Fieldwork Surveying FS01

8. Lecture

Measurements for thematic mapping and for as-built documentation of constructions

Presentation was supported by 105 1052201A003 FCE CTU in Prague Internal Project

Methods:

1. spatial polar method
2. photogrammetry
3. laser scanning
4. remote sensing
5. GNSS

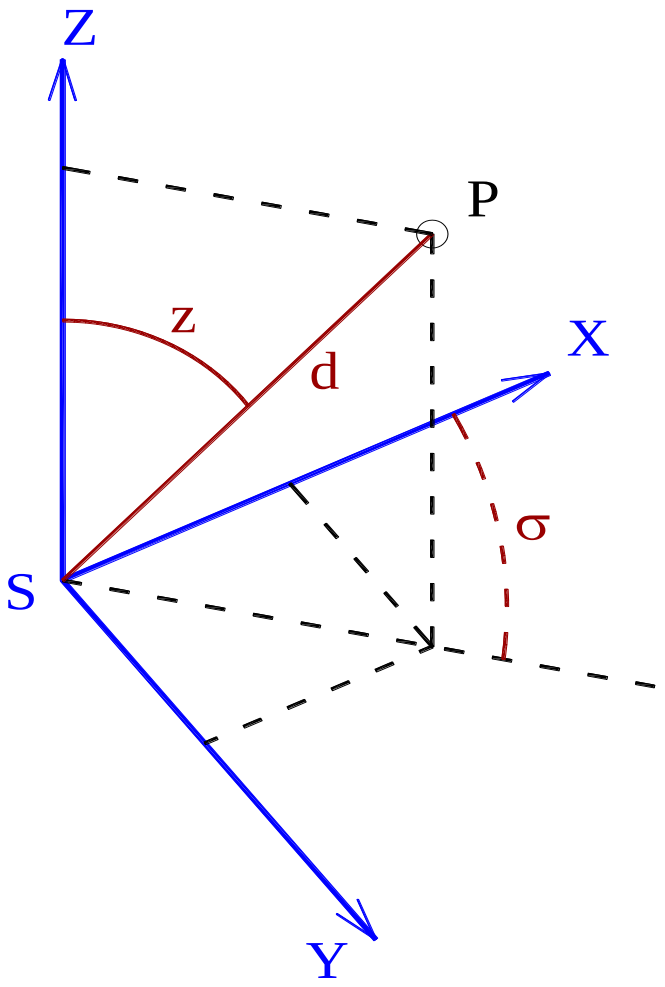
Thematic mapping

- Thematic map is the map of large scale with special content.
  - Map of plant (factory) 1:200
  - Technical map of city 1:1000
  - Map of railways
  - Road map
  - Map of forest 1:5000
- Special content: engineering network, equipment of railways (rails, switch,...), technical infrastructure, vegetation,...

1. Spatial polar method

- coordinates Y, X, Z of a point are determined
- a network of survey stations for detailed measurement has to be created in the area in which the mapping is carried out
- determination of survey stations coordinates – methods presented in 2nd lecture (e.g. traverse)

Principle



Measured:

slope distance *d*

horizontal angle *ω*

zenith angle *z*

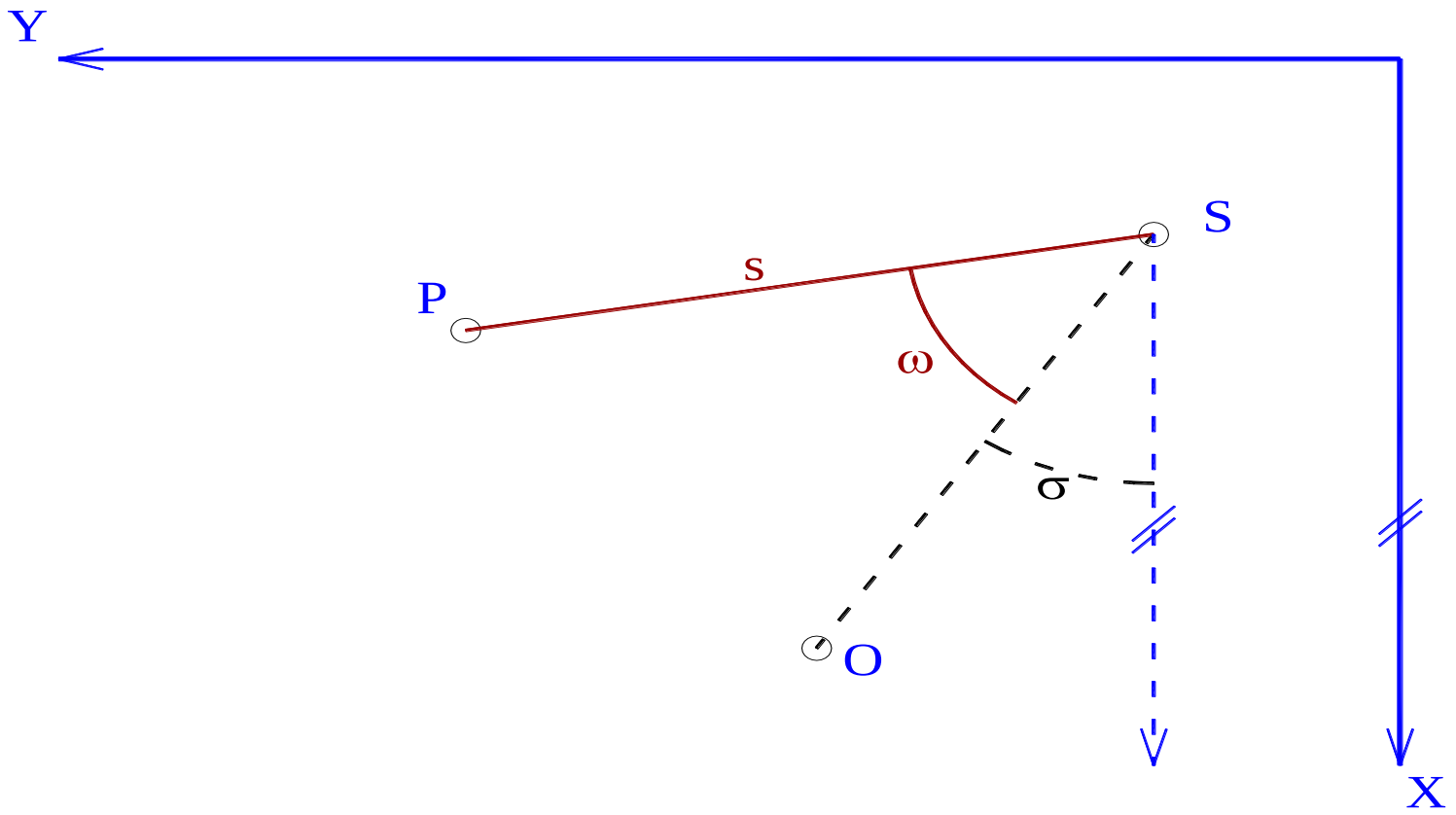
$$\Delta x = s.\cos\sigma = d.\sin z.\cos\sigma$$

$$\Delta y = s.\sin\sigma = d.\sin z.\sin\sigma$$

$$\Delta z = d.\cos z$$

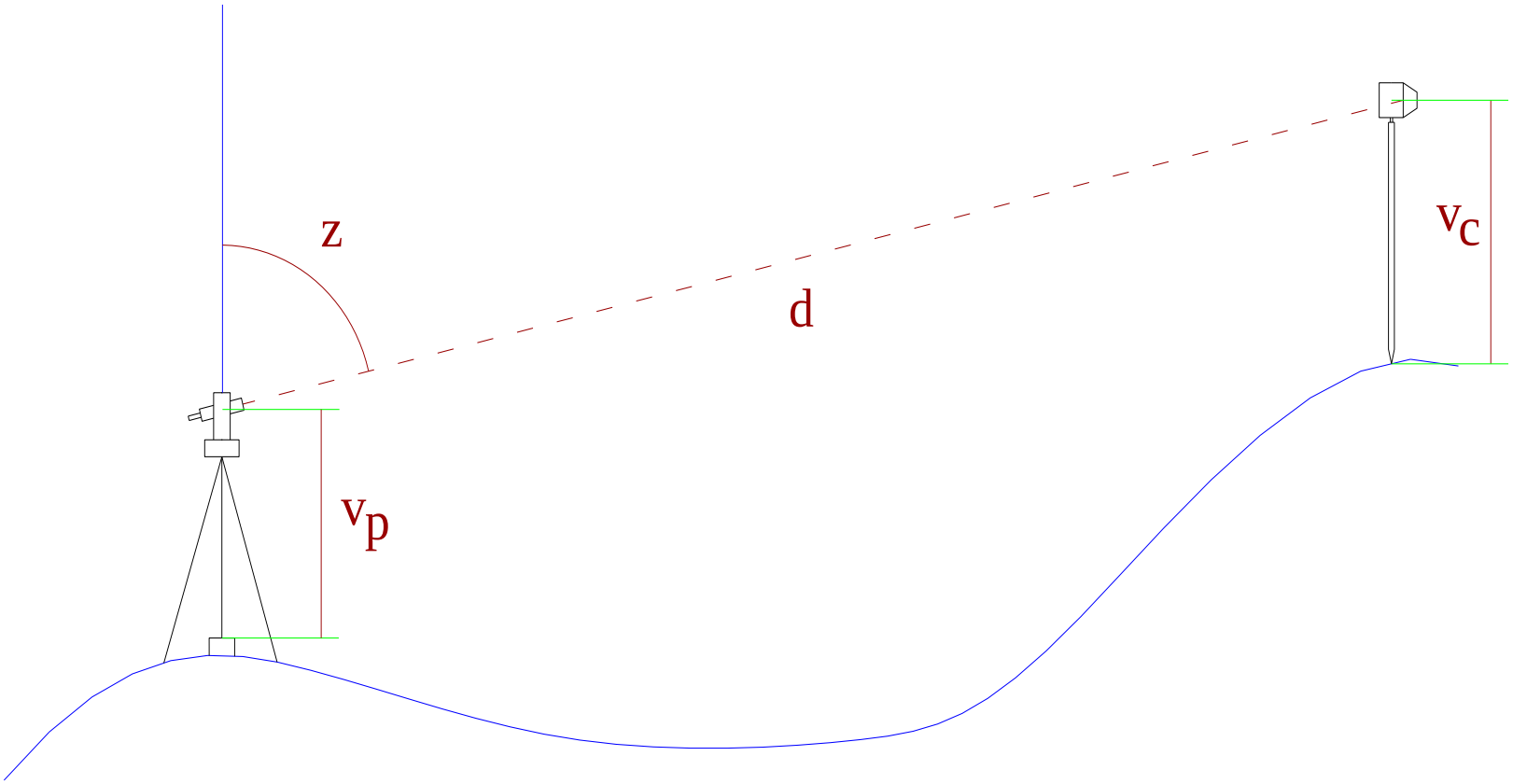
s … horizontal distance

Problem: there is not a possibility of a bearing measurement therefore the horizontal angle ω between the orientation point O and unknown point P is measured. The bearing SO is calculated using known coordinates of these points and then the bearing SP is calculated.



