Metrology, Instruments, Sensors, Beaconing, Signalisation

Content

- Overview
- General Specification (Quality) of Sensors/Instruments/Methods
- Sensors/Instruments/Methods

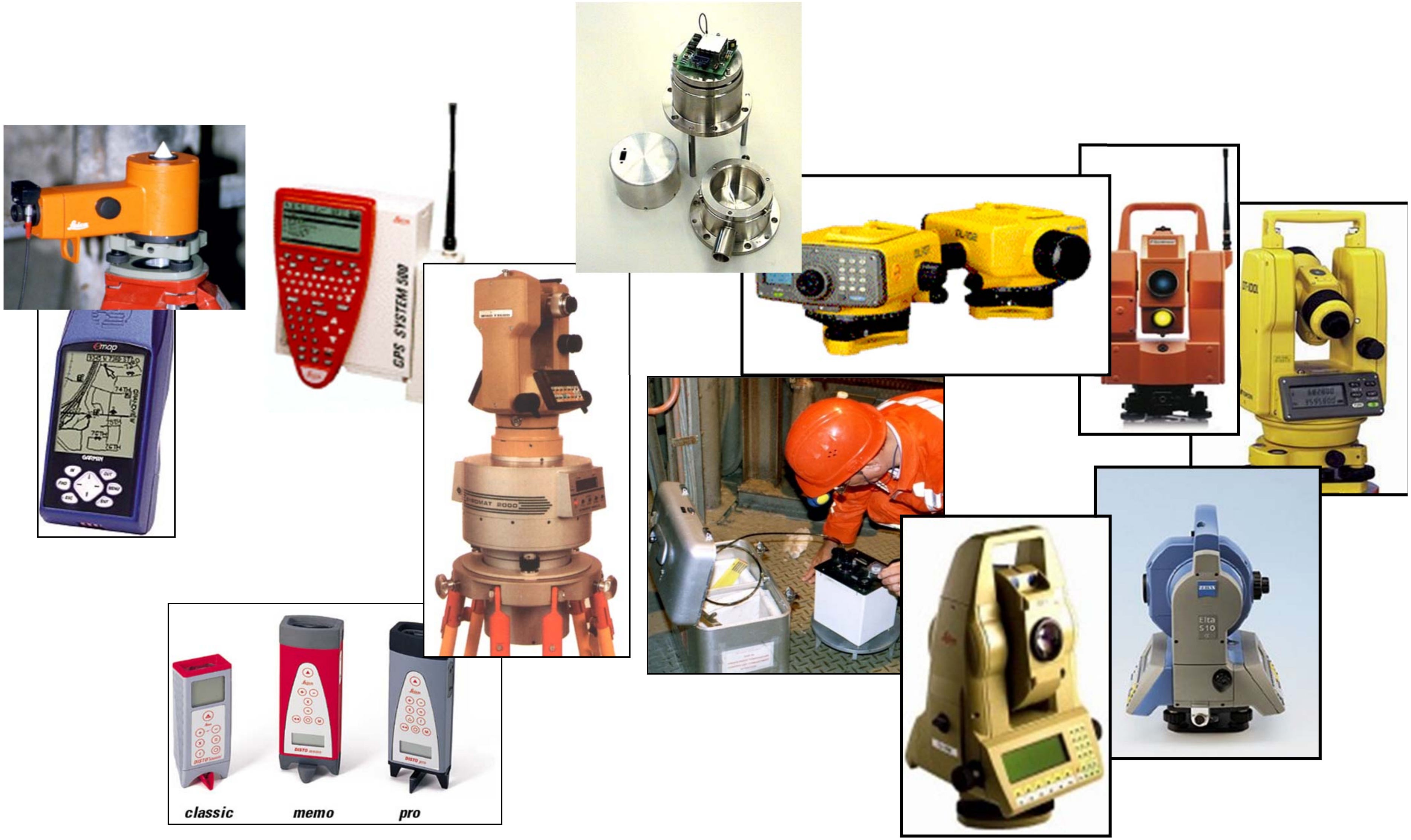
  1D Length – Height – Alignment – Plumbing – Direction – Rotation

  2D Coordinates/Position

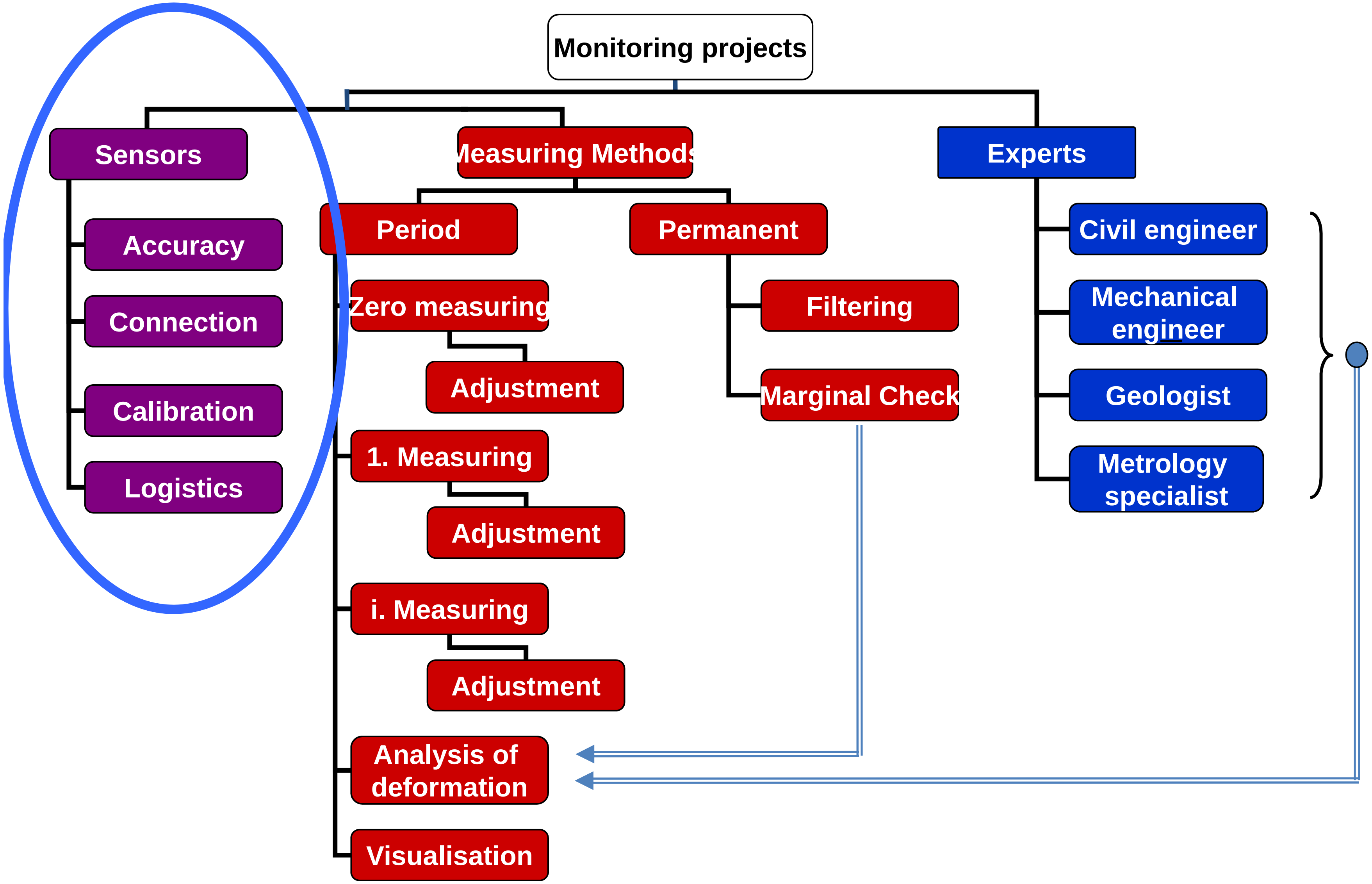
  3D Coordinates/Position

- Beaconing/Centring/Signalisation

The Variety of Sensors,Instruments and Methods in EG



The Environment: Sensors – Measuring Methods – Expert



Monitoring Sensors, Instruments: Overview

- Pressure sensors
- Hydrostatic systems
- Displacement transducers (extensometers, crack- and jointmeters,
- Strain gauges (tension gauges)
- Tiltmeters, including vibrating wire
- Load cells (force measurement)
- Fixed removable micrometers (FIM)
- Optical fiber
- Optical positioning sensors

- Motorised total stations; Terr. Scanner
- GPS
- Digital levels, including those with motorisation
- Remote Sensing methods

- Meteorological sensors
- Temperature sensors
- pH and conductivity meters
- Gas sensors

Geotechnics

GEOPHYSICS

GEODESY

CHEMISTRY

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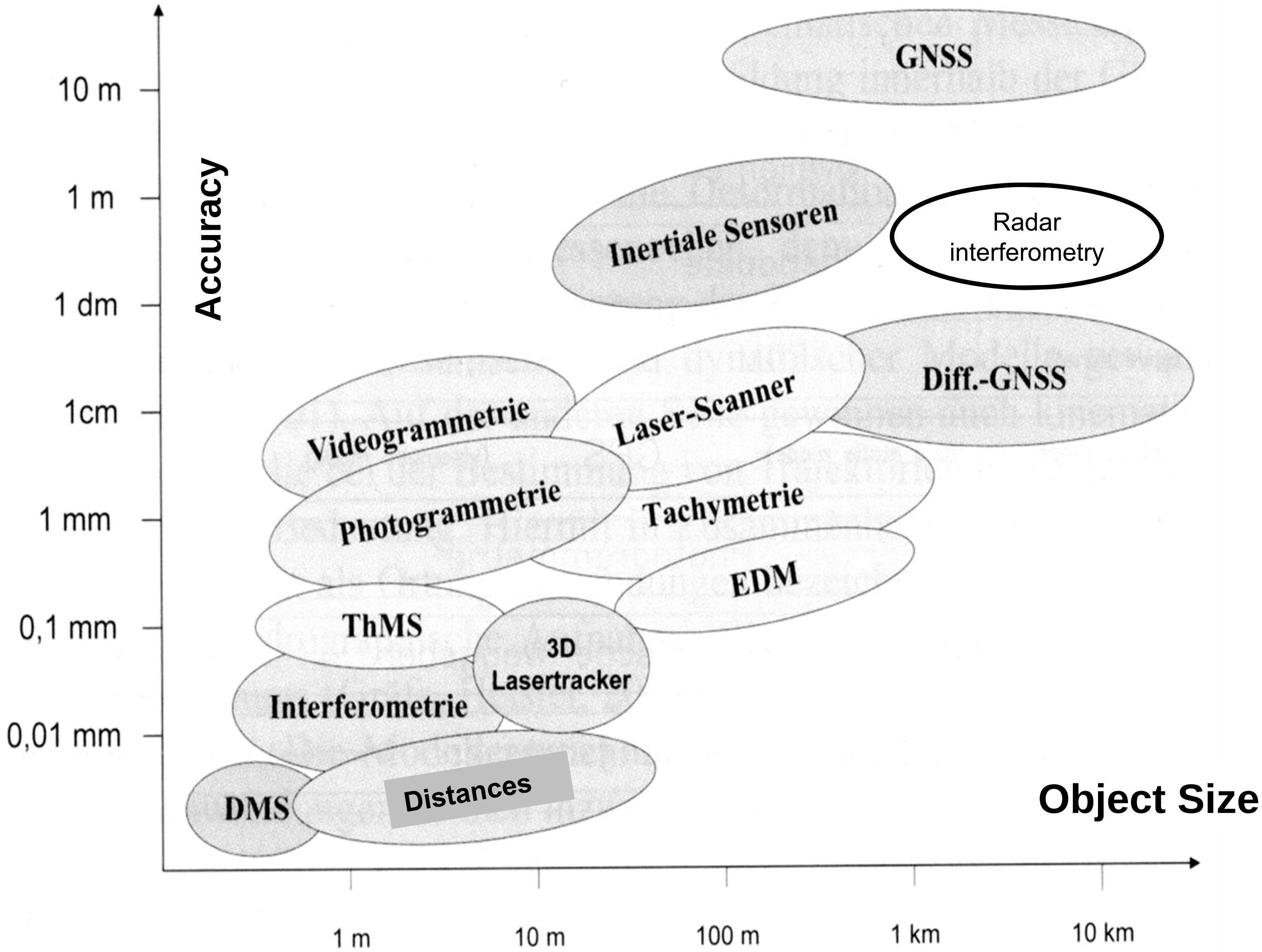
Methods: Accuracy versus Range



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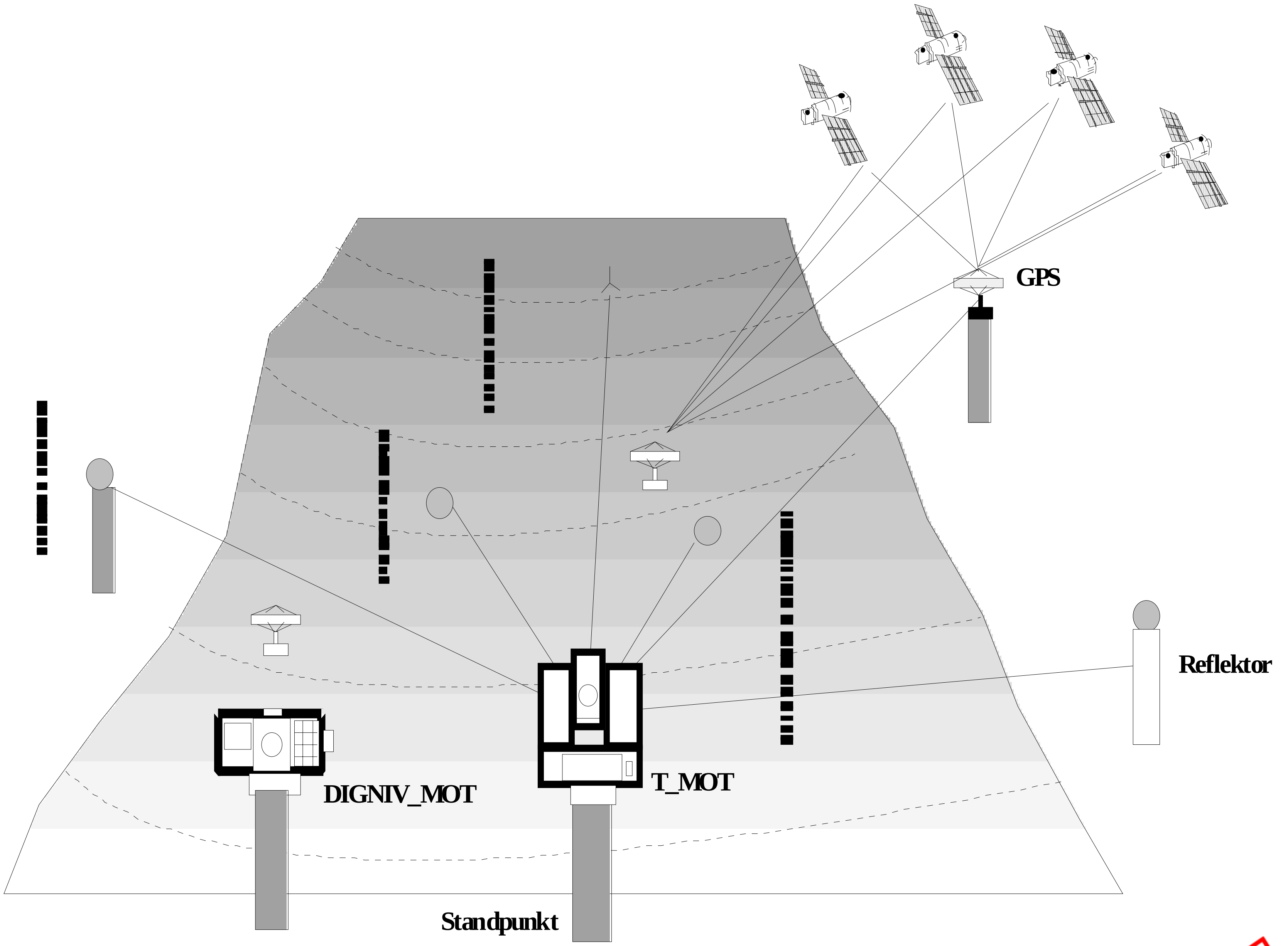
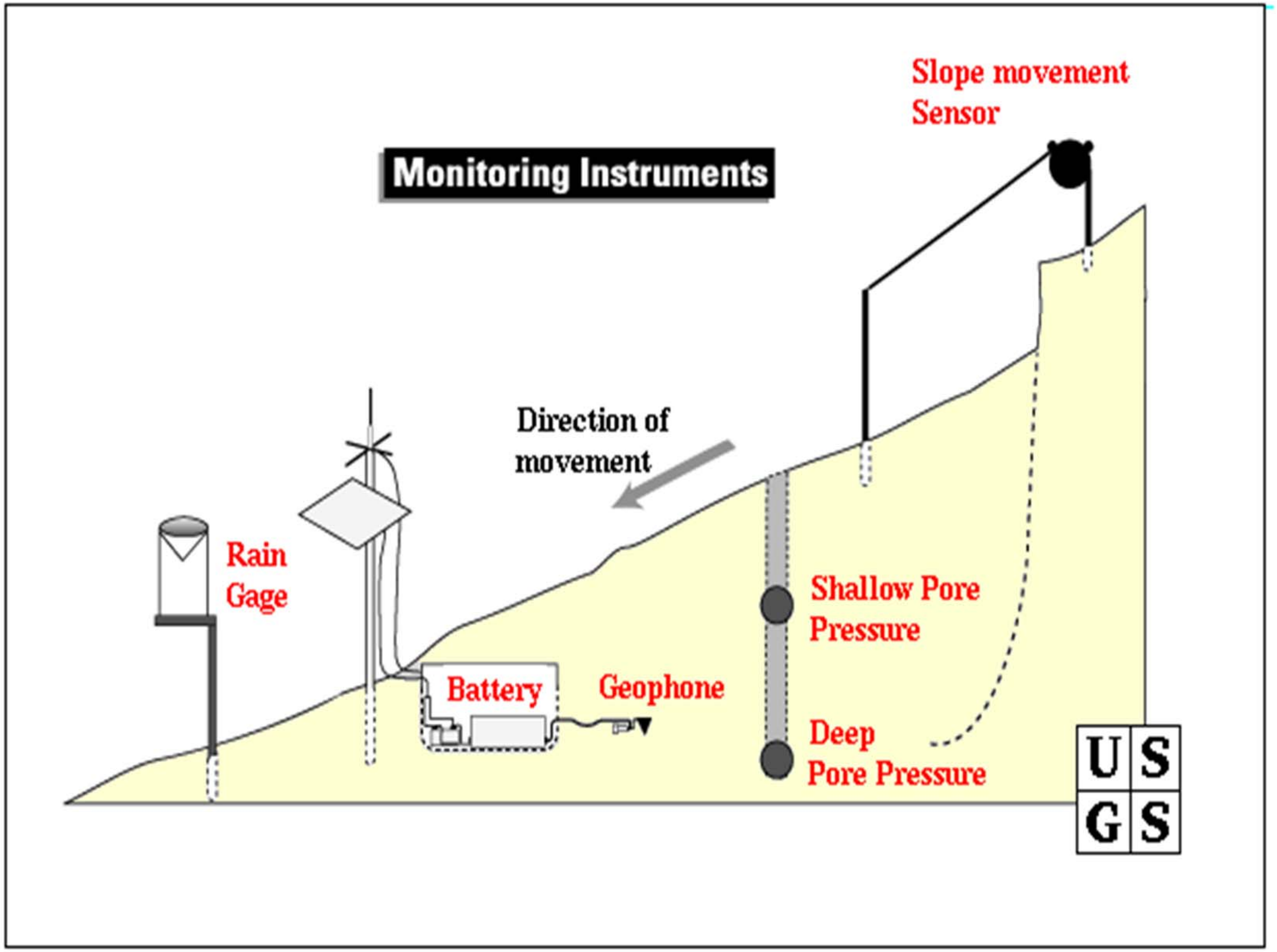
Geodetic Measurement Scenario for Slope Movements



