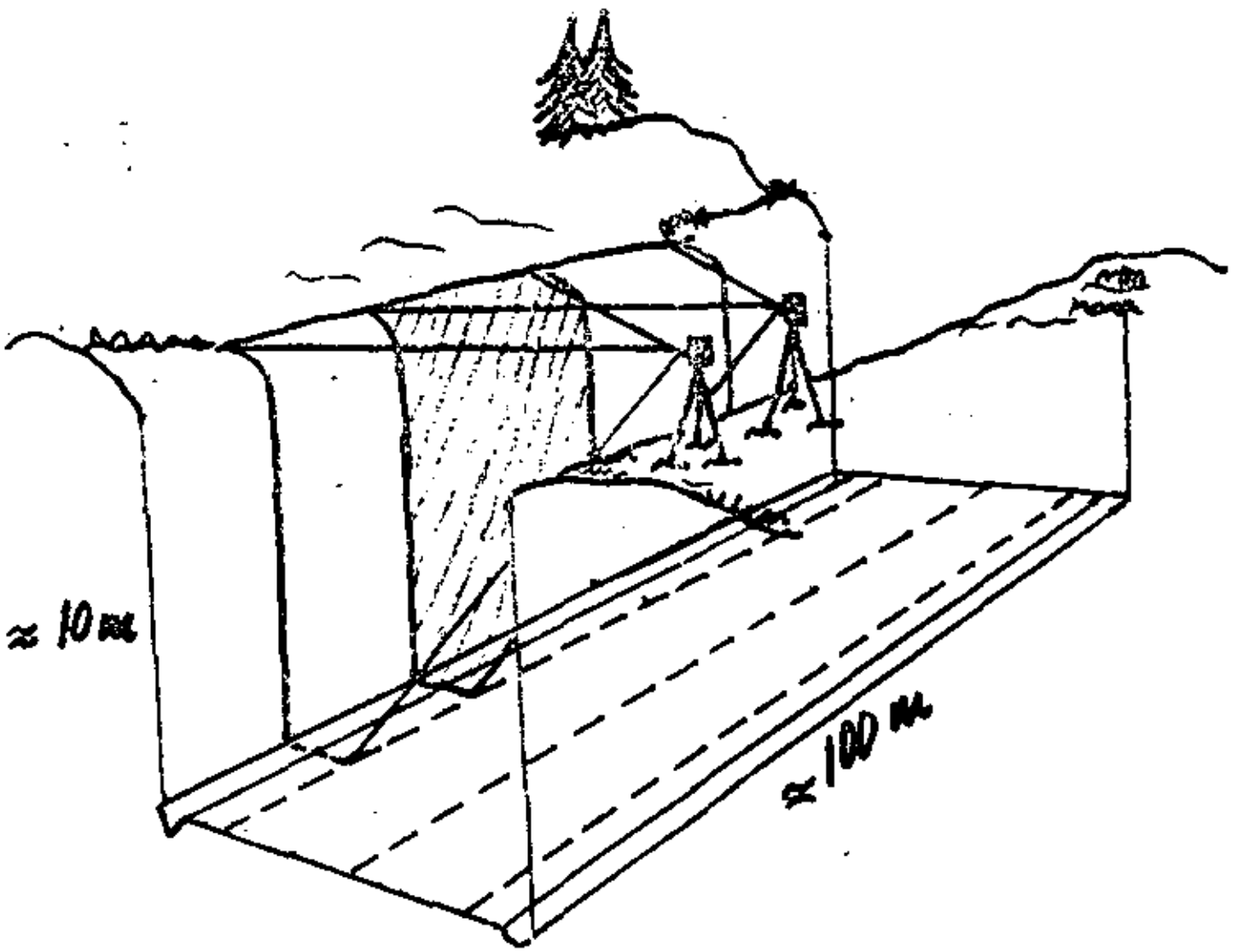
engineering
- highways
- railways
- buildings
- bridges
- dams

geology
- rock mechanics
- soil studies

application of close-range photogrammetry

- industry
  - mining
  - cars
  - aircraft
  - ships
- architecture
- archeology
- medicin
- ...

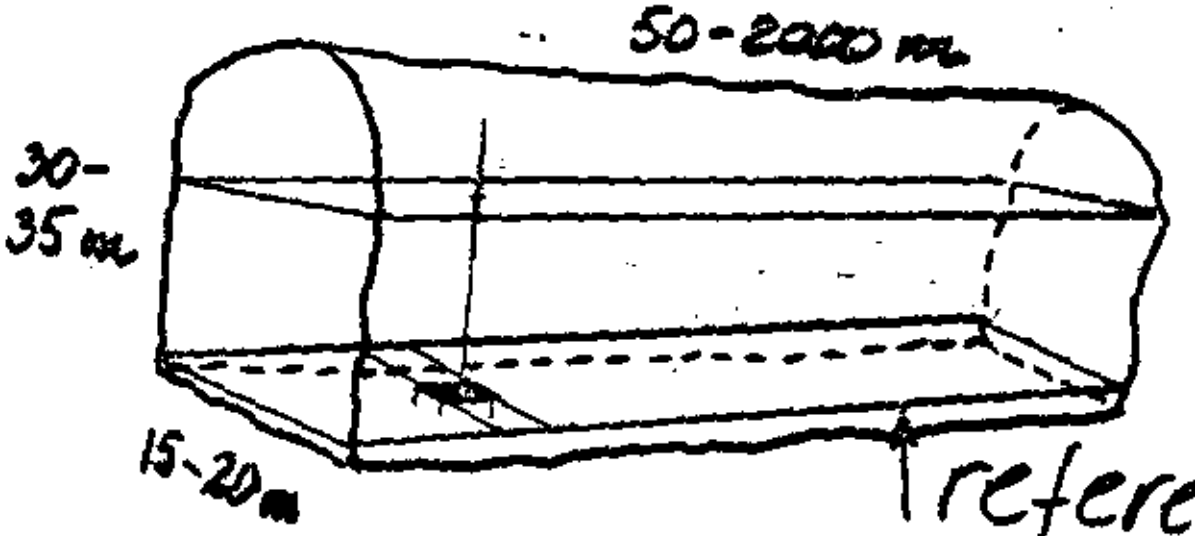
TERRESTRIAL PHOTOGRAMMETRY



DETERMINATION OF THE VOLUME OF A ROCK EXCAVATION USING DIFFERENT METHODS

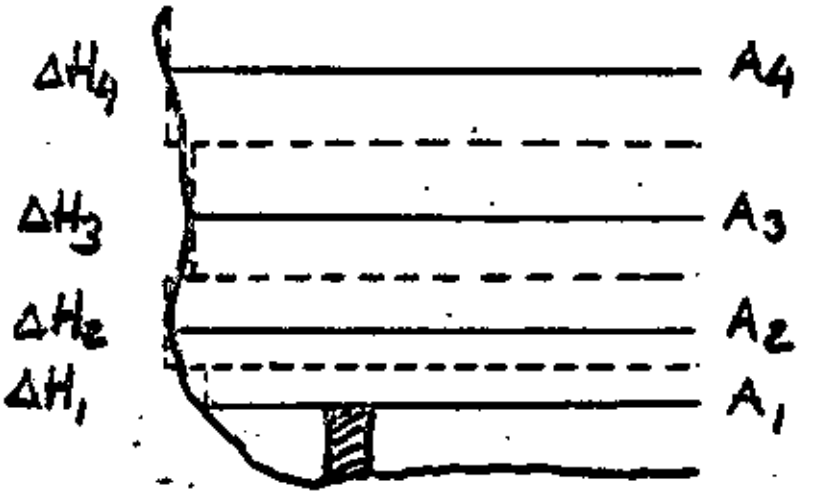
METHOD	VOLUME M^3	DIFFERENCE	
		M^3	%
TERRESTRIAL TACHEOMETRY	21418	—	—
TERRESTRIAL PHOTOGR CROSS SECTIONS	21877	+459	+2.1
TERRESTRIAL PHOTOGR DTM	21925	+507	+2.4

oil storage



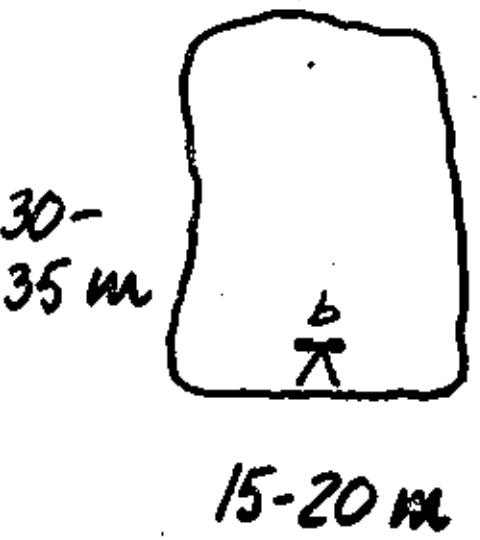
depth readings ⇒ volumes from table

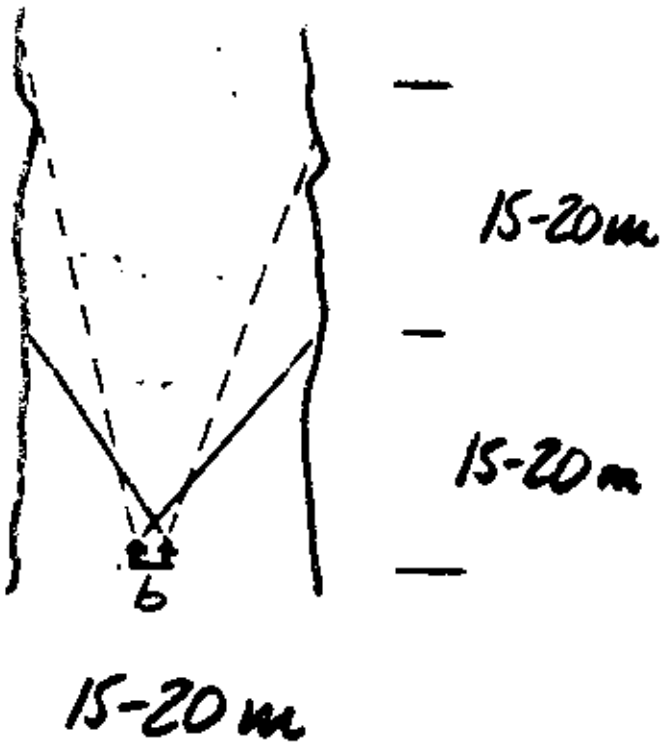
horizontal sections



$$V = \sum A_i \times \Delta H_i$$

photography

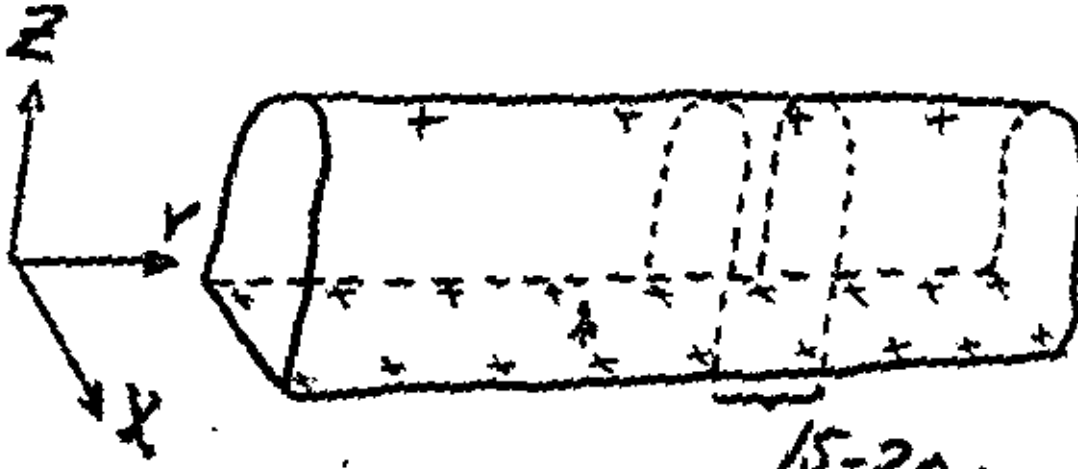




stereo-camera

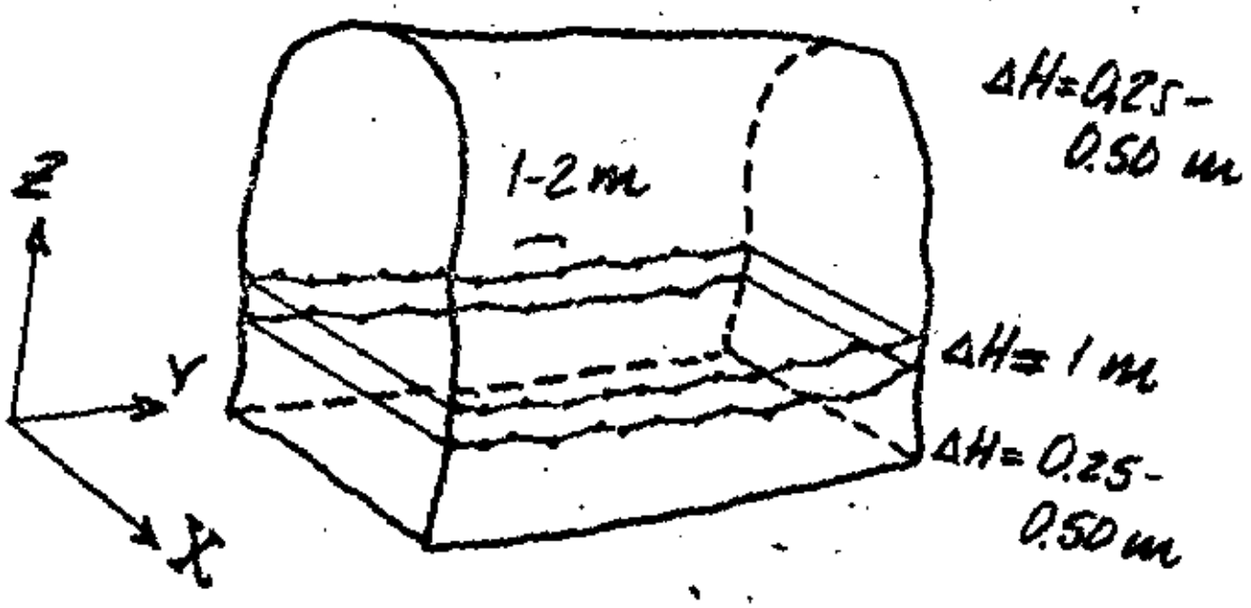
b = 120 cm

control points



+ XYZ

evaluation



- xy measured
  z given

accuracy

0.1-0.2 % of volume

vertical sections ($\approx 500\ m^2$)

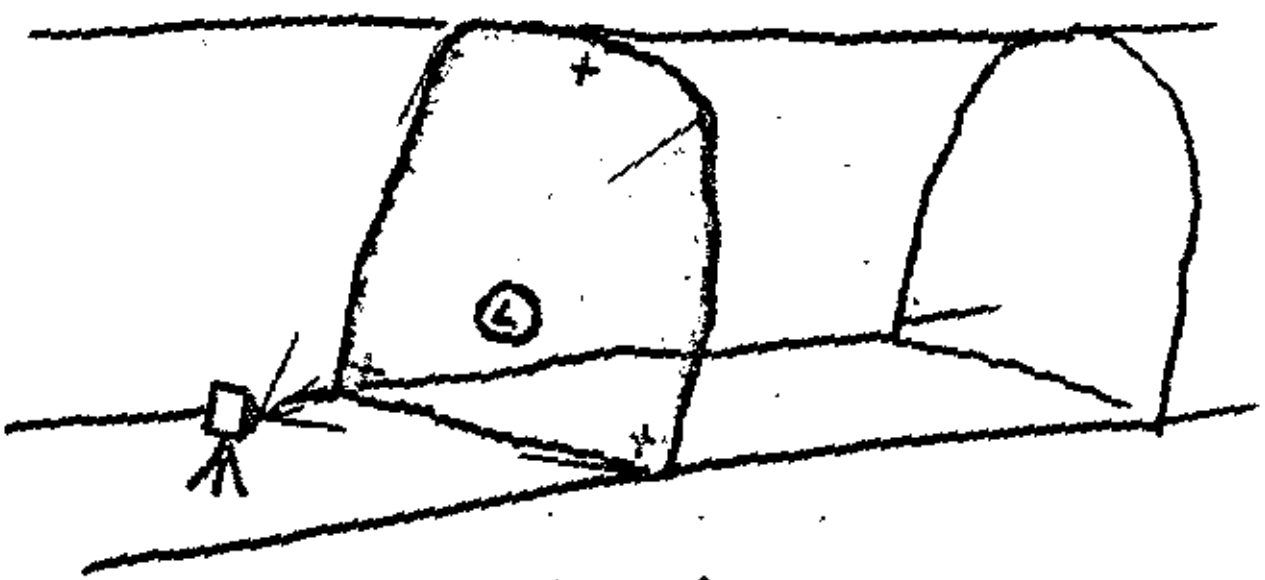
Systematic errors	‰
light slit orientation	0.7
scale	1.1
end sections	0.5
camera/film	0.7

irregular errors	
operator	$0.3/\sqrt{n}$
camera/film	$1.8/\sqrt{n}$
interpolation ("shape")	$(9.3+1.1D)/\sqrt{n}$

D = section interva

n = number of

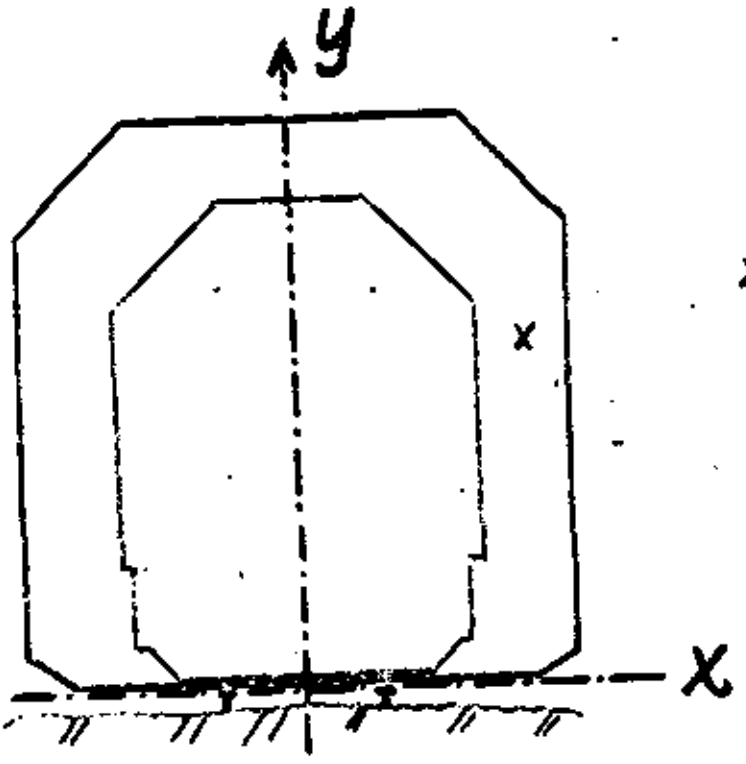
vertical sections



L = Light slit generator

+ = control points

free space along railways for large cargoes

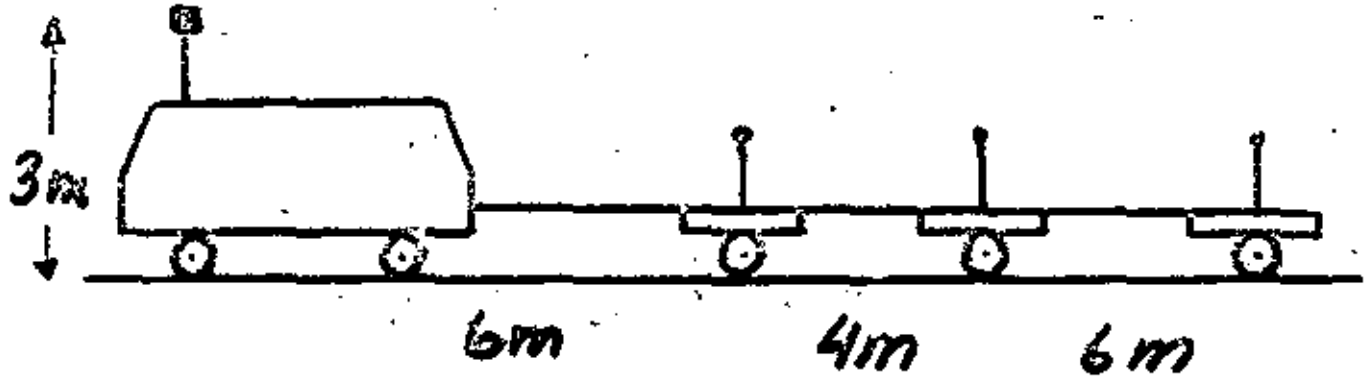


× "FOMUL"

normal load section 3400×4650 mm

investigation section 5200×5400 mm

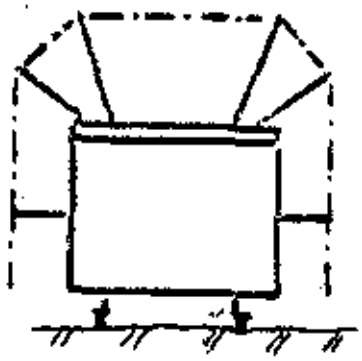
FOMUL - photography



Hasselblad MK70

53×53 mm c=60 mm

base = 1.60 m



7 reference points

foldable point-ters

FOMUL - evaluation

computation

- image coordinate refinement
- model coordinates in camera system
- FOMUL coordinates