$$X_P = X_S + s_{SP} \cdot \cos(\sigma_{SO} + \omega)$$

$$Y_P = Y_S + s_{SP} \cdot \sin(\sigma_{SO} + \omega)$$



$$Z_P = Z_S + v_p + d.\cos z - v_c$$

Record of measured data

1. field book

2. field sketch

Field book

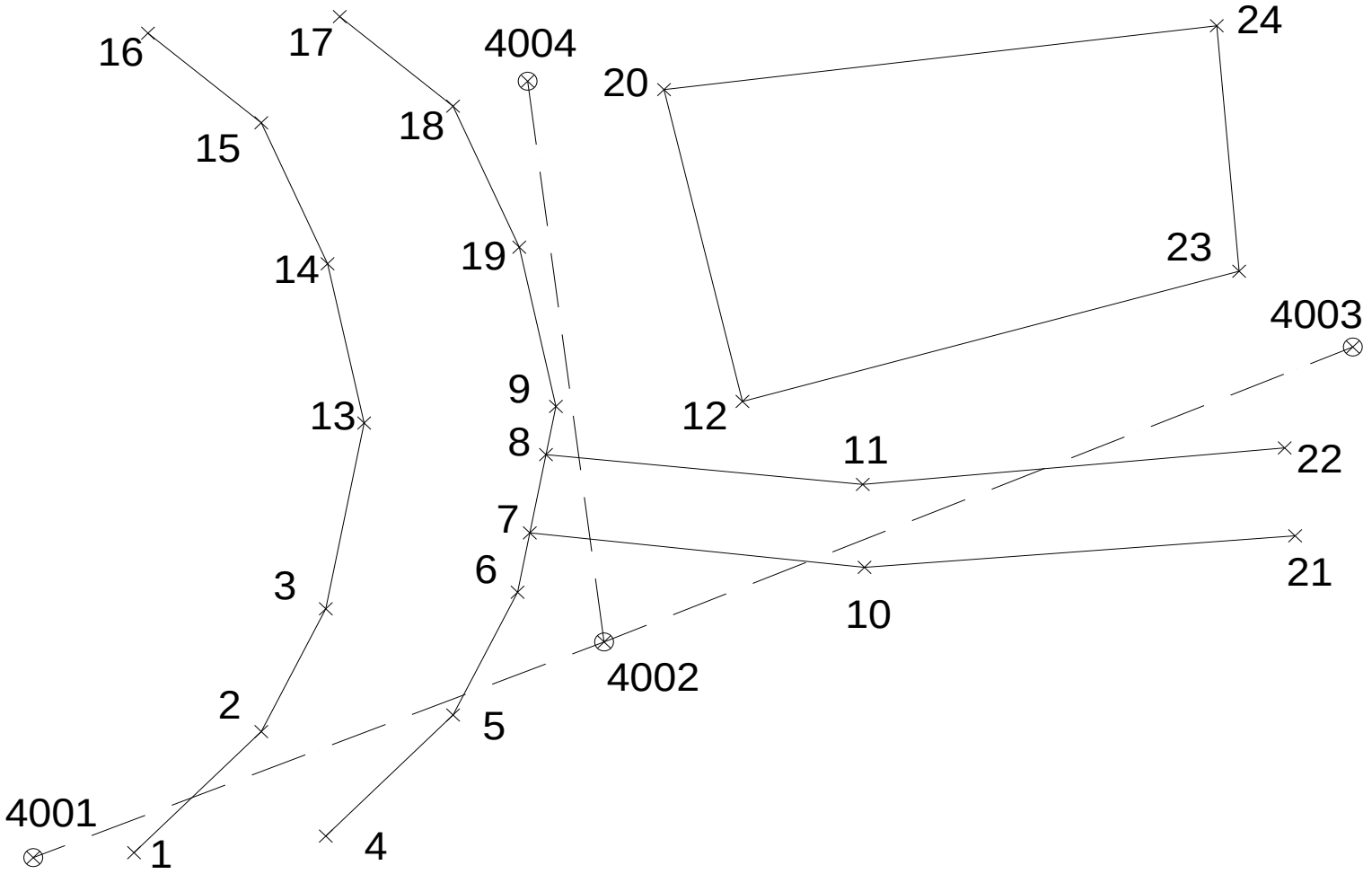
- number of the survey station
- measured orientation angle
- height of the instrument v_p

For particular detailed points:

- height of the target v_c
- measured values of *d, ω, z*

The best field book is a table with needed data. There is also a possibility of measured data registration at a memory card of a total station (if a total station is used).

Field sketch



Equipment for the spatial polar method

1. a theodolite and a measuring tape
2. a tacheometer with stadia lines
3. a tacheometer with an electronic distance meter (total station)

Measurement with a theodolite and a tape

- if better equipment is not available
- for distances shorter than length of the tape (mainly in interiors)
- a horizontal distance is measured by the tape $\rightarrow$ it is used if the altimetry is not measured (only coordinates Y, X are determined)

Tacheometer with stadia lines

- equipment = theodolite + rod
- a theodolite is placed at the survey station, a rod is set on the determined point
- upper, middle and lower readings are read on the rod, a horizontal and a zenith angles are measured
- horizontal distance *D* and height difference *h* are calculated:

$$D = k \cdot l \cdot \sin^2 z$$

$$h = \frac{D}{\tan z}$$

Tacheometer with electronic distance meter

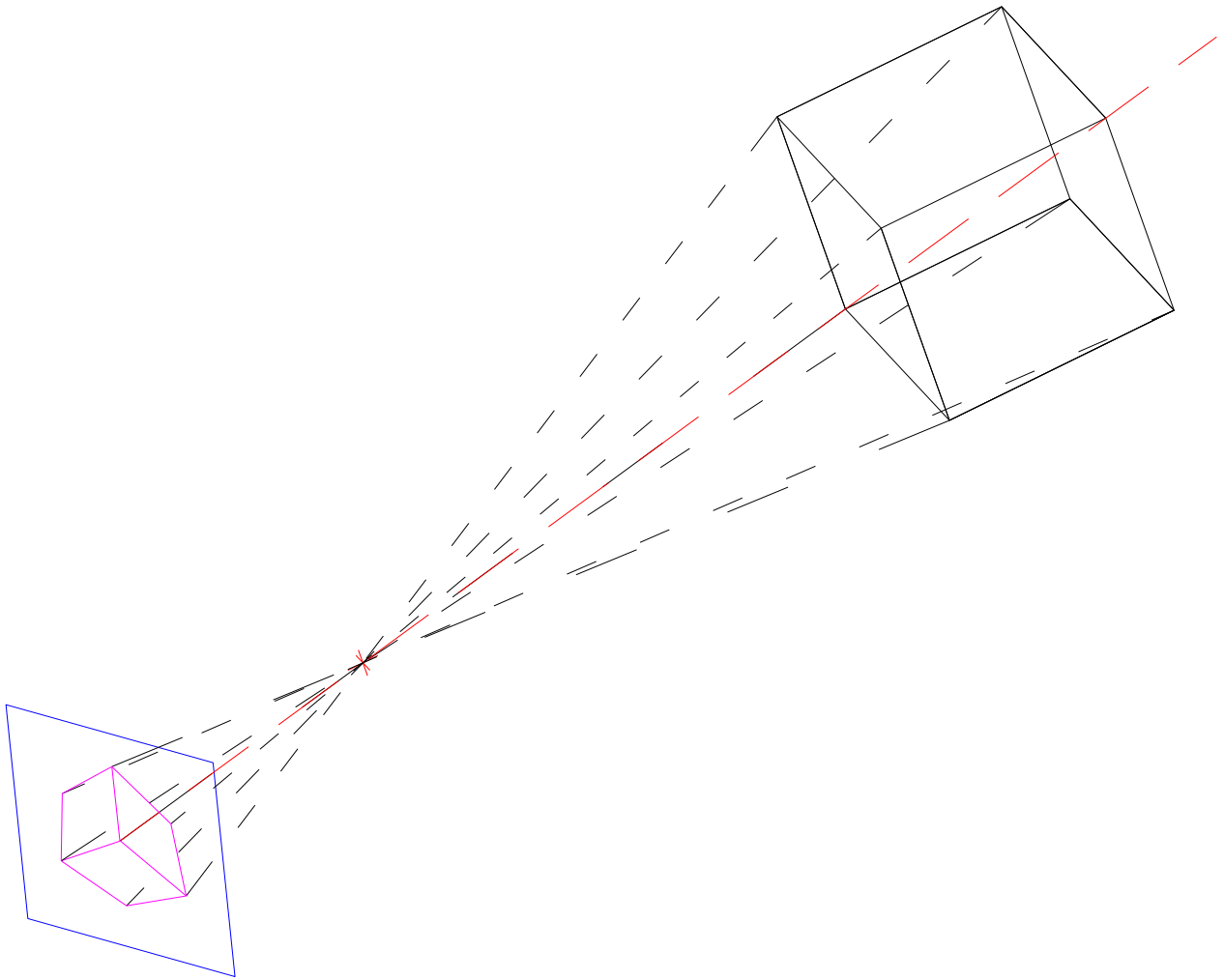
- most widely used nowadays
- distance is measured using a prism as a target or using a reflector less distance meter
- total stations enable measurement, registration and measurement processing (calculation of coordinates Y, X, Z)
- advantages = 1. high accuracy

  2. great range of a measurement (more than 1 km), therefore less survey stations are necessary

2. Photogrammetry

- method which makes use of photos to obtain measuring information
- analogue or digital photos are used
- equipment – non-professional cameras (for simple tasks with low requirements for accuracy) or special photogrammetric cameras
- photo = central projection of reality to the plane of photograph

Central projection



These parameters must be known for determination of a shape, size and spatial position of an object :

1. **elements of interior orientation**: they define internal relations in the camera,

2. **elements of exterior orientation**: they determine relation between the camera and the object.

Elements of interior orientation

a) camera constant (calibrated focal distance *f*)

b) position of the principal point of photograph = position of the view axis and photograph plane intersection point (x_0, y_0)

c) lens distortion = object-lens deficiency

Elements of exterior orientation

a) center of projection position = entrance pupil (X_0, Y_0, Z_0)

b) turning of the photo expressed by rotational angles ω, ϕ, κ (rotational angles of axis x, y, z)

If the elements of orientation are not known, it is possible to calculate them using so-called **control points** = points whose coordinates are known.

Photogrammetry:

1. **terrestrial photogrammetry**

   survey station is stationary $\rightarrow$ elements of exterior orientation can be determined

   reach about 500 m

   accuracy from cm to dm

2. **aerial photogrammetry**

   camera is in plane $\rightarrow$ terrestrial control points have to be used

   accuracy from dm to m

Photogrammetry:

1. single image photogrammetry

- only plane coordinates of an object are determined (Y, X)
- it is used if the measured object is plane, e.g. flat front of a building
- photo plan