Slope Movements (Geotechnical Installation)



General Specification (Quality) of Sensors/Instruments/Methods

- Accuracy / Precision/ Resolution
- Linearity
- Calibration
- Stability (long term stability)
- Synchronisation
- Interfaces/ Remote control
- Power level; Power Consumption
- Protected against meteo-influences
- Electromagnetic shielding
- Availability
- Customer Support
- Costs

Sensors/Instruments

1D Length – Height – Alignment

2D Coordinates/Position

3D Coordinates/Position

“Imaging” Systems

One Dimension: Distance

Single/Multi Distance Measurements

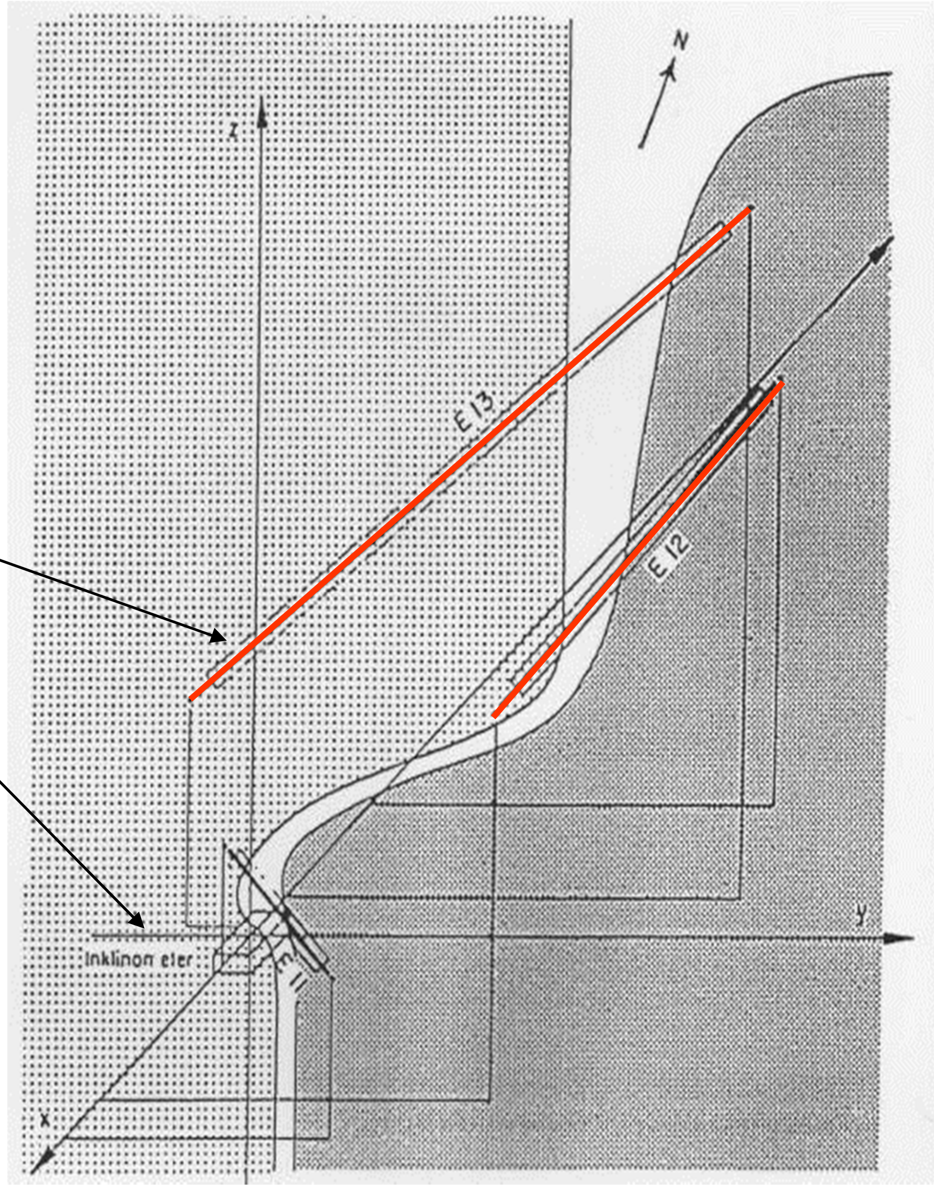
-Extensometers Bars/Wires/Fiber-Optical Sensors (relative Distance)

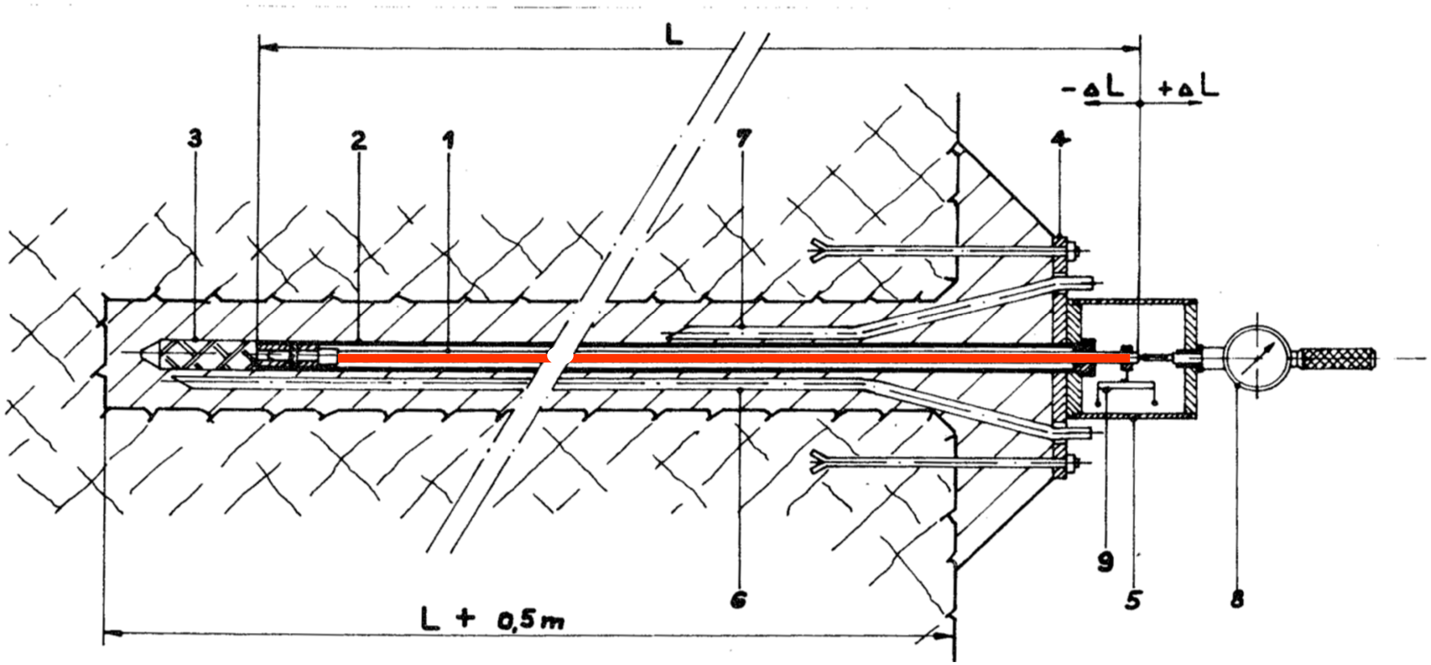
-EDM (relative and absolute distances)

Instrumentation for Rockfall Measurements

Extensometer

Inclinometer

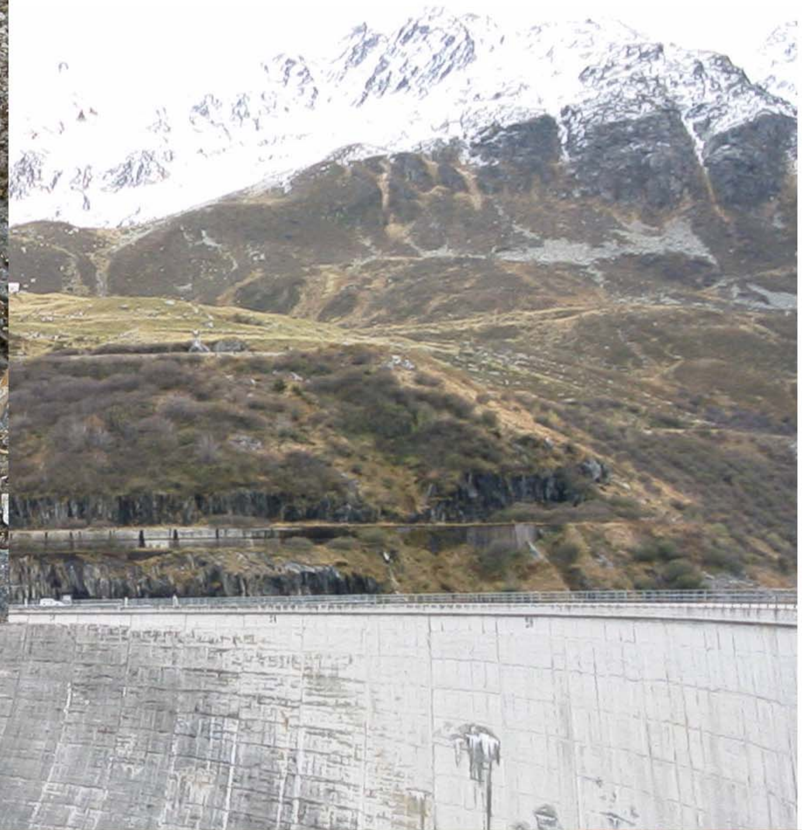




Bar Extensometer

One or multiple bars, shielded by plastic coating, are fixated at one end with an anchor plate in the rock/concrete. The relative distance variation is measured by micrometers or inductive length transducers

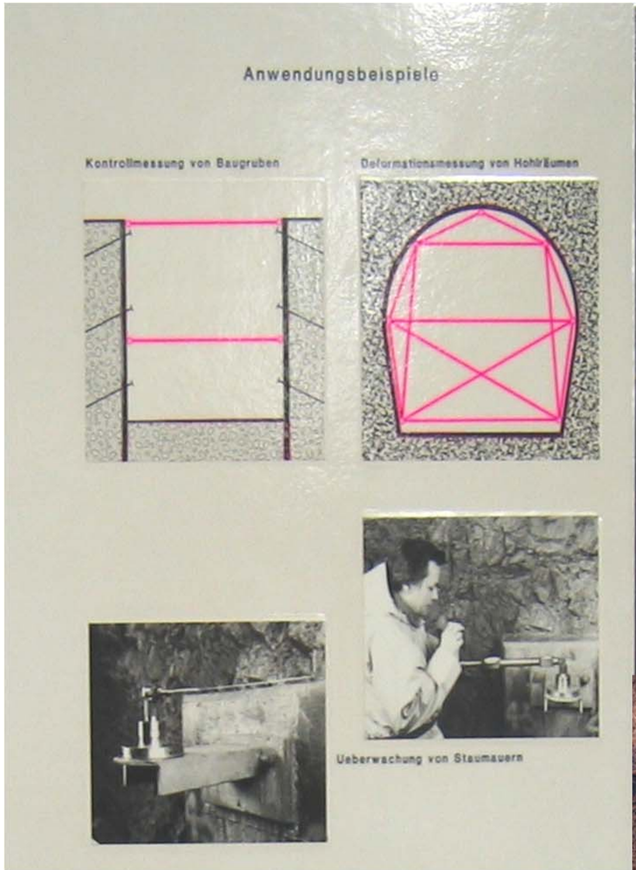
Borehole Extensometer “Nalps”



Teletensometer (Huggenberger)

Telejointmeter (Huggenberger)

Distometer System (ISETH), Developed at ETH

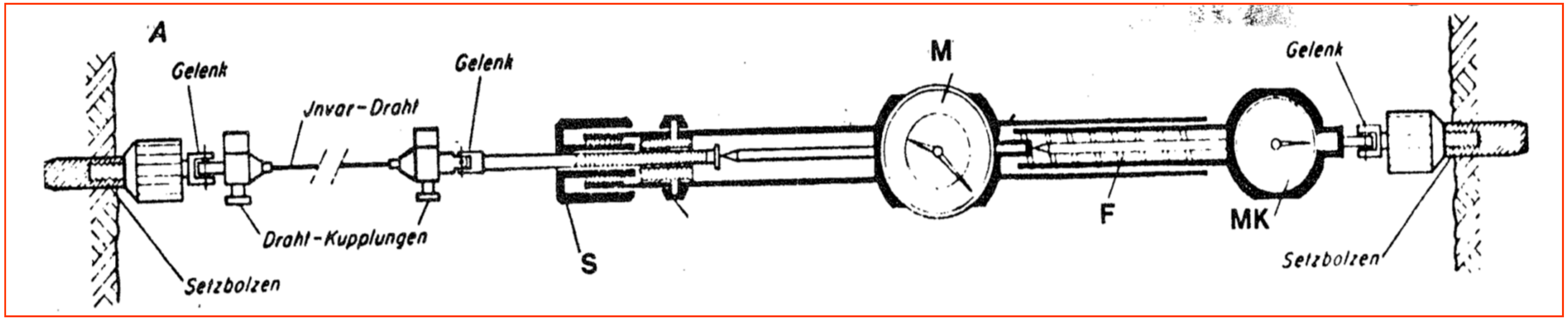


Manufacturer: SOLEXPERTS

Length: Invar-wires from 1 m to 50 m

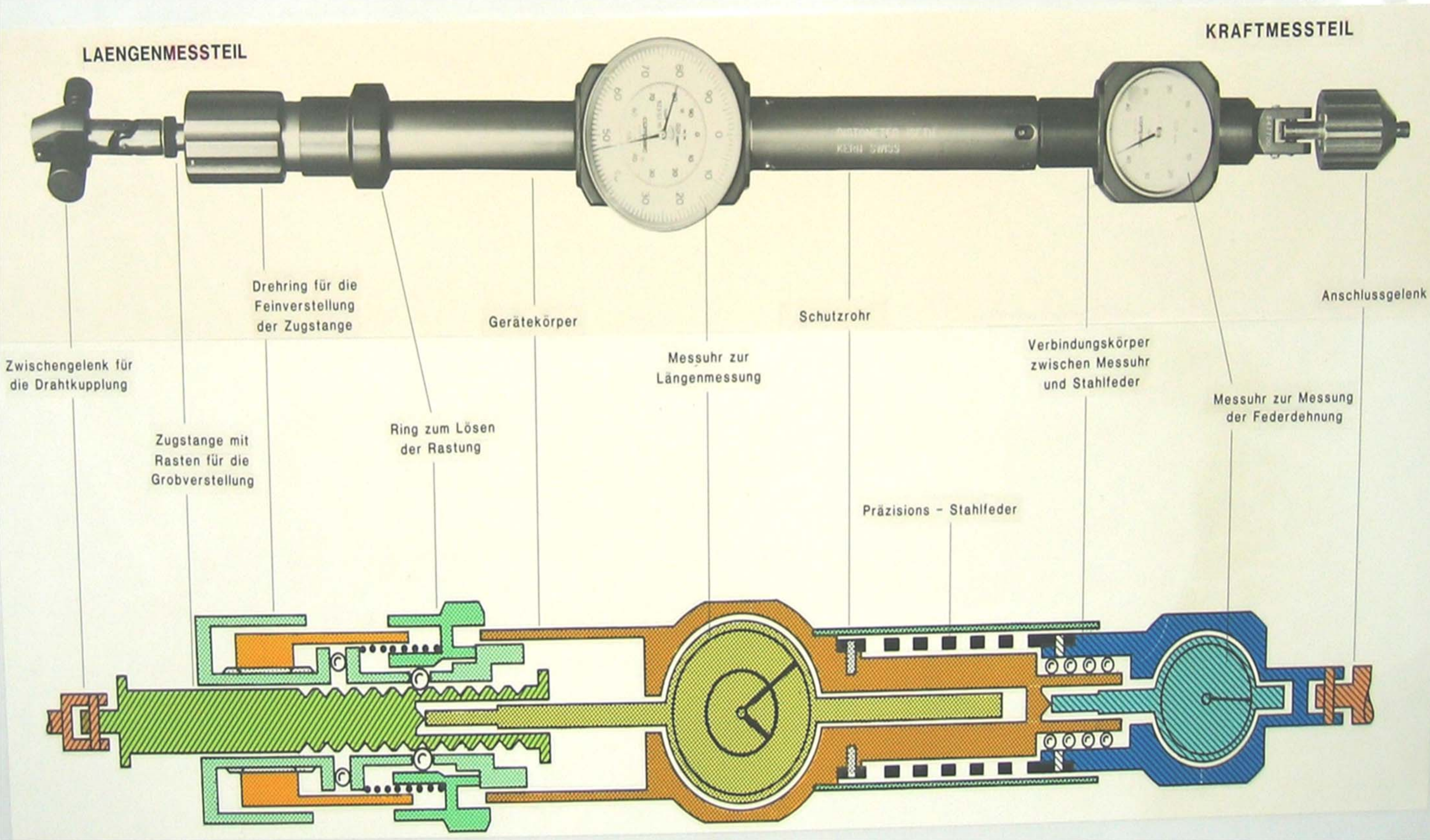
Range: 100 mm

Accuracy: 0,02 mm @ 20m



Function principle: The wire is constantly tensioned by a spring. The tension is adjusted by the screw S and the correct value can be checked by the dial MK. The dial M indicates the length variation. The length of the wires can be checked against the interferometer of IGP

Wire Extensometer (ISETH)



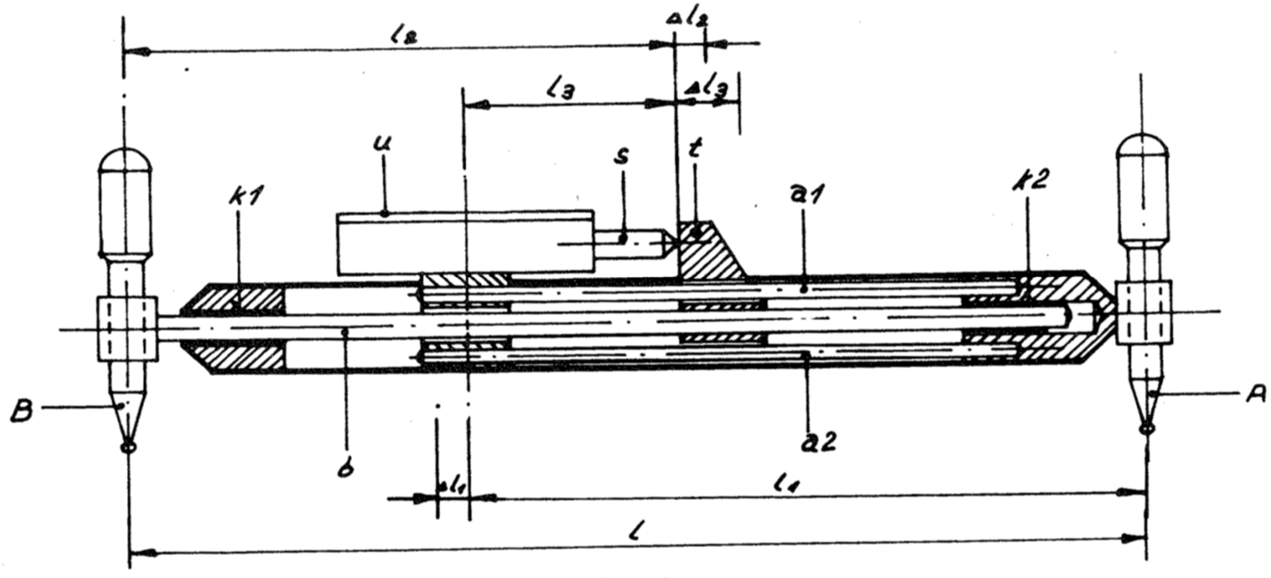
Crack Meter (Rissmikrometer)