FOMUL

accuracy : 10-40 mm

capacity : one vehicle (2 men)
= eleven vehicles
(44 men!) with
previous method

production : 80 000 objects
5000 obj./year

FOMUL - evaluation

measurement in Wild Stk and Zeiss Jena Stecometer

image coordinates and parallaxes

≥ 4 reseau points

7 reference points

FOMULs

deformation measurements

- change in geometry
- period of time
- size of object
- application
  - mechanical engineering
  - civil — " —

deformation photogrammetry

flat objects

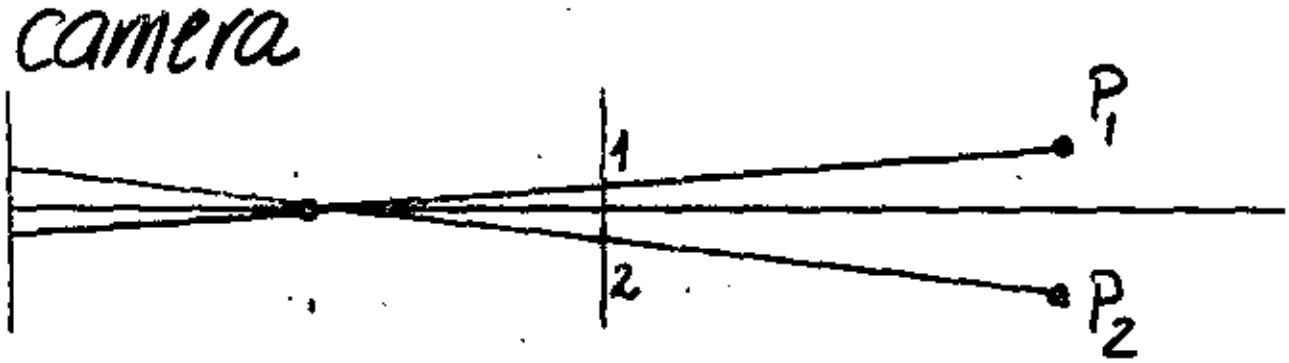
- rectification
- stereoscopic vision

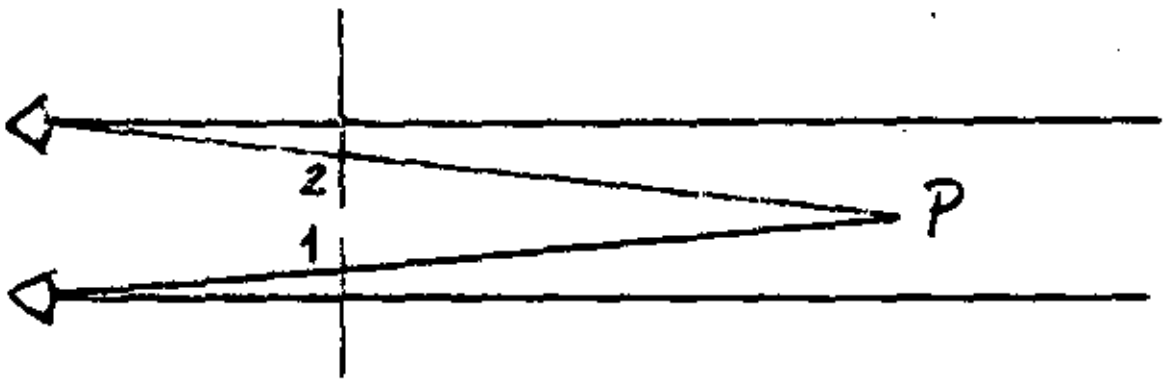
3D-objects

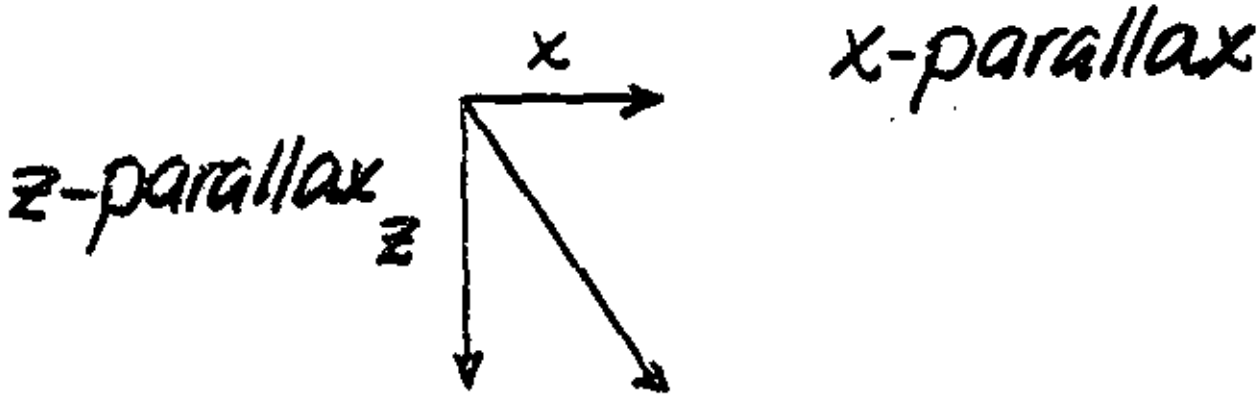
- stereophotography
- stereoscopic meas. in comparator

method	duration	object size m	relative accuracy
aerial phot.	month	10^2–10^5	10^{-5}–10^{-4}
geodesy	month	10^2–10^7	10^{-6}–10^{-5}
workshop measuring	minute	10^{-3}–10^1	10^{-5}–10^{-3}
close-range photogr.	week	10^{-1}–10^2	10^{-5}–10^{-2}
hologrammetry			

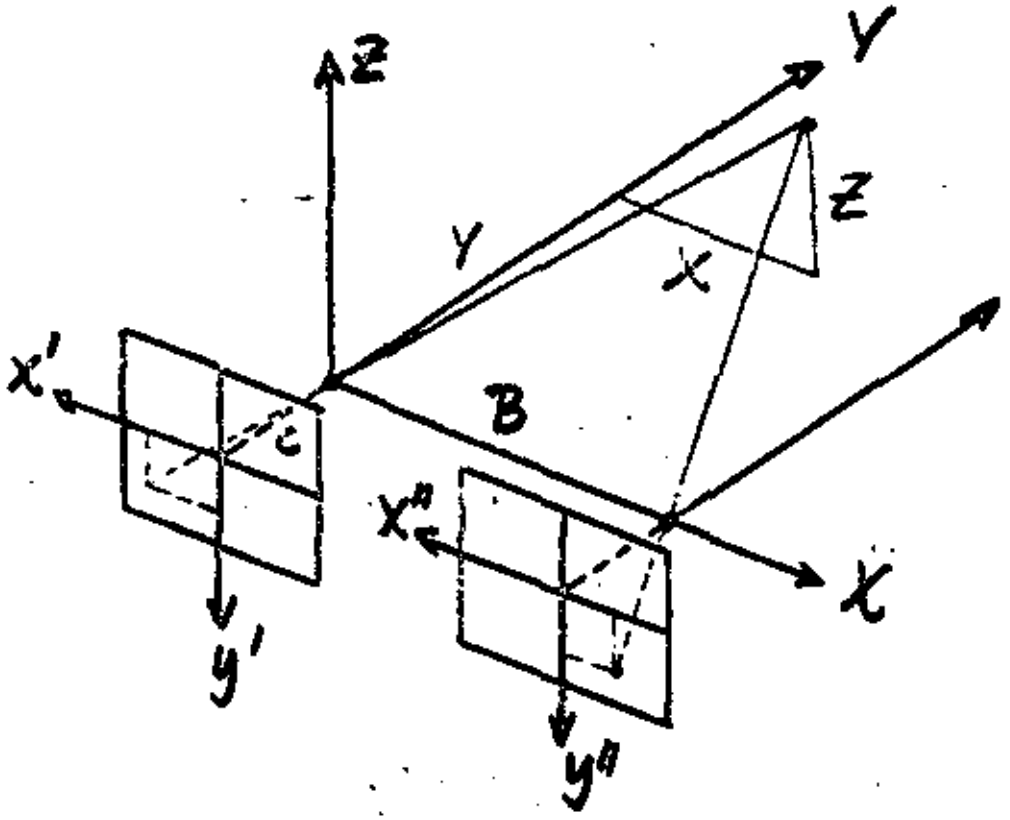
false parallaxes







the time parallax method



$$X = \frac{B}{p'} x'$$

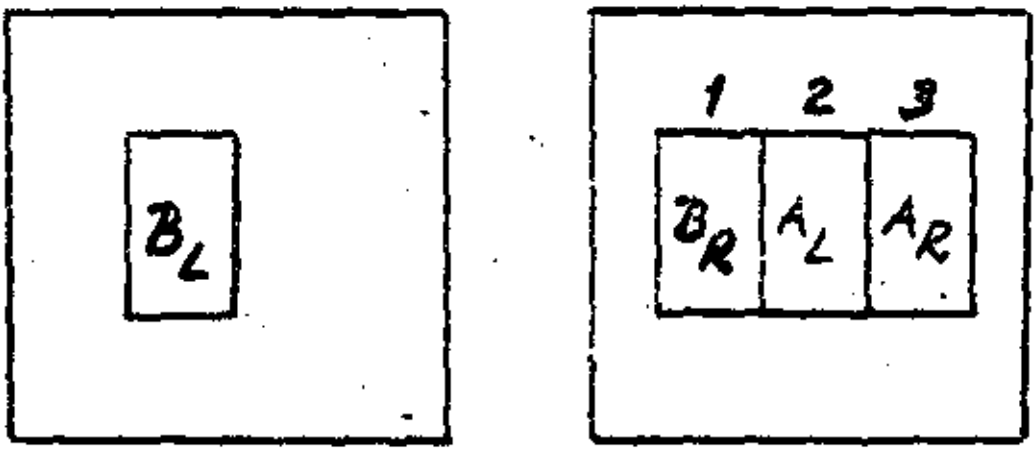
$$Y = \frac{B}{p'} C$$

$$Z = \frac{B}{p'} y'$$

$$p' = x' - x''$$

the time parallax method

stereocomparator



B = before
A = after

L = left
R = right

model	result
1 (real)	$(XYZ)_B \quad x'_B \quad y'_B$
2 (fictitious)	$x'_B, y'_B, x'_B - x'_A, y'_B - y'_A \Rightarrow x'_A \; y'_A$
3 (— " —)	$x'_B \; y'_B, x'_B - x''_A, y'_B - y''_A \Rightarrow x''_A \; y''_A$

$(XYZ)_A$

orthophotography in architectural photogrammetry

photography

- narrow-angle camera
- low $\Delta s/s$ ratio
- protruding parts off border

orthoprojection

- Y-scanning
- small scan width
- interpolation between profiles
- slow, stoppable scanning

products

- orthophoto
- line map or overlay from orthophoto
- combination of orthophoto and line map

application

+ • objects, curved or extended in depth
  • especially when painted or decorated
  • mosaics, frescos, cupolas etc.

- objects composed of staggered planes and protruding elements which cover other details (temples, cathedrals etc)

production time

stereoplotting : orthophoto

5-10 : 1

stereoplotting : line map from orthophoto

3 : 1

accuracy (true scale)

control points	1-10 mm
image/model	1 mm
orthoprojection	10 mm
copying	1 mm
assembling	7 mm
in total	15 mm

analytical plotter in close-range photogr.

+ orientation of photographs
  orthogonal projections in different planes
  improved stereo-vision
  non-metric photographs

close-range photogrammetry

state-of-the-art

metric cameras

- >30 types
- c-values: 56 — 190 mm
- format: 55×55 — 130×180 mm
- cone angle: 33 — 88 gon
- exp. time: ≥ 1/500 sec
- aperture: 3.5 — 64
- glass plates
- cut sheet film
- roll film
- reseau (Hasselblad MK70)

non-metric cameras

+ flexible focusing
  easy to handle
  cheap

- lenses have high distortion
  instability of interior orient.
  lack of fiducial marks
  no means for orientation

non-metric cameras

complete	calibration
partial	— " —
self	— " —
on-the-job	— " —
no	— " —

state-of-the art

evaluation instruments

- plotters for "normal case"
- universal first order plotters
- mapping plotters
- analytical instruments

state-of-the-art

results

graphical

digital

prel design

- photography
- block triangulation
- evaluation of photos
- map specifications

prel design

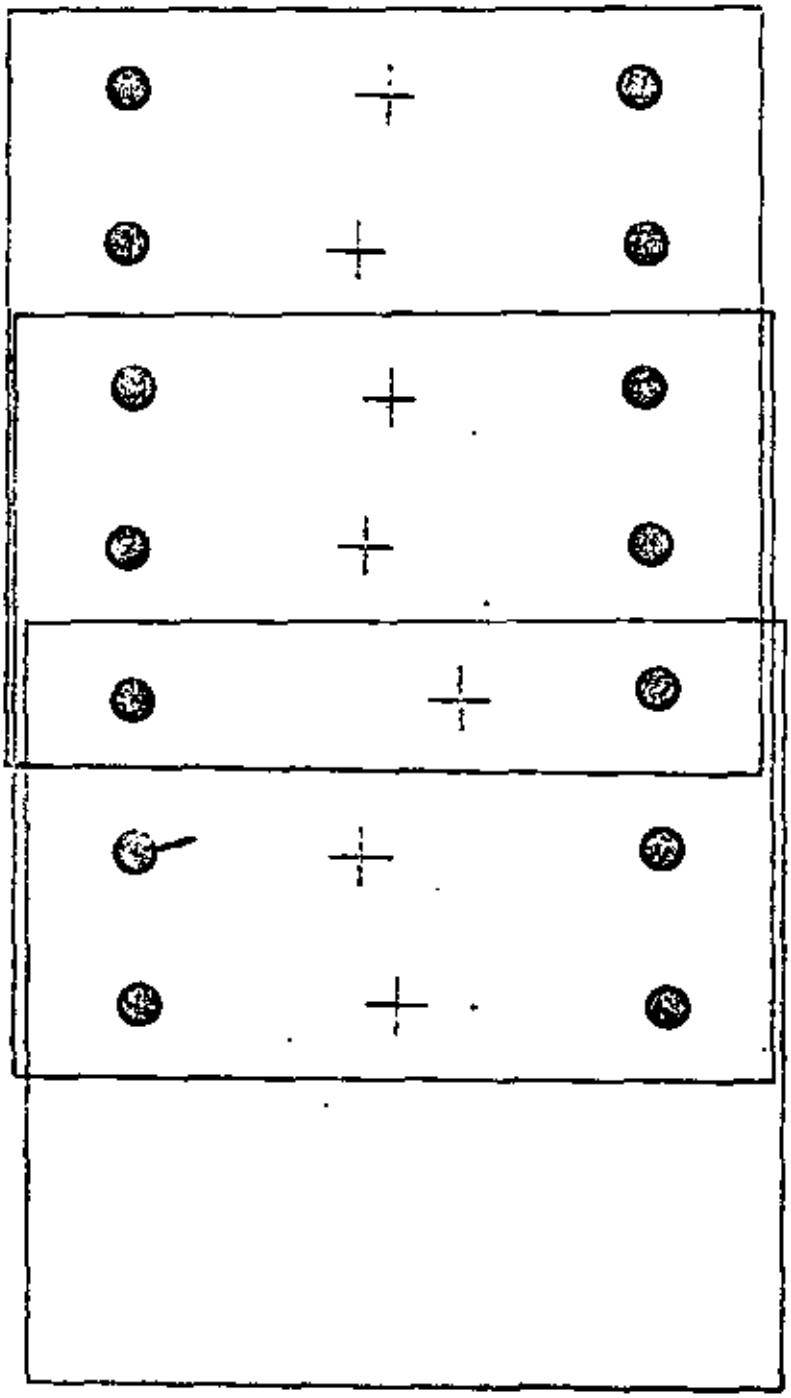
aerial photography

- photo scales 1:8000-1:15000
- b/w
- colour

ground control

- planimetric
- elevation

geodetic control



● = Planimetric and elevation (XYZ)

+ = Elevation (Z)

aerial triangulation

strips – blocks

size

analogue – analytic

mono –

stereo –

bundle – independent model

systematic errors

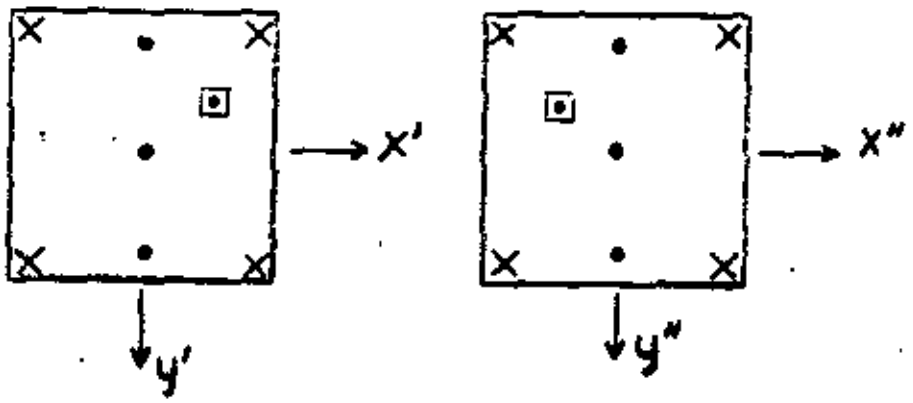
tie-points

aerial triangulation

decisive factors

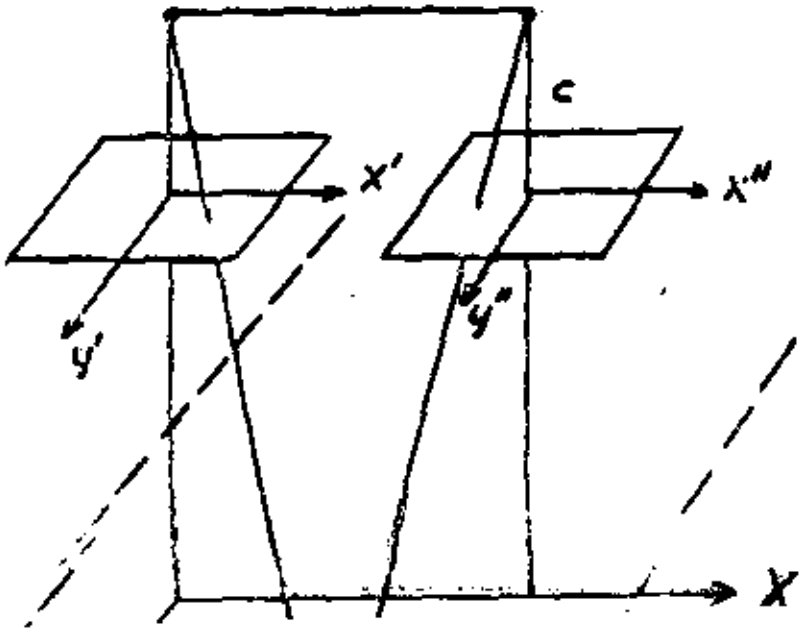
- accuracy requirements
- state of superior triangulation net
- topography and vegetation
- field surveying technique
- personnel and instrument costs

three dimesional analytic model triangulation

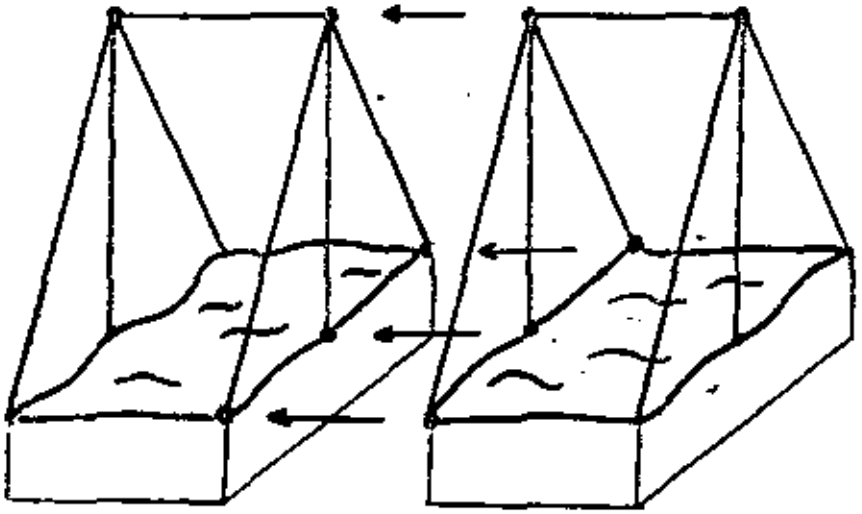


meas. of photo coordinates

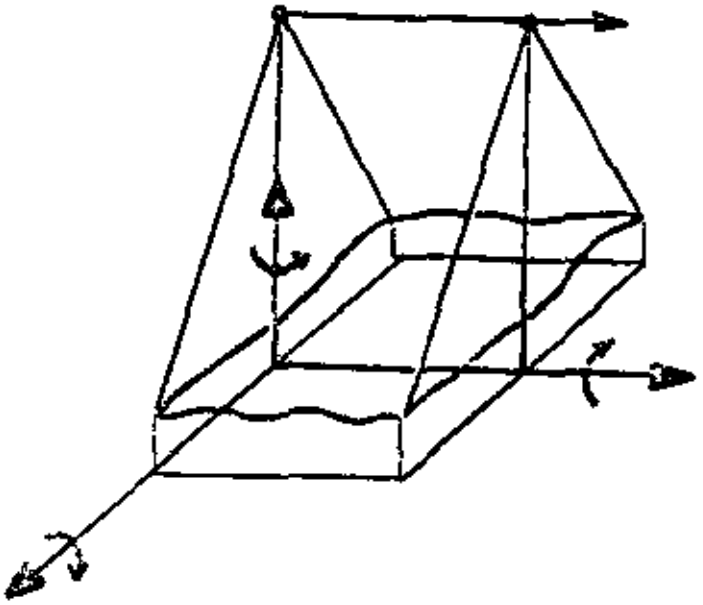
× = fiducial marks
• = tie points
⊡ = control points



numerical relative orientation

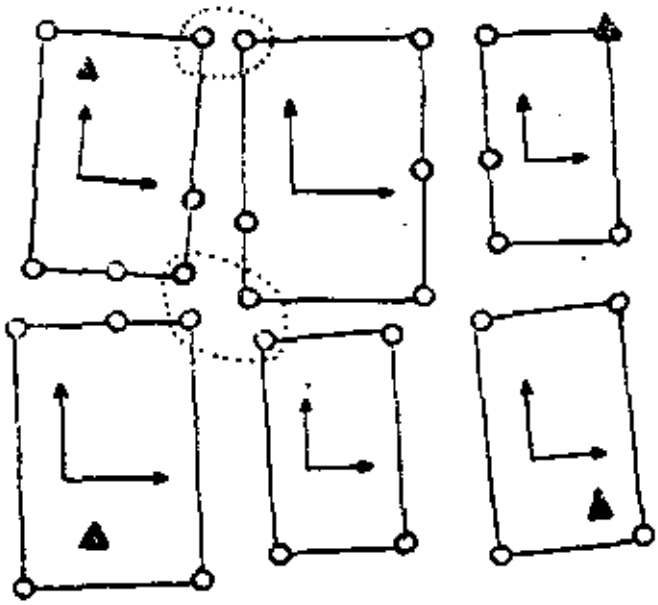


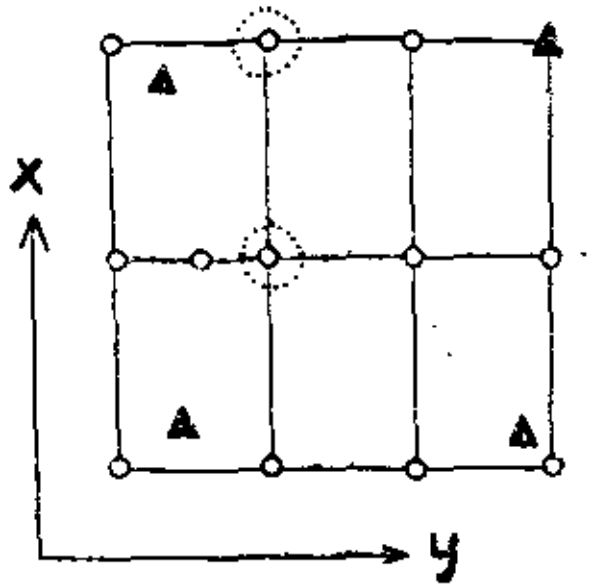
connection of models



final adjustment

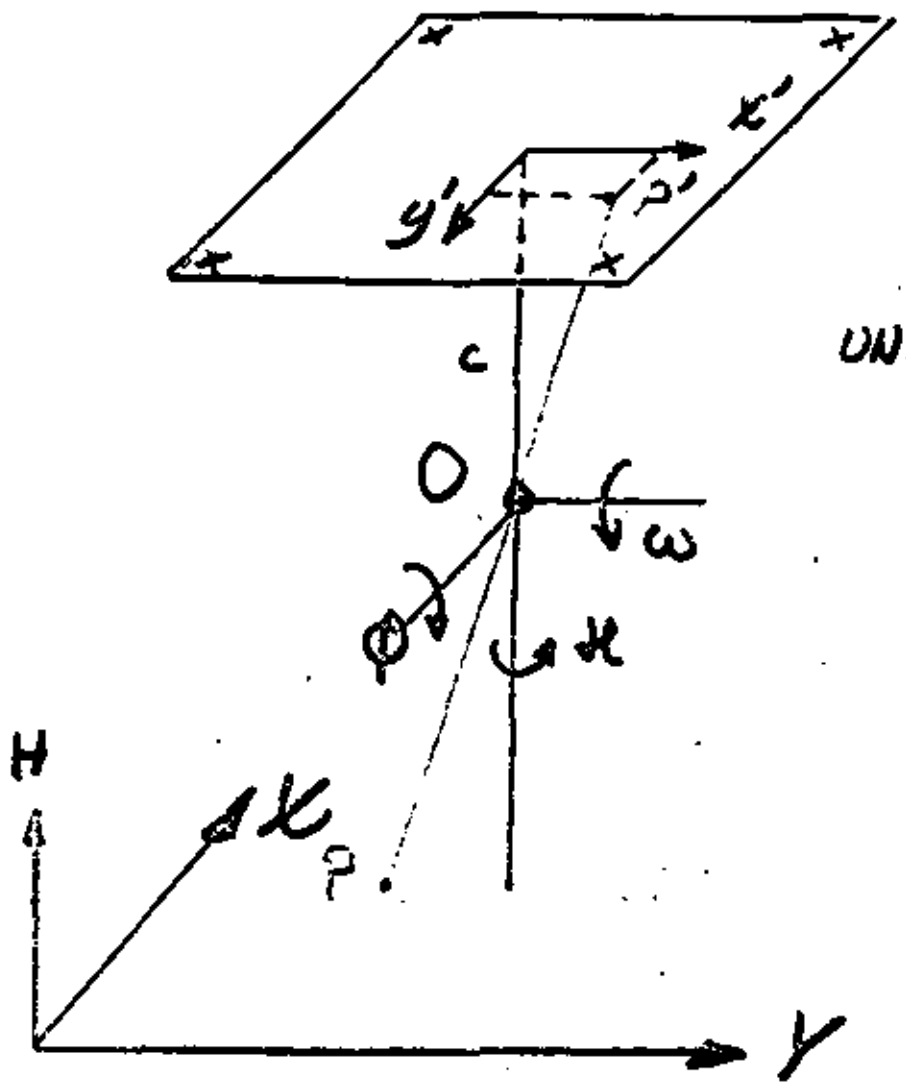
photogrammetric block adjustment





AERIAL TRIANGULATION

BUNDLE ADJUSTMENT



UNKNOWNS

$X_o\ Y_o\ P_o$

$\kappa\ \varphi\ \omega$

$X_p\ Y_p\ H_p$

method of adjustment		number of unknowns
independent models	model	$dX_o\ dY_o\ dZ_o$ $d\eta\ d\xi\ d\alpha$ S
bundle adj.	photos	$X_o\ Y_o\ Z_o$ $\varkappa\ \varphi\ \omega$
	tie points	$X\ Y\ Z$
	elevation control	$X\ Y$
	planimetric control	Z

block adjustments

accuracy studies

1. theoretical
   - algebraic
   - numerical
     - matrix inversion
     - simulation