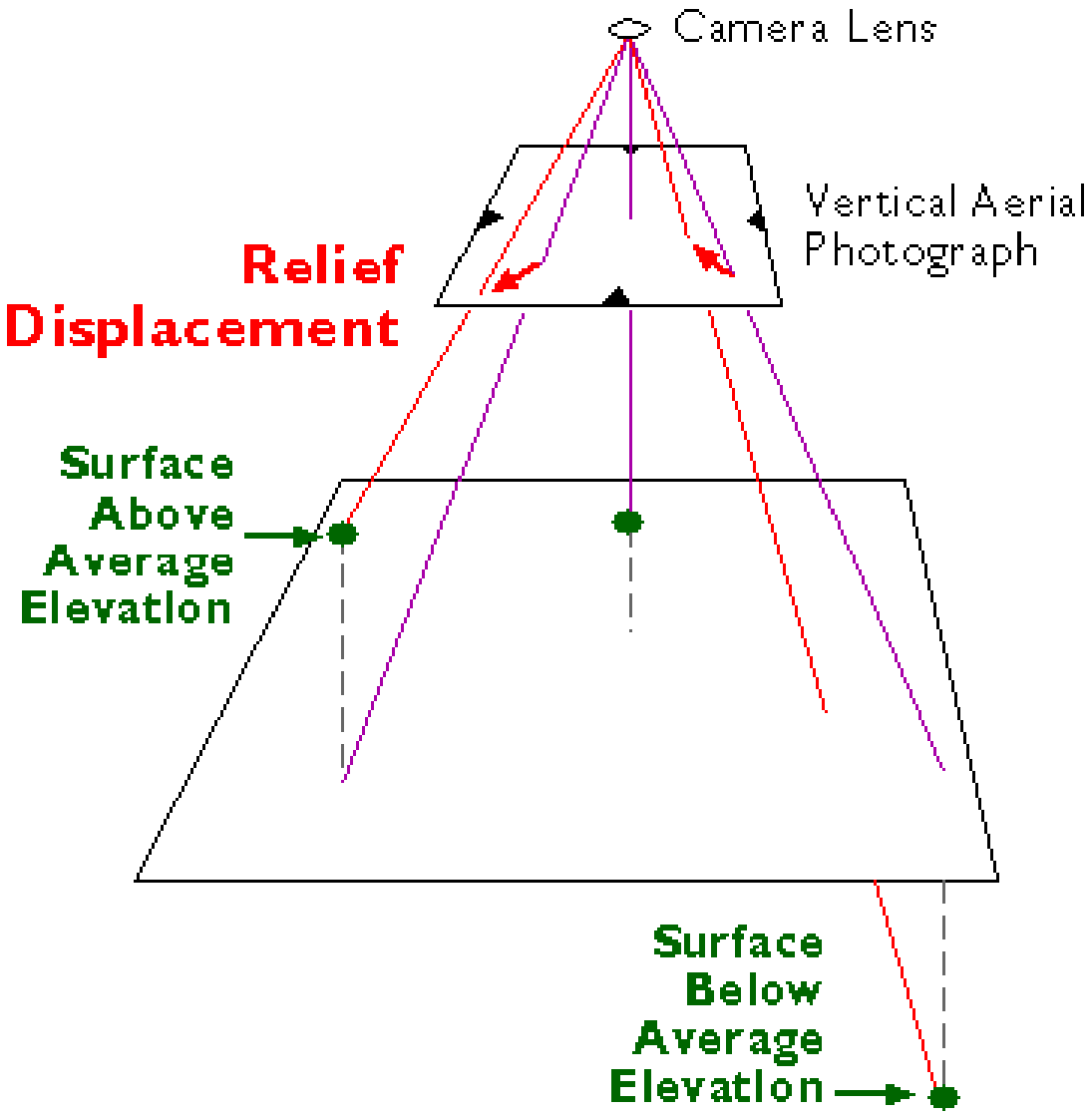
2. Multi-image photogrammetry

- orthophoto
- 3D model

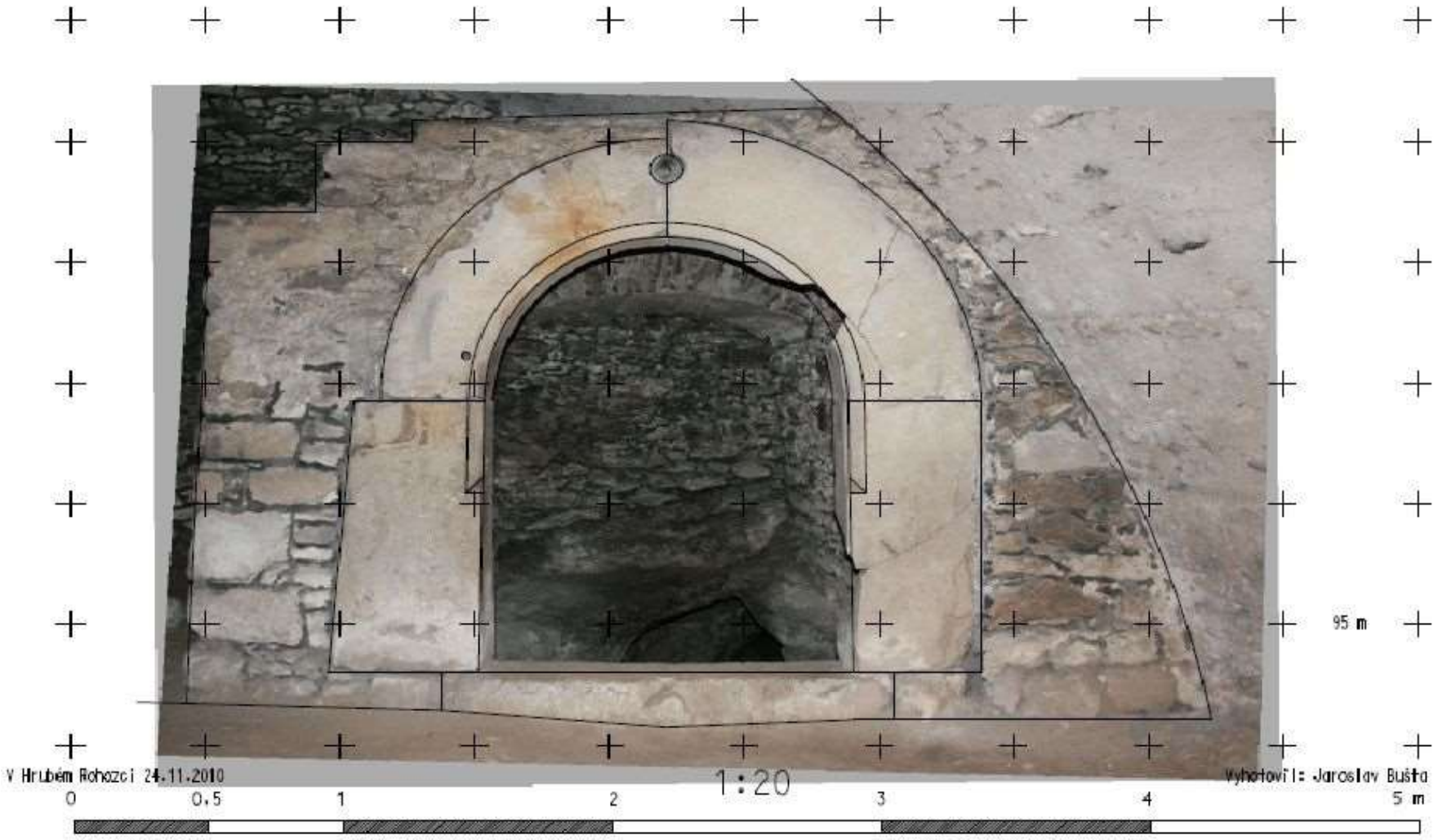
Single image photogrammetry

Photo plan is a photographic image corrected and rectified so that the image plane represent the plan of the real object in scale and metrically measurably. It is created from single photograph where central point of view produced small perspective deformations (relief displacements).

Single image photogrammetry



Single image photogrammetry- photoplan



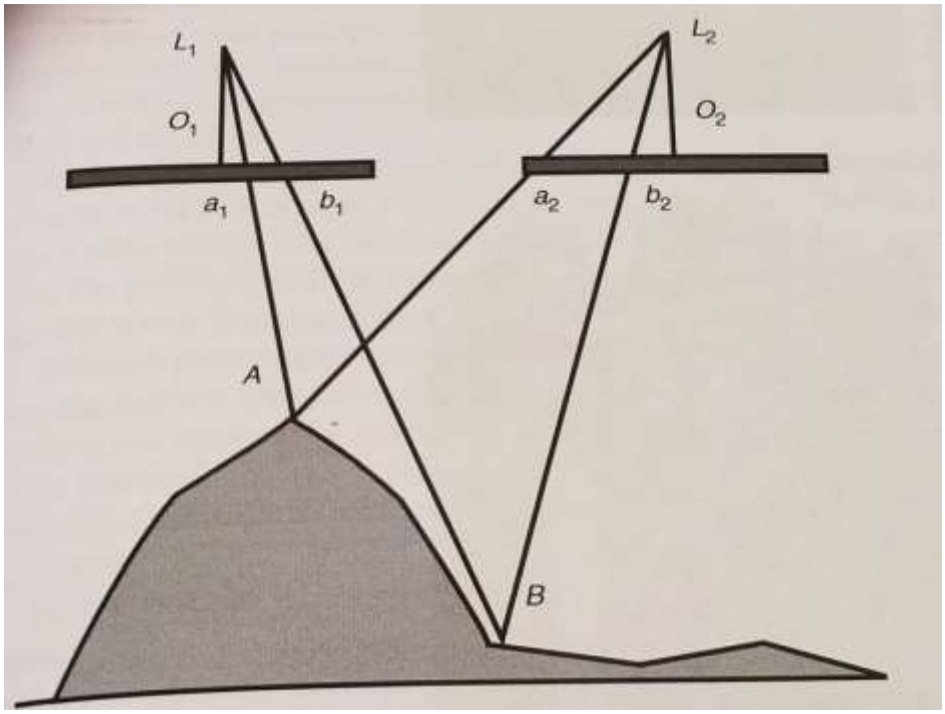
Multi-image photogrammetry

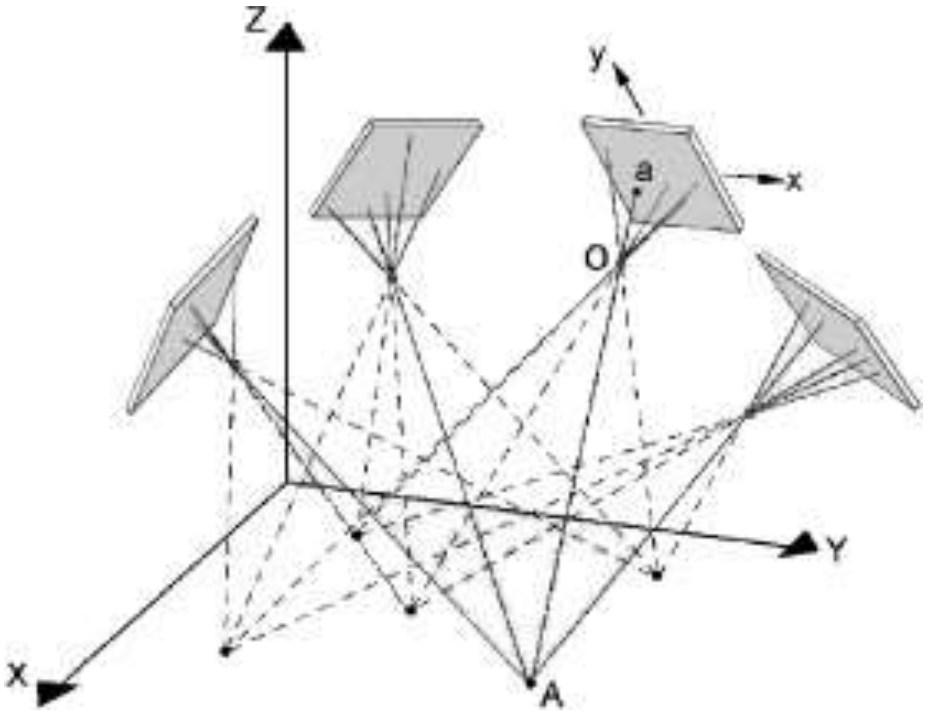
- spatial coordinates of the object are determined (Y, X, Z)
- **stereophotogrammetry (two-image photogrammetry)** is used most frequently – 2 photos are provided and analyzed:

  formerly analogue instruments

  nowadays digital methods – spatial perception is created by means of a display and special glasses