Manufacturer: Huggenberger AG Zurich

Length: 250/500 mm

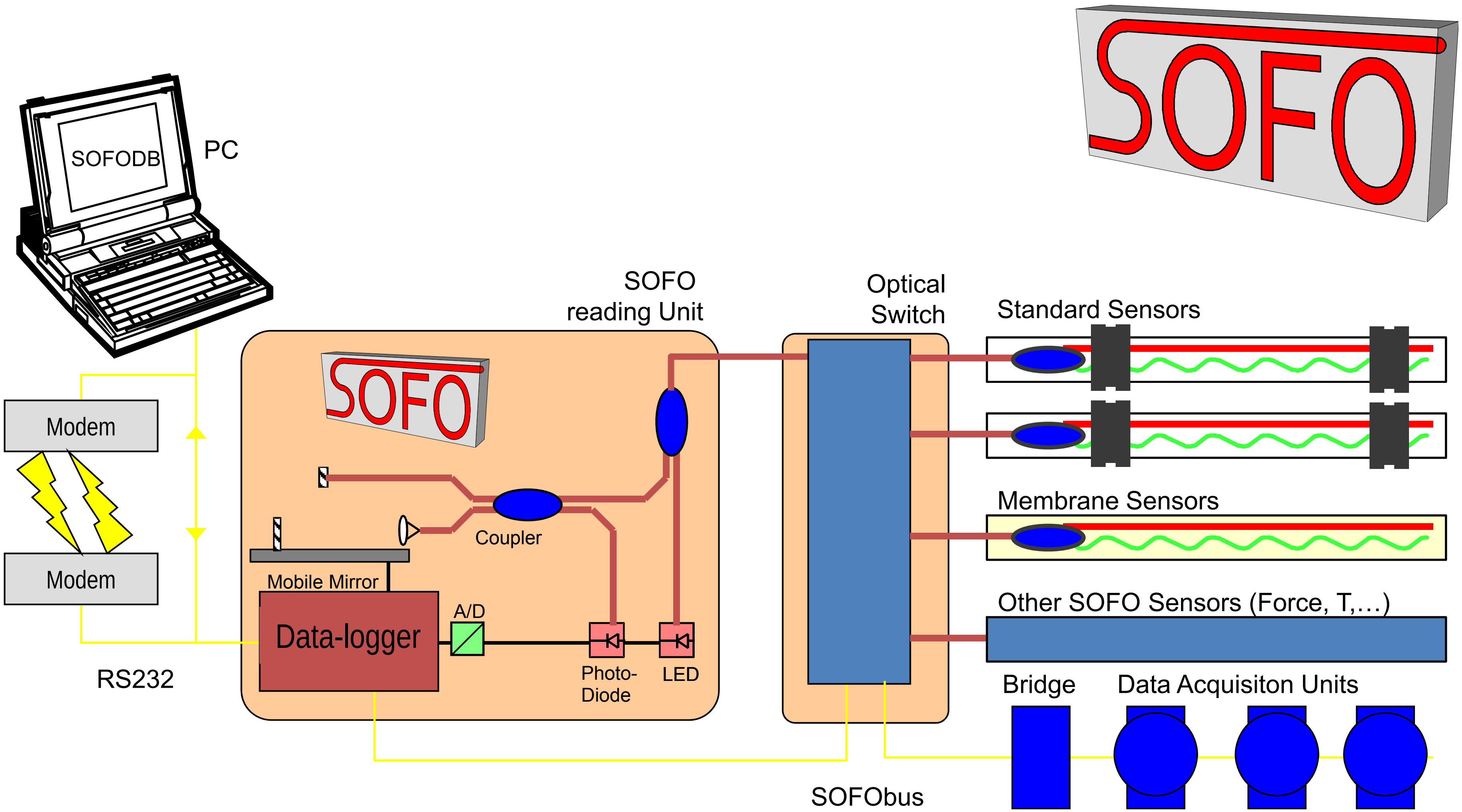
Range: 5 mm

Accuracy: 0.002 mm



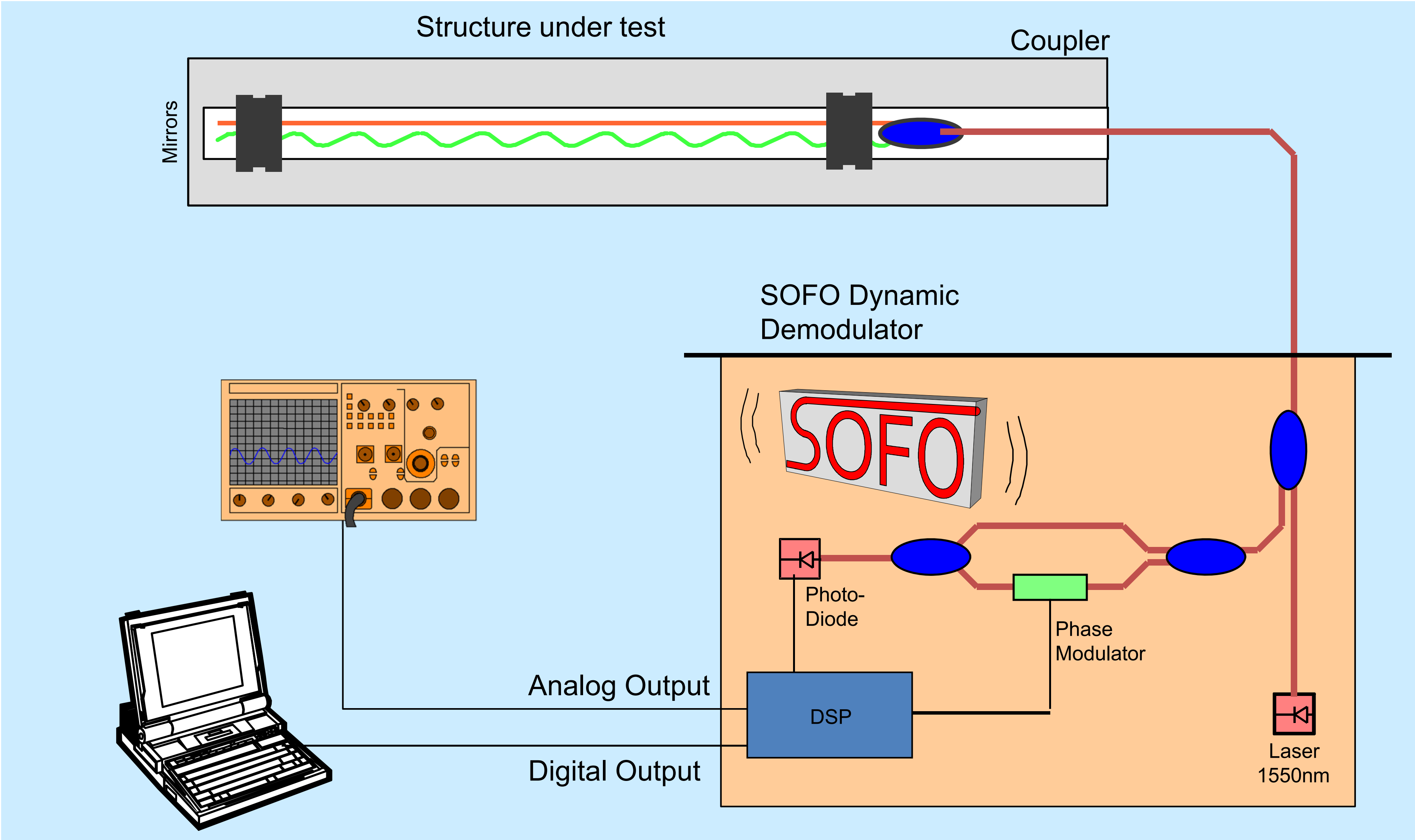
Fiber Optical Sensors

Interferometry: SOFO V System



Click or press spacebar to advance in the animation

SOFO Dynamic

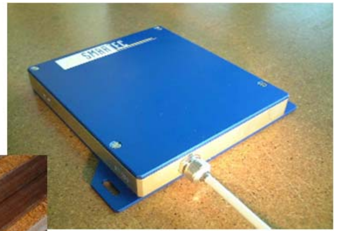


SOFO Reading Units

	SOFO V	***SOFO Dynamic***
Application	*Short- and long-term static monitoring*	*Dynamic measurements*
Type of measurement	*Self-referenced relative*	*Incremental relative*
Sensor compatibility	*Compatible with all SOFO sensors*	
Bandwidth	*Static*	*0 to 1 kHz*
Output	*SDB monitoring database*	*Analog output* *Digital output*
Number of channels	*Unlimited*	*8 per module*
Acquisition	*Sequential*	*Simultaneous*
Data logging	*Yes, integrated*	*Through 3rd party DAQ*

SOFO System Components





Sensors

- Rugged, watertight.
- Insensitive to temperature, EM fields, corrosion,…
- Easy and rapid to install.
- No calibration required.


Reading units

Portable, rack or permanent.
- Battery / AC power supply.
- Rugged and waterproof.
- Integrated Datalogger.
- Modem connection.

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SOFO Sensor Family

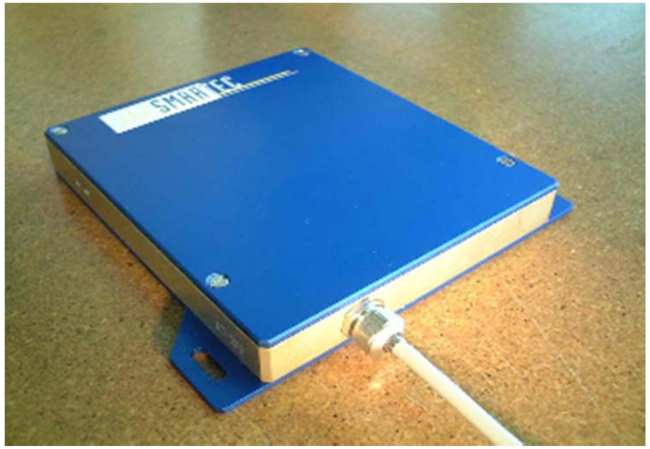
Standard Sensor

SMARTape

Concrete Setting Sen.

DETAN Force Sensor

Displacement Sensor

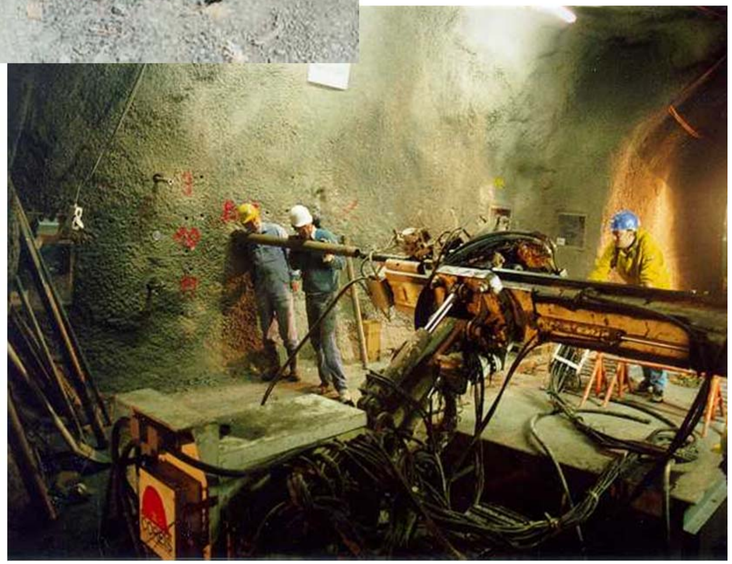


Inclinometer

Standard Sensor Installation

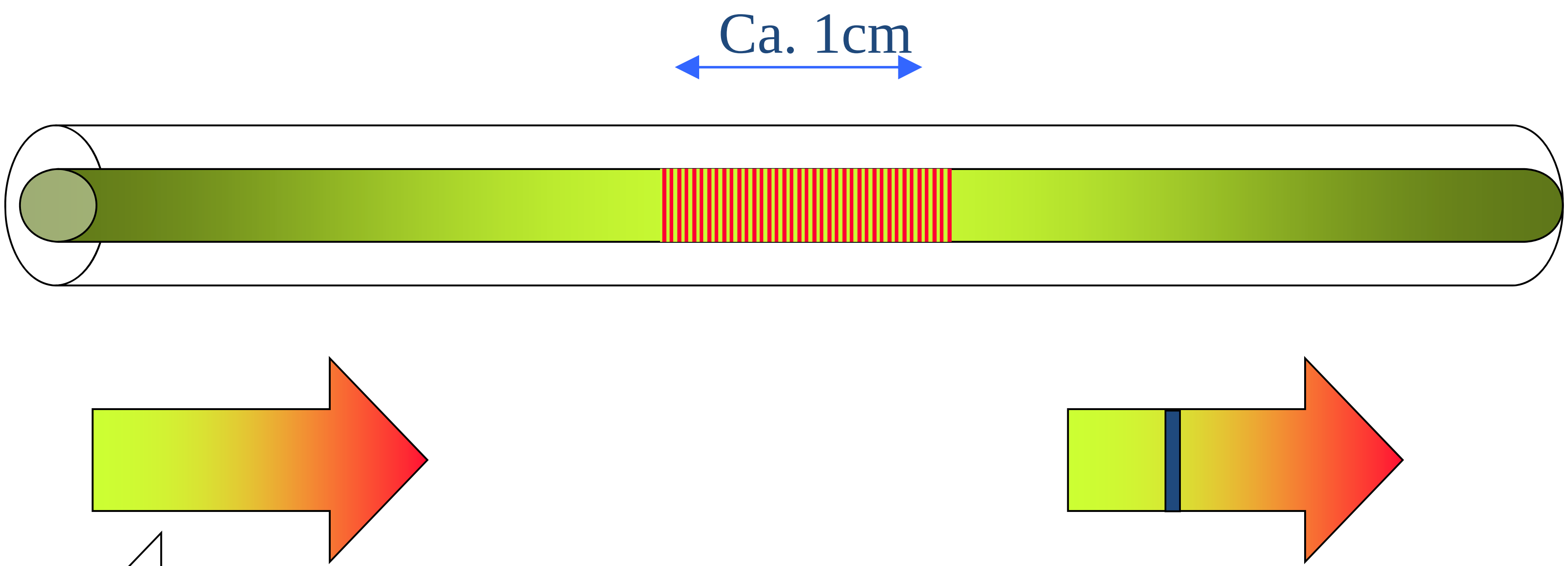
Concrete Embedding

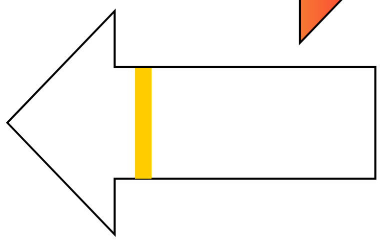
Borehole Injection



Surface Installation

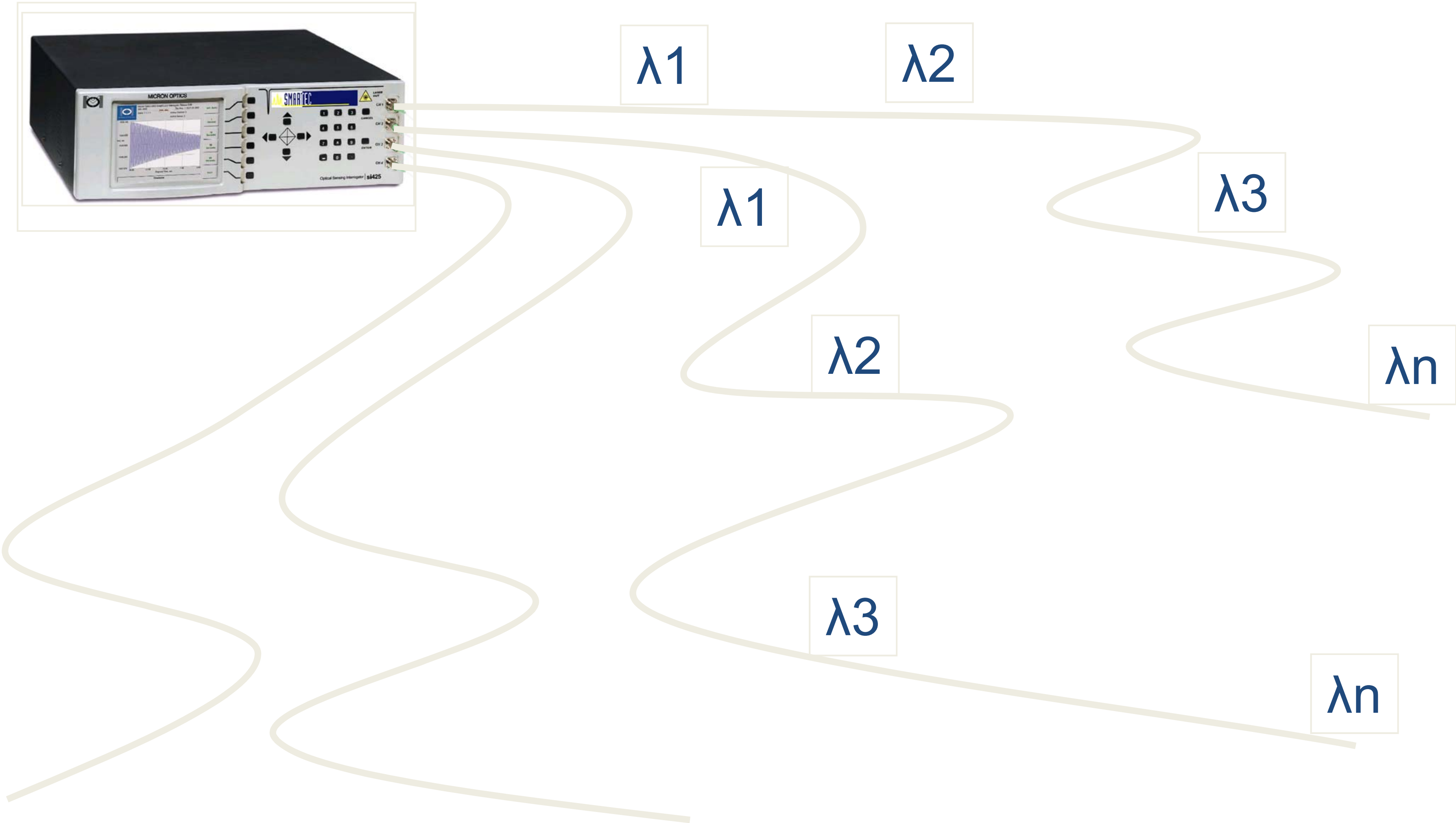
Fiber Bragg Grating Sensors





The reflected wavelength depends on the strain and temperature of the fiber

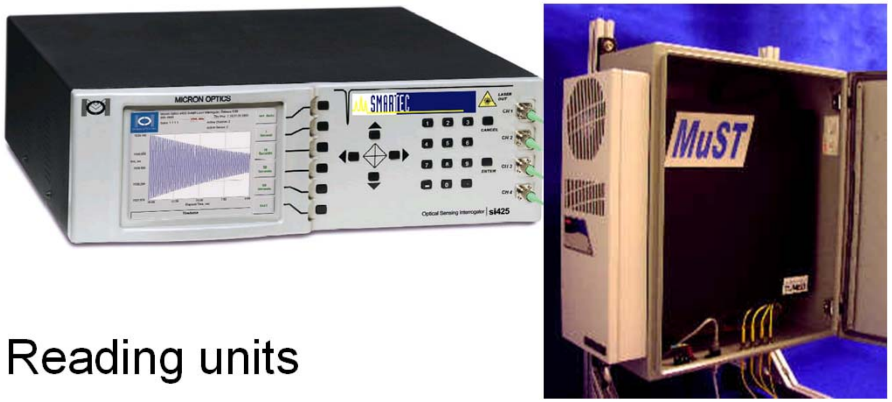
Multiplexed Sensing



MuST System Components

Sensors

- Strain and temperature multiplexed sensors
- Rugged, watertight.
- Insensitive to temperature, EM fields, corrosion,…
- Easy and rapid to install.
- Embeddable in concrete and composites.