2. empirical
   - test field
   - controlled experiments
     (repeated measurments)

analytic independent model triangulation

empirical results of sub-operations

1) transformation on fiducial marks	10 µm (30 µm)
2) relative orientation	7 (15) µm
3) model connection	13 (30) µm

Systematic error correction

I. directly
system calibration
on test field

II indirectly
compensation of effects
= self calibration by
additional parameters

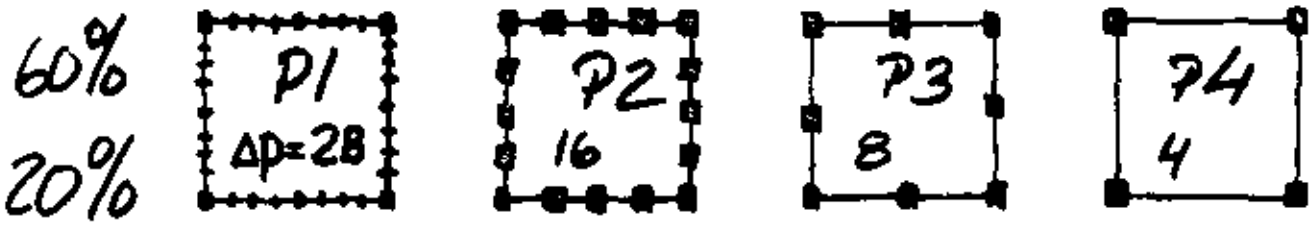
- proper choice
- correlation
- significance
- automatic operational

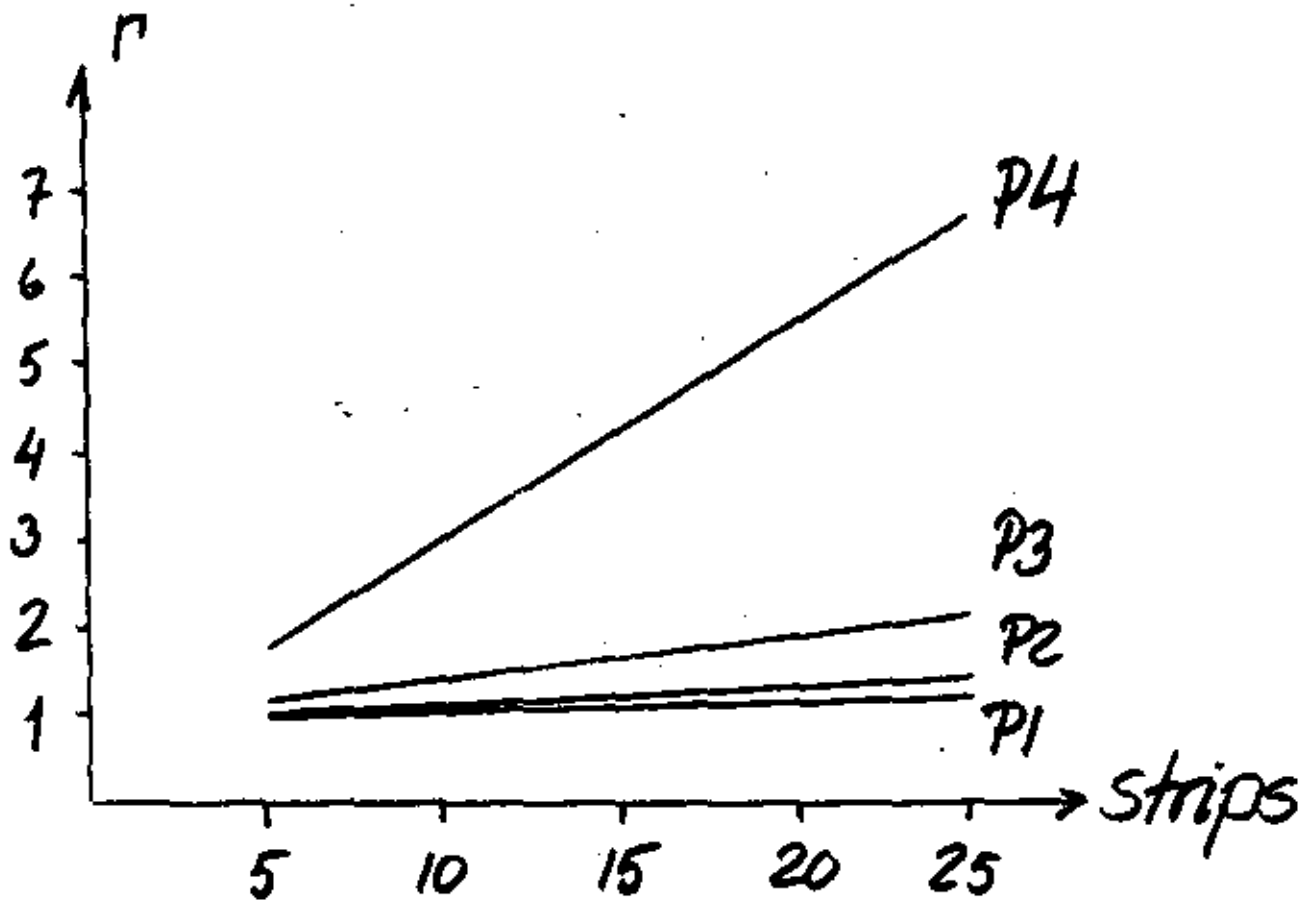
block adjustment, results

2) Oberschwaben independent models

control		rmse, μm			
		without self calibration		with self calibration	
x, y	z	x, y	z	x, y	z
i=2	i=4	10	15	6	14
4	8	13	19	7	17
8	12	20	22	7	19
11	25	22	65	8	27

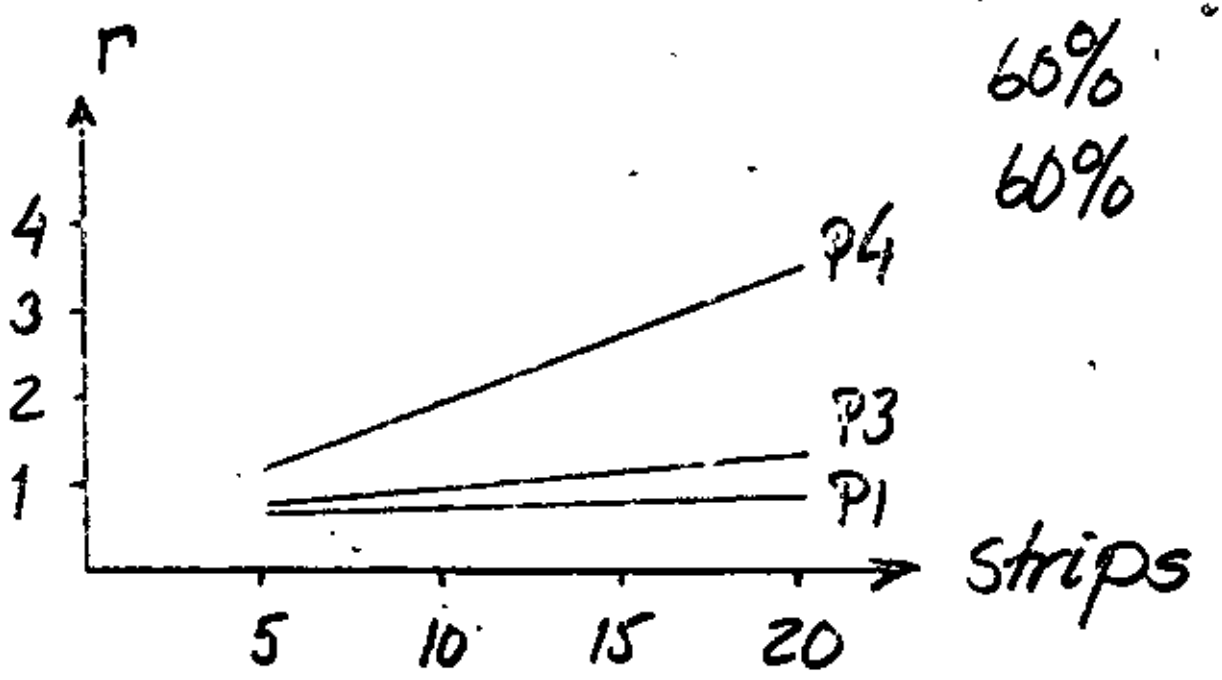
planimetric accuracy





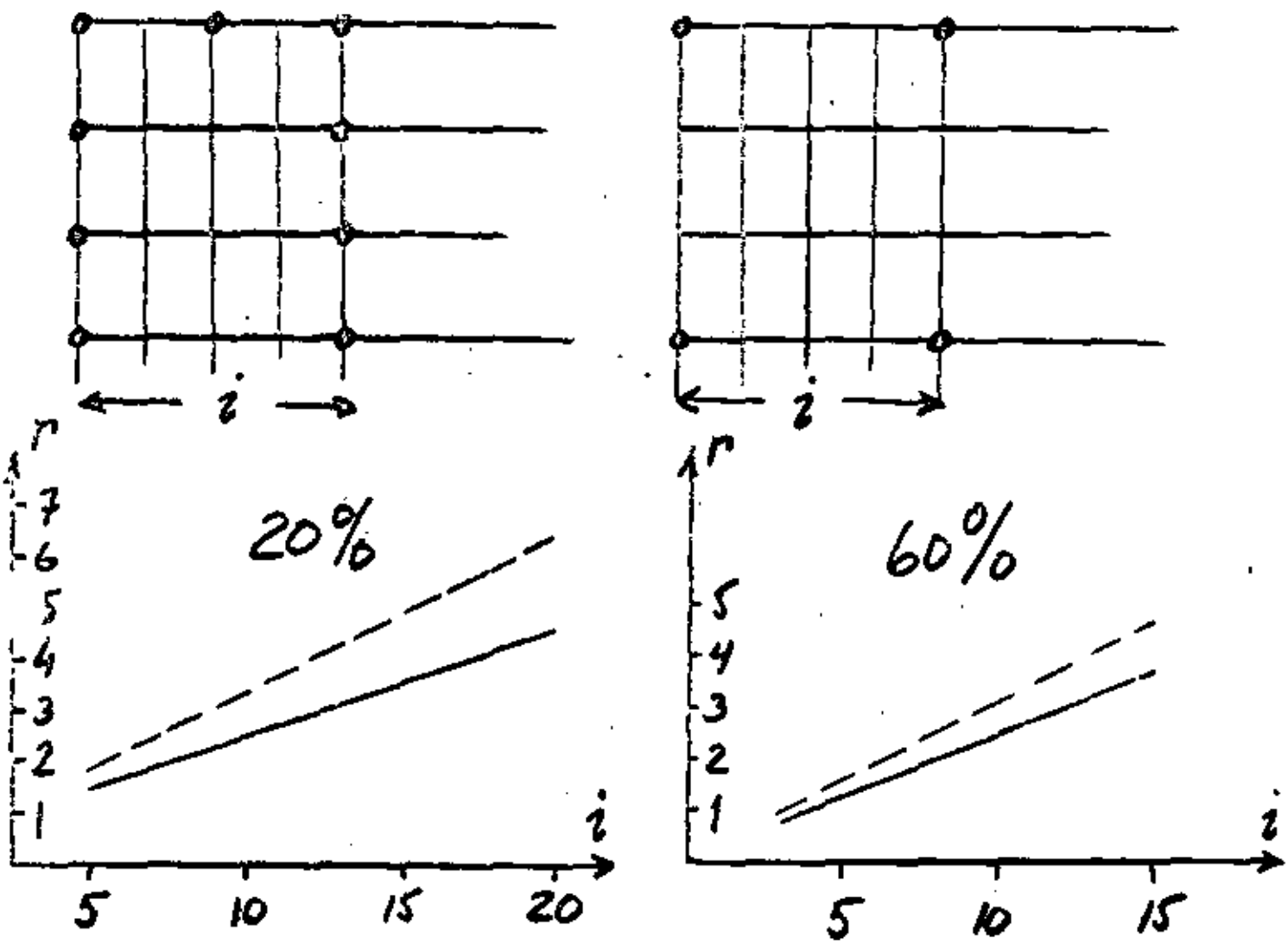
$$r = \frac{\text{"block adj."}}{\text{"single model"}}$$

planimetric accuracy



$$\frac{r_{20\%}}{r_{60\%}} = 1.4\text{-}1.6$$

height accuracy



block adjustment, result-

1) Oberschwaben — bundle block
1:28000 q=20% 104 photos

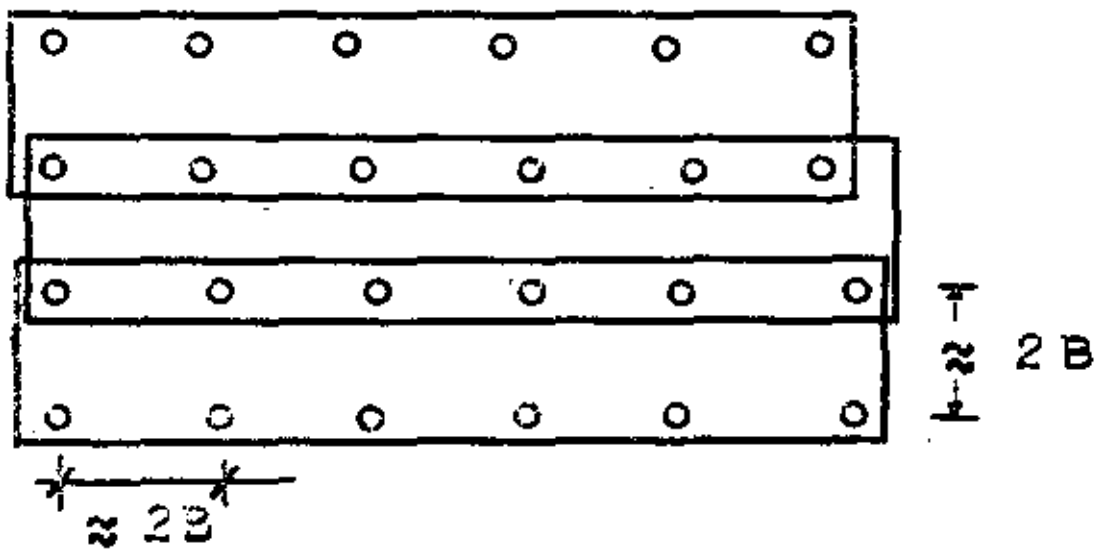
control		rmse, µm			
x,y	z	x,y	z	x,y	z
i=2	i=4	9	16	5	12
4	8	14	22	6	15
8	12	24	28	7	16
11	25	25	44	8	19
		without self-calibration		with	

bundle adjustment

$X, Y \approx 0.65$ · "independent model"

$h \approx 0.75$ · "independent model"

geodetic control in blocks



○ planimetric control

□ elevation control in every model

prel design

evaluation of photos

maps 1:1000 – 1:5000

contours 1 – 5 m

cross-sections, profiles

DTM

3D – design

analog

computer-aided

instruments

analog

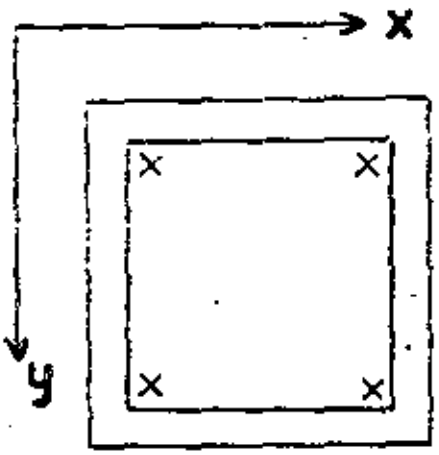
- optical projection
- mechanical projection

analytic

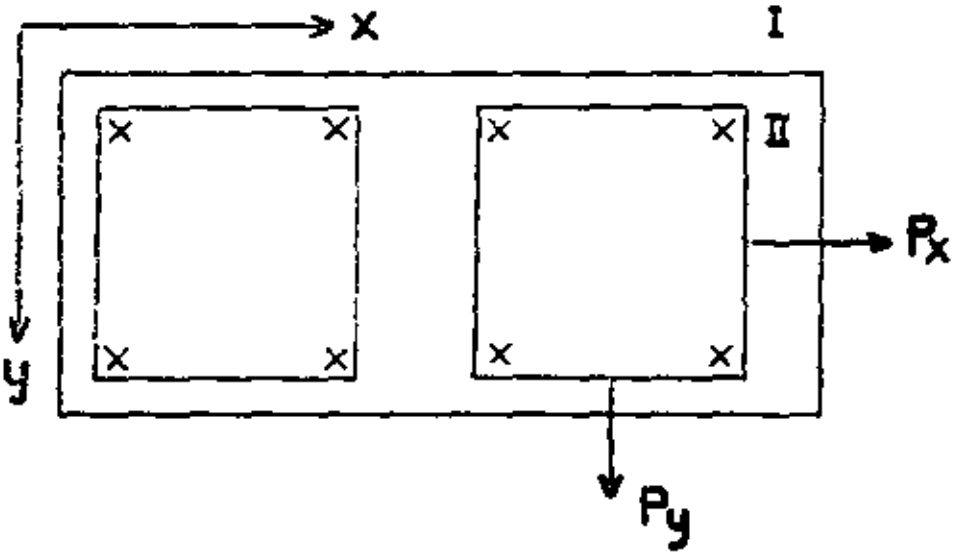
- comparators
- analytic plotters

comparators

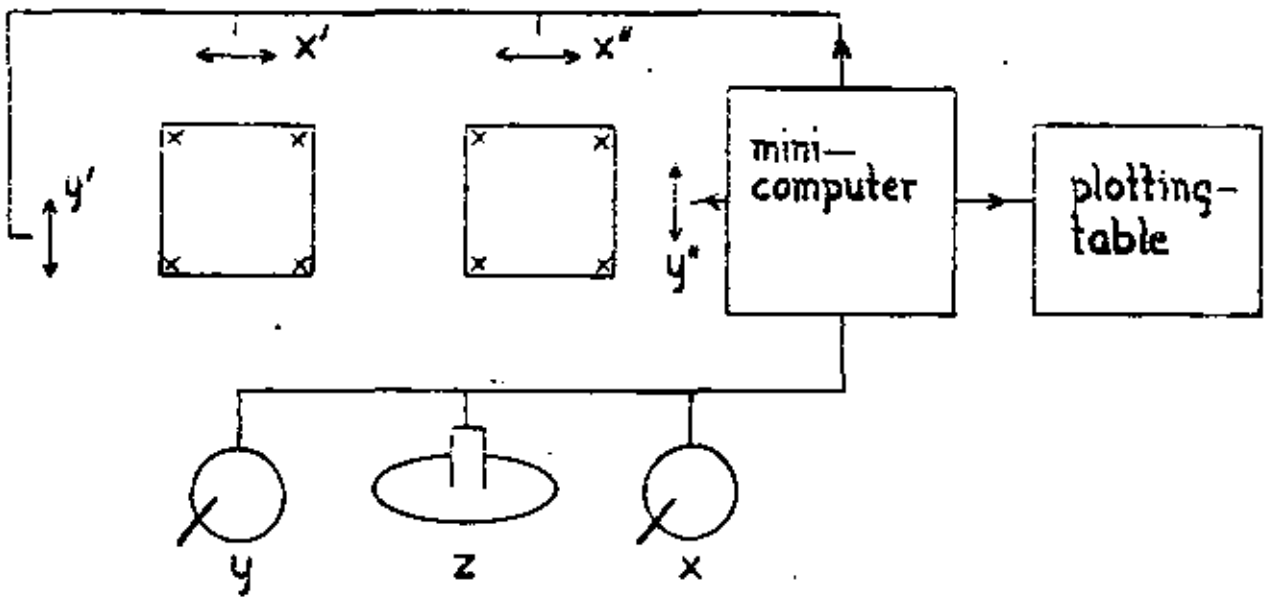
mono-



stereo-

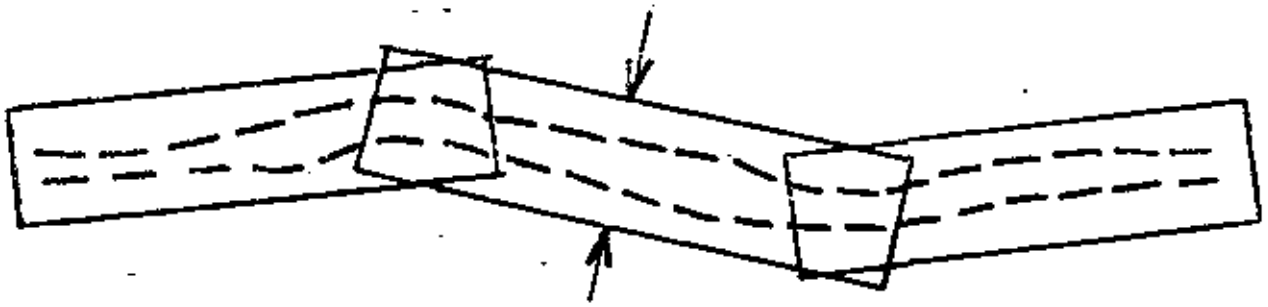


analytic plotter



prel design

aerial photography



2-3 km

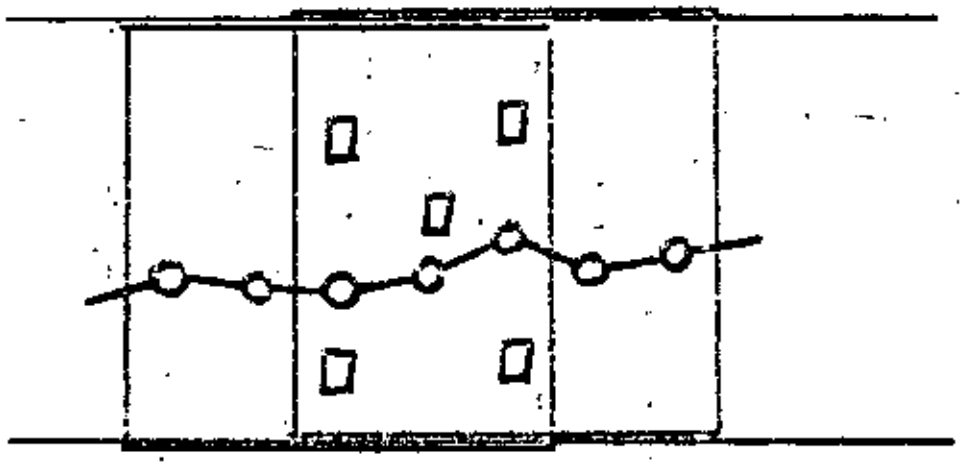
photo scale 1:10000 - 1:13000

altitude 1500 - 2000 m

panchromatic
or
coloured film

prel design

ground control



○ planimetric control

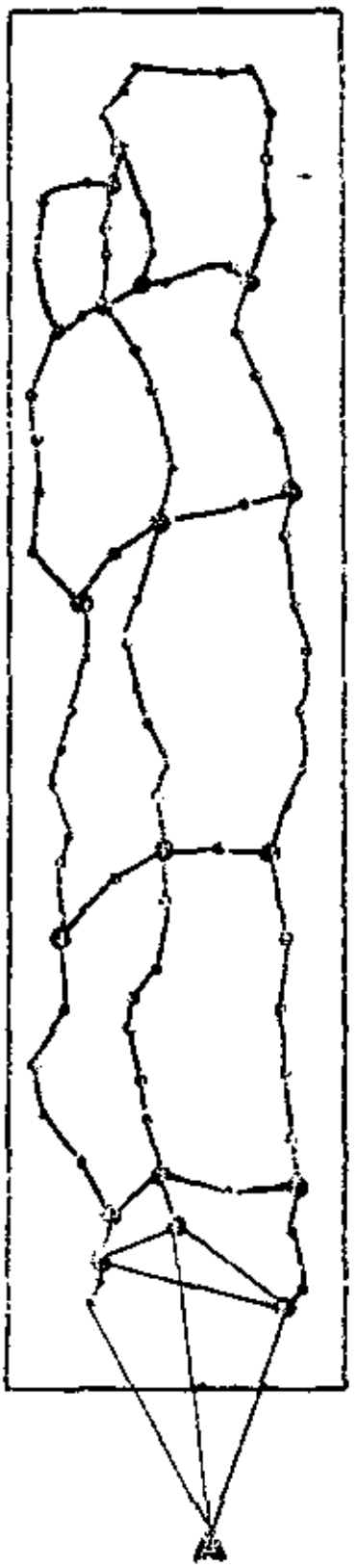
□ elevation control

aerial triangulation

basic situation

- single strip
- photo scale 1:10000
- appr. 10 models
- narrow area of interest
- basic traverse necessary
- levelling will always be made within the area of interest