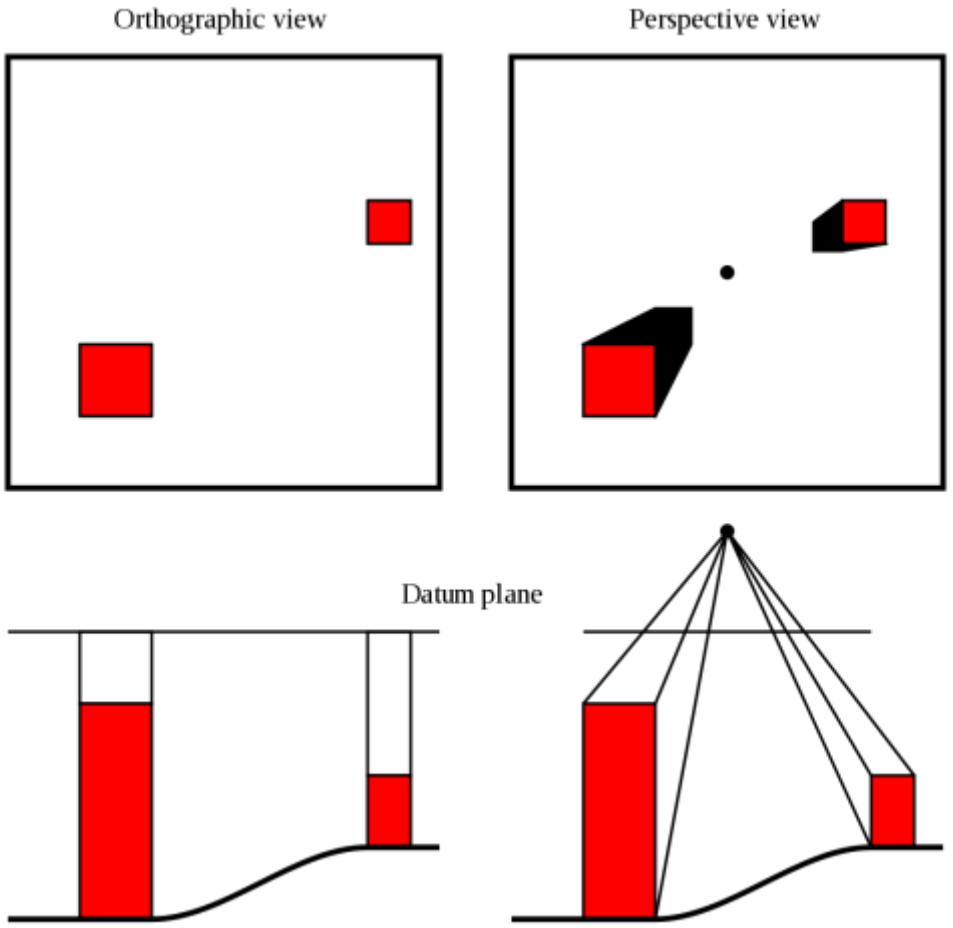
Multi-image photogrammetry





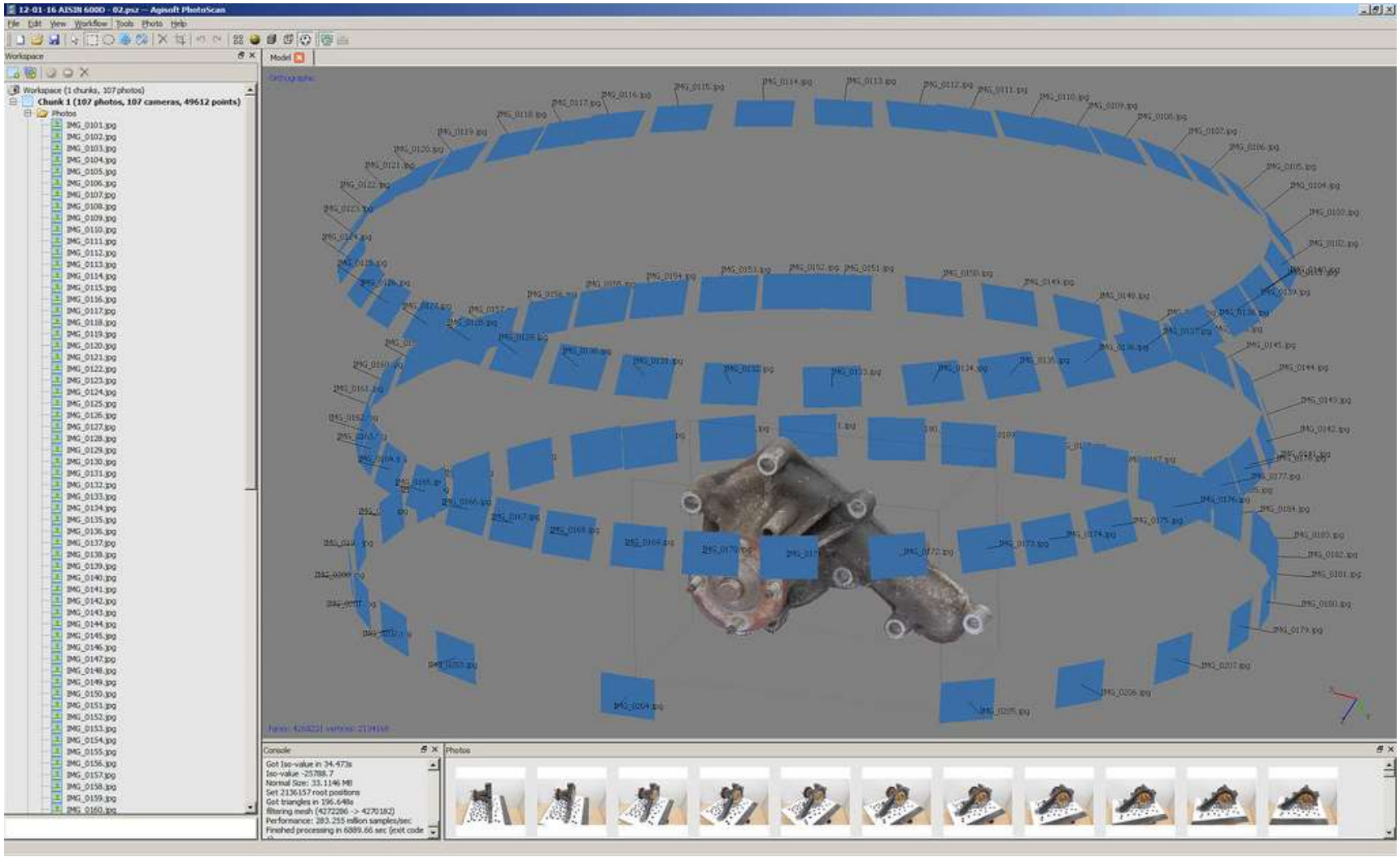
Multi-image photogrammetry – orthophoto

Geometrically corrected (orthorectified) image (relief displacements are removed from image)



Multi-image photogrammetry - orthophoto

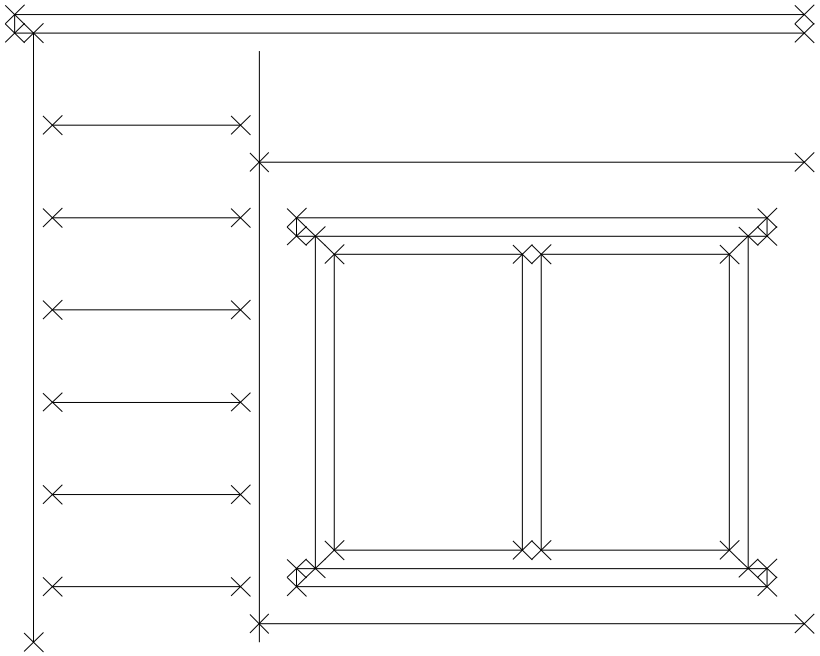
Multi-image photogrammetry – 3D model

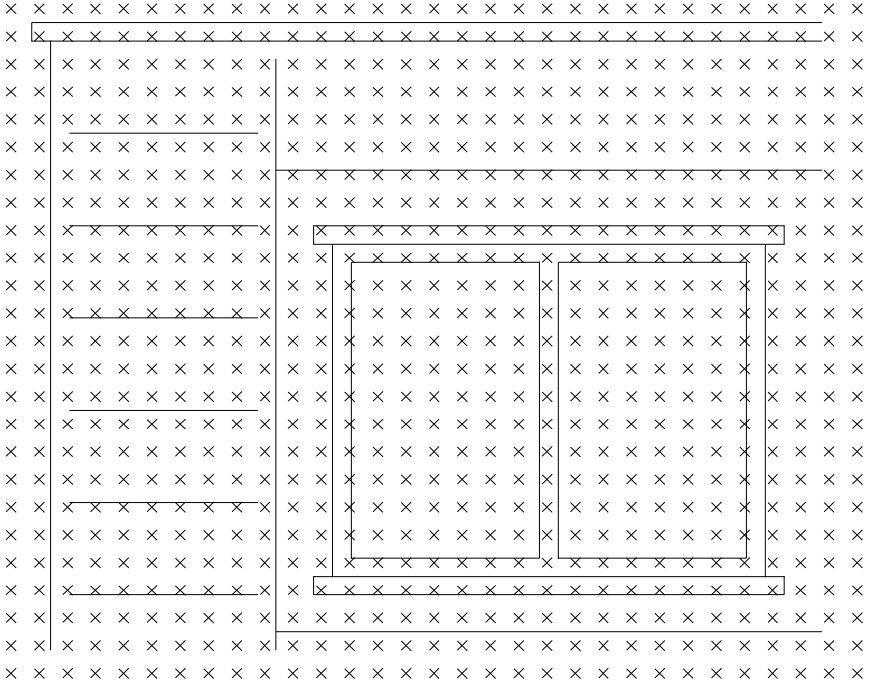


3. Terrestrial laser scanning

- new technology based on the principle of the spatial polar method
- instruments = laser scanners which enable a non-selective measurement of a huge number of points on the object surface (thousands points per second)
- result of a measurement = point cloud