Reading units

Permanent installation.
- AC/DC power supply.
- Rugged and waterproof version.
- Ethernet connection.

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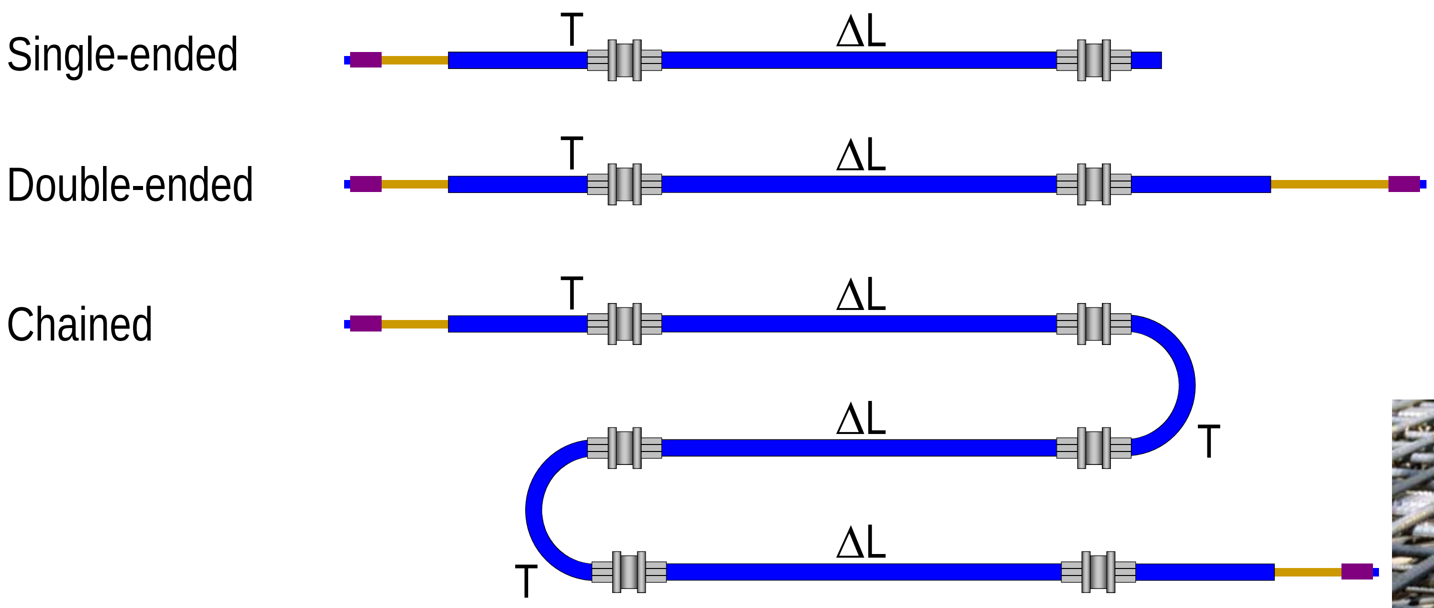
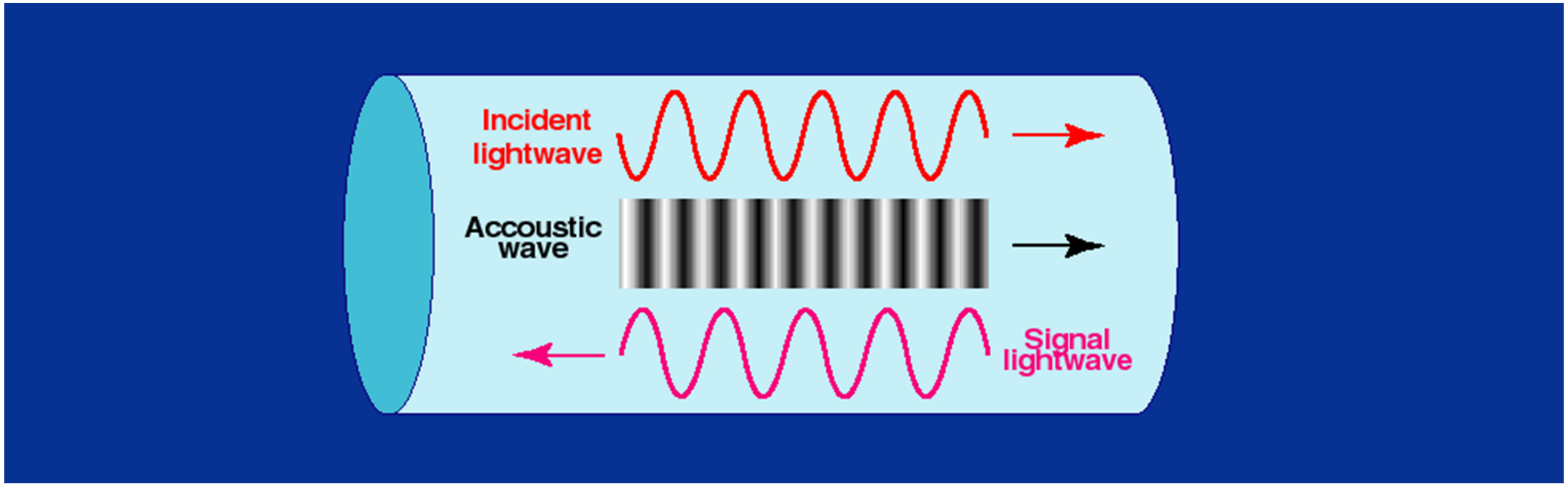
MuST Deformation Sensors



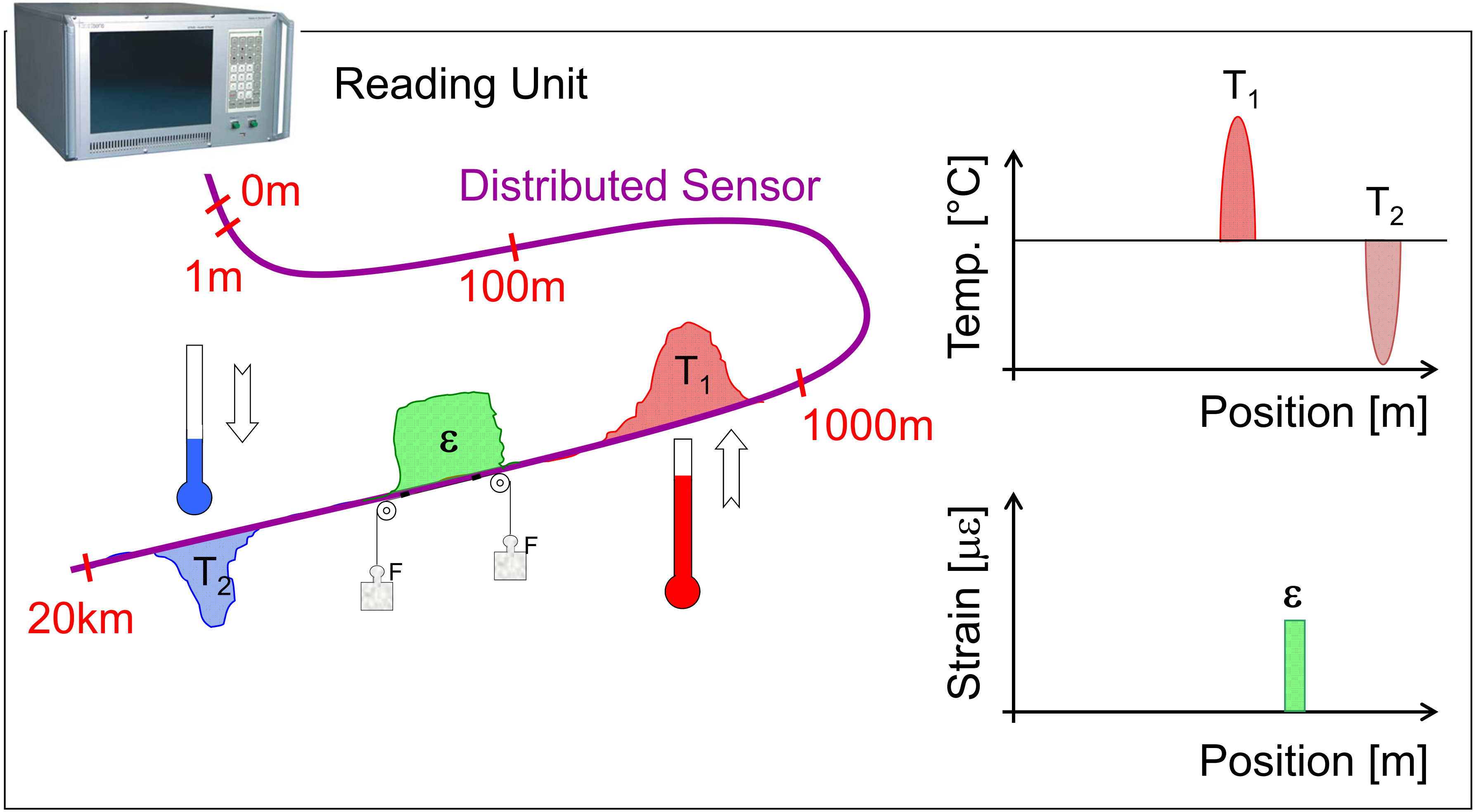
- Temperature measurement and compensation for each sensor
- Up to 5 sensors per chain
- Measurement basis: 25 cm to 2 m

DiTeSt Brillouin Scattering



The interaction between acoustic and optical waves depends on the strain and temperature state of the fiber.

Distributed Sensing



Electro optical **D**istance **M**eter (EDM)

DICLAS: Continuous Distance Measurement by laser

Soil Mechanics Laboratory (LMS)
OCB (Ecublens) CH- 1015 LAUSANNE
☏: 021 - 693 23 15 TÉLÉFAX: 021 - 693 41 53
http://lmswww.epfl.ch/lms_f.html; e-mail: lms@dgc.epfl.ch

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

DICLAS : Continuous distance measurement by laser

The LMS has developed a new device for continuous distance measurement by laser called DICLAS (DIstance en Contigu par LASer). The system includes a Data Disto RS232, a reflecting prism, a portable micro-computer and a power supply system which may be self-contained (Fig. 1).

This device aims at the automatic logging of the evolution of the displacement of a mobile point with time, which is located for instance in an unstable zone (Fig. 2), or on an excavation wall (Fig. 3). These DICLAS are available at a reduced price.

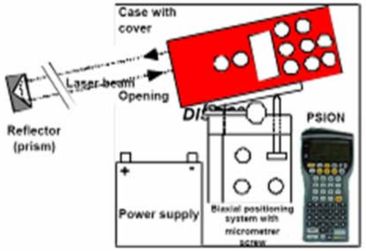


Fig. 1: Outline of measurement system DICLAS
Obtained precisions: ±1 mm at 10 m
±3 mm at 140 m
±5 mm at 400 m

The Disto™ emits a modulated laser beam and calculates the distance to the reflector prism by the measurement of the dephasing between the emitted and reflected beam. This distance, which can be averaged on several readings, is recorded in a file of the micro-computer which also provides the piloting of the device. The measurement is done according to the direction of the movements, with a possible lateral offset of the prism of some 40 cm at 400 m.

The nominal range of the Disto™ of 140 m can be extended to more than 400 m by the use of an adequate reflector, considering that the information sought after is a distance variation. In order to obtain a good precision, the installation of the device must be optimal (concrete base for the DICLAS, and prism tightly fixed to the observed point).

The system can operate day and night, even in extreme climatic conditions, but not in case of fog or intense rainfall. The autonomy, limited by the size of the data file, exceeds one month with readings every 15 minutes.

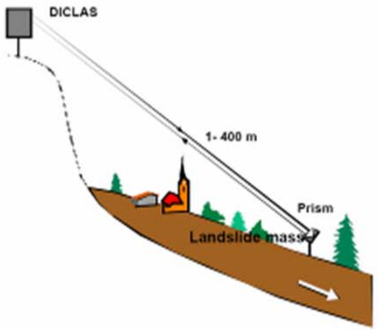


Fig. 2: Setting of the DICLAS device on a landslide.

The advantage of this device in comparison with the Invar wire classical system lies in a larger measuring range, in the lack of sensivity to the wind and rime and to a reduced impact on the environment.

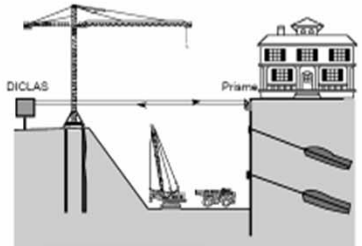


Fig. 3: Application to an urban working site.

Publications

Ch. Bonnard, G. Steinmann, 1996. A new distancemeter for continuous measurement of landslide displacements. *Revista Italiana di Geotecnica* N° 2/97, pp. 8-14.

G. Steinmann, 1996, DICLAS: Un appareil de mesure des distances en continu par laser. Rapport interne LMS, EPFL, Lausanne.

GSt - August 1998

Dimetix Polydist

Shift of a bridge

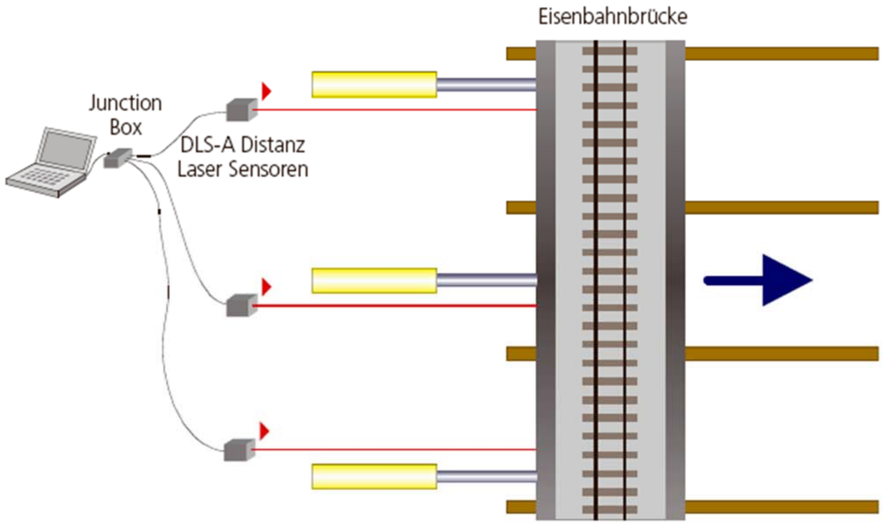
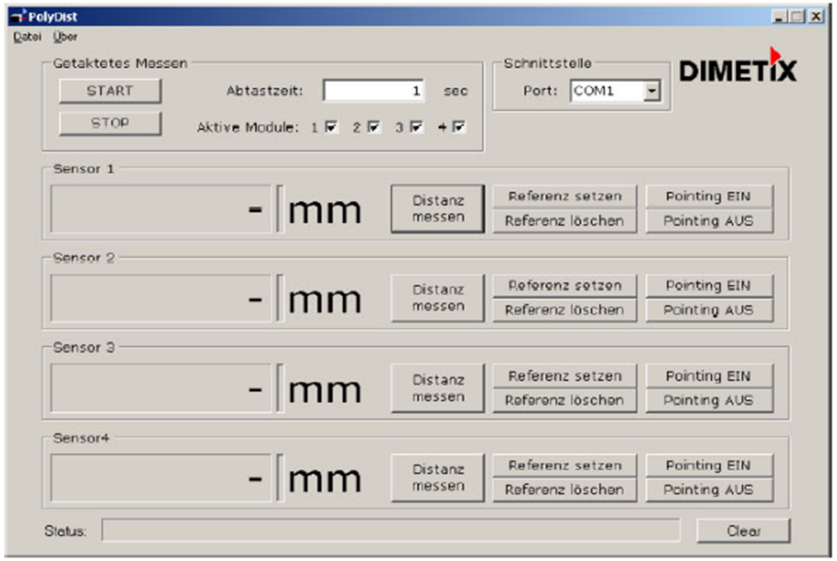


Abbildung 1 Verschieben einer Brücke



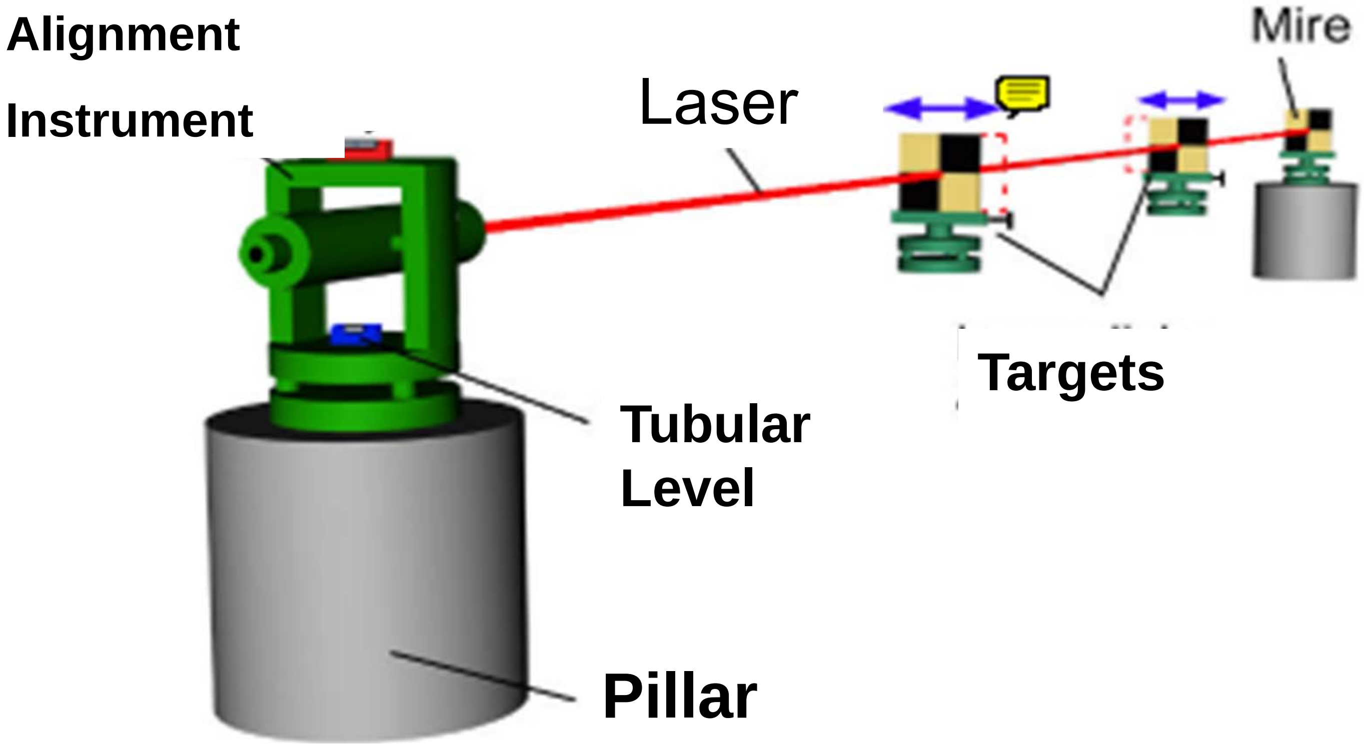
Direction Measurements

- Alignment Systems
- Plumbs -
- Theodolites
- Photogrammetry
- Gyrotheodolites

2D Alignment tools

- wires
- optical alignment
- laser alignment

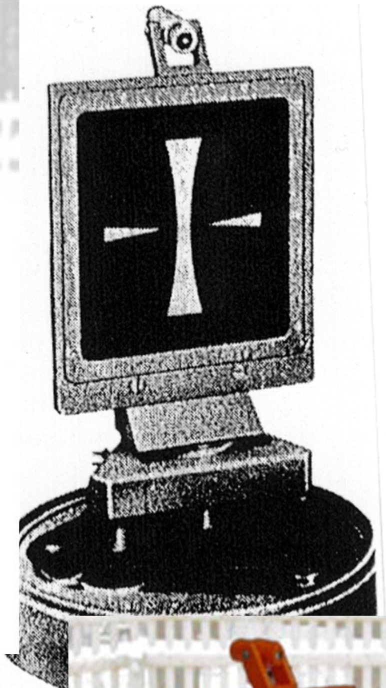
Alignment Principle (Dam Monitoring)