Test area Örebro



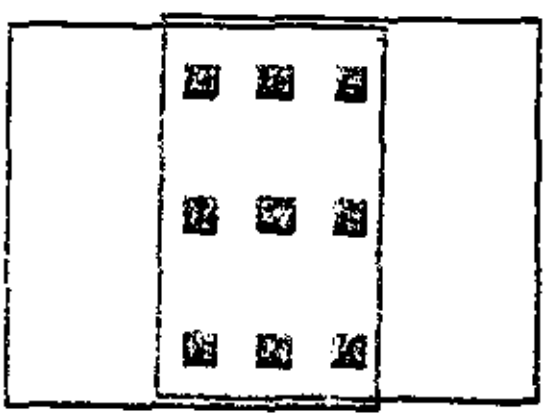
flying height: 2000 m

photo scale: 1 : 13000

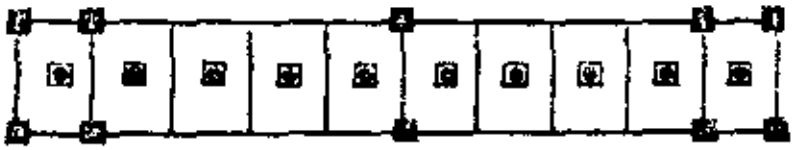
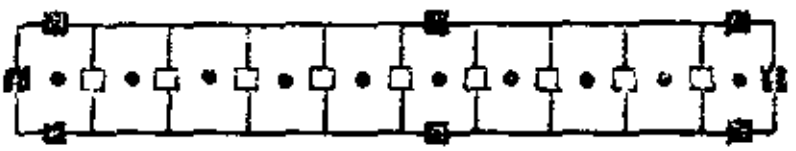
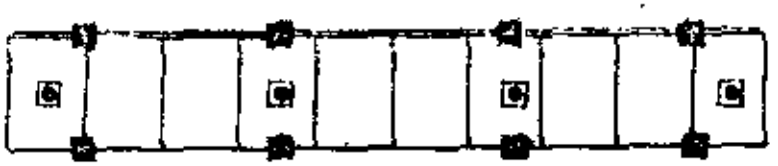
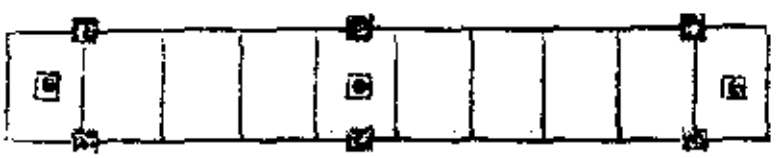
strip length: 10 mod

number of sign. points: 87

number of natural points: 63



Results

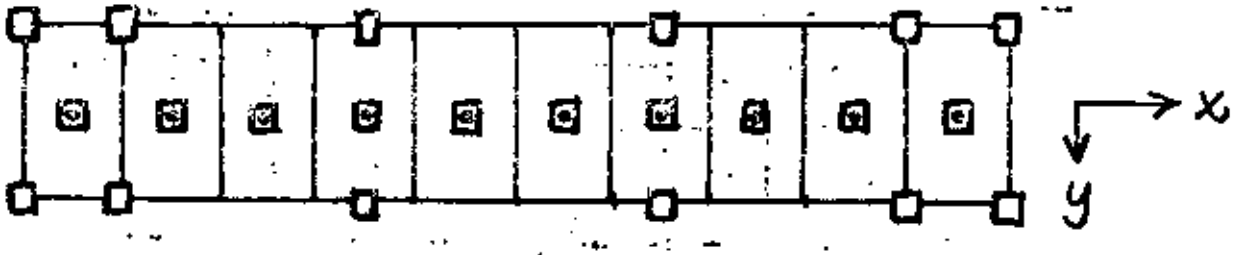
	$\hat{f}_x$	$\hat{f}_y$	$\hat{f}_n$	$\hat{f}_{nn}$
	cm			
	11	14	16	19
	11	14	14	18
	11	14	20	23
	11	14	14	17
	10	17	13	18
	18	33	15	20

- = Signalized planimetric control

.. = Signalized elevation control

■ = Natural elevation control

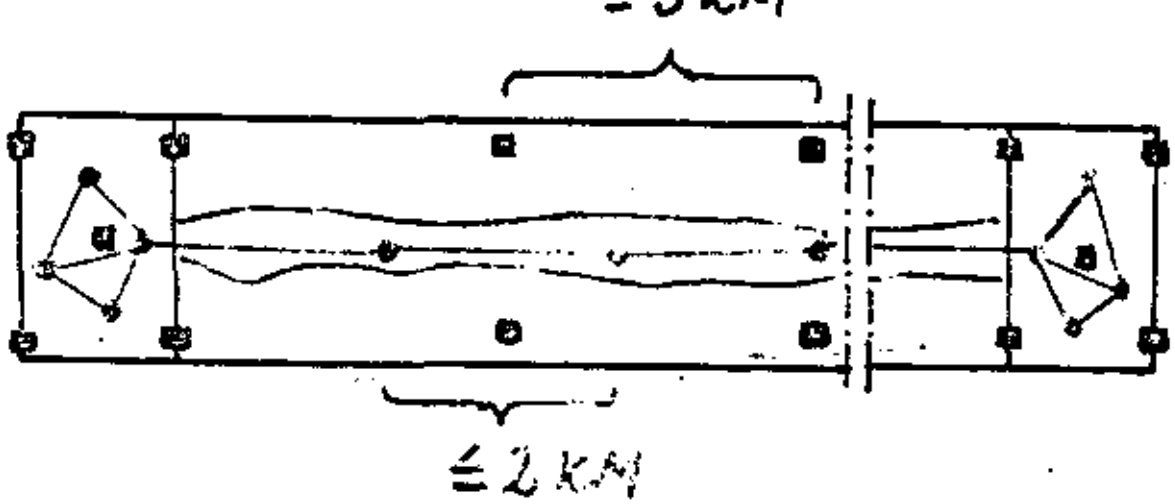
test area "Örebro"

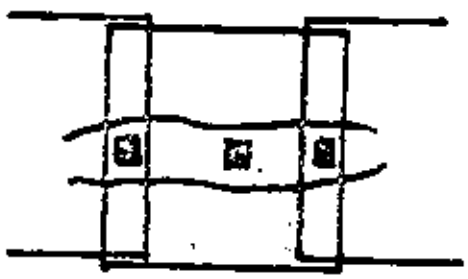


	x sign.	y sign.	z sign.	z nat.
No. of test points	47	47	47	41
aerial triang. rmsq errors, cm	11	14	16	19
separate models rmsq res., cm	8	9	10	14

AERIAL TRIANGULATION

recommended distribution of geodetic control



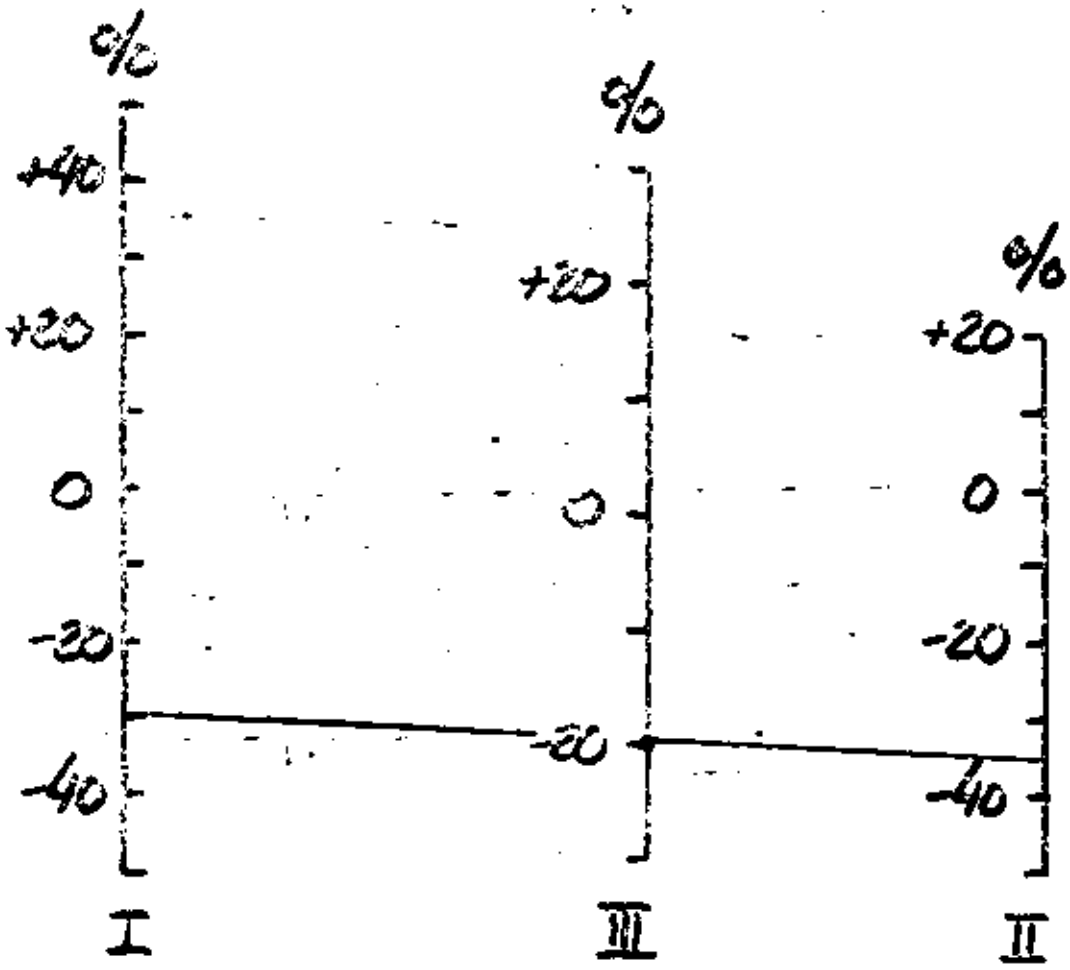


φ

dH

aerial triangulation

economic aspects



estimated changes in costs when using aerial triangulation

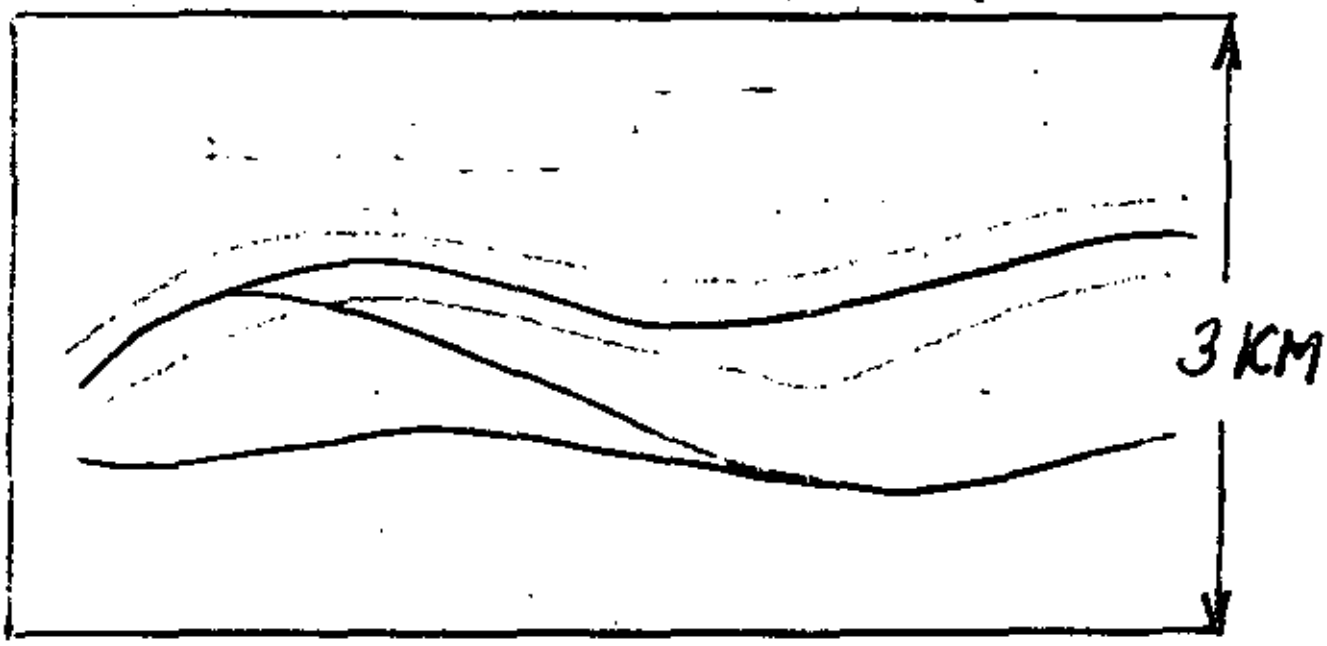
I reconnaissance and bench marks

II measurement of traverse

III total costs

PRELIMINARY DESIGN

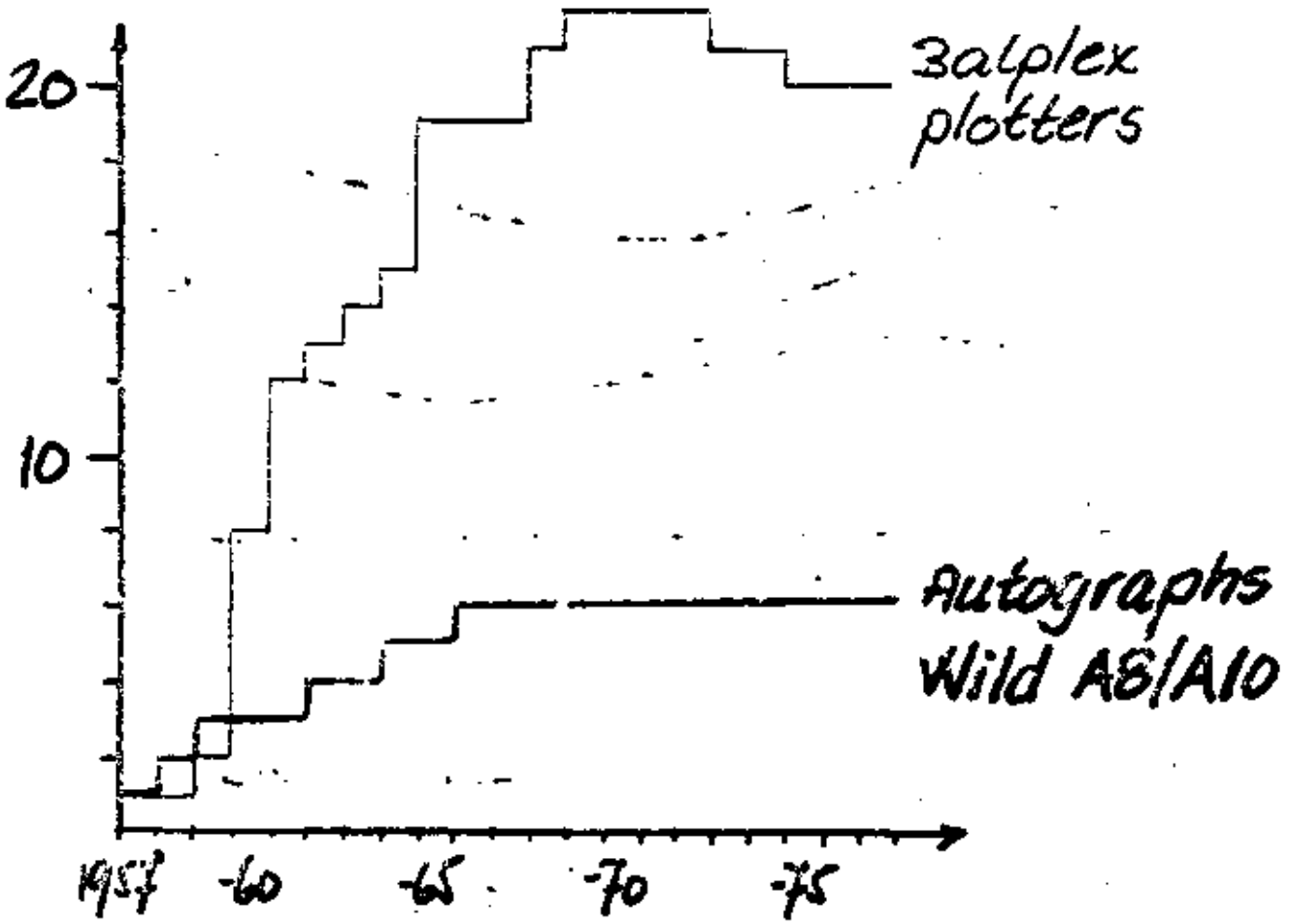
DETERMINATION OF FEASIBLE ROUTES



BALPLEX PLOTTER

1:4000

map production instruments



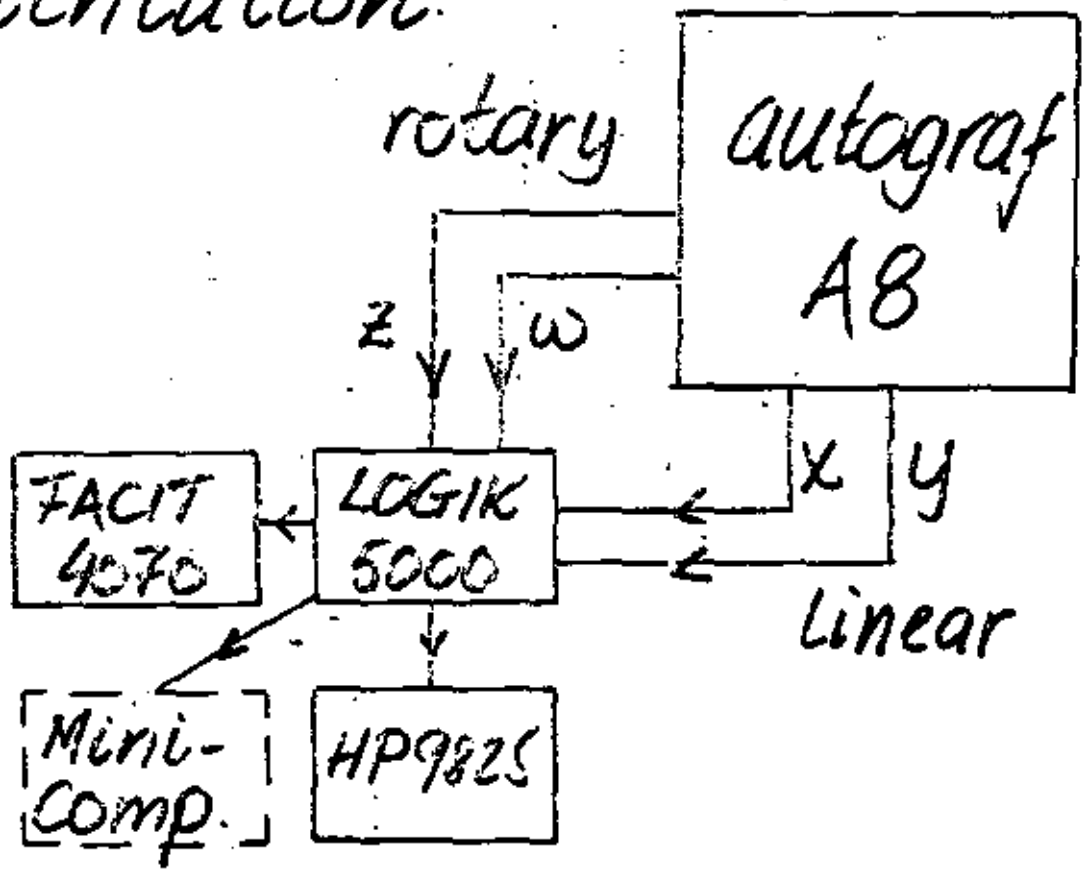
map production

instruments	coordinate recording device
1 Wild A10	Ek 8
2 Wild A8	LOGIK 5000
1 Wild A8	SAAB UE-211-1
1 Wild A8	Ek 20
1 Wild A8	