Non-selective measurement

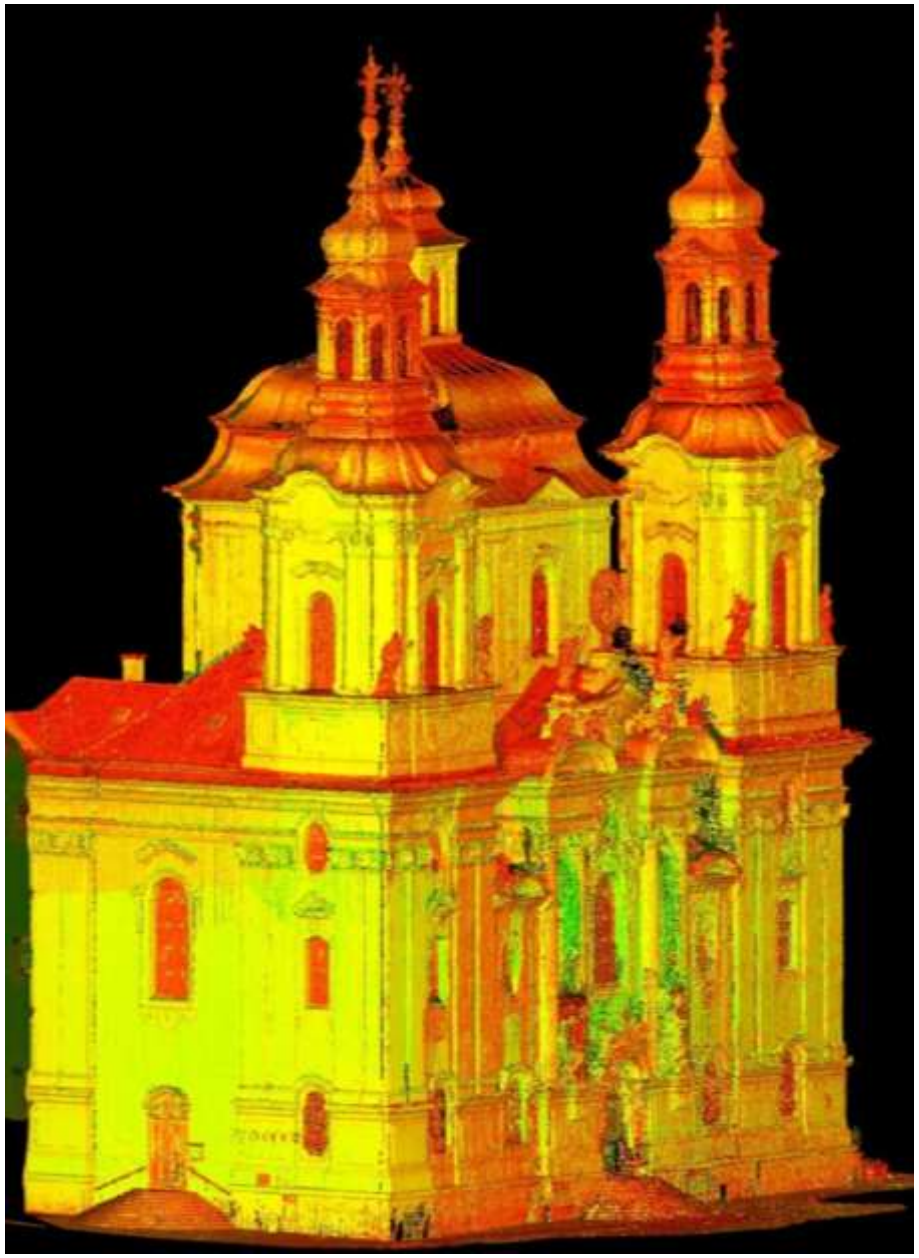


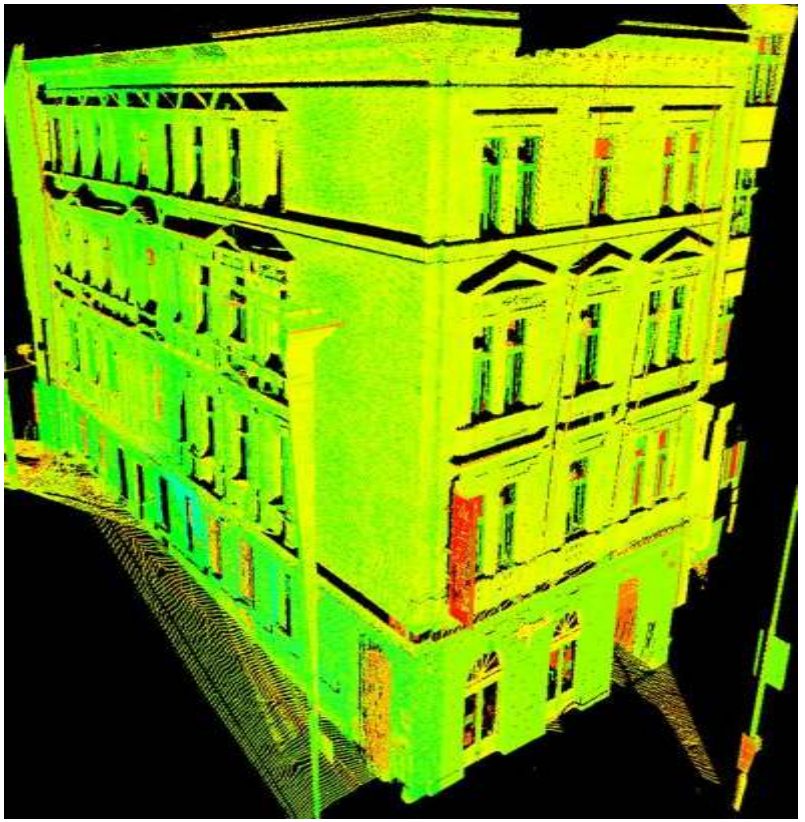


- Range of scanner measurement is usually from 1 to 1000 m (terrestrial scanners)
- Accuracy is in range from 1 mm to 50 mm
- Results: point cloud, CAD model, TIN
- Use – documentation of the present condition of an object (e.g. historical monument), volume determination,...
- Advantages: fast measurement, large amount of data (millions points)
- Disadvantages: large amount of data (millions points), data processing, software