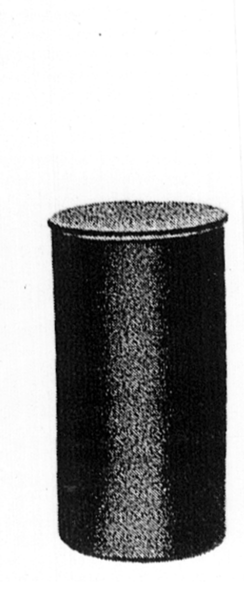


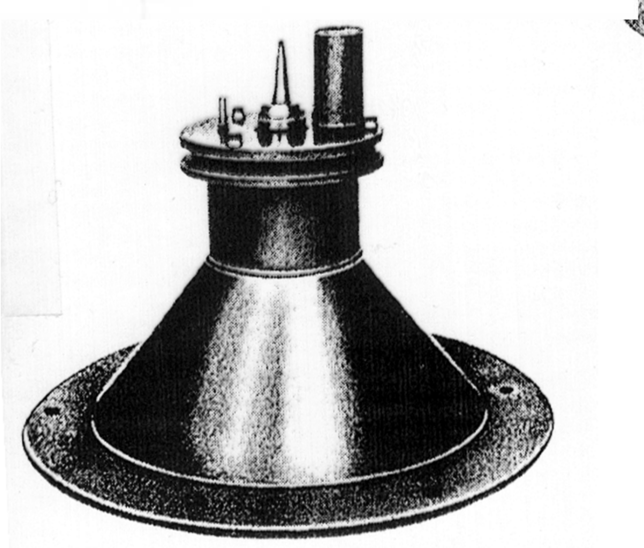
Principle of optical alignment:

Between two permanently installed points (alignment instrument and target mark (Mire)) a vertical plane is set. Measured are the shortest horizontal distances between the alignment points (marked with alignment target signs) and the vertical layer.

Optical Alignment (Freiberger Präzisionsmechanik)







Special Alignment Instruments

Telescope	
Image	normal
Magnification	20x
Vision Angle	2° (3,5m / 100m)
Diameter	30mm
Shortest Focus	1,2m
Multiplication Constant	100
Bubble Levels	
For Vertical Axis	45" / Intervall
Leveling	20" / Intervall
Temperature	
Working Range	-20°C...+50°C
Instrument	
Size	265x140mm
Weight	2,7kg

2 D Plumbing

- optical plumbing
- mechanical plumbing (wires)

Optical Plumbs

Zenith Freiberger Präzisionsmechanik

Accuracy	
Mean deviation@ 100m	1 mm
Telescope	
Imagepostion	upright
Magnification	32 x
Shortest distance	2,2 m
Lens diameter	40 mm
Compensator	
Range	± 10´
accuracy	0,15"
Temperature	
Range	-25°C...+45°C
Instrument	
Size	140 x 295 mm
weight	3,5 kg

Nadir/Zenith Plumb Leica

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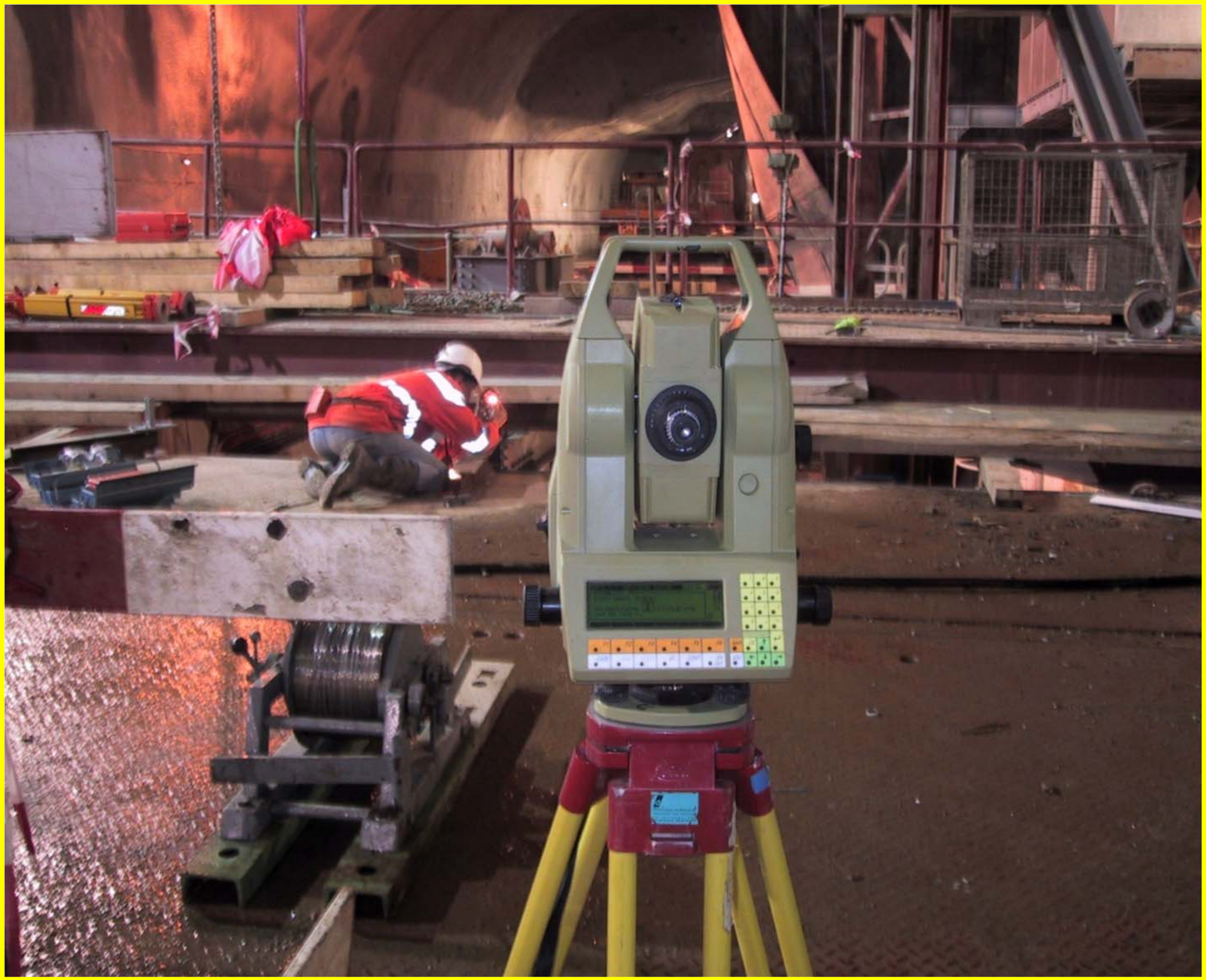
Performance of Optical Plumbs

Depth 800 m
Accuracy 5 mm

Mechanical Plumbing



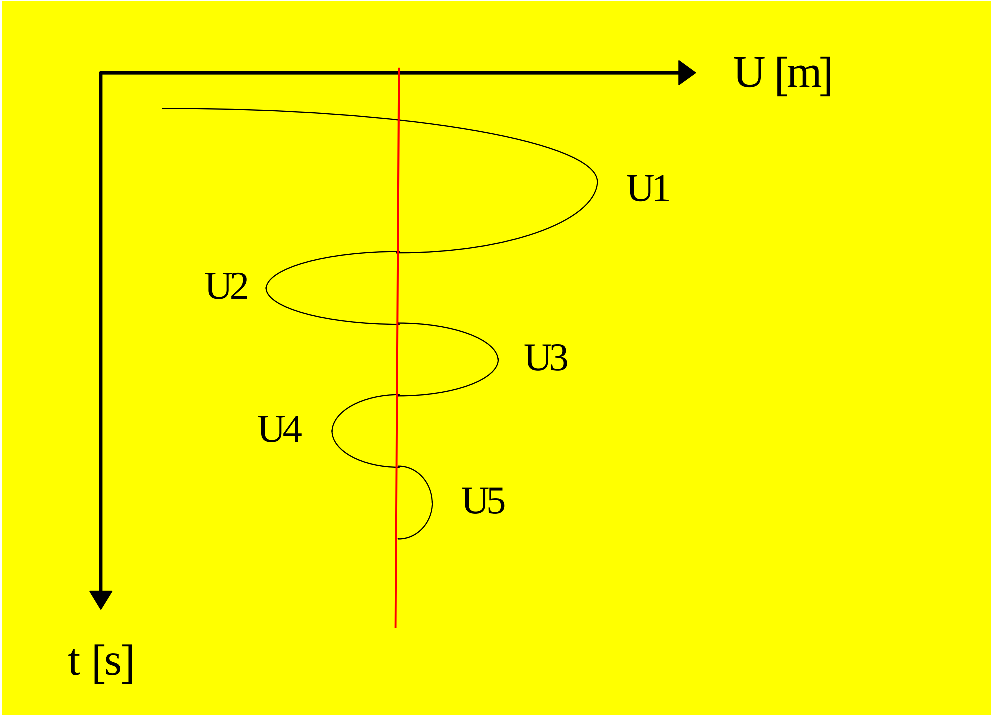
Measuring plumb lines on top

Guide Roller

Mechanical Plumbing: bottom

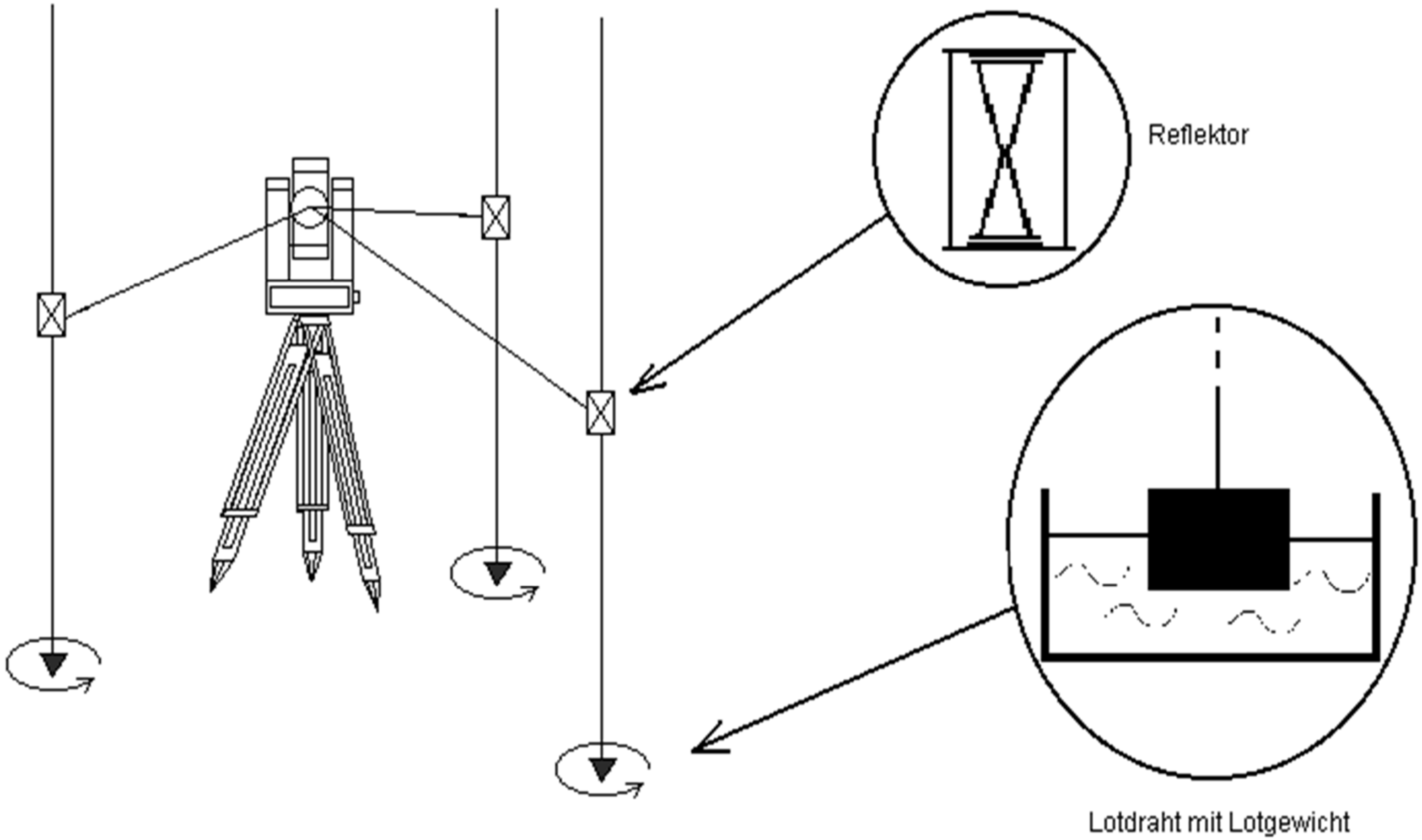
Observation using T 2002

Computation of the damped Oscillations



$$m_i = \frac{1}{2} \cdot \left(\frac{u_i + u_{i+2}}{2} + u_{i+1} \right) \qquad x = \frac{[m_i]}{n}$$

Ideas for observation of the plumb line using LPS

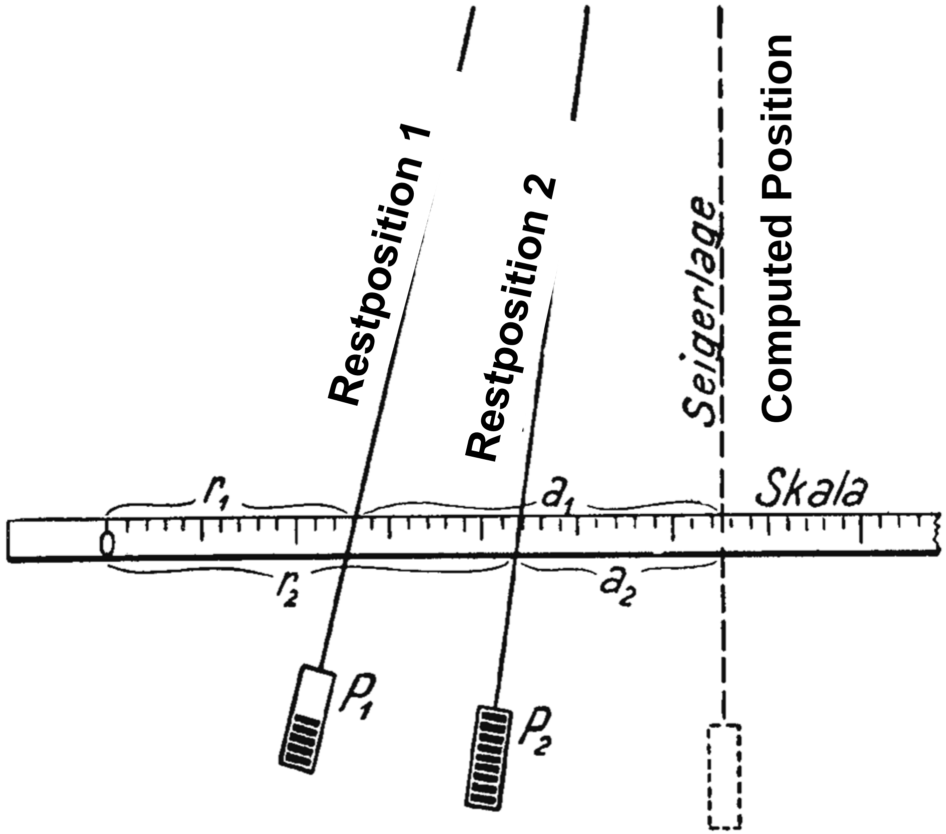


- Plumb oscillates around the rest position
- The deviation of the rest position can be determined under the assumption that a double weighted plumb is half the way deviated.
  [SCHULTE, LÖHR, VOSEN, 1968; SCHULER, 1954; EMSCHERMANN 1938].
- In multi weight plumbing different weights a used sequentially
- The observation of the different rest positions as a function of the weight allow for the computation of the plumb line

Principle of Multi Weight Plumbing

$$\frac{a_1}{a_2} = \frac{P_2}{P_1}$$

$$\frac{a_1 - a_2}{a_2} = \frac{P_2 - P_1}{P_1}$$



$$a_1 = \frac{a_1 - a_2}{P_2 - P_1} \cdot P_2 \quad \text{and} \quad a_2 = \frac{a_2 - a_1}{P_1 - P_2} \cdot P_1$$

Influences in Mechanical Plumbing

- Torsional Oscillations
- Oscillations induced by spiral whirls in the shaft
- Water dribs
- Plumb line deviations by eccentric plumb wire
- Plumb line deviations by in-homogenous gravity distribution

Direction determination or direction transfer

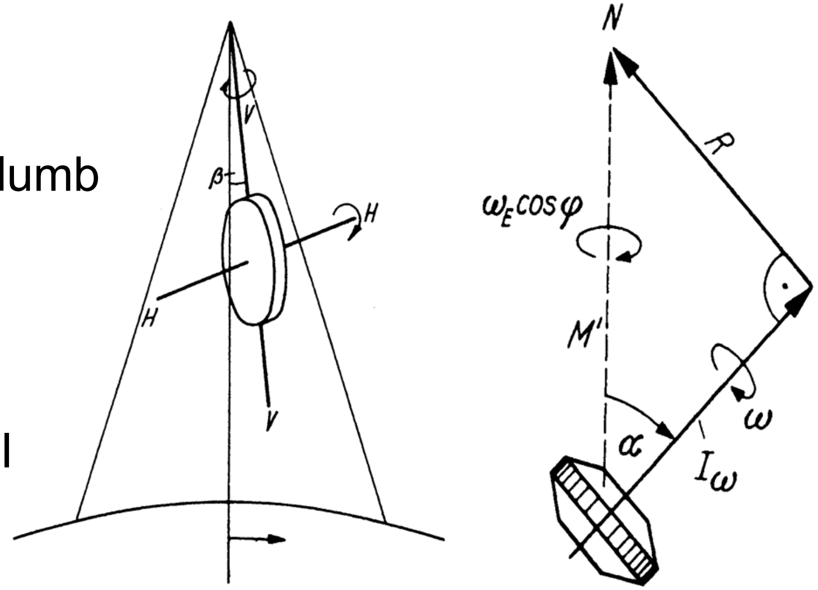
- Theodolites
- Gyrotheodolites
- Inertial Navigation Systems