20 Balplex Plotters

map production

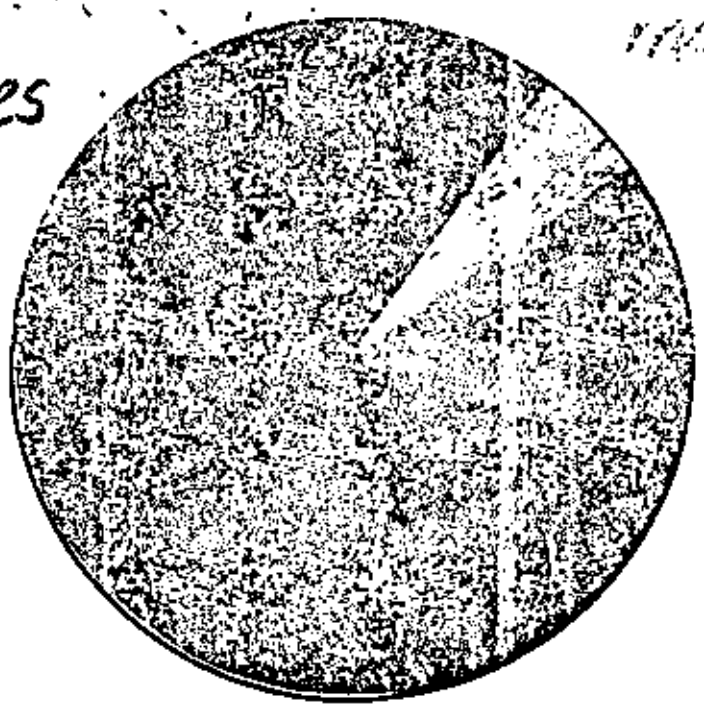
numerical orientation



map production

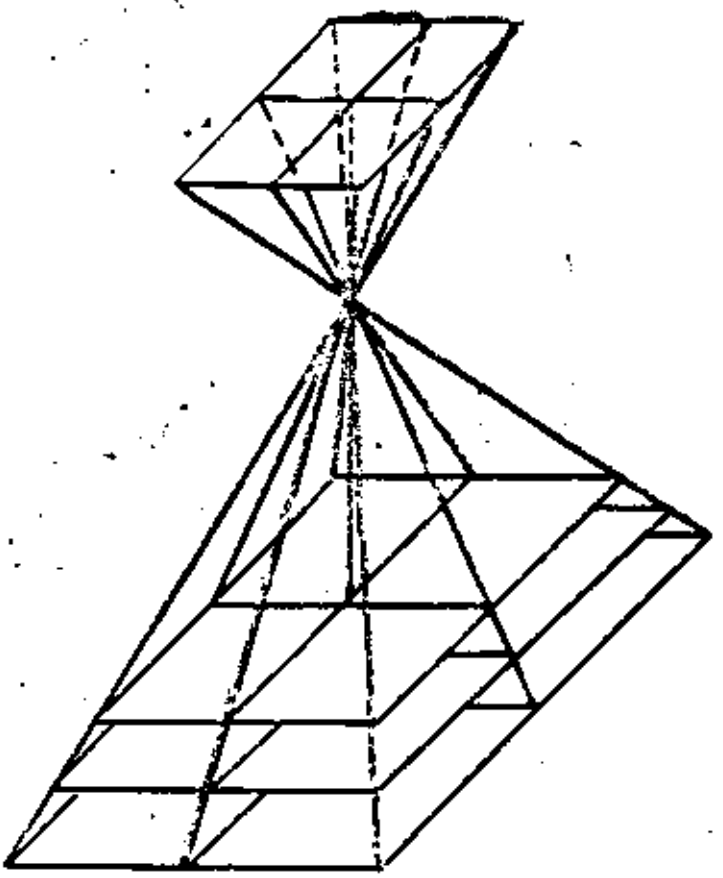
map scale	%
1:2000	90
1:1000	10

cost distribution



map production

instrument tests



standard errors

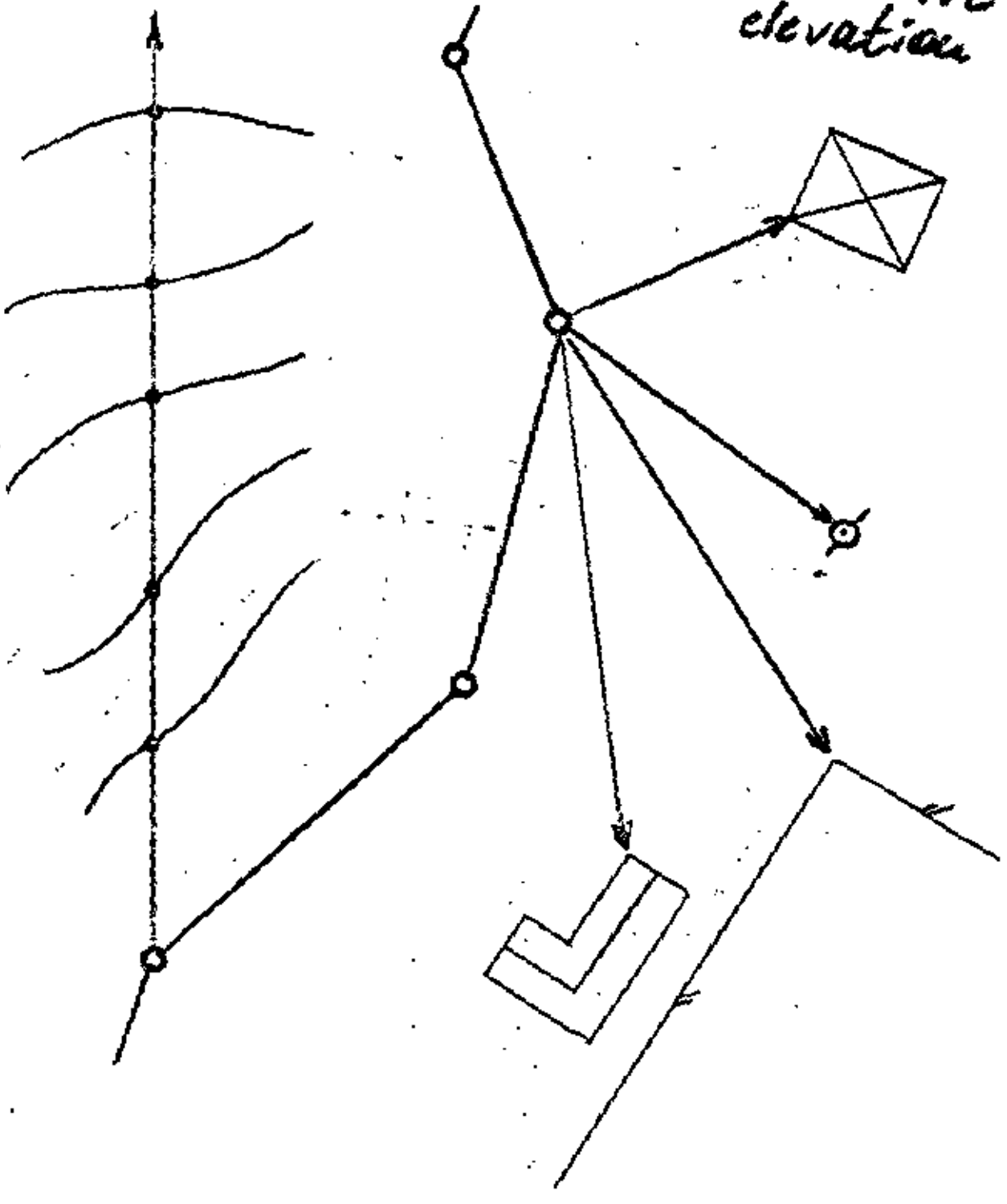
AB : 3.5 – 7.0 μm (1967 – 1977)

A10 : 2.5 – 3.7 μm (1972 – 1977)

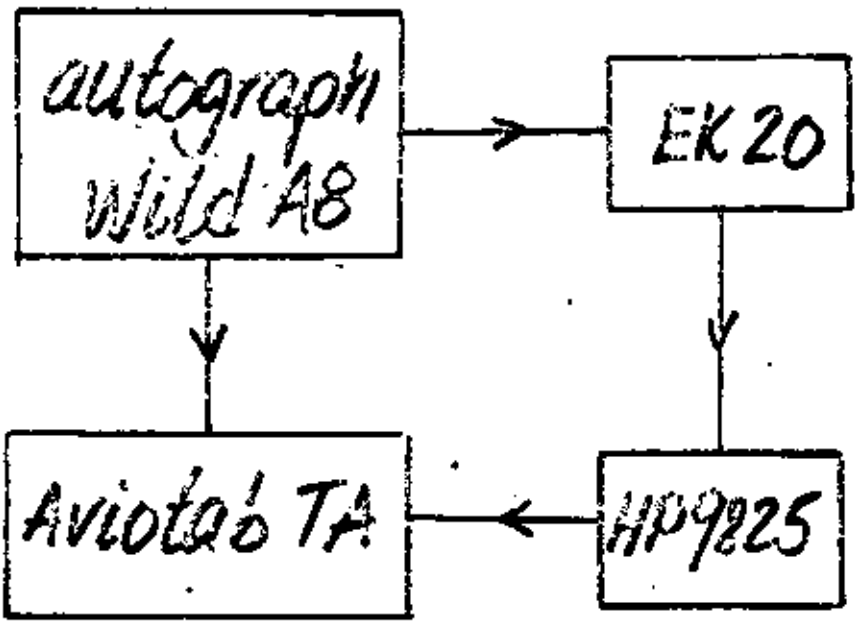
map production

field check

position
content
elevation



computer assisted mapping



map production specifications

accuracy level	application
I	special projects
II	city areas
III	towns and rural areas with high land values
IV	other rural areas

map specifications

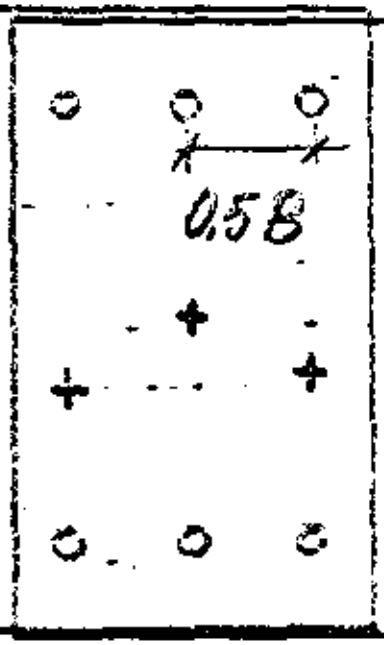
examples

accuracy level	mapping		field survey closing errors	
	map scale	photo scale	traverse	levelling
II	1:500	1:4000	$0.125\sqrt{L}$	$0.015\sqrt{L}$
III	1:1000 1:2000	1:8000 1:10000	$0.250\sqrt{L}$	$0.030\sqrt{L}$
IV	1:1000 1:2000	1:10000 1:30000	$0.600\sqrt{L}$	$0.060\sqrt{L}$

L = total length in km

geodetic control; no a.t.

II:



○ XYZ

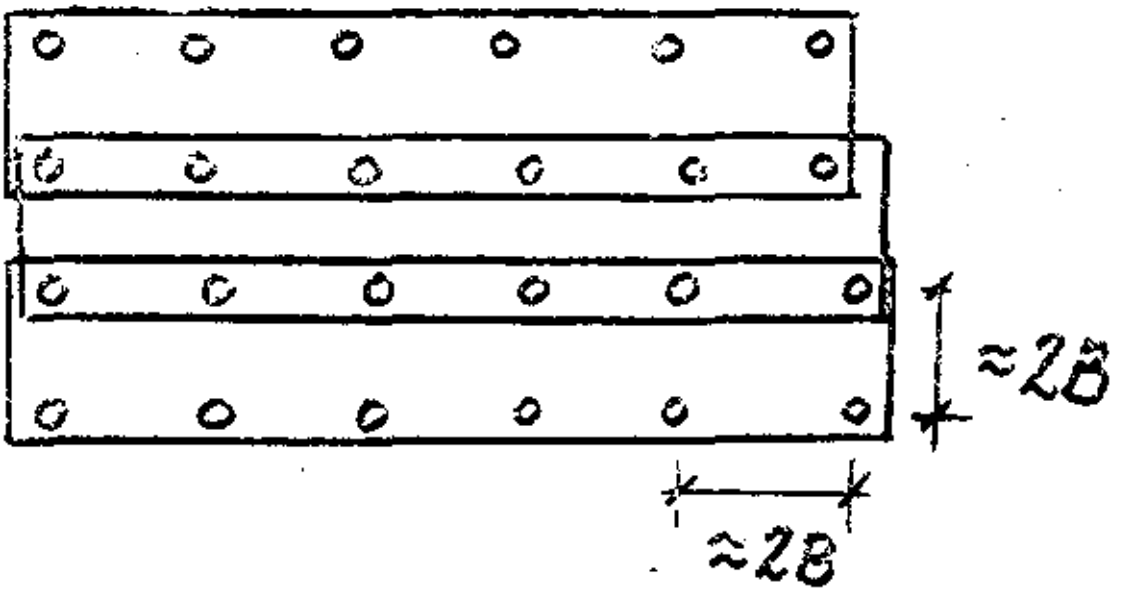
\+ Z

B = base

III: as in II but with less + (1/3)

IV: 4 ○ and 6 +

geodetic control, block triang.



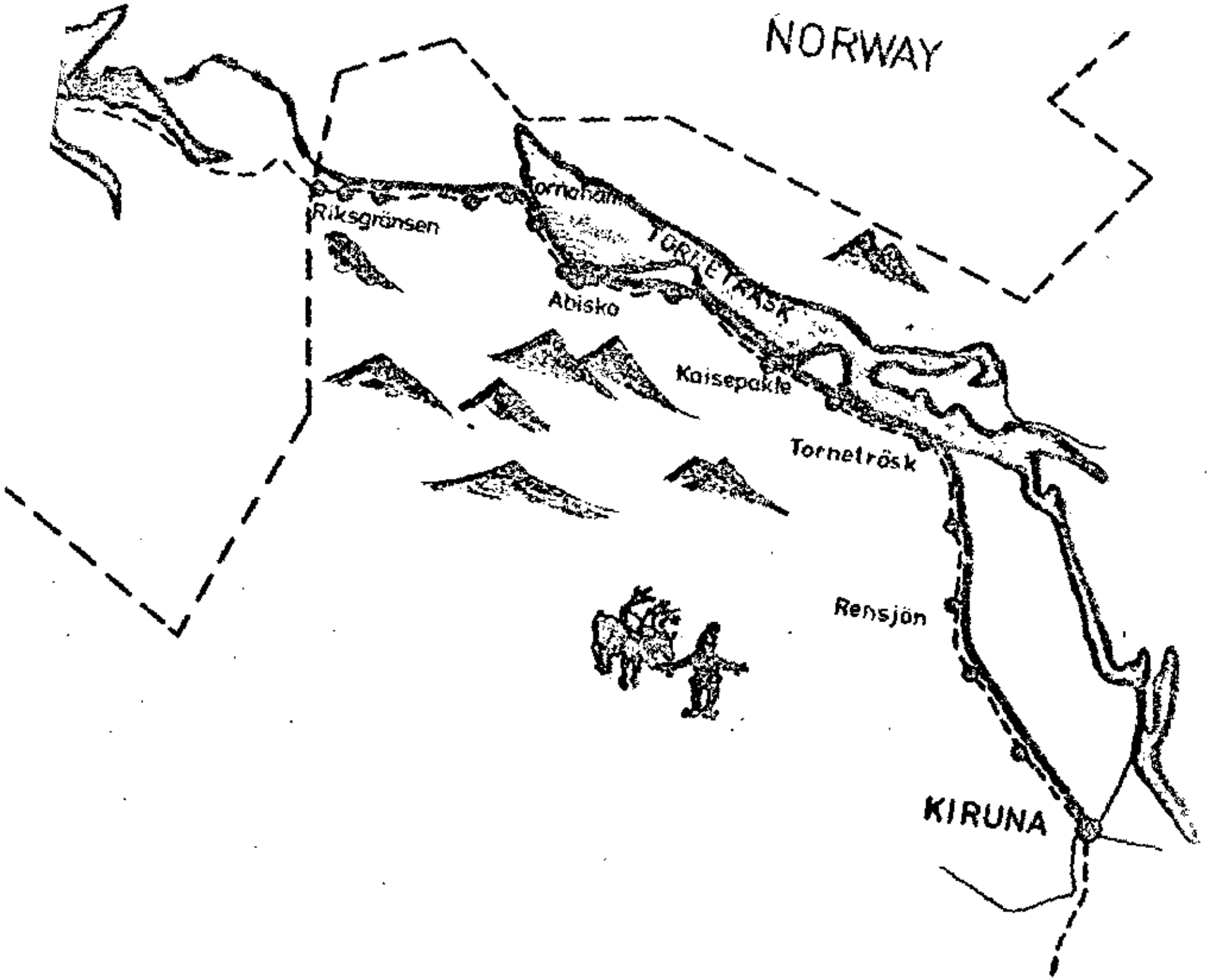
○ XY

II-III + Z 5-9 in each model

IV ○ inside block can be left out

maps for air ports in Sweden

Photo scale	1:4000
Map scale	1:500
Contours	0.5 m
DTM	


NORWAY
Riksgränsen
Abisko
Kaisepakte
Torneträsk
Rensjön
KIRUNA

KIRUNA - RIKSGRÄNSEN

Some project data

total length: 130 km

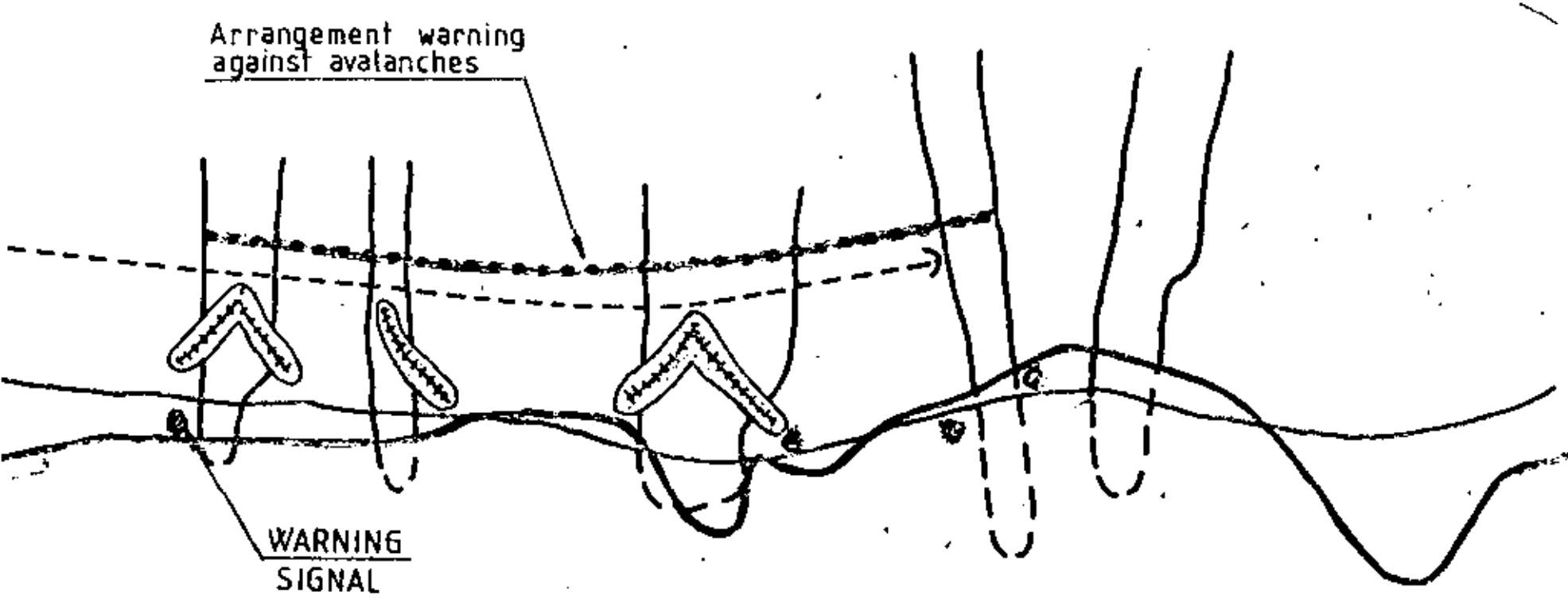
aerial photography:

	1:13000	130 km
	1:5000	90 km
maps:	1:2000	65 km^2

cross-sections: ≈ 10000

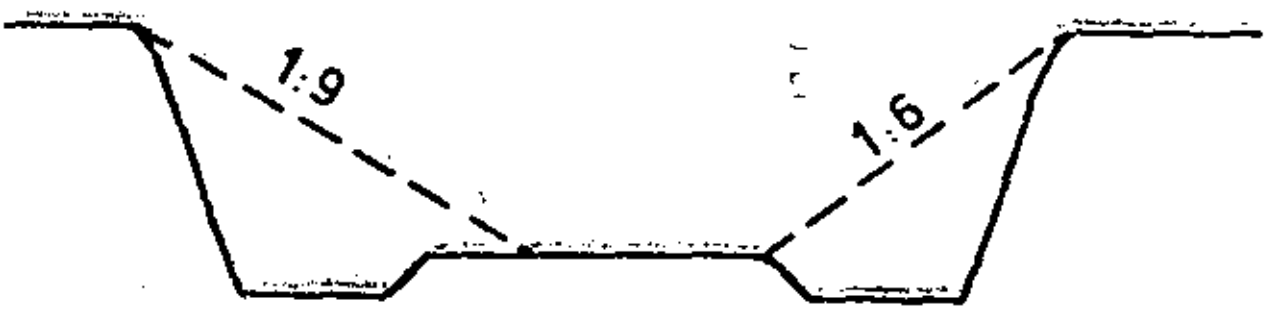
≈ 250000 points

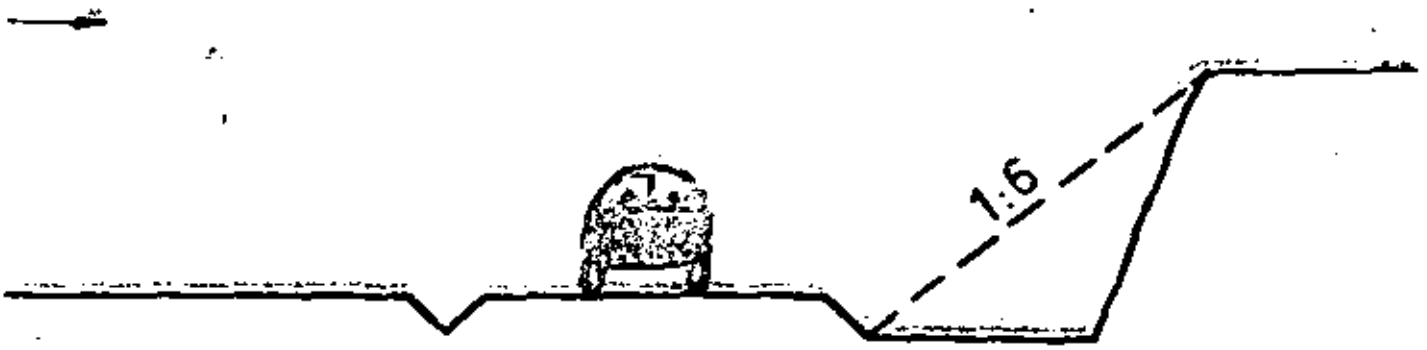
AVALANCHE ARRANGEMENT

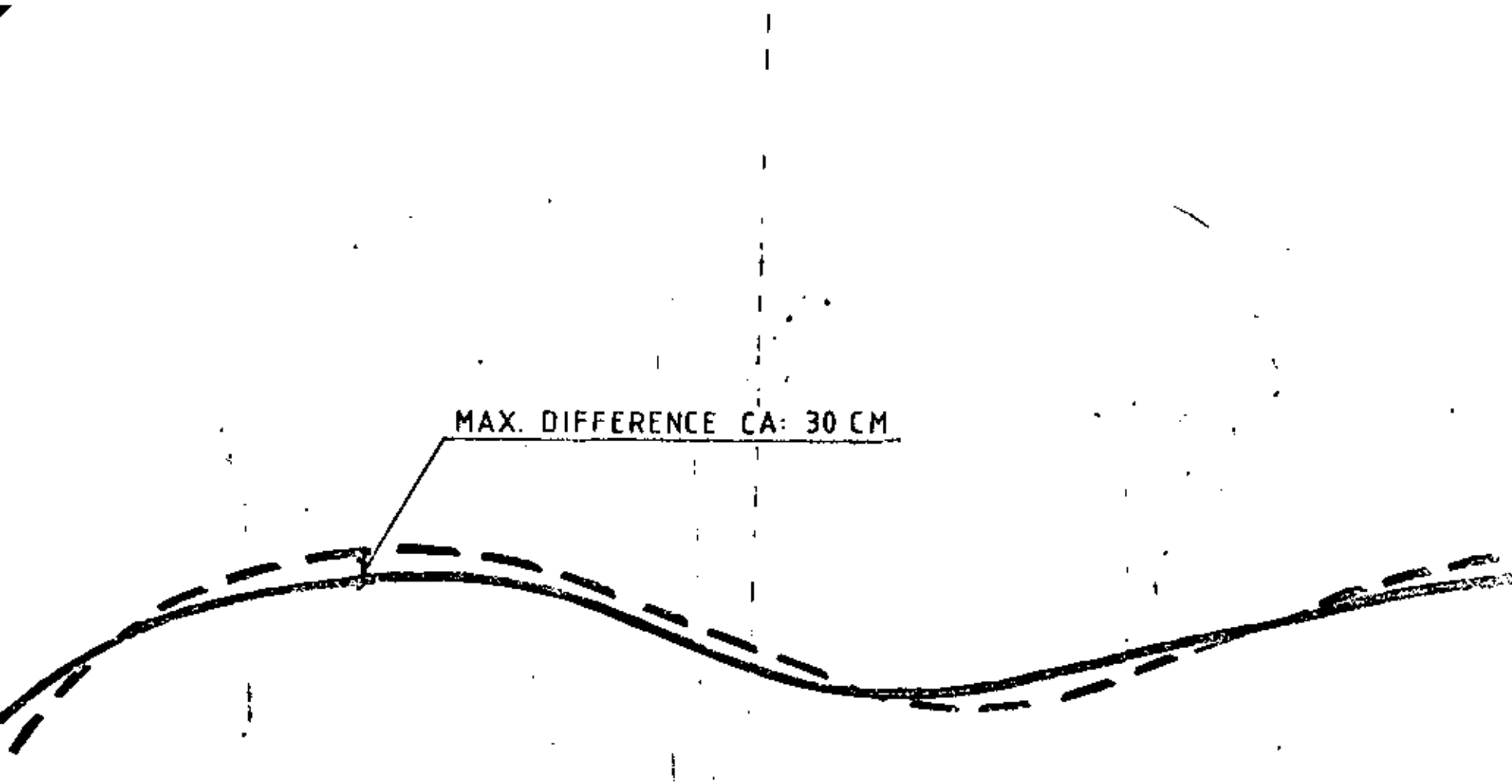


WIDEN SECTION

WIND
DIRECTION





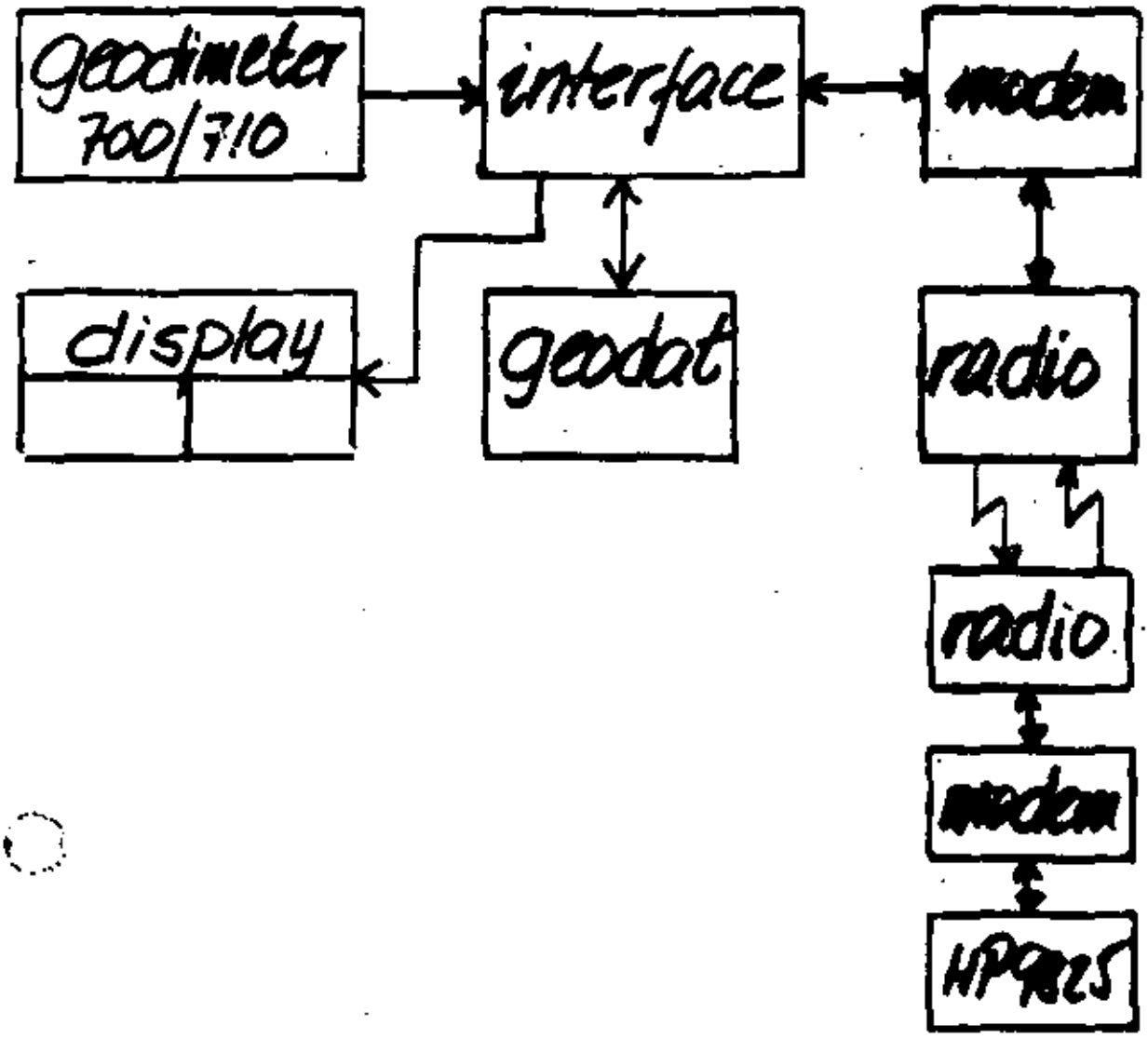


3 KM 30 P. + 2 CM
2 KM 20 P. - 6 CM

Empirical accuracy of a stereo model

	‰ of flying hight	
	point by point	mapping
S_{xy}	0.10	0.25
S_z	0.15	0.20

an interactive field station



field surveying

data acquisition
- solid state
- electro optical tacheometer
- radio transmitted data
- computing + solid state

setting out
- distance display etc
- at reflector bar (Kern)

field surveying

electro-optical tacheometry

data acquisition

- solid state memories
- wireless transmission

setting out

- computer supported
- distance display at reflector station

GIS funds

joint conference ICA/ISP Zürich summer 1979

Major trends in 2D IGS

manual digitizing is operational in many countries

interactive editing increases

interactive 3D digitizing in progress

raster scanning / laser line following = research and development stage

Data base management = primary concern

- types of data to store
- structuring of for optimum use
- storage medium
- ~~availability of data~~
- national policy of availability of cartographic data bases
- up-dating procedures

displays

- selective retrieval
- generalization

color ink ~~on paper~~

scribing

light head

raster plot = in development

DETENAL

- investigate thoroughly needs and demands ~~present~~ present and future
- study existing ~~procedures~~ systems in operation
- survey ~~work~~ of equipment (implementation and handling)
- be prepared of large organizational changes and a great organizational change (education)

Systems

Applicon
MOS
Computer Vision
Huntings England
SYNERCOM ("Wild")
ARISTO

digitization

key-board
menu
"coordinate coding"
voice recognition

digital mapping

activities in Sweden

- National Land Survey
- city of Malmö
  Göteborg
  Stockholm
- private firms
  K-Konsult
- Technical University
- National Road Administration
- National Building
  Research Council

feature coding

structure of codes

code setting

- key-board
- menu
- "coordinate coding"
- voice recognition

data base concerns

- types of data to store
- structure for optimum use
- up-dating procedures
- national policy of availability of map data banks

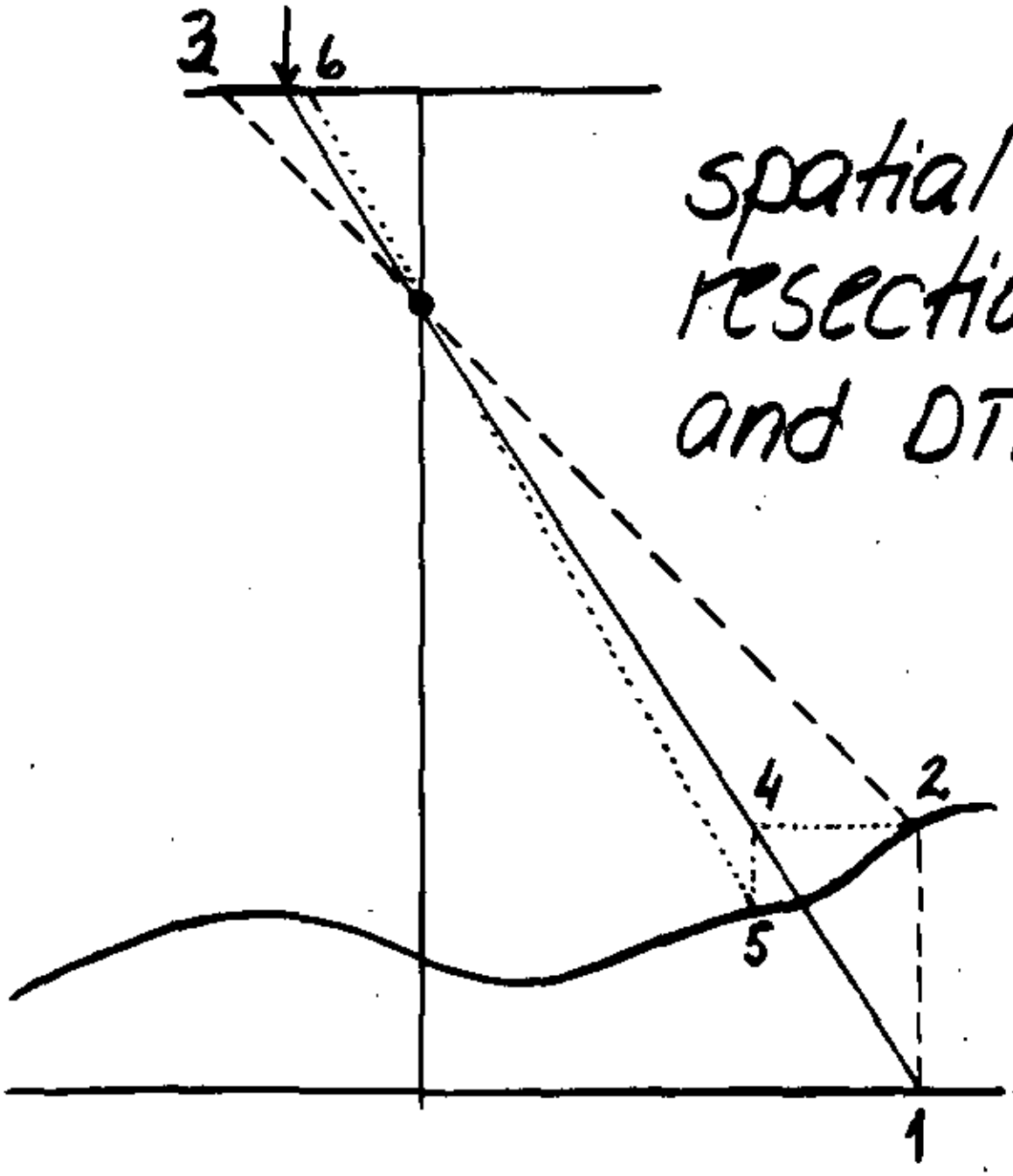
Interactive Graphic Systems

IGS

major trends

- 2D-digiteing mostly used
- 3D-digitizing in progress
- interactive editing increases
- raster scanning/plot in development
- data base management is a primary concern

digital mono plotting

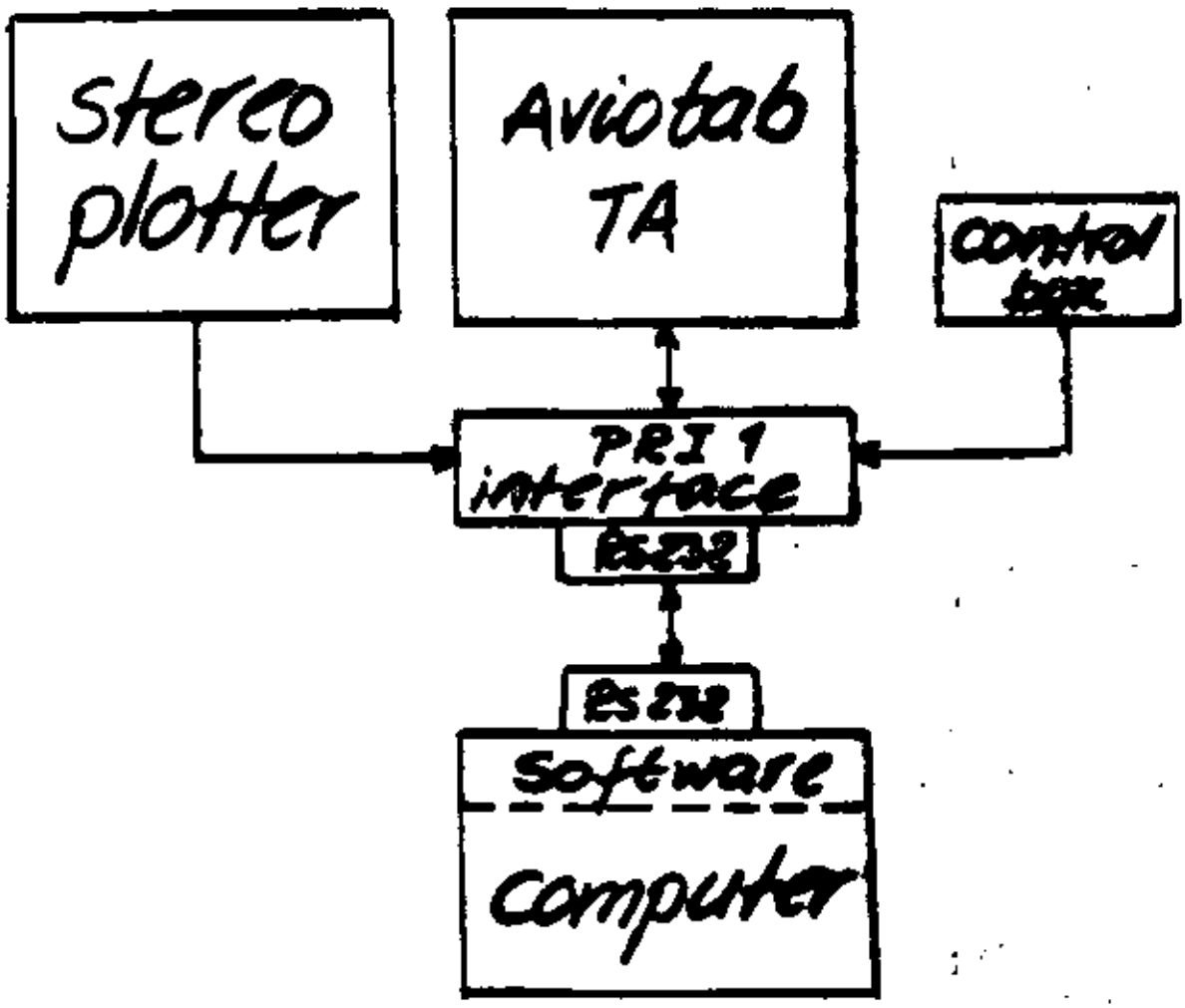


spatial resection and DTM

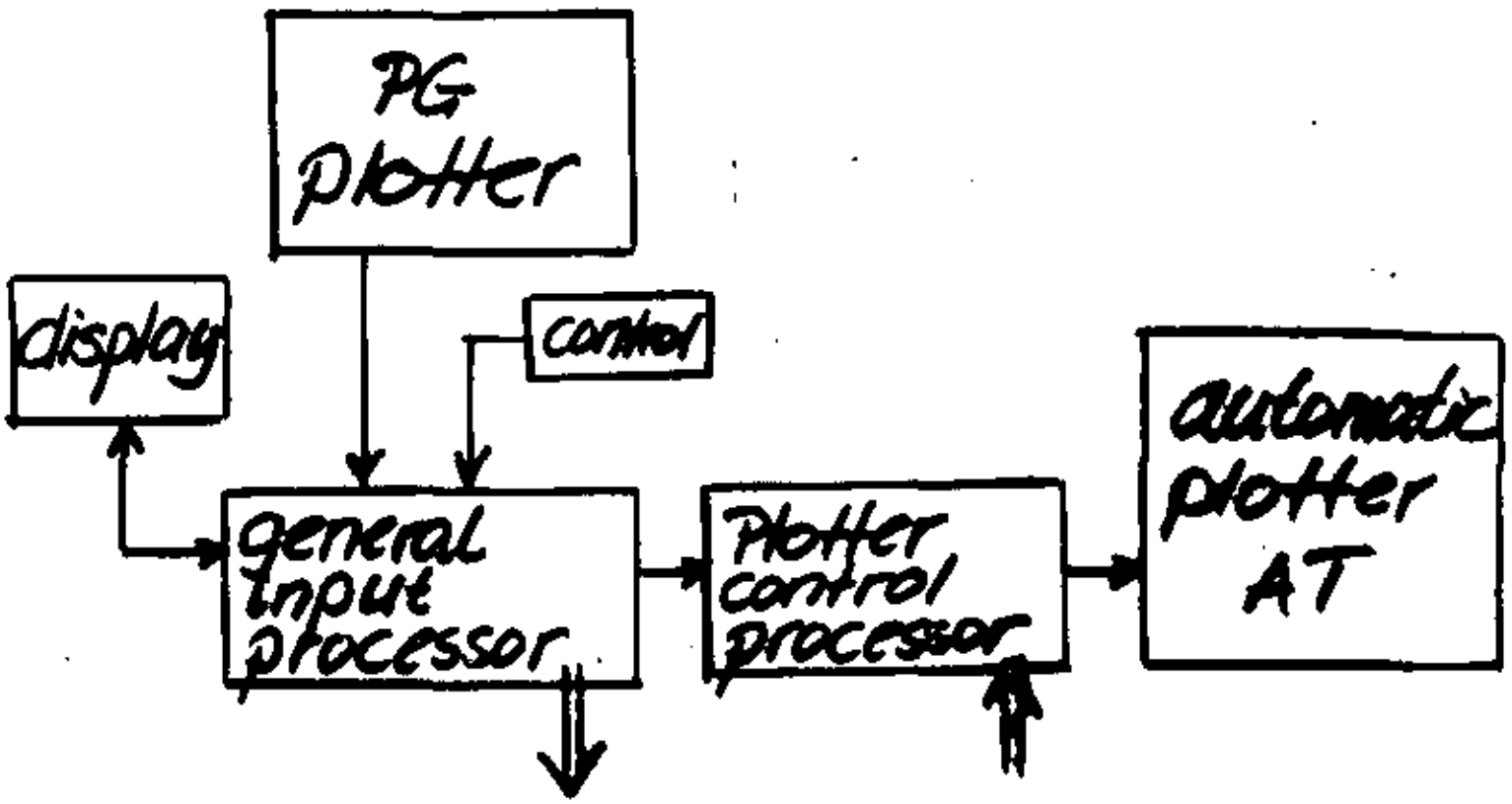
Digital Terrain Models

interpolation
progressive sampling
on-line control
filtering
mono plotting

Wild Aviotab/PRI 1 System



Kern DC2-B computer-supported plotting system



plotting

analytical plotters (7 nya i H-fors)
bara Wild saknar

CAM kan Wild PRI

Digital mono plotting

IGS

nationwide (~~resources~~ land use) inventory

"feature extraction by interactive digital image processing system"

WAMS Wetlands Analytical Mapping System III
US Fish and Wildlife Service Florida
Triangulation (ADPS III analytical plotting system III)
Digitizing (of wetland delineations)
Wetland Data Base

Varför automatisera kartproc?

+	−
mindre kartor	svårförändrade
databank	personal utbildas
kvalitetshöjning	stora engångsinvesteringar
flexibel skiromätn.	

Flood elevations areas interactive PG2/HP1000
(~~US~~) (Tennessee, US)

fruts

analog plotters

- electronic plotting tables
- fast coordinate recording
- computer-controlled DTM-measurements
- computer supported orientation and plotting

orthophotography

numerical control

correlators

analytical plotters

independent of interior and exterior orientation

automatic scanning

semi — " — profiling and cross-sectioning

increased accuracy

progressive block triang.

great flexibility

Analytical plotters

1957 →

Dell

US KRE/H. Dellfeiter CSS-300-II

Italy Galileo Digital Stereocartographe

US OMI AP/C4

US Bendix DS-1

France Matra Traster 77 (with gr. light)

W.Germ. Zeiss Planicomp C-100

+ ~~nobedrift~~ autom. installation p.a.