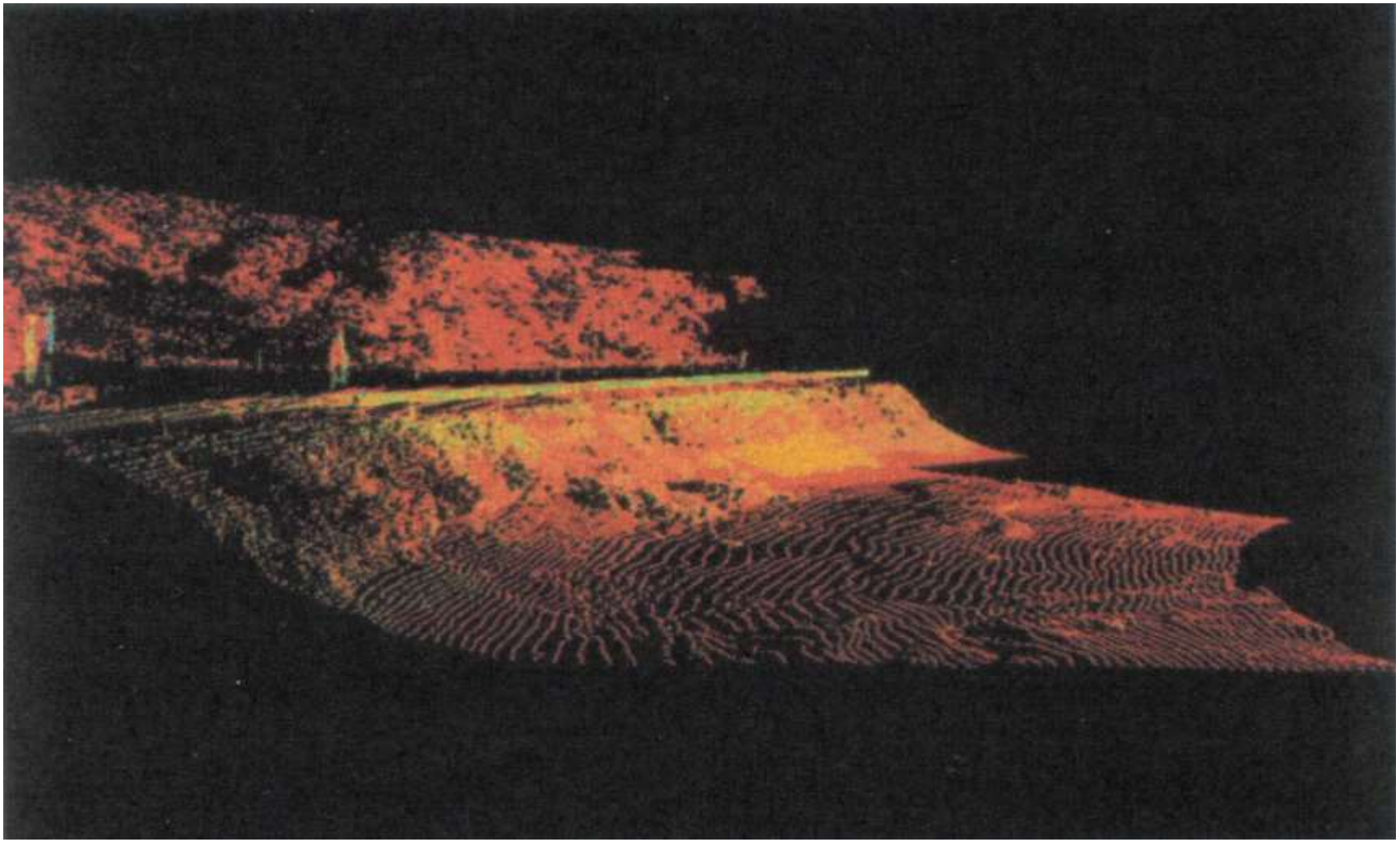
Laser scanners

Point cloud

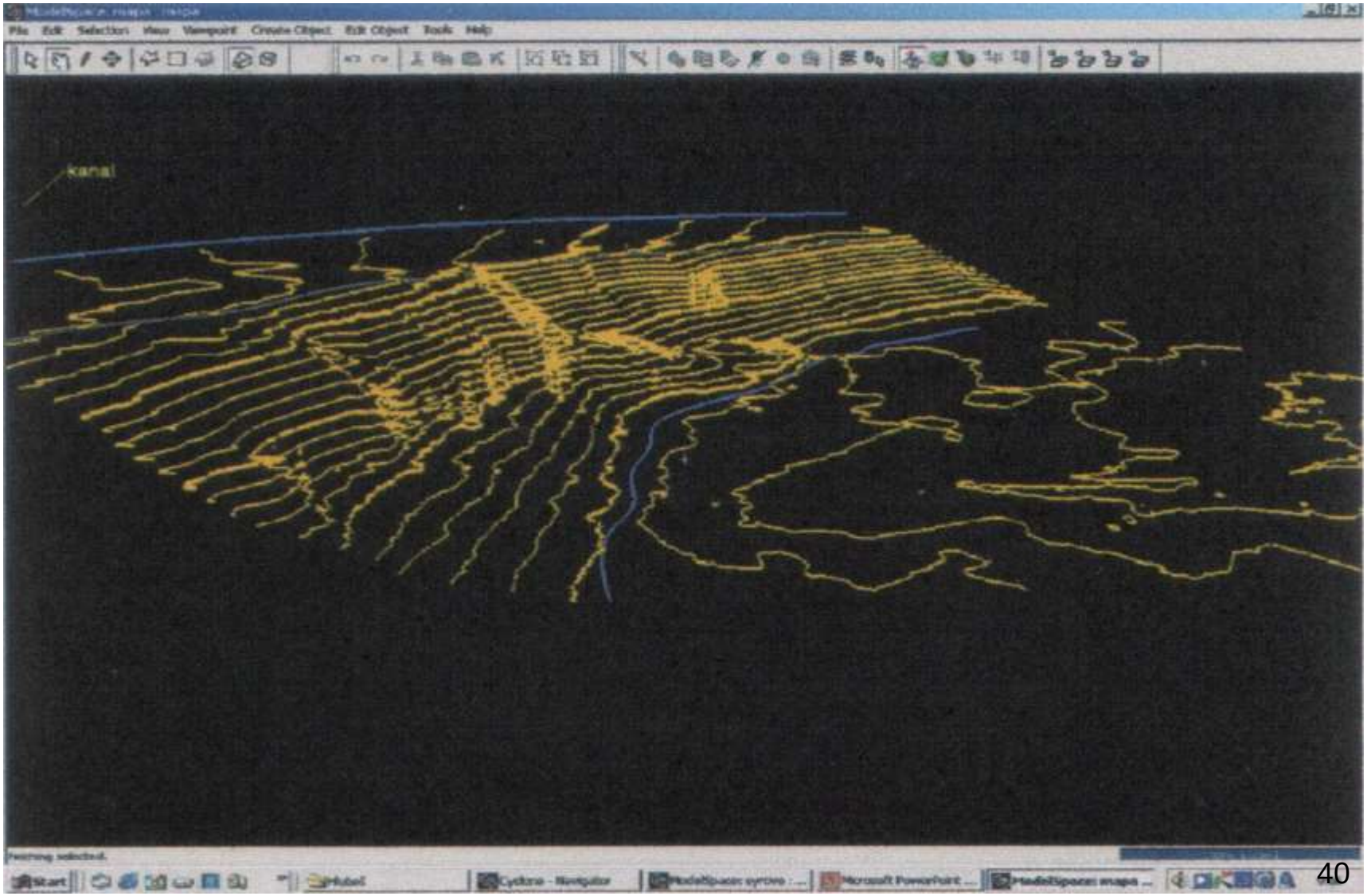




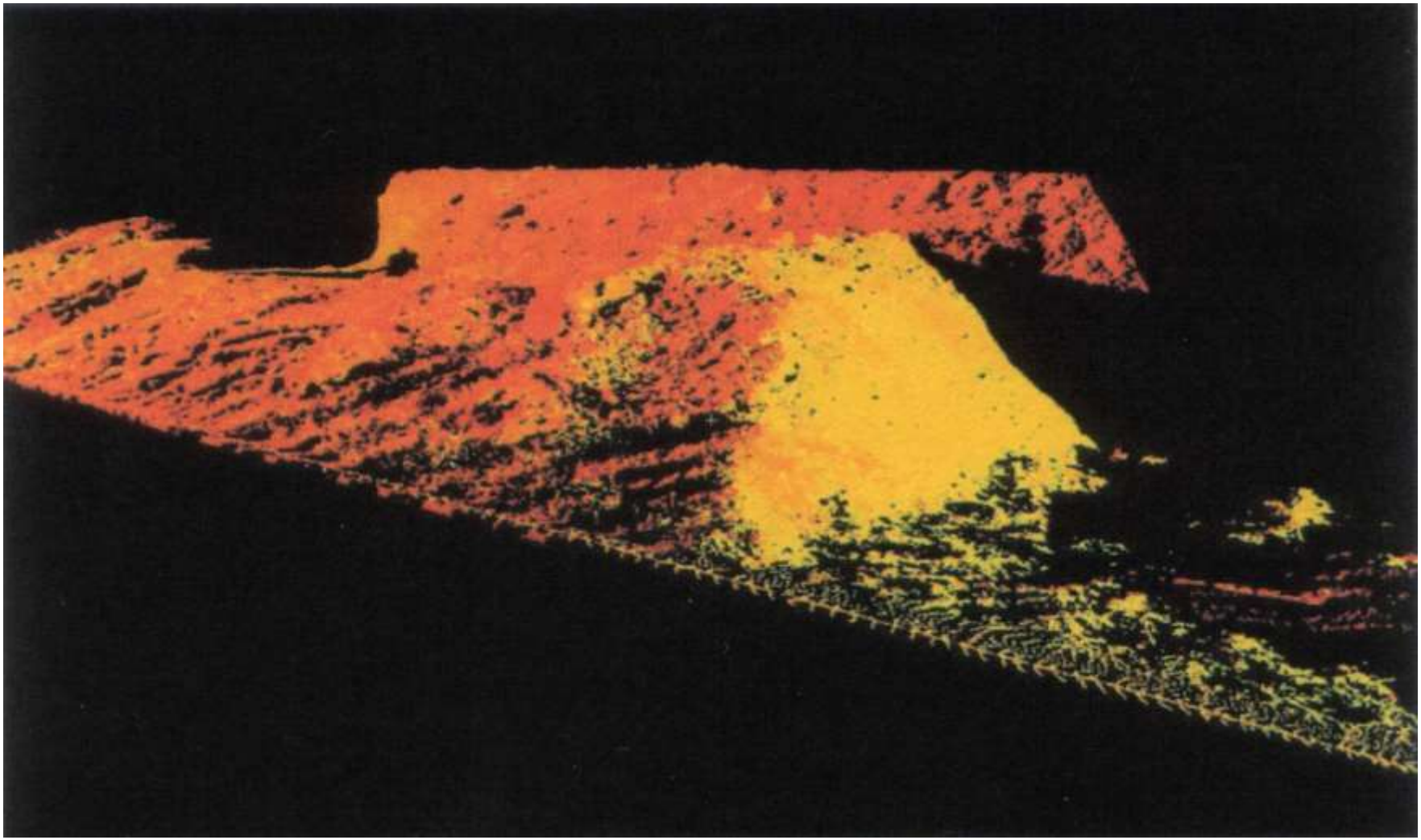
Earth surface – scan



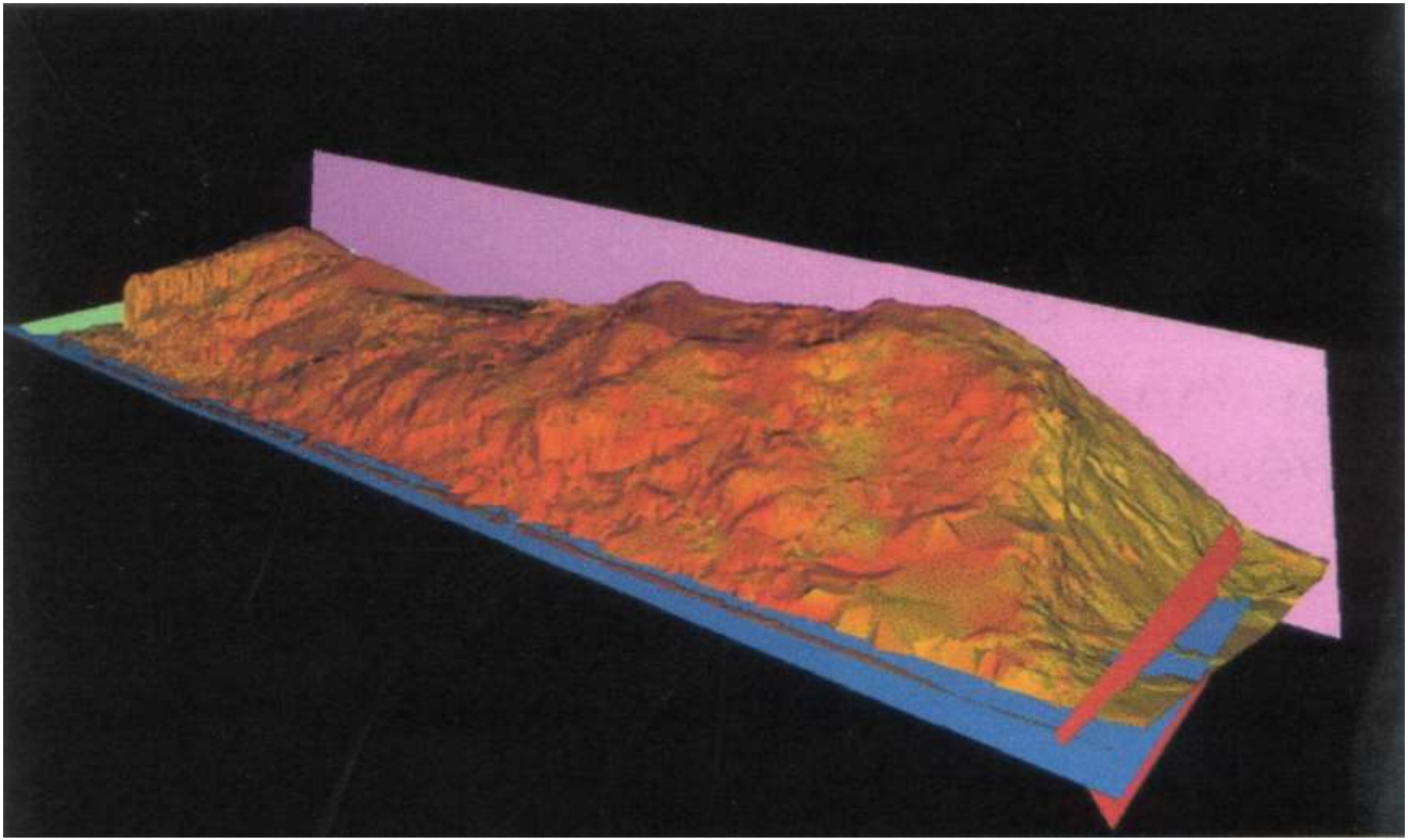
Earth surface – contour model



Rocky massif – scan

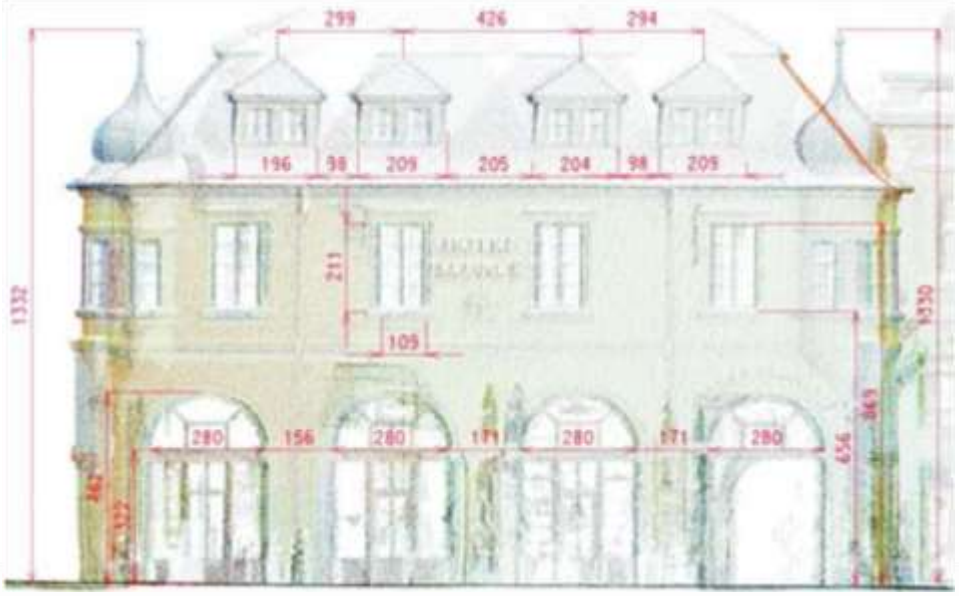


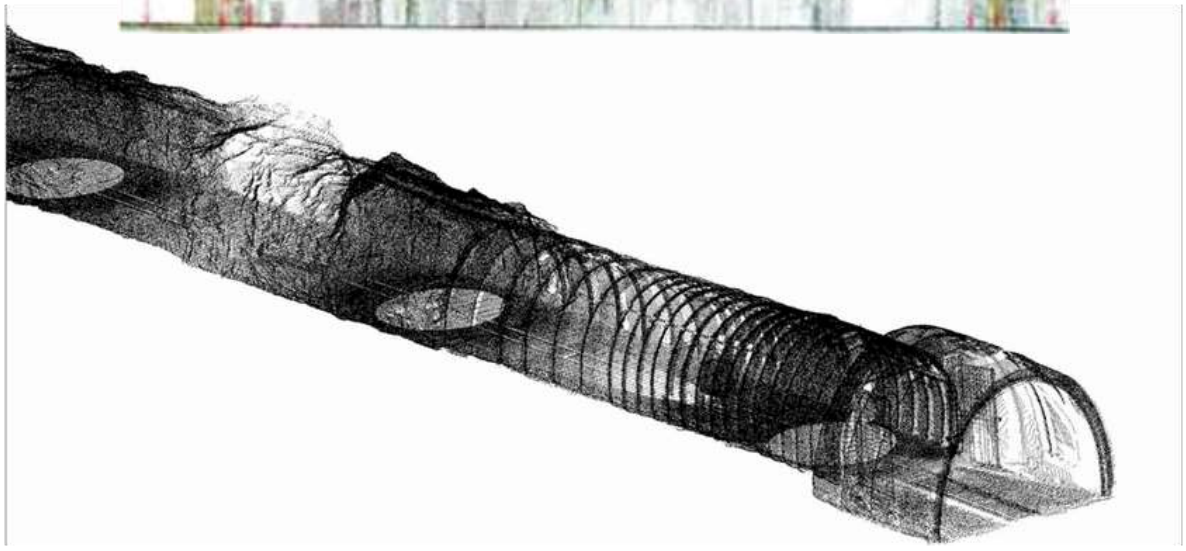
Rocky massif – 3D model

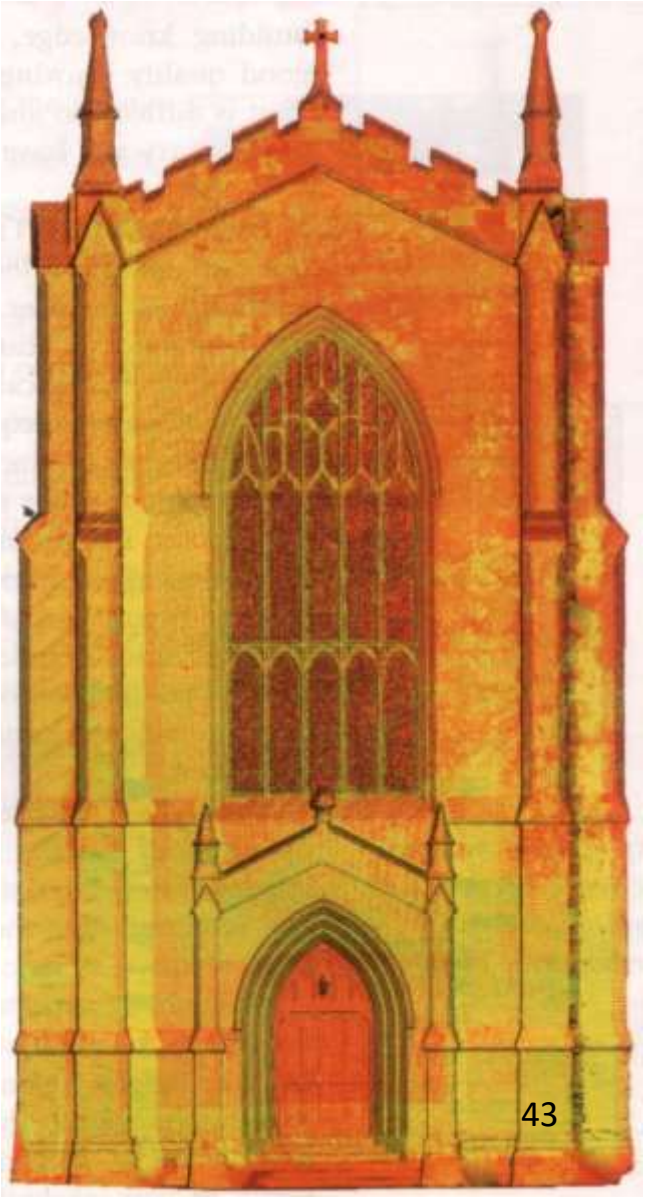


Results:

Point cloud

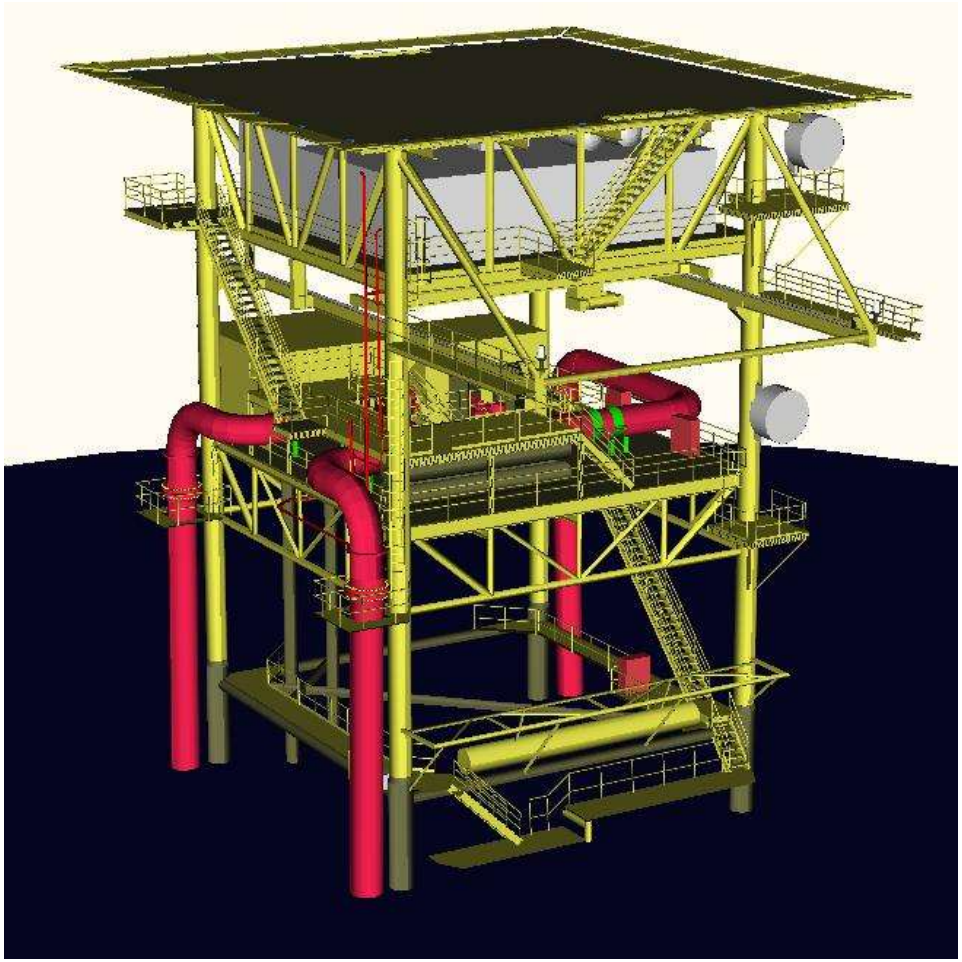


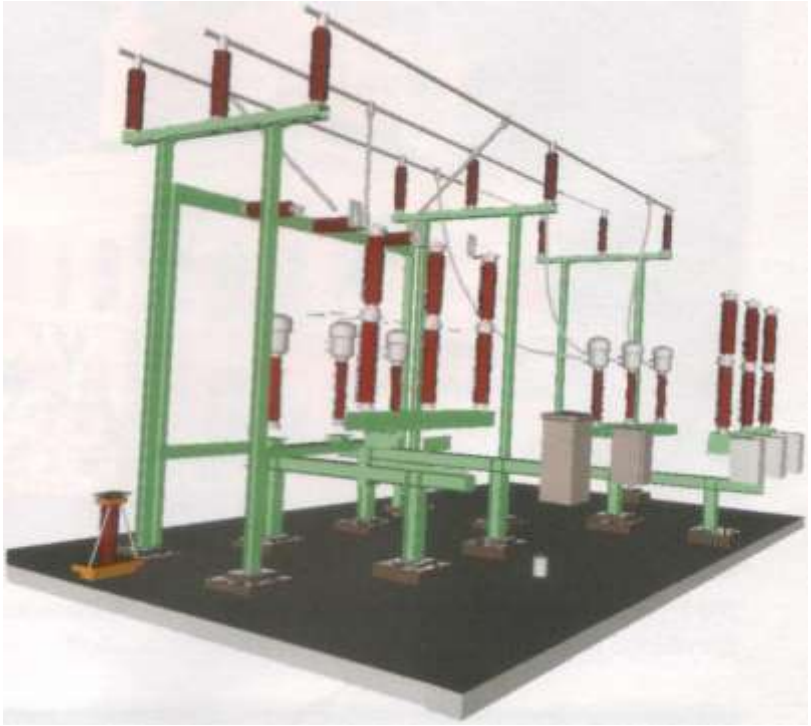




Results:

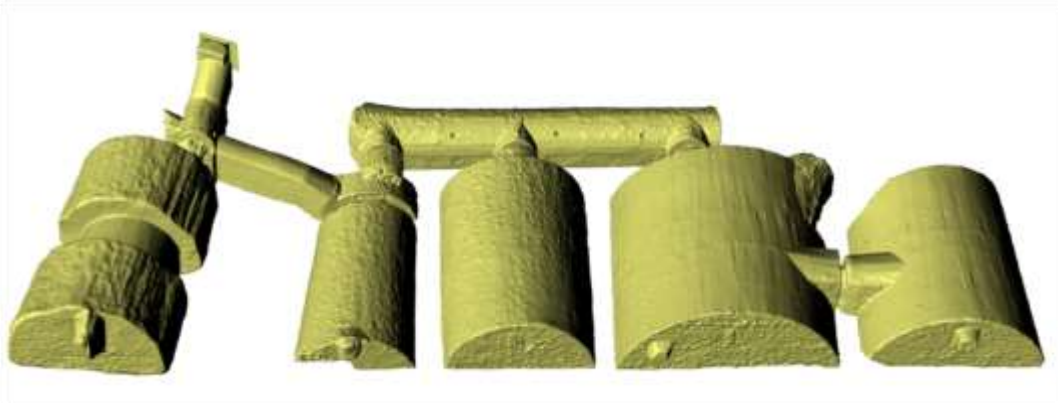
3D model, replacing of the point cloud by geometric primitives

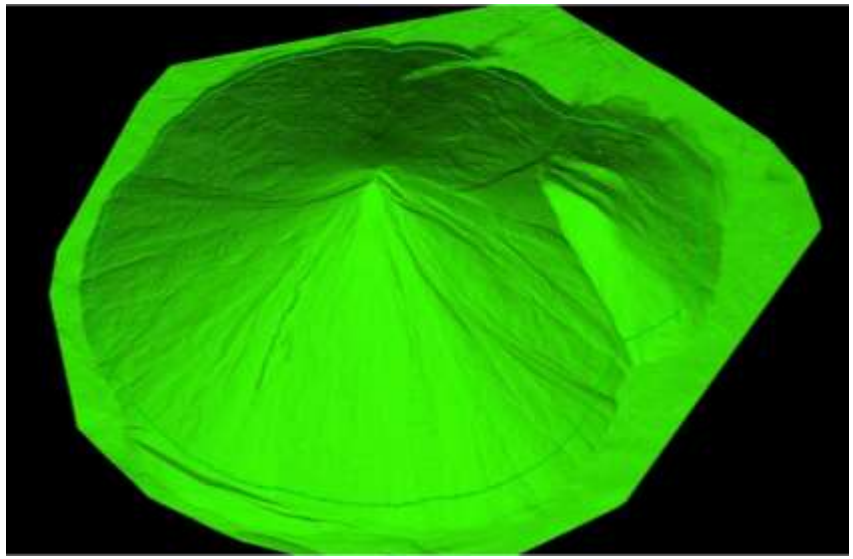




Results:

3D model, replacing of the point cloud by mesh





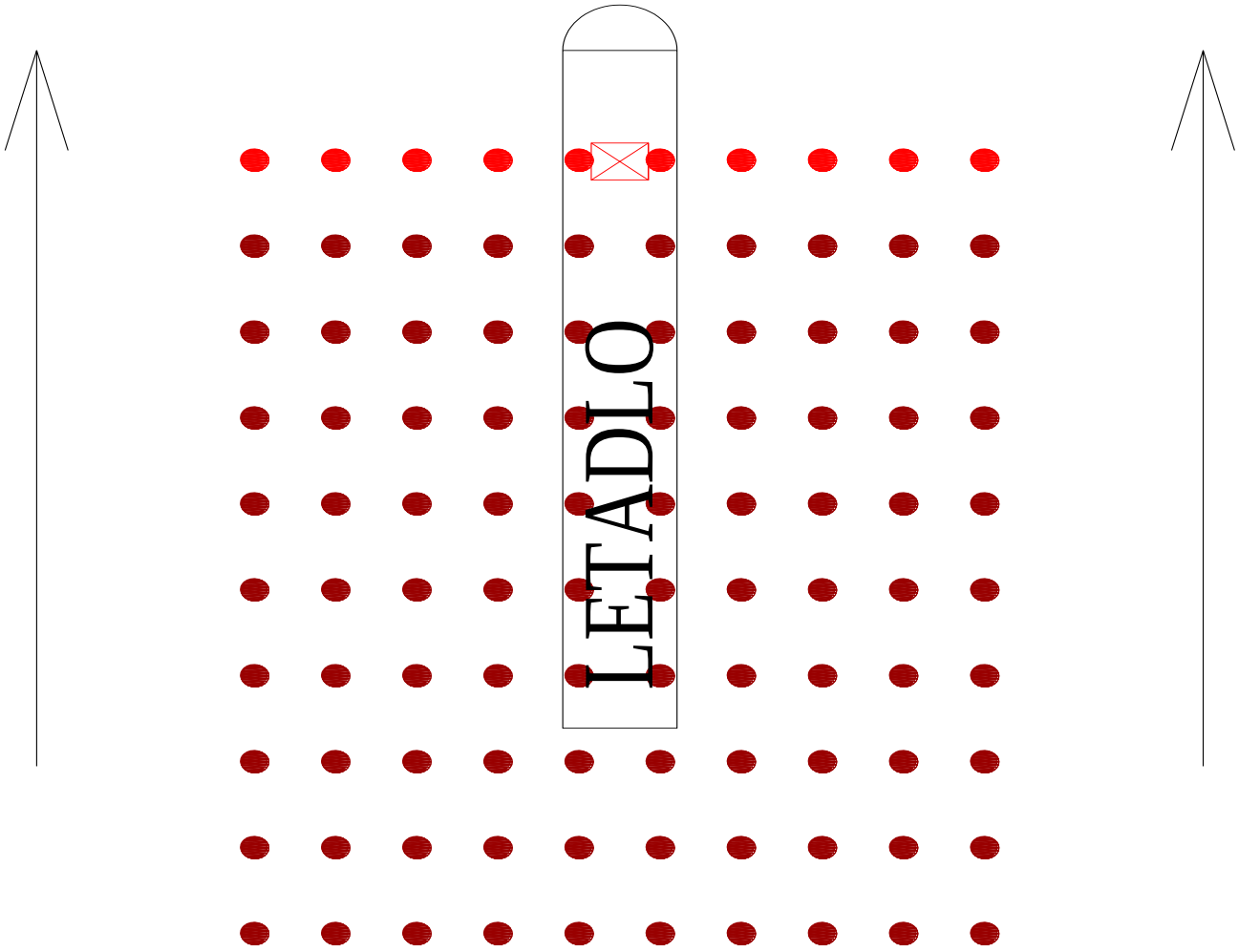
Results:

Combination of previous procedures:

Aerial laser scanning

- the same principle as the terrestrial (previous) one
- more robust and efficient scanners are used (plane is moving during scanning)
- aerial scanners are usually line scanners and the other dimension is created by the plane motion
- accuracy in cm
- aerial photogrammetry is fill up by this technology (advantages = speed and flexibility) in some situations

Aerial laser scanning



Town 3D model created by laser scanning

4. Remote sensing

- satellite images are created, analyzed and processed $\rightarrow$ thematic maps creation
- information is obtained using electromagnetic radiation

1. **passive data acquisition system:** only receiving of radiation, thermal radiation of the Sun or of the Earth is used,
2. **active data acquisition system:** radiation is emitted and then it is reflected by the investigated object, the reflected radiation is recorded, artificial source of radiation is used (radar)

Every object (e.g. terrain without vegetation, vegetation, water etc.) has its characteristic reflectivity. If object's reflectivity is known, the type of object can be determined by receiving signal processing.

accuracy about 1 m

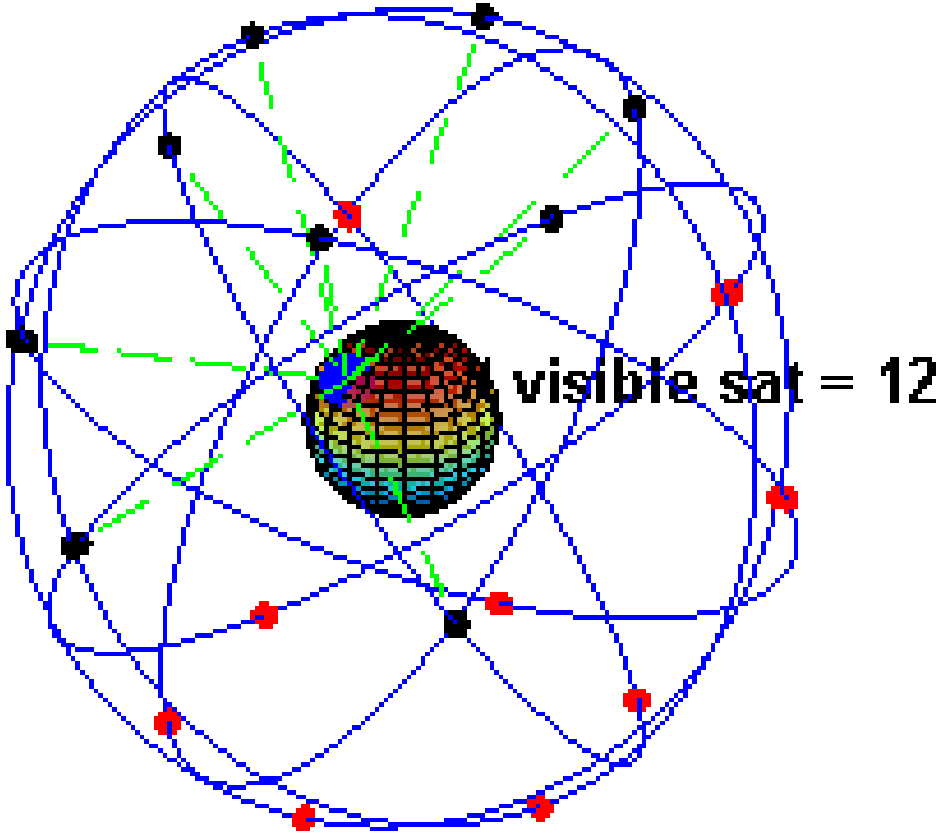
5. GNSS – global navigation satellite system

- GNSS are used for navigation in real time, and it is possible to use it for geodetic measurements.
- satellite passive telemetric system
- satellites circle the Earth on orbits in specific height
- all satellites emit coded information about their positions and sending time
- satellites' signals are received by means of a special instrument processing information (= calculate distance between the satellite and the receiver)

- calculation results from knowledge of the satellite signal speed and the difference between sending and receiving time
- signals of 3 satellites at least are necessary for positioning (geographic longitude and latitude are determined)
- signals of 4 satellites at least are necessary for determination of position and height
- We need teoretically 3 satellites, but we must determine the time error of receiver – it is fourth unknown
- originally GPS was military navigation system of United States Army, it has been available for civil users since 1990s

GNSS

- Visibility of the satellites from a specific place



GNSS signal processing

1. **Navigation GNSS** (the simplest)

   accuracy several m

2. **Differential GNSS**

   algorithm is the same as previous one, in addition several corrections are introduced

   accuracy about 1 m

3. **geodetic GNSS**

   2 special instruments are necessary, computational procedure is sophisticated, only positional differences are determined

   accuracy in cm

   accuracy in mm for distances shorter than 10 km and for long observations (12 hours)

RTK method

RTK (real time kinematic) – two instruments, the first (base) is placed on known point, the second (rover) is placed on measured point.

Measurement is in real time. It is necessary to have permanent direct data connection (GSM) between base and rover.

Nets of reference stations are operated (CZEPOS, WRS NOW, TOPnet) – advantage – you need only one instrument.

NAVSTAR GPS

Structure of the system

Cosmic segment

24 satellites circle the Earth on 6 orbits in height of 20200 km (now 31), all satellites emit coded information about their positions and sending time.

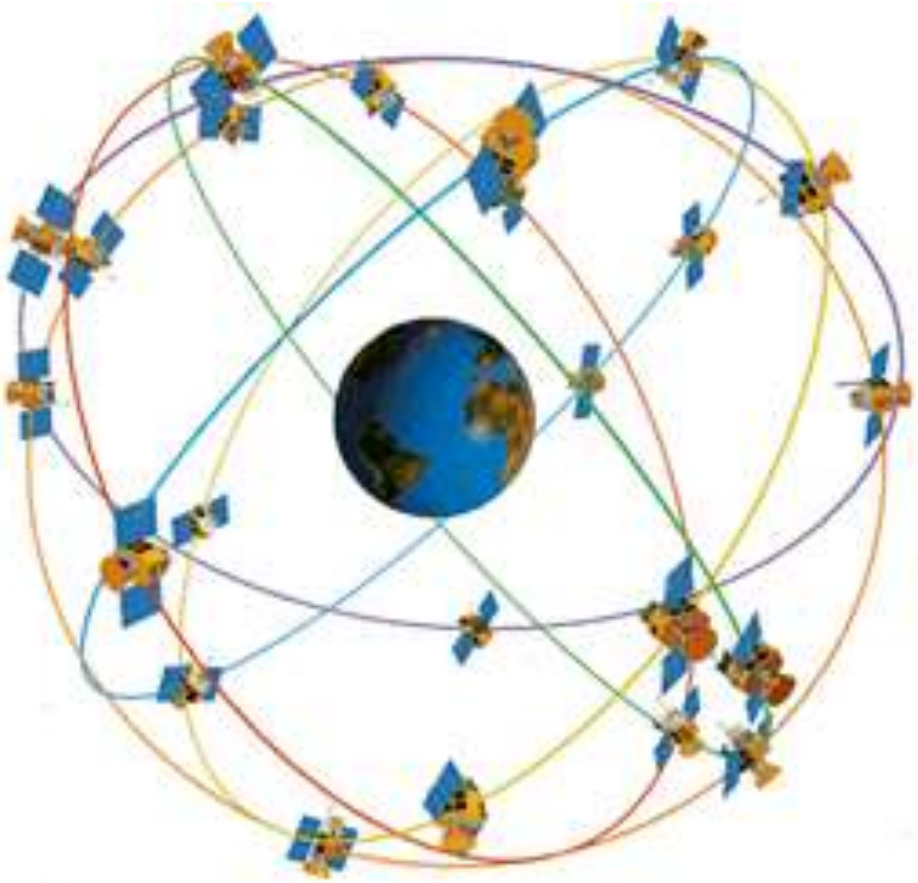
Control segment

Terrestrial control centers for control and revision of space segment.

Users segment

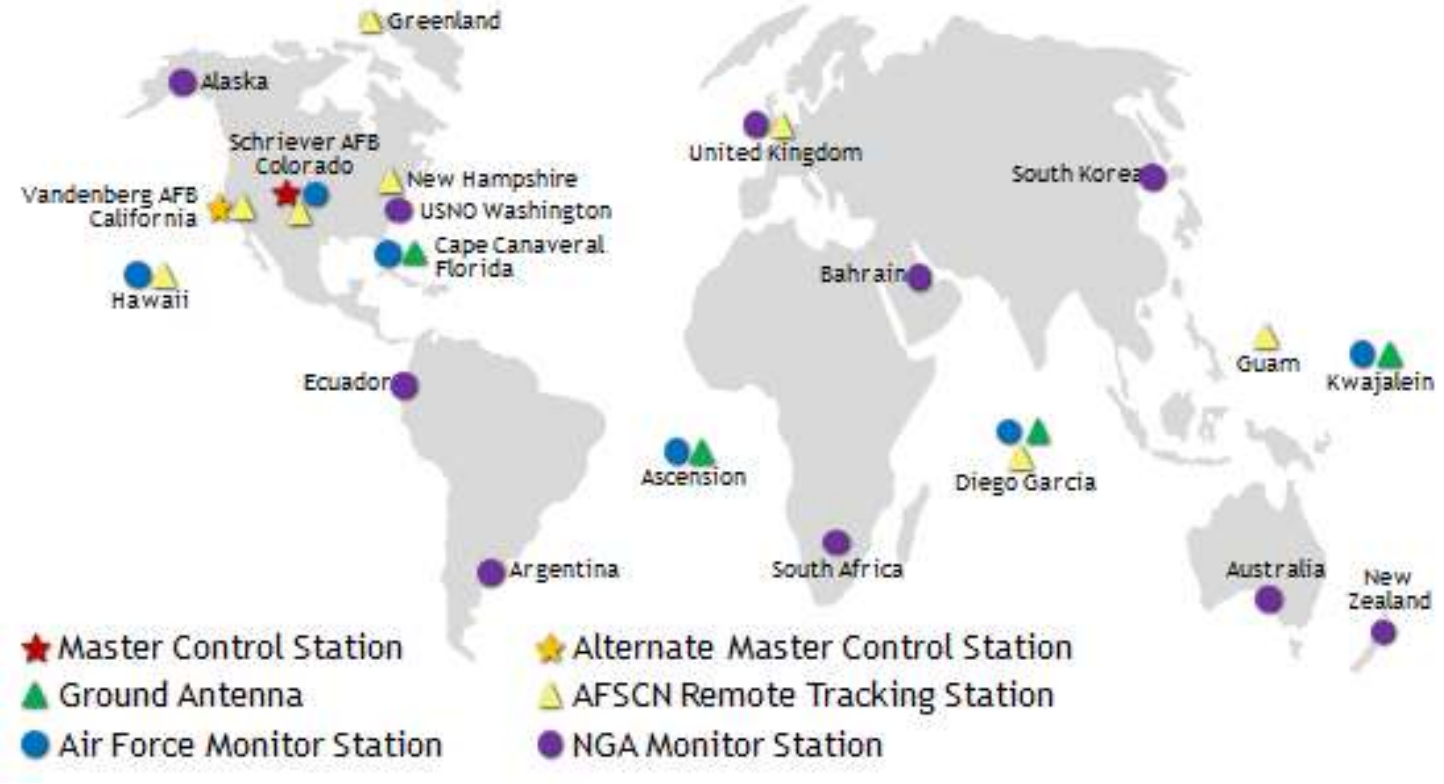
Users receive the satellite signals by receiver and determine their position and time.

Cosmic segment



Control segment

Terrestrial control centers for control and revision of space segment.



Users segment

Users receive the satellite signals by receiver and determine their position

Another systems

Russia – GLONASS – 22 satellites

EU – GALILEO – 23 satellites

China – BEIDOU-2 (COMPASS) – 35 satellites

Local GNSS
Japan – QZSS – 4 satellites
India – IRNSS/NAVIC – 7 satellites

Thank you for your attention!