Gyroscope Measurements

- Absolute azimuth measurement
- Direction transfer

Gyrotheodolit „Gyromat 3000“.
Source: http://www.gyromat.de

- How it works:
  - Gyro has two degrees of freedom
    - No rotation around horizontal axis (realized by gravitation, fixed in horizontal plane)
    - Rotation around HH (gyro axis) and VV (vertical axis)
  - Due to inertia the rotating gyro keeps its position
  - Earth rotation causes deviation of the plumb line by centrifugal forces of suspension
  - Gyro starts to rotate around plumb line (precision)
  - Gyro axis orientates to the geographical north direction



Principle of a gyro with two degrees of freedom and deflecting force diagram.
Source: Instrumentenkunde Deumlich/Staiger

Gyroscope Measurements

- Earth rotation and local plumb line influence gyro measurements
  → according to astronomical azimuth

- Required corrections and reductions
  - Chandler Wobble (instantaneous rotation axis → CIO pole)
  - Deflection of vertical (astronomical azimuth → ellipsoidical azimuth)

    $$A = \alpha - \eta \cdot \tan \varphi - (\xi \cdot \sin \alpha - \eta \cdot \cos \alpha) \cot z$$

    ξ: north-south component, η: east-west component

  - Chart convergence (ellipsoidical azimuth -> plane azimuth)

    $$T = A - \lambda$$

  - Reduction of direction (great circle -> straight line)

    $$t = T + \frac{\rho^{\text{gon}}}{6R^2} (y_z - y_s) (x_z + 2x_s)$$

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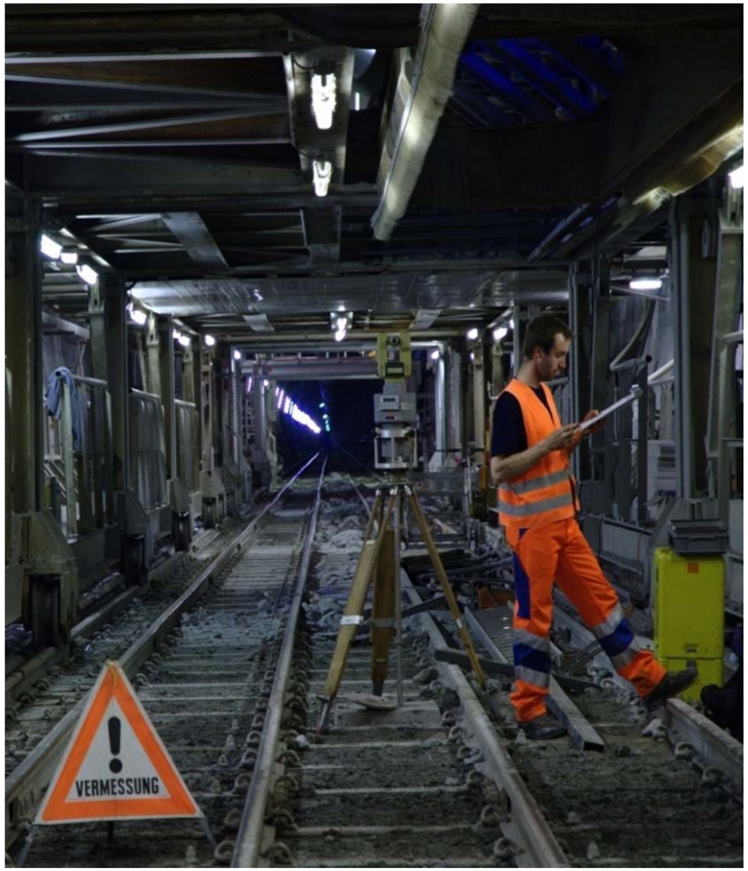
Gyroscope Measurements

Keep in mind:

- The first two corrections/reductions base on physical conditions, the second two are purely mathematical
- For relative azimuth measurements (direction transfer) the last three corrections/reductions are sufficient for most applications
- Correction of influence of vertical deflection
  - in Switzerland (Latitude ca. 45°) the north-south component has the factor 1 (tan 45° = 1)
  - Differences in vertical deflections are decisive (reference track -> tunnel track)
  - This is in contrast to polygonal networks, where the vertical deflection has only an impact for steep sightings (tunnel sightings are usually horizontal)



„Gyromat 2000“ measuring in the Gotthard basetunnel near Faido.
Source: Stephan Schütz

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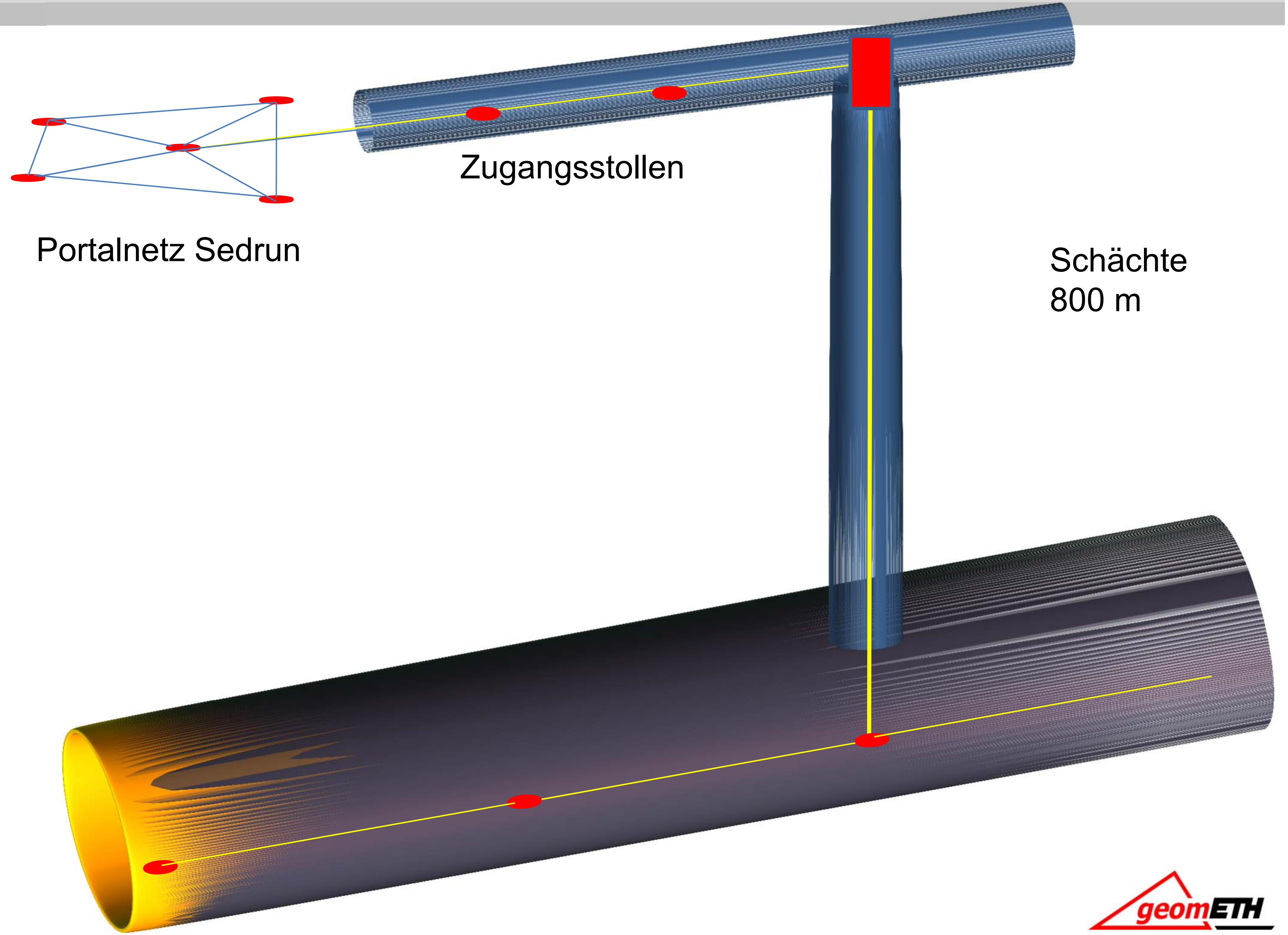
INS direction transfer at Sedrun



Inertial Measurement System

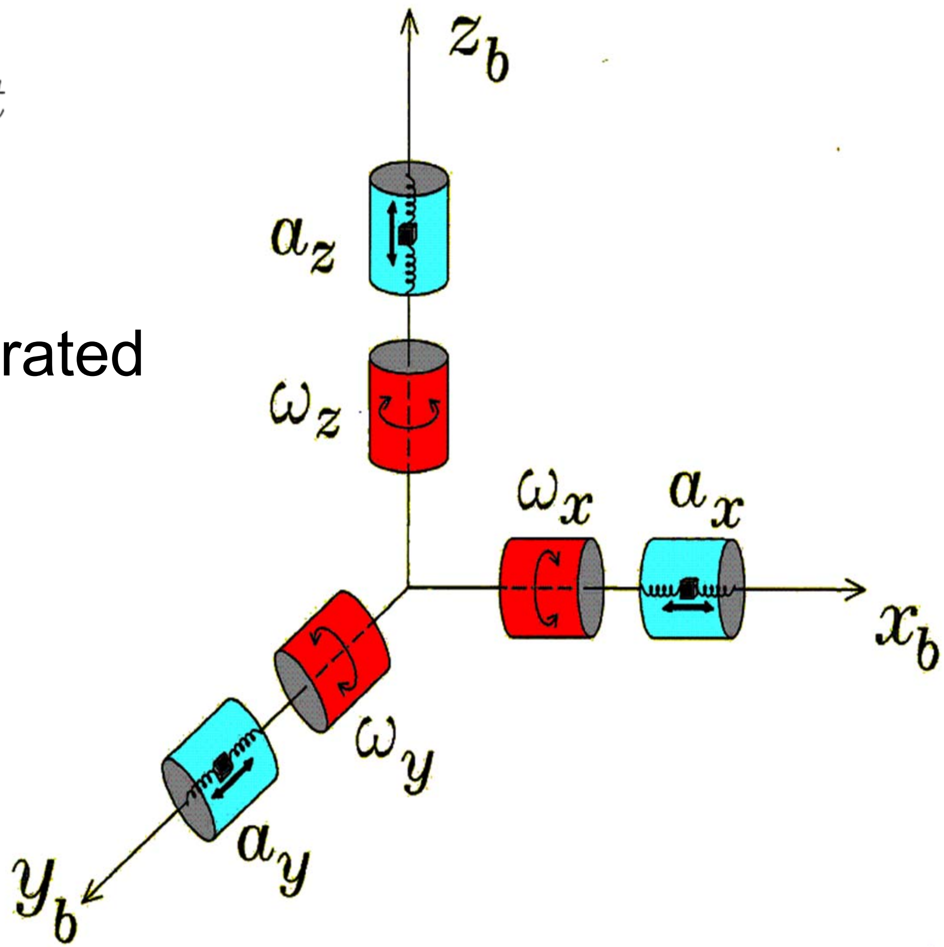
- 3 orthogonal acceleration indicators

$$\vec{F} = m \cdot \vec{a} \qquad d = \iint_{t_1}^{t2} \vec{a}\, dt\, dt$$

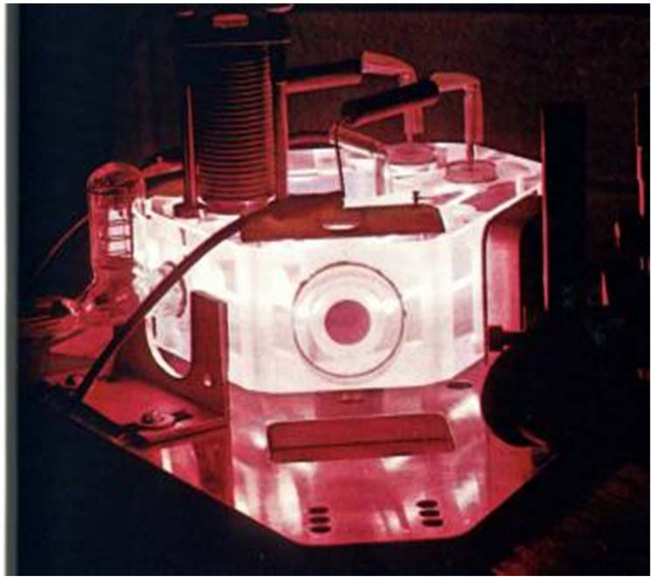
- 3 orthogonal gyroscopes
  - e.g. ring laser gyros, integrated gyros

- Coaxial arrangement

- Processing unit

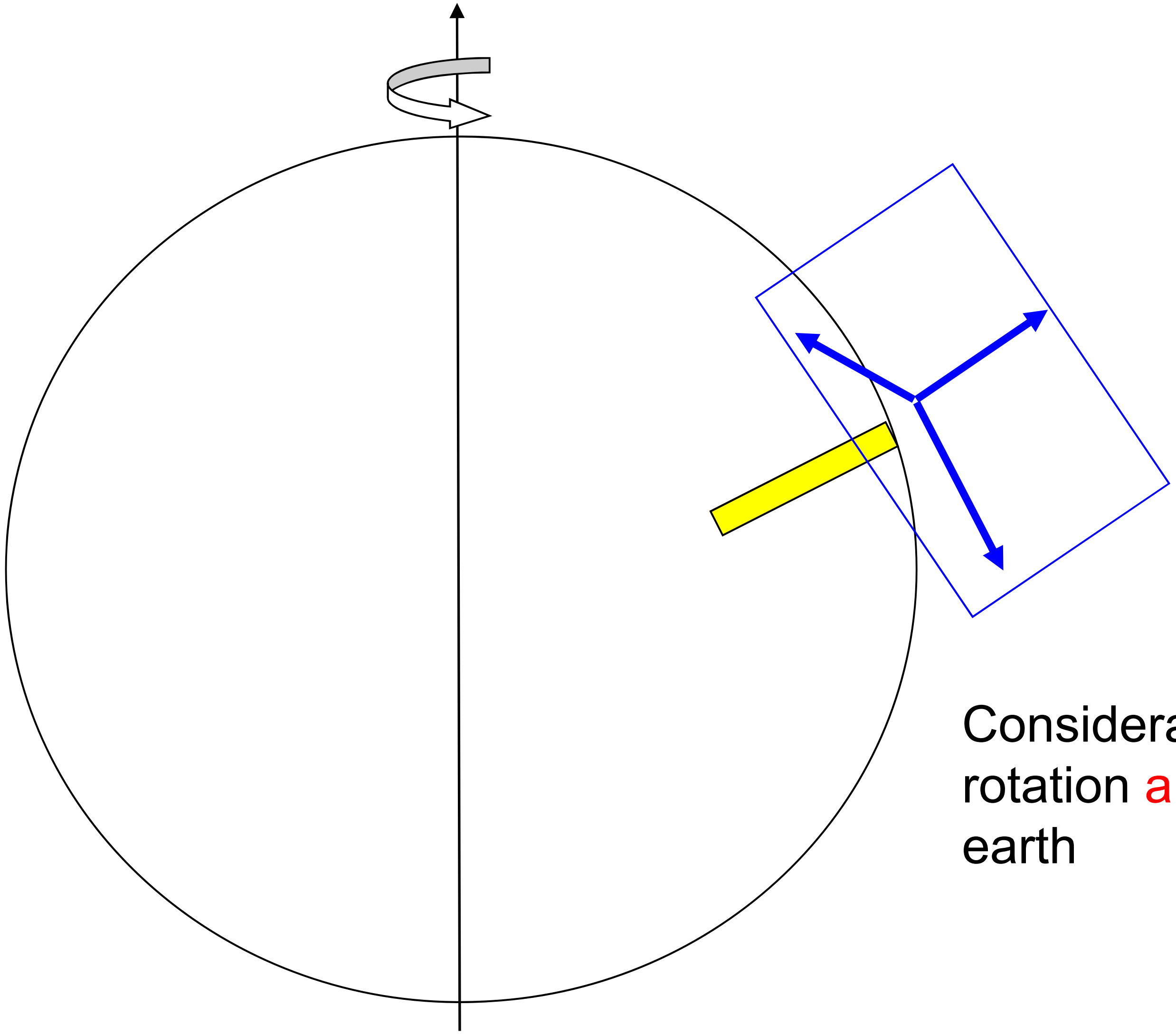


Inertial Measurement System



Resolution 0,1 mgon Drift 0,002^{0}/h

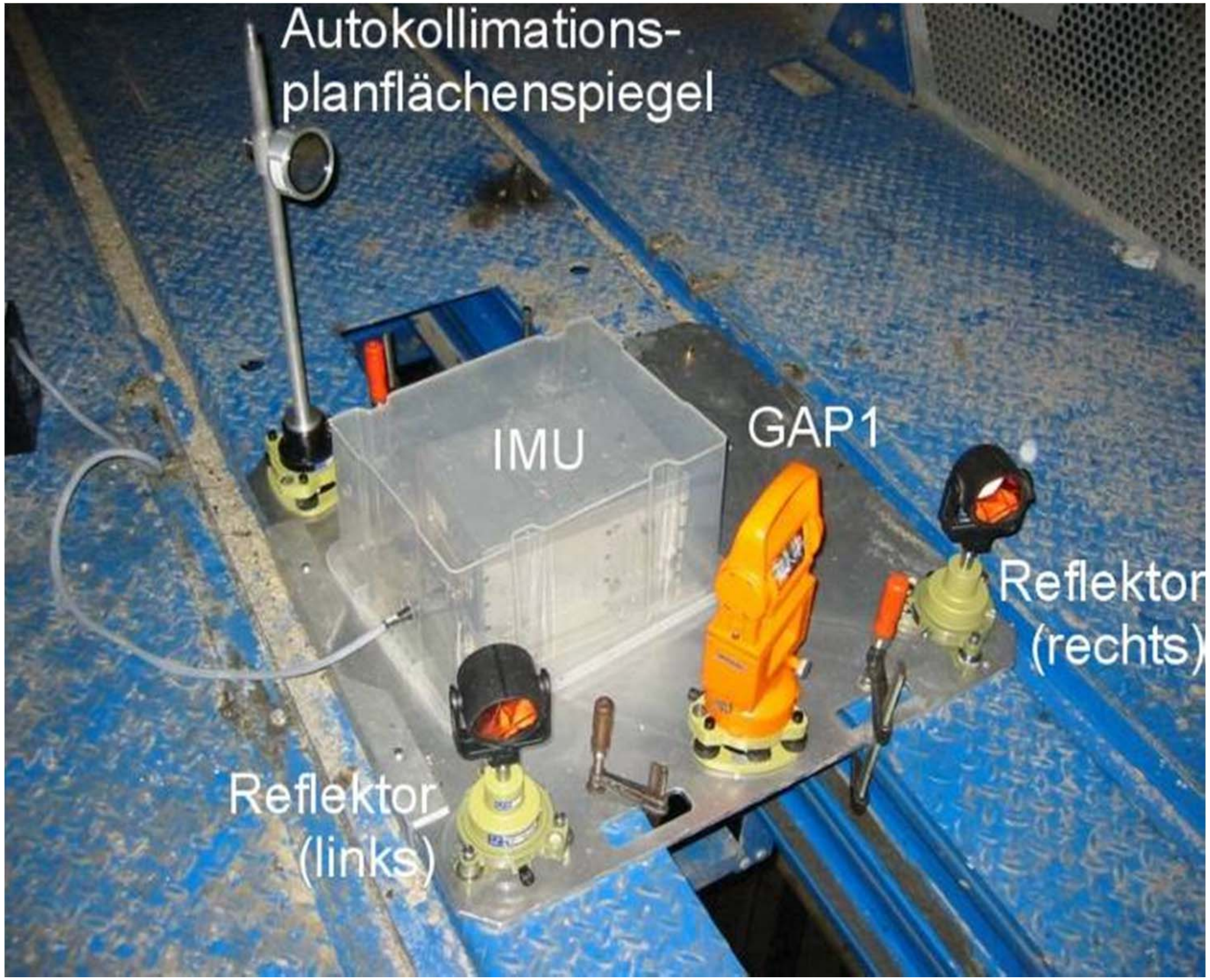
Situation of the Inertial System to the Axis of the Earth