Std

autom. clipping i profilerbeel

~~to~~ transfer points ⊗

progressive ~~direkt~~ block triangulation

relative = 4-6 μm ⇒ 2-3× bättre als

5× snabbare än analog

(se Kennedy)

| System for evaluation (Makarovic)

s_{xy} = 2-3 μm

⊗ 1. signalized (between strips OK, between models = pinpointed, always expensive

2. natural points (30% av stereotiden) — s_{xy} = 3-7 μm monoscopic y, s_{xy} = 3 μm stereoscopic y

3. artificial points (fail on film comparators)

4 three-plate comparator

5 analytical plotter

analytical plotters

K&E/H. Dell Foster	US	RSS-300-II
OMI	US	AP/C4
Bendix	US	US-1
Matra	France	Traster 77
Zeiss, Oberkochen	W. Germ.	C-100 Planicomp

block triangulation

self calibration

progressive adjustment

attainable accuracy

position	1. comparator	12-25 μm
	2. analog plotter	25 μm
	3. analytical plotter	12-25 μm
height	1.	20 μm
	2.	25-40 μm
	3.	20 μm

data processing

pocket calculators

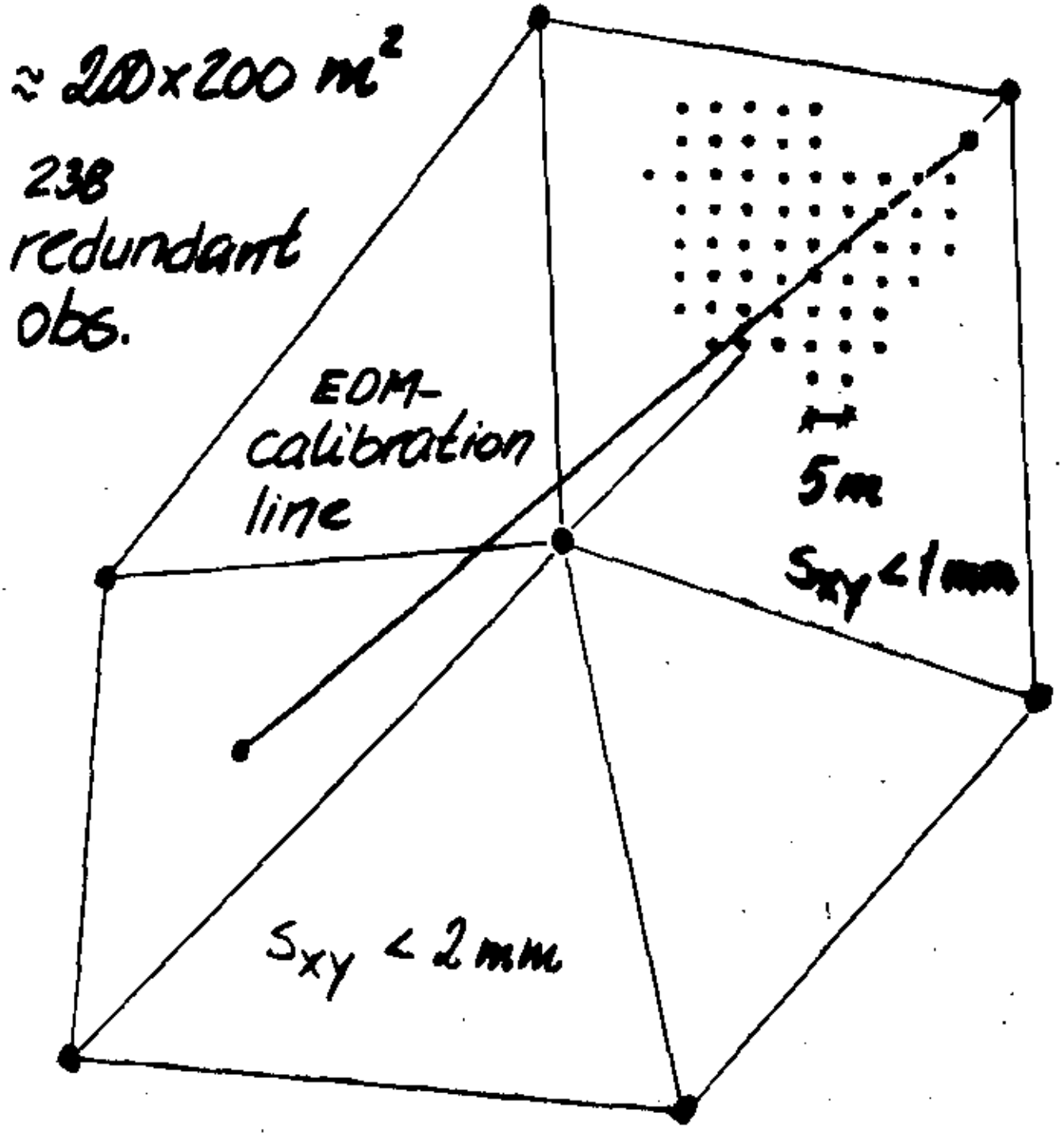
desk top computers

mini computers

large computers

terminals

a high-accurate test field



accuracy studies

theoretical

simulation

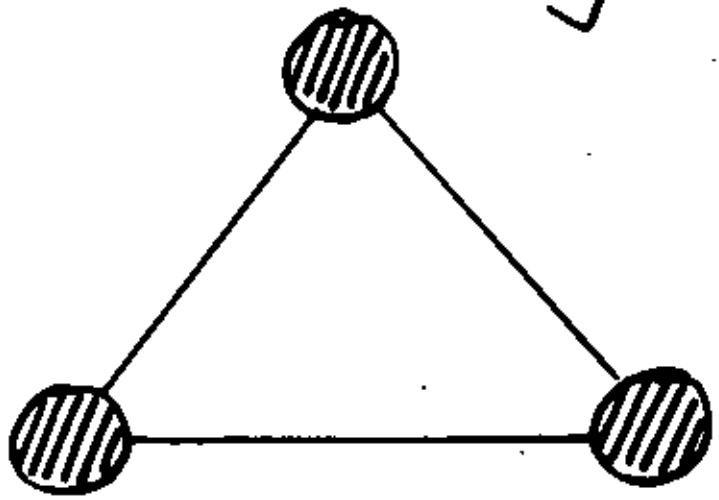
empirical

test field

practice

survey planning

accuracy

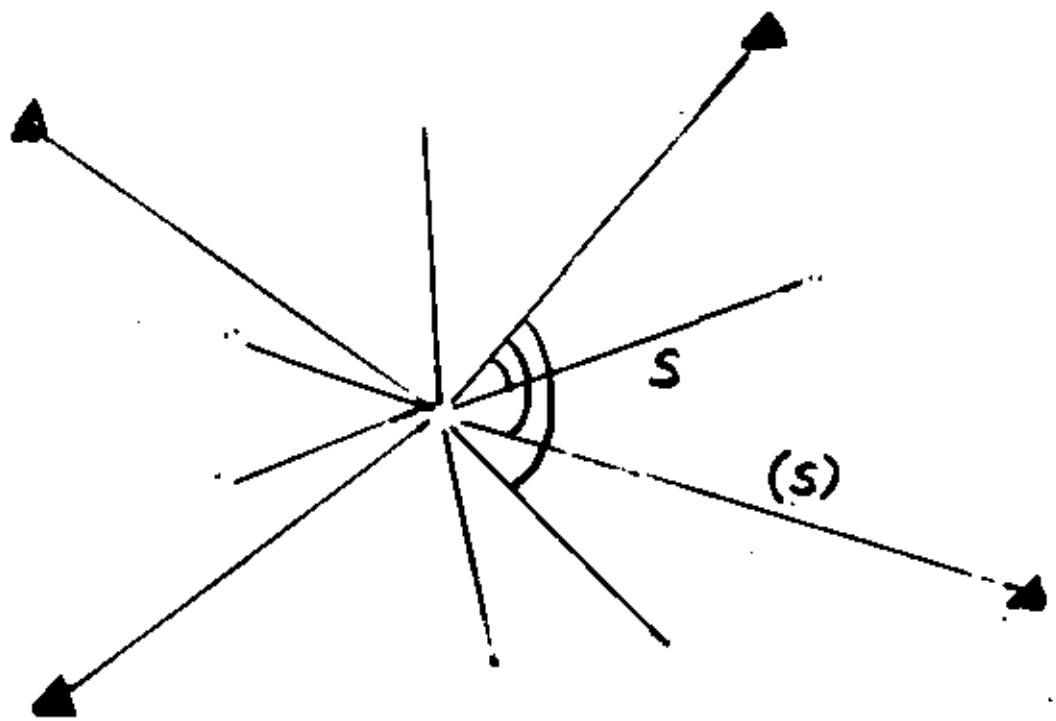


geometry

method

ELECTRO-OPTICAL TACHEOMETRY

SURVEY SYSTEMS



RESECTION TECHNIQUE

setting out methods

orthogonal
polar
intersection
resection + polar

EDM-instruments at the Swedish National Road Adm.

AGA	Geodimeter	6
"	"	12(A)
"	"	14
"	"	120
"	"	700
Kern	DM 501	
"	ME 3000	
Wild	DI 3 (S)	
"	DI 10	

CODE
0 CODE
1 DATA

STN
2 STN
3 IH

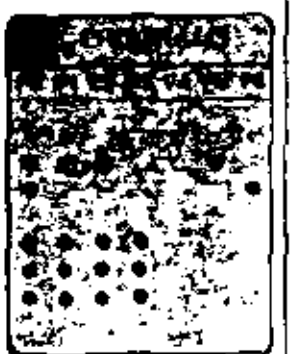
4 PCOD
5 PNO
6 SH

7 HOR
8 ELE
9 DIST

f FUNCTIONS

f0	ON/OFF
fENT	REG ANM POS
f1	TAPE OUT
f2	TAPE IN/CHECK
f3	V24/RS-232 OUT
f4	CALC OUT
f5	
f6	
f7	JMP POS 0
f8	SEARCH
f9	CONTINUE
fi	MEMORY
fC	CLEAR ALL
f ←	DELETE
f →	INSERT

AGA Geodat 120



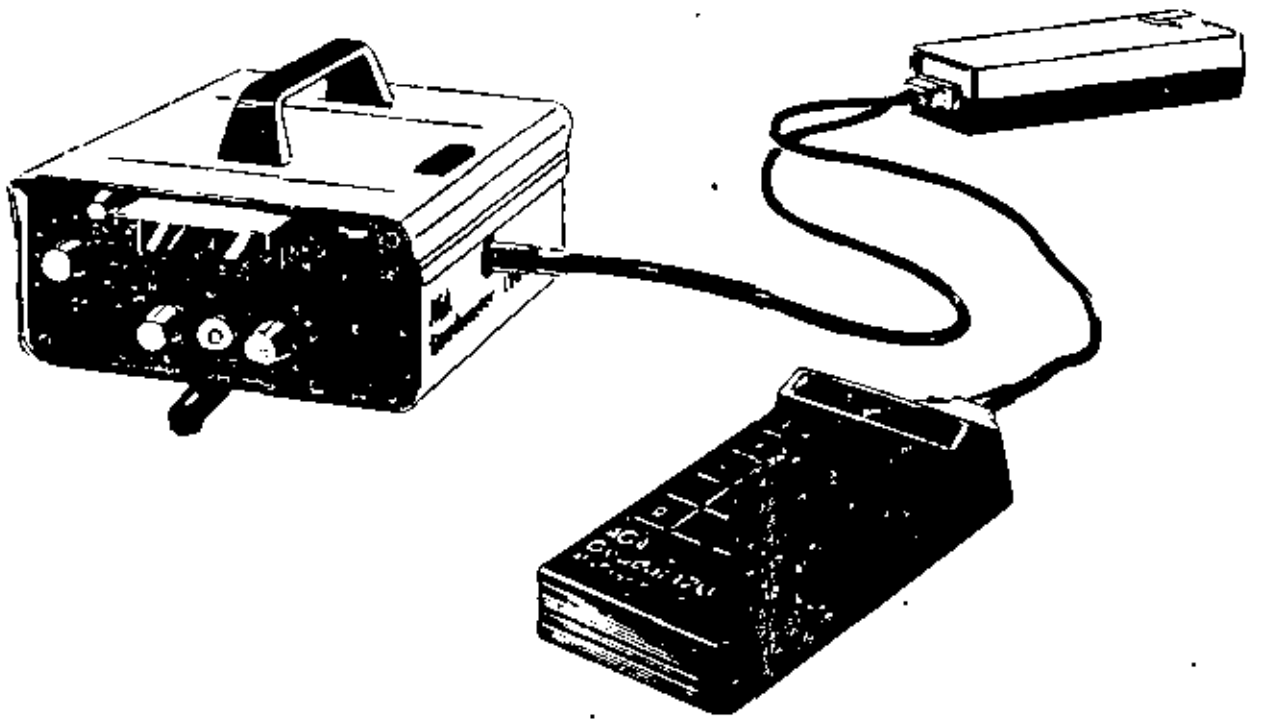
SWITCHES

1 RESTART
2 POWER
3
4
5 300/1200 BAUDE
6 INSTRUMENT

0	1	DIST REG
1	0	ELE REG
1	1	HOR REG

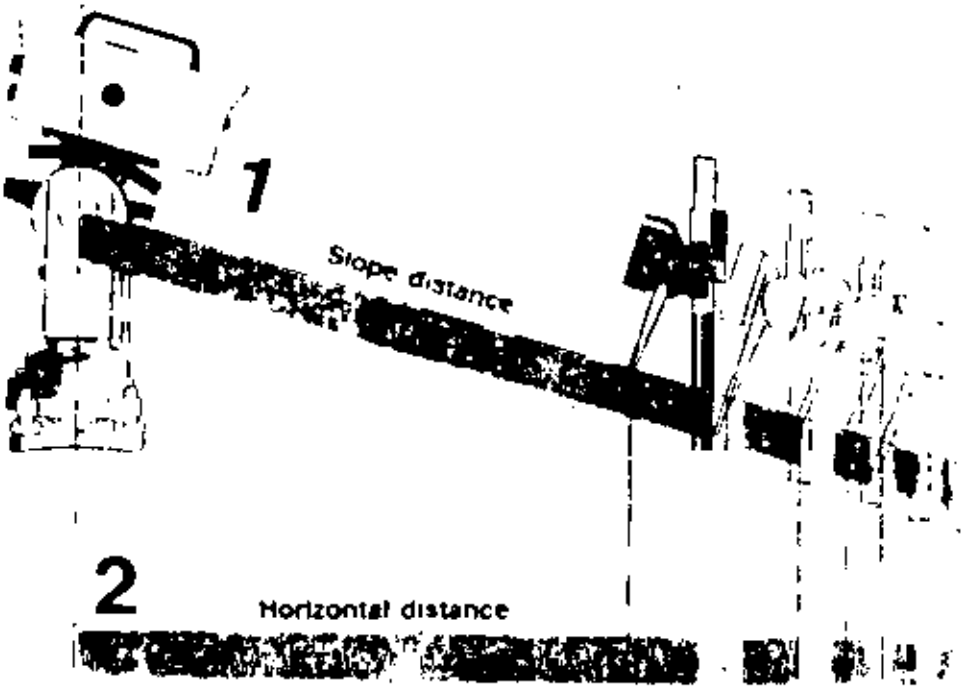
AGA

MEASURING SYSTEM 120



- Storage capacity: 16.000 characters
- Automatic storage of:
  - Slope distance
  - Vertical angle
- Manual storage of horizontal angle and station data
- Recall of stored data

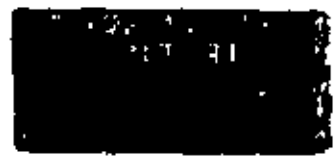
THERE ARE THREE STAKE-OUT FUNCTIONS



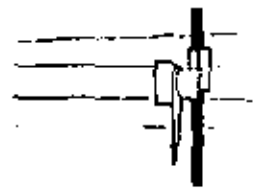
3

STAKING-OUT

- Distance measurement 2.5 times/second



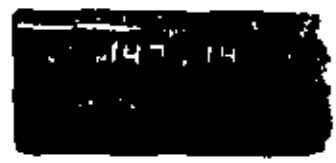
- Tracks moving targets



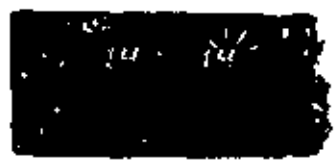
Max (4m / s

- The display warns against poor accuracy

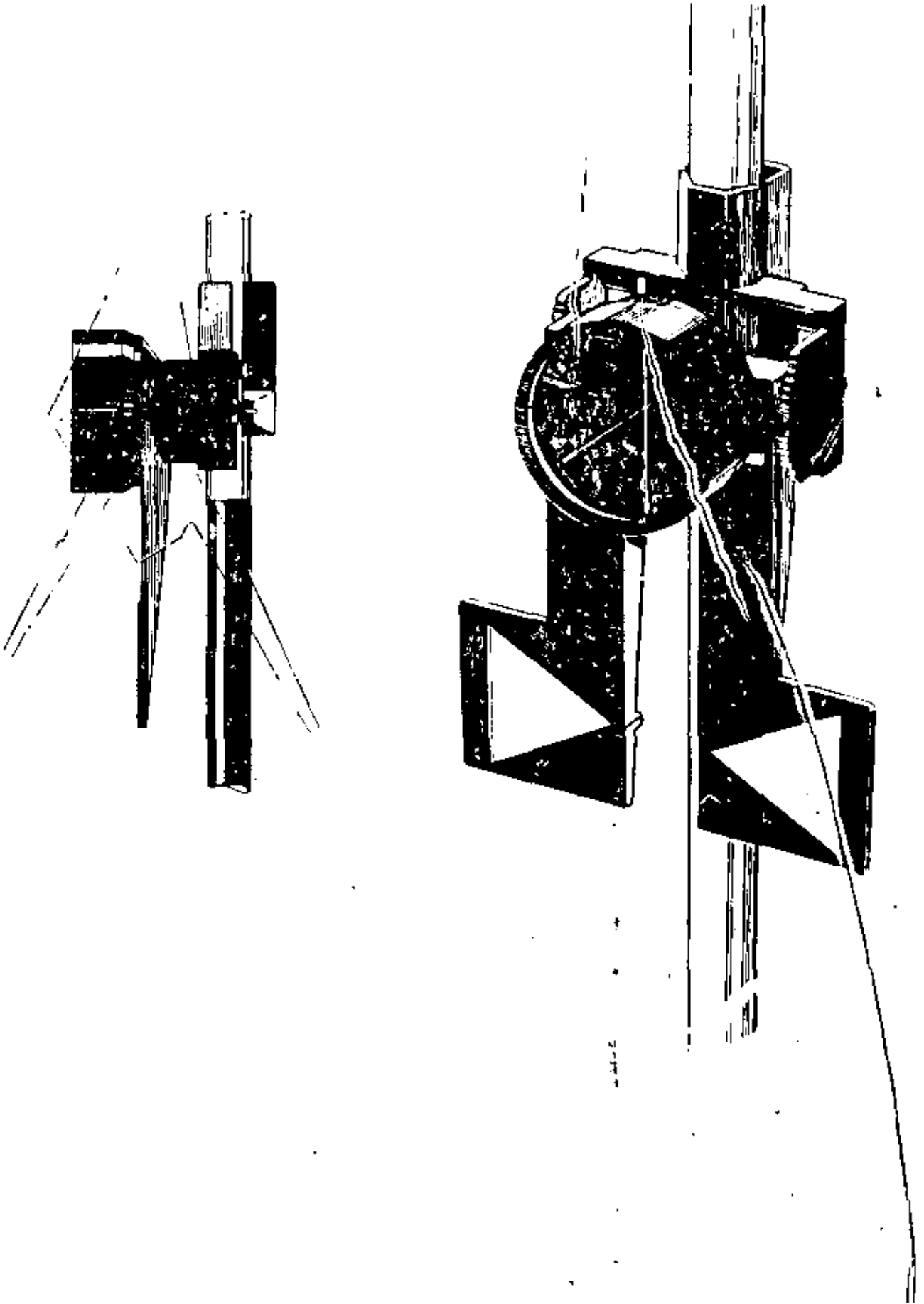
  The instrument automatically checks if accuracy is to specification



Good accuracy

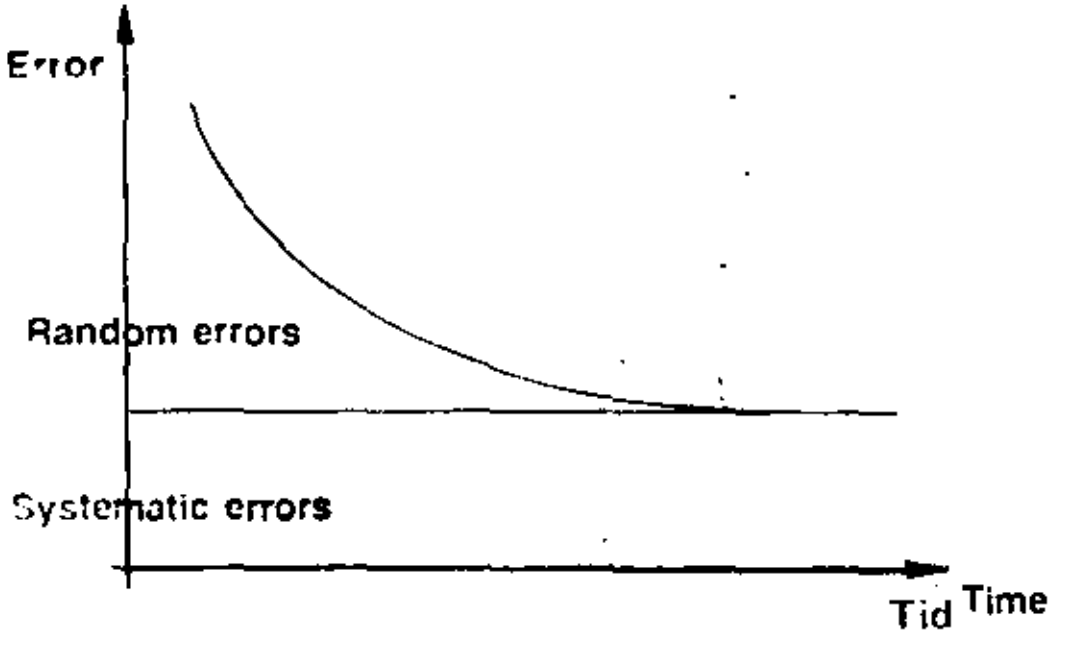


Flashing last figure
indicates poor

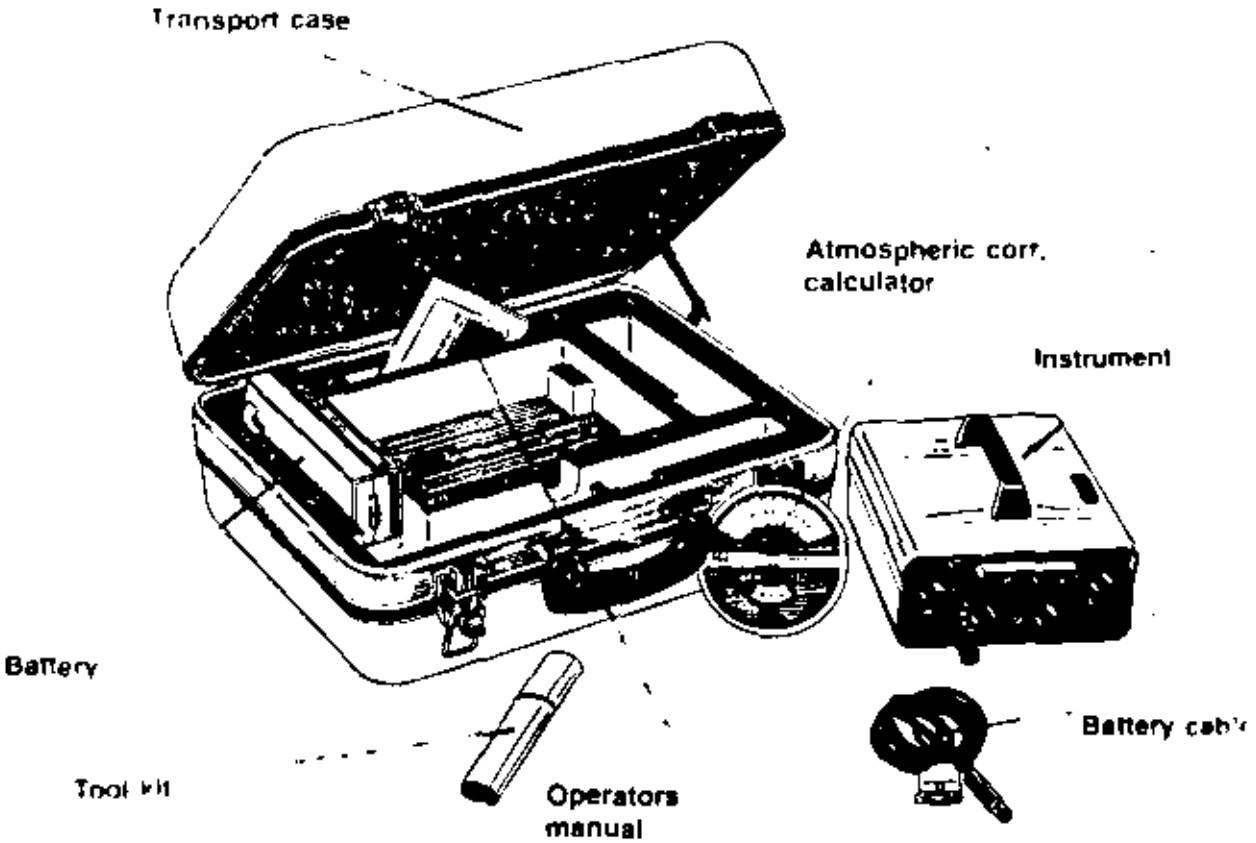


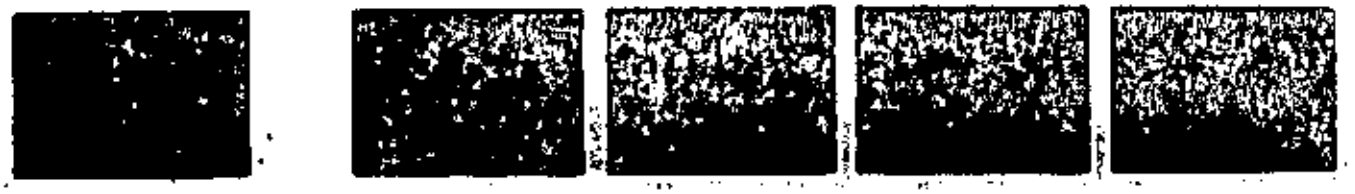
THE COMPLETE DISTANCE DISPLAYED NO AMBIGUITY