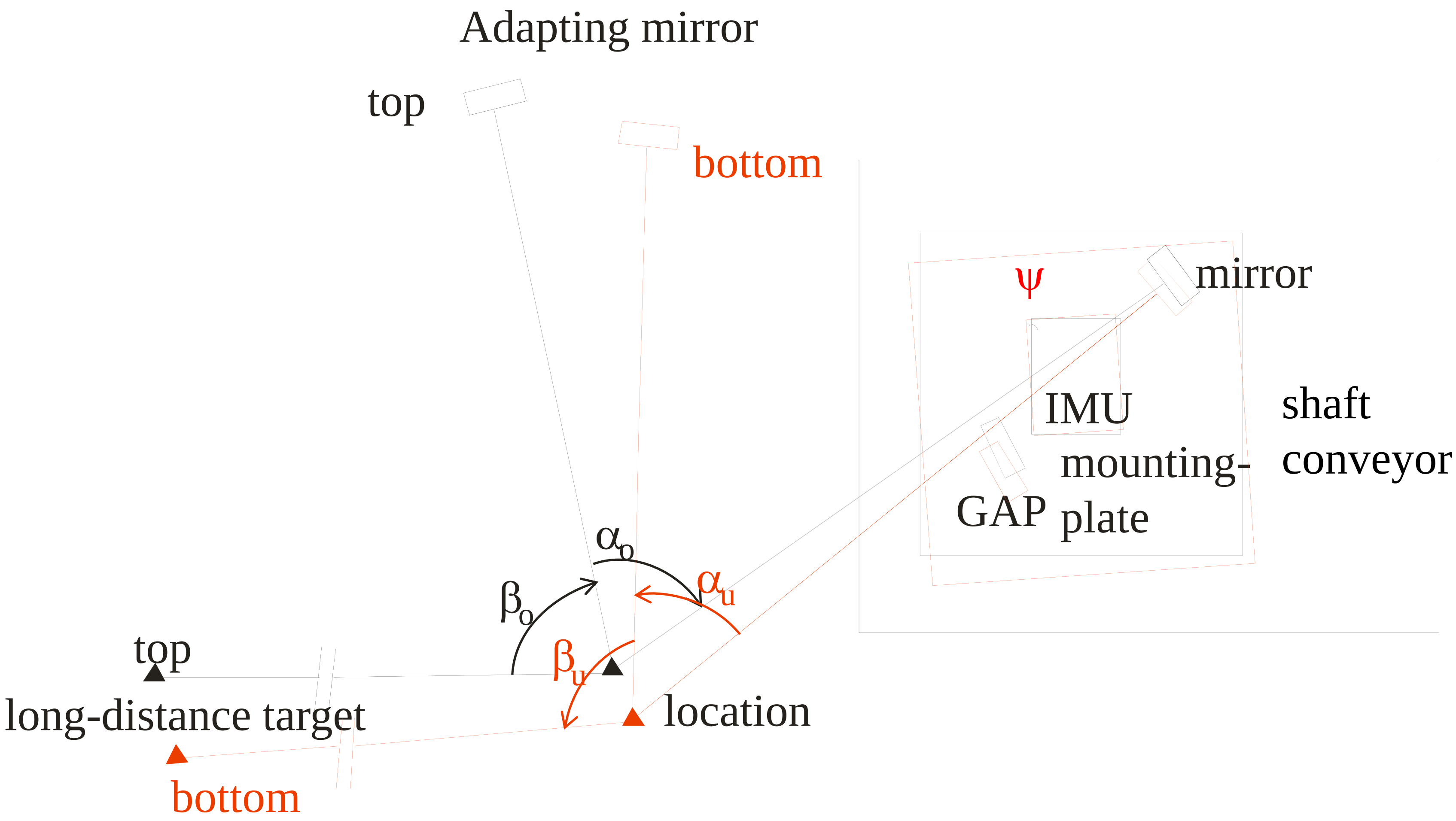
Considerating the rotation amount of earth

Measurement Setup

Measurement Setup in the Conveyor



Measurement Setting (Dissertation Neuhierl, 2005)



Direction angle:

$$t_u = t_o + \beta_o + \alpha_o + \psi - (\beta_u + \alpha_u)$$

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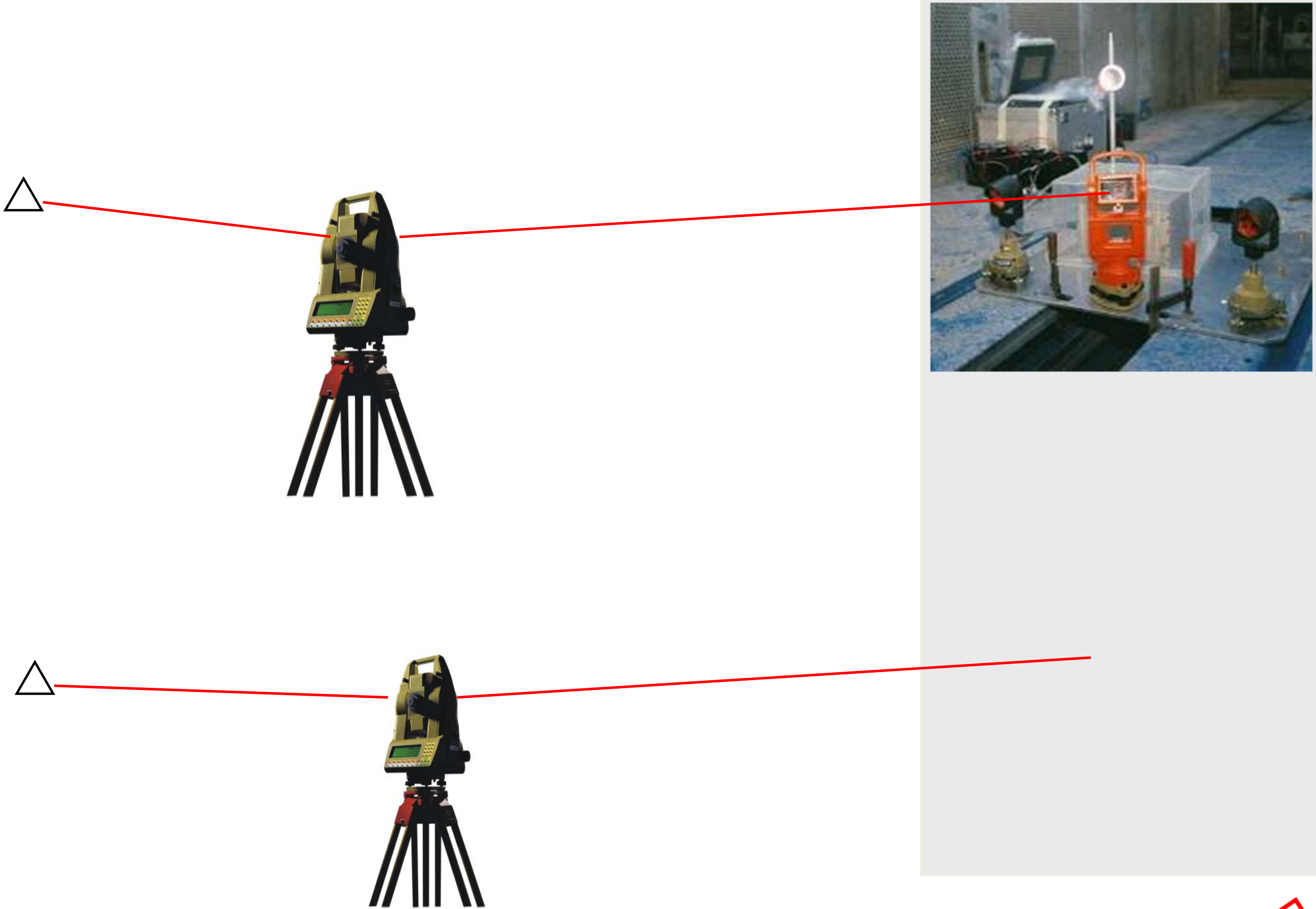
Measurement Process

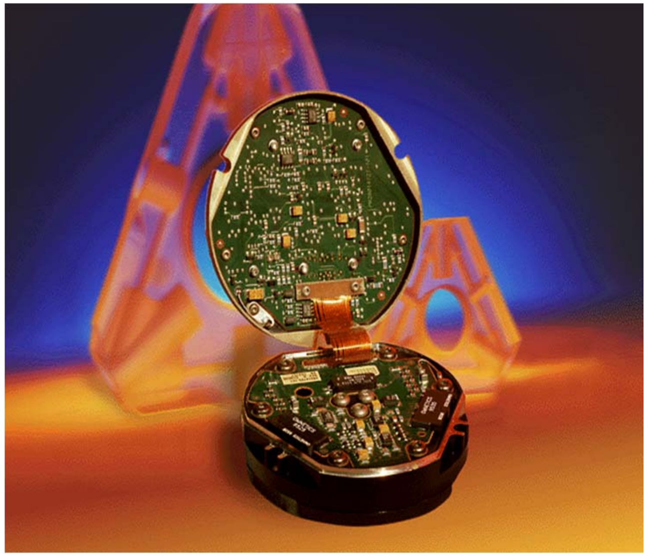


Results pit Sedrun (Dissertation Neuhierl, 2005)

- Difference between tunnel network and IMU: Δ = 2.2 mgon
- A priori analyses: ca. 1.5 mgon
  - Difference is not significant, no further corrections required

- Advantage using two independent methods: increase in reliability

Honeywell QA2000 accelerometers. ($2,920 to $17,045 US), One-year Composite Repeatability [μg] <160
Source: www.honeywell.com

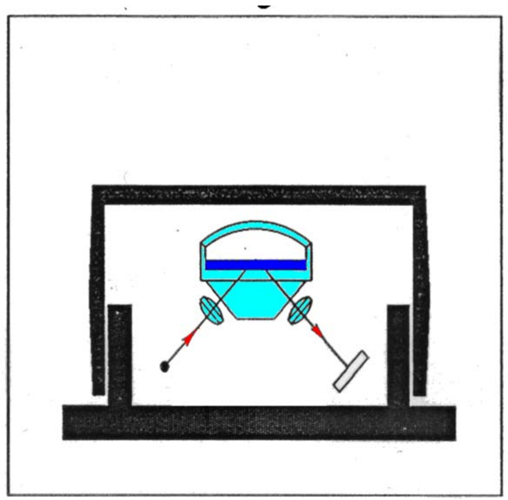


Honeywell GG1320 ring laser gyro.
Source: www.honeywell.com

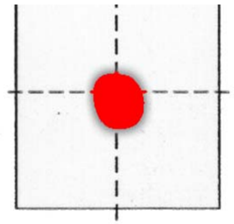
IMAR IMU with QA2000 and GG1320.
Source: www.imar-navigation.de

Inclination Sensors

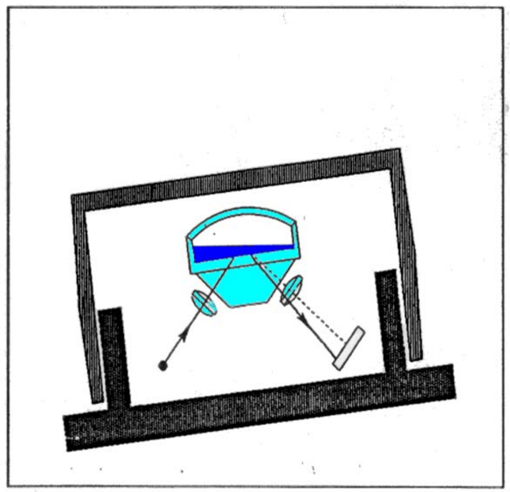
Liquid Surface with optical position sensor (PSD)

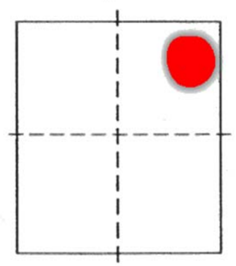


Position sensitive detector



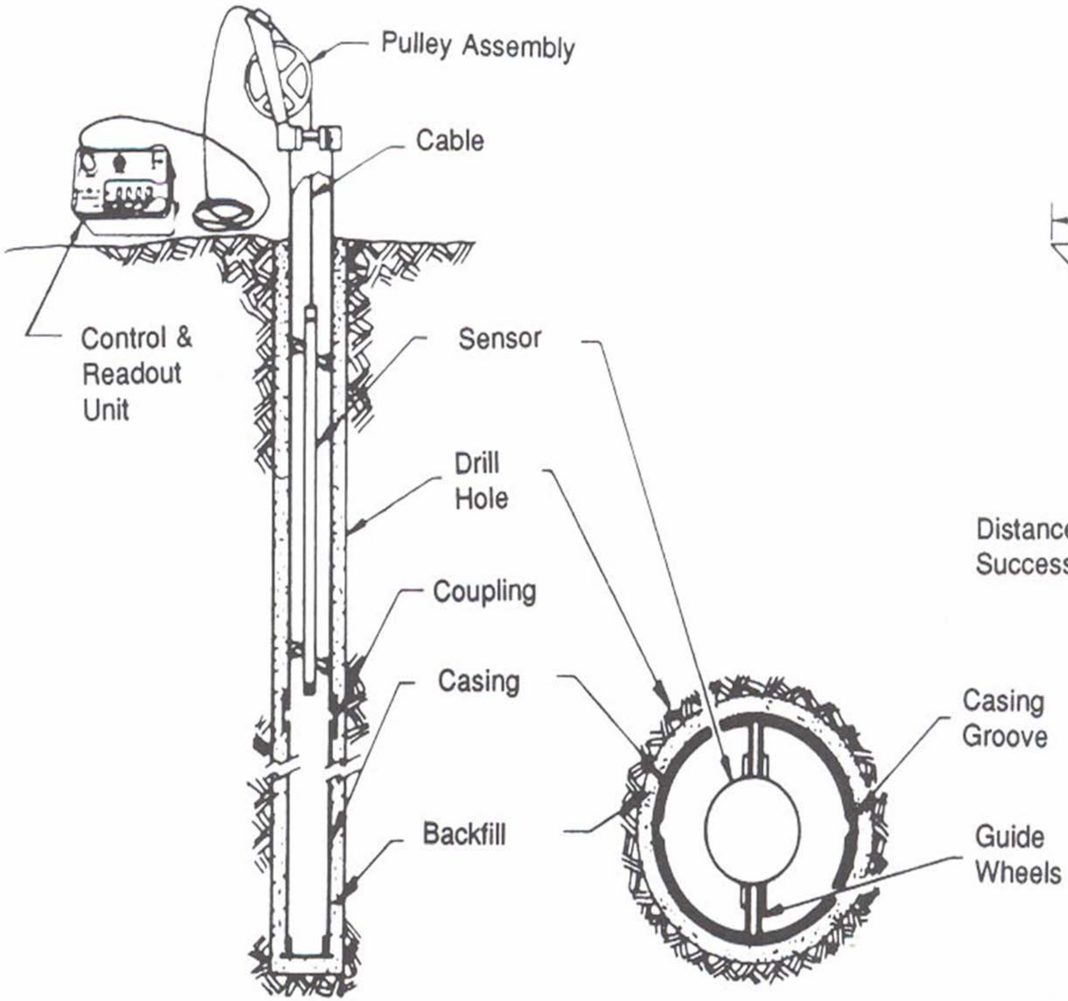
inclined

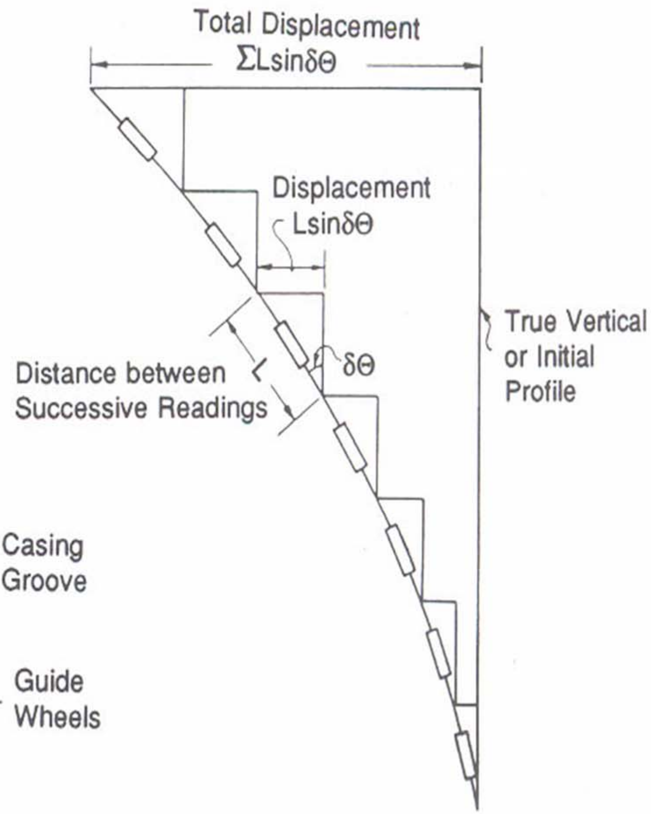




Borehole Inclination Sensor

Use: landslide monitoring
Principle: pendulum causes amplitude detected by position sensor, reset force of servo motor is measured in volts.