AUTOMATIC AVERAGING OF REPEAT MEASUREMENTS



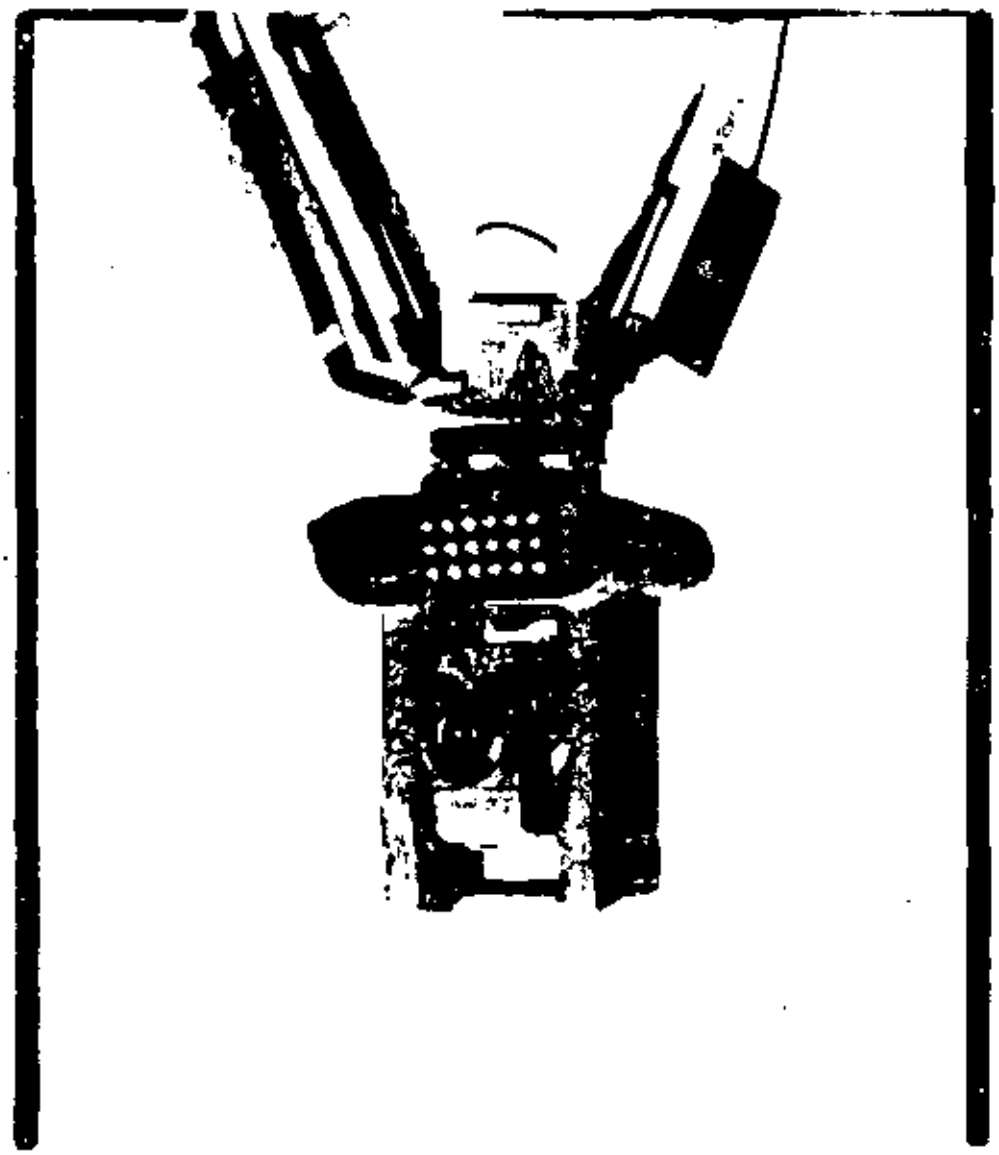
BASIC EQUIPMENT

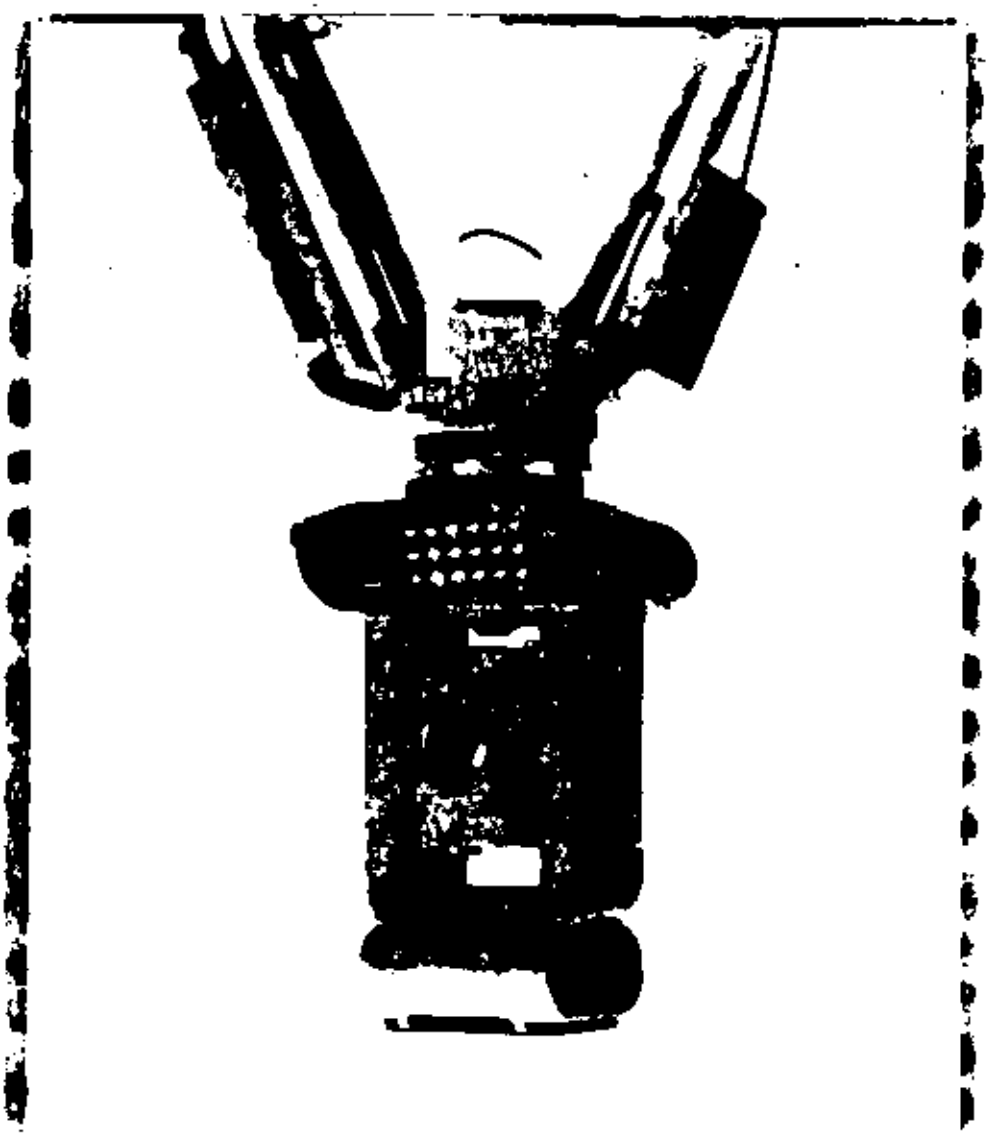




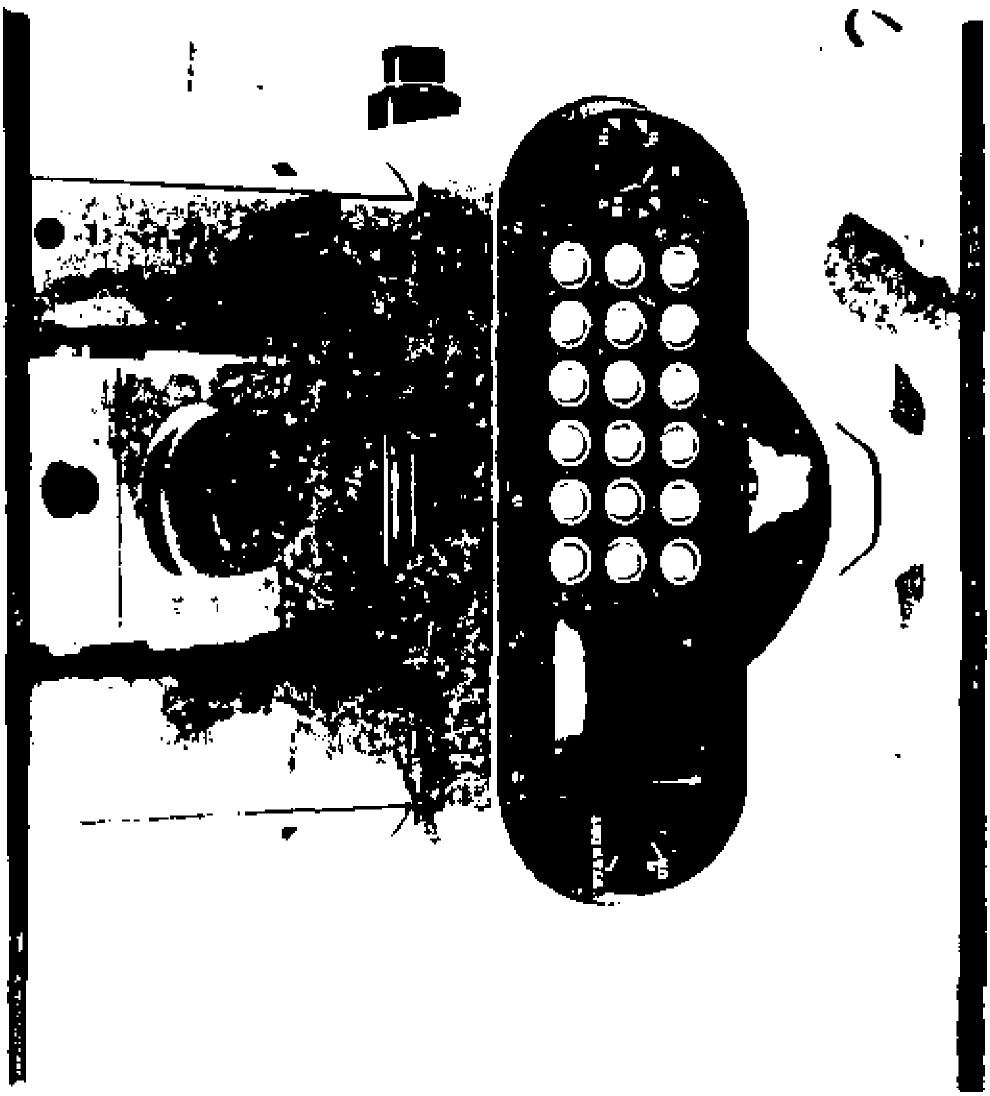
120

1 Totally automatic measuring
2 Weight incl. batteries
3 Tracking mode
4 Good range
5 Automatic data registration
6 Flexibility
7 Easy to use
8 Automatic calculation of horizontal dist.



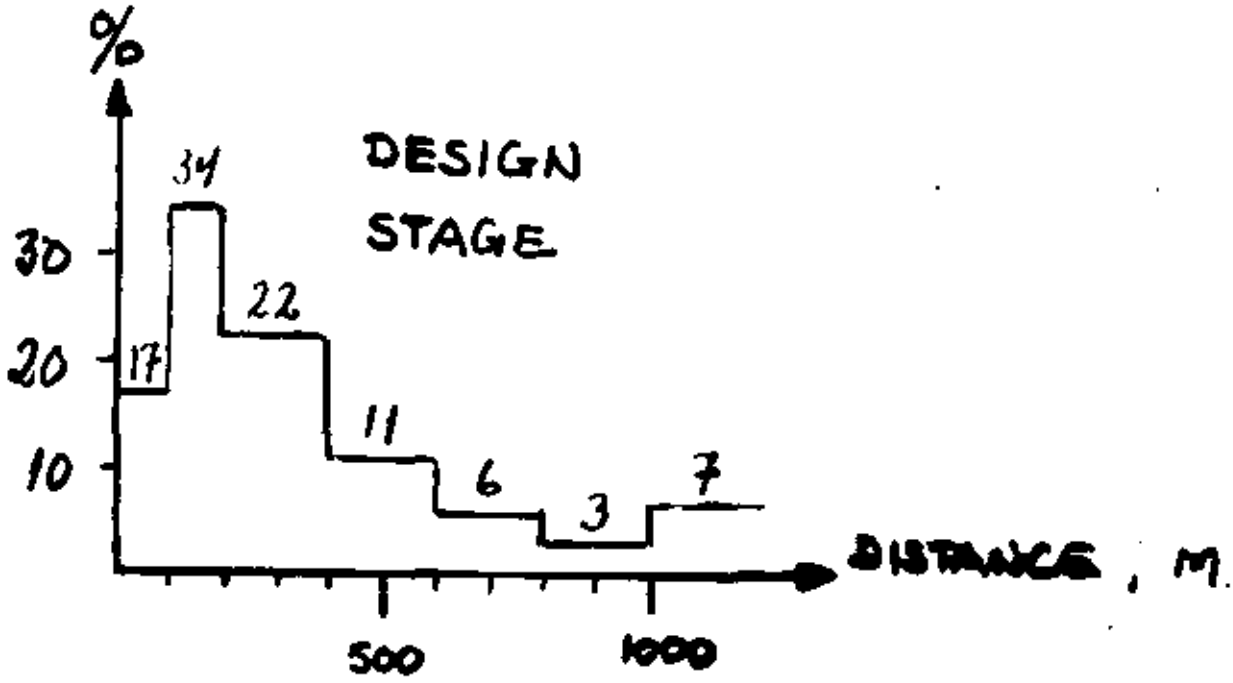


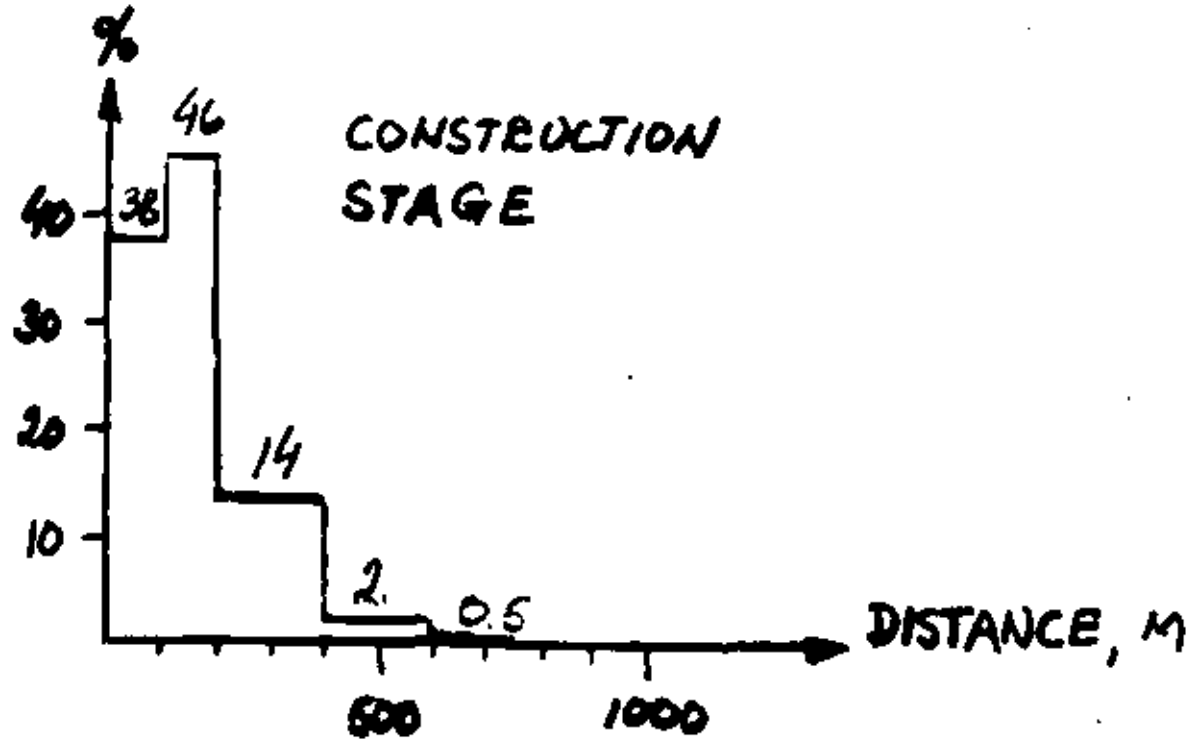

Verbatim
data cassette



EDM-tachometers

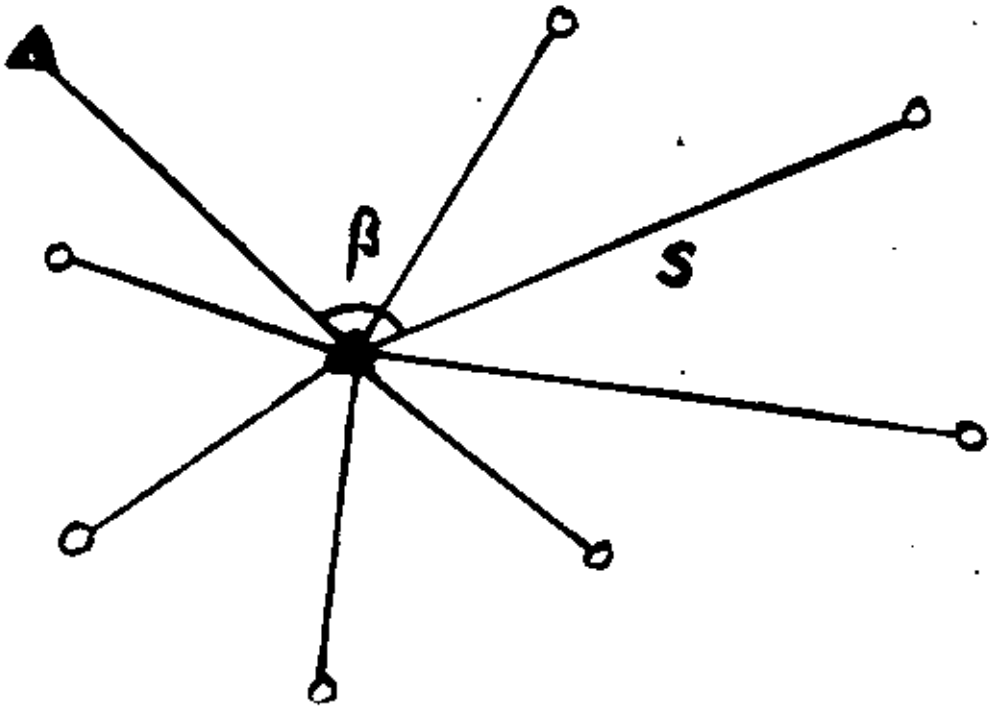
type	display					recording
						
HP3820	x	x	x	x	x	memory
Kern E1/Dahlta	x	x	x	x	x	memory
Wild TC1	x	x	x	x	x	tape
Zeiss Elta 2	x	x	x	x	x	memory
AGA GRO	x	x	x	x		memory
Jena EDT 2000	x	(x)	(x)			tape
Wild DI3S	x	(x)	(x)			memory
Zeiss Elta 4	x	x	x	x	x	—


%
DESIGN
STAGE
34
30
22
20
17
11
10
6
3
7
DISTANCE, M.
500
1000


%
46
CONSTRUCTION
STAGE
40
38
30
20
14
10
2
0.5
DISTANCE, M
500
1000

ELECTRO-OPTICAL TACHEOMETRY

SURVEY SYSTEMS



- POLAR MEASUREMENT
- WIDE RANGE
- LESS DEPENDENT OF TOPOGRAPHY, VEGETATION, TRAFFIC ETC.
- HIGH MEASURING SPEED
- CONSTANT AND HOMOGENEOUS ACCURACY
- SAFE DATA COLLECTION

surveying methods

- polar measurements
- traverses
- intersections
  - directions
  - distances
- resection

Serdeliter

uppst
målinriktning
avläsning
höjdindex
registrering

Gyrostesdelit!

Levels

funktionskontroll
planscope

Laser

öken
riktning
enhetcats

ECM

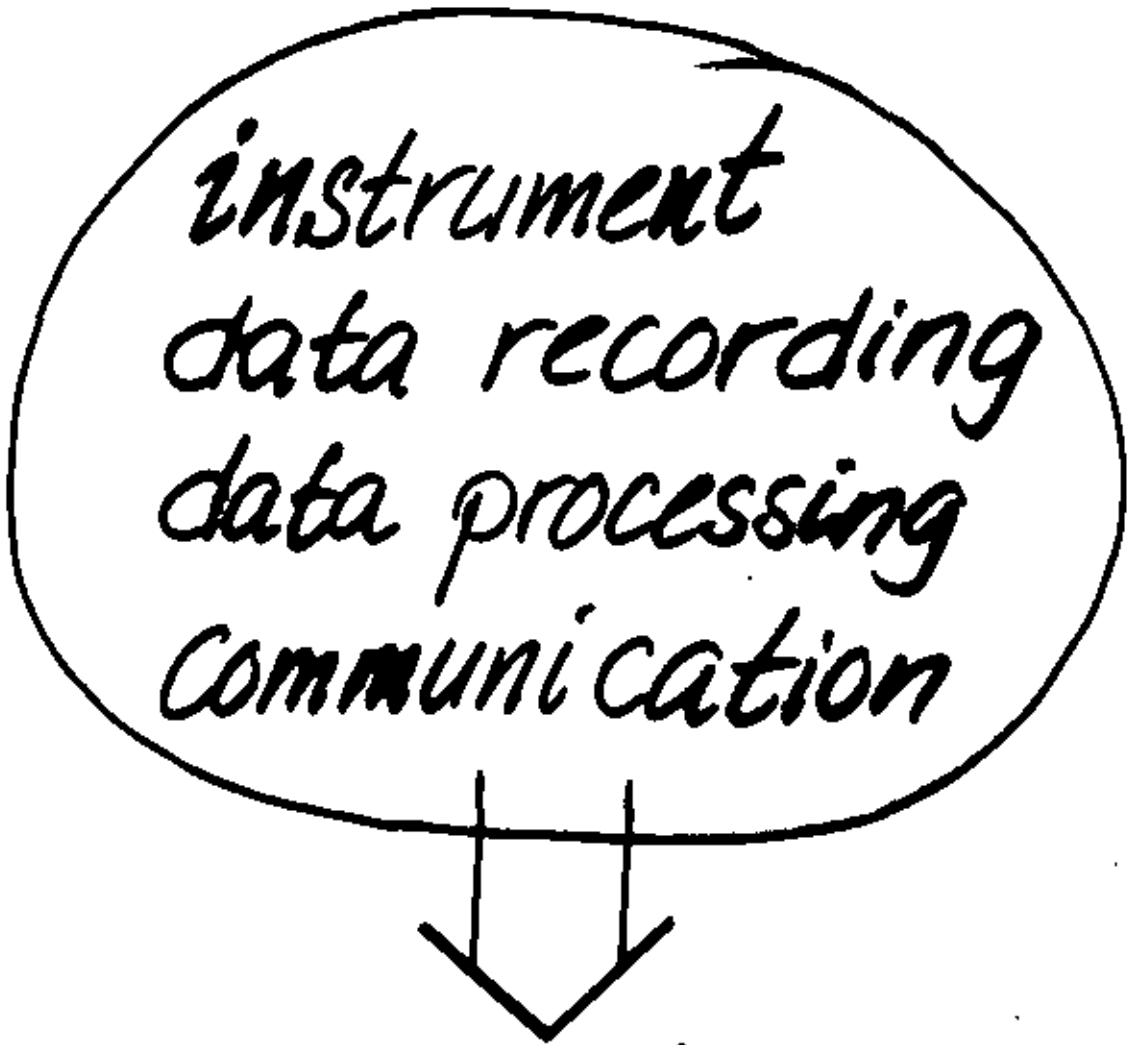
Gjordelta
modulation
optiska delar
~~inmatning~~
resultat presentation
registrering

~~[illegible]~~ paper tape
cassette
solid state
interface

instruments

theodolites
levels
lasers
EDM
optical tacheometers
EDM-tacheometers

field surveying



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