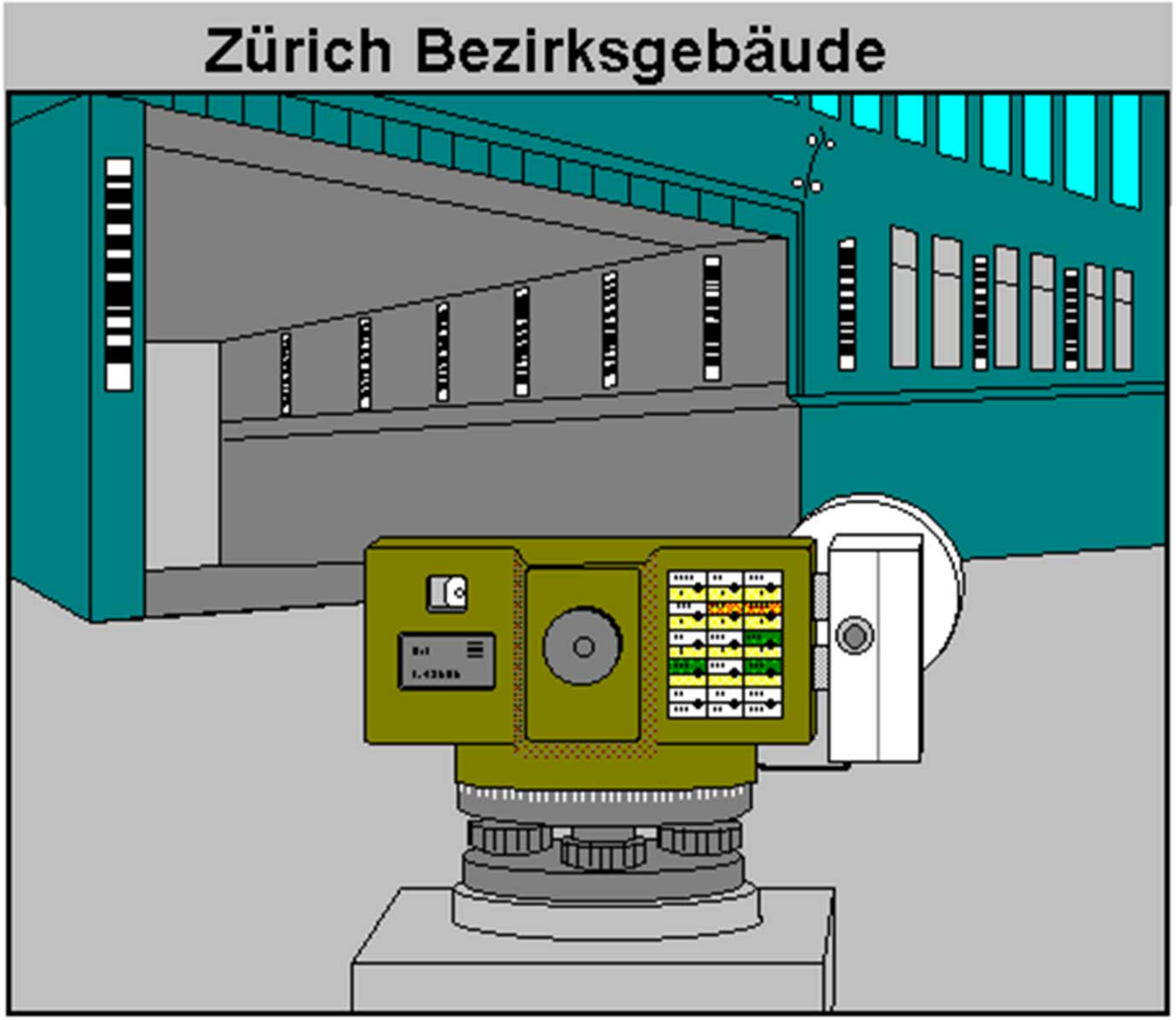




Fixed bottom point

Height Determination

- Levelling
- motorised digital levelling for permanent monitoring
- hydrostatic systems

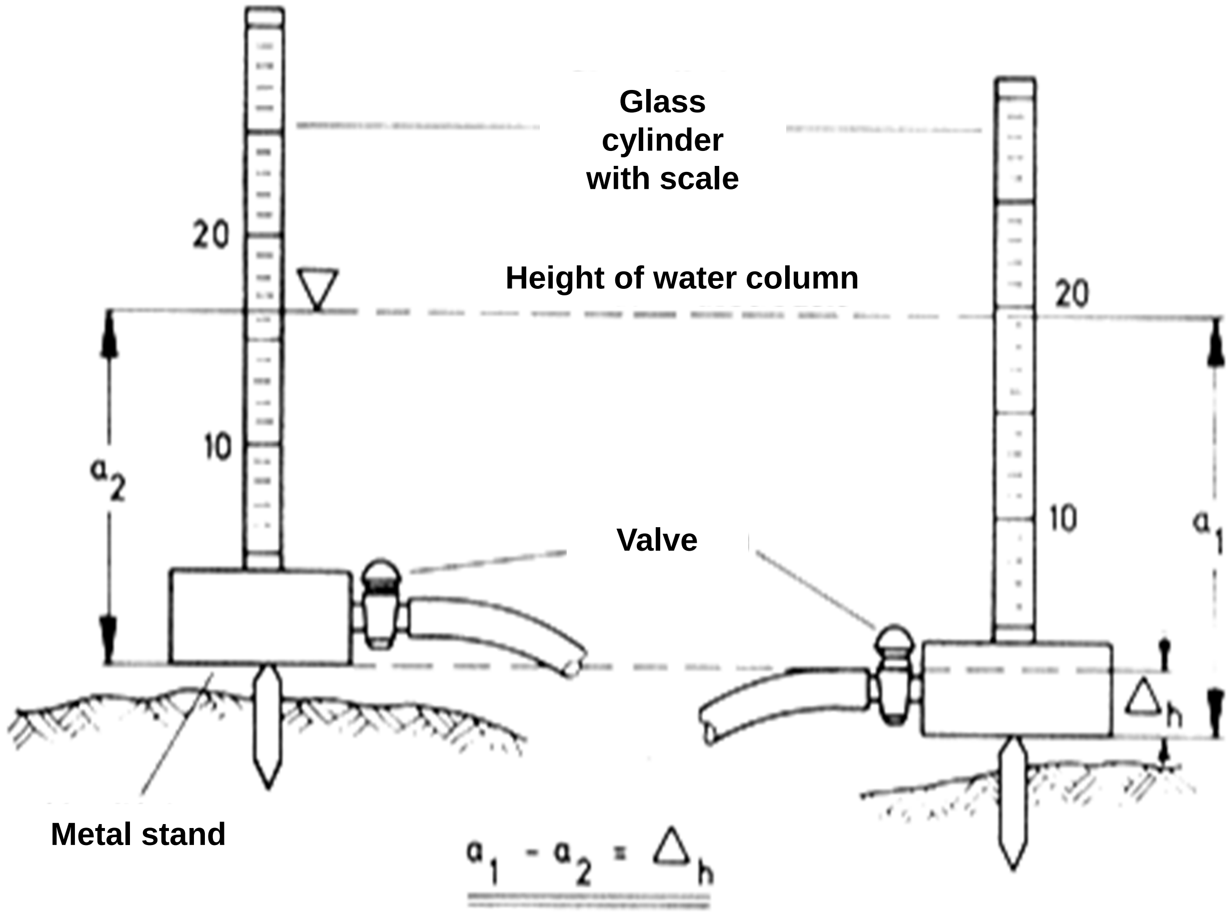


Solexperts

Hydrostatic Systems

Basic Setup of a Hydrostatic Levelling System

$$p = \rho g h$$



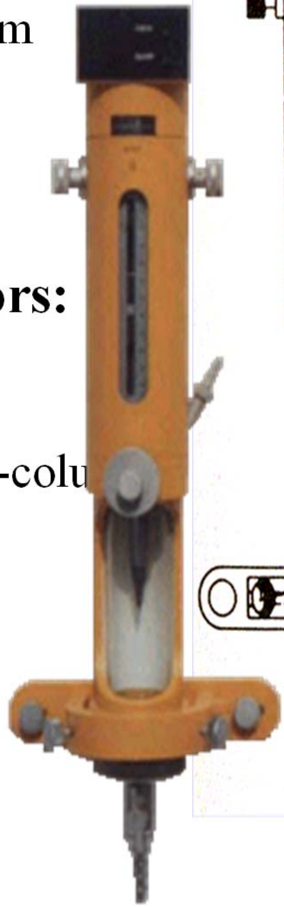
Parameters:

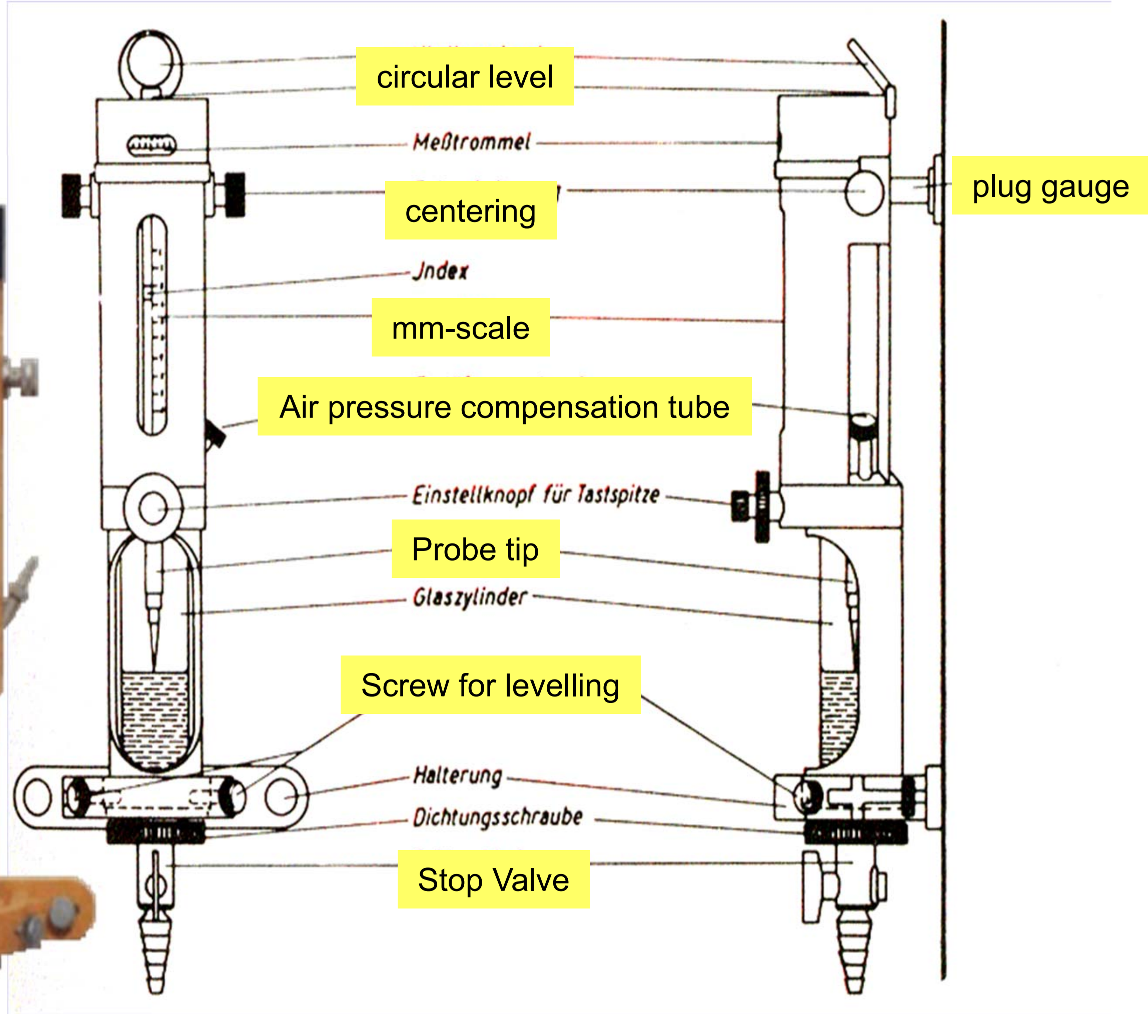
- Range: 100 mm
- Tube length: 30-50 m
- Accuracy: 0.01 mm

  (in closed rooms)

System specific errors:

- Capillary forces
- Vibrations of fluid-colu
- Fluid-viscosity



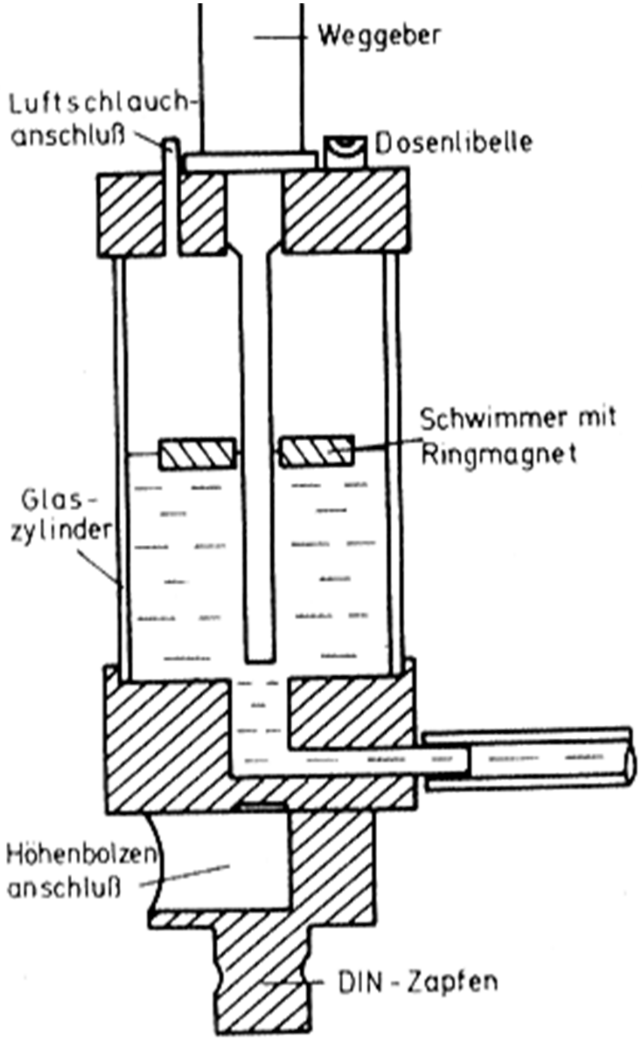


"Aachener Schlauchwaage"

Use: geomonitoring, detection of settlements

Principle: permanent magnet and electrical pulses on a wire cause changes in the length of the wire, which is measured by ultrasonic TOA

Range: 10 mm
Accuracy: 0.02 mm

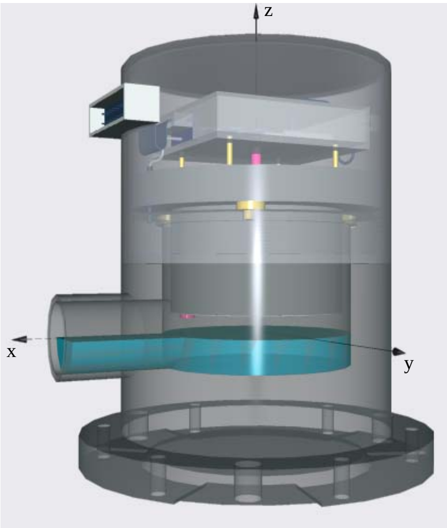


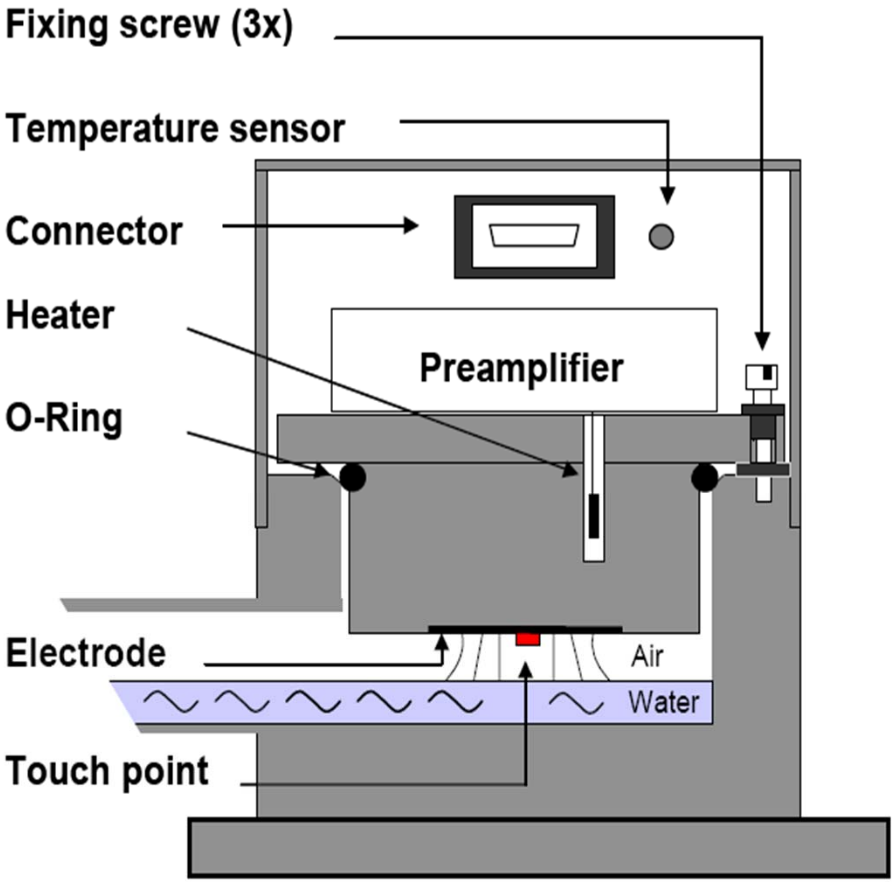
HLS – Hydrostatic Levelling System

Precise levelling – low tilt
Fluid velocity – slow movements

Technical Data:
Range: 45 mm
Resolution: <2 microns (0.002 mm)
Accuracy: <10 microns (0.010 mm)

Principle: fill level is determined capacitively. Fluid surface and electrode act as capacitor plates.

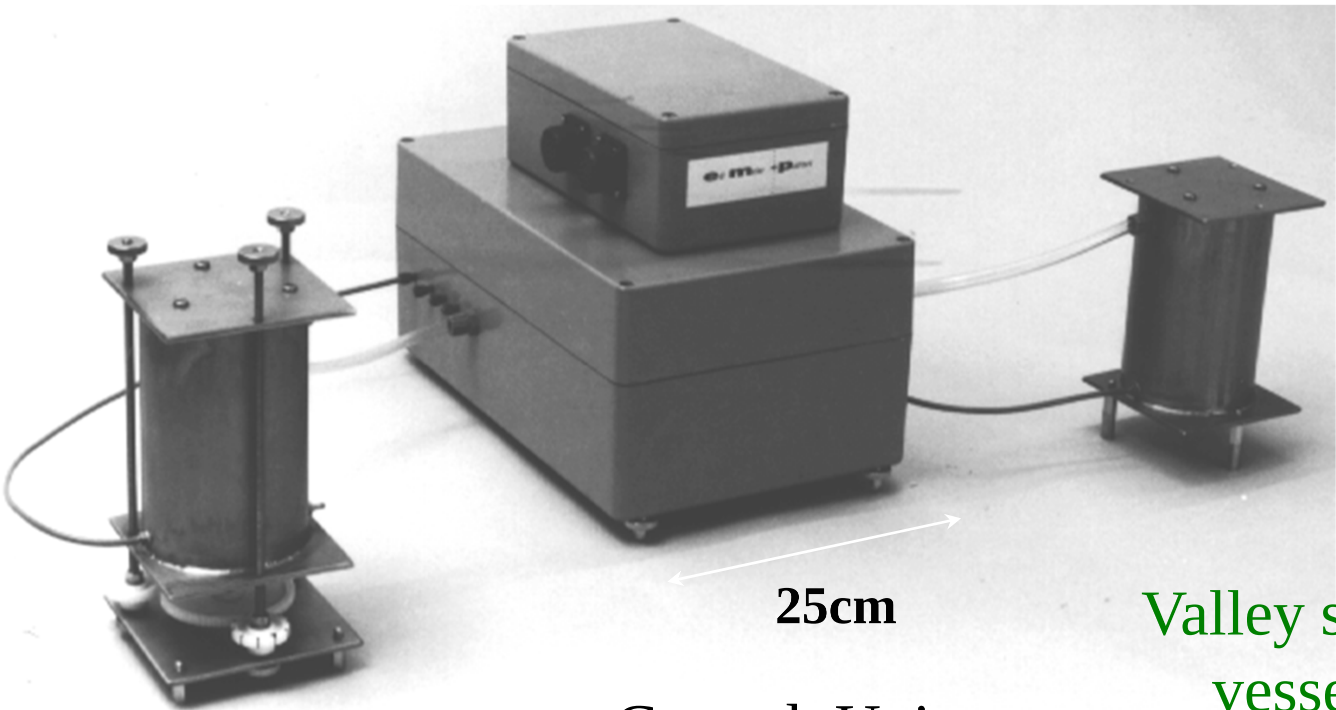




Cross Section of HLS level sensor

Source: IWAA2004 CERN

First Large Area Settlement Instrument - „Albigna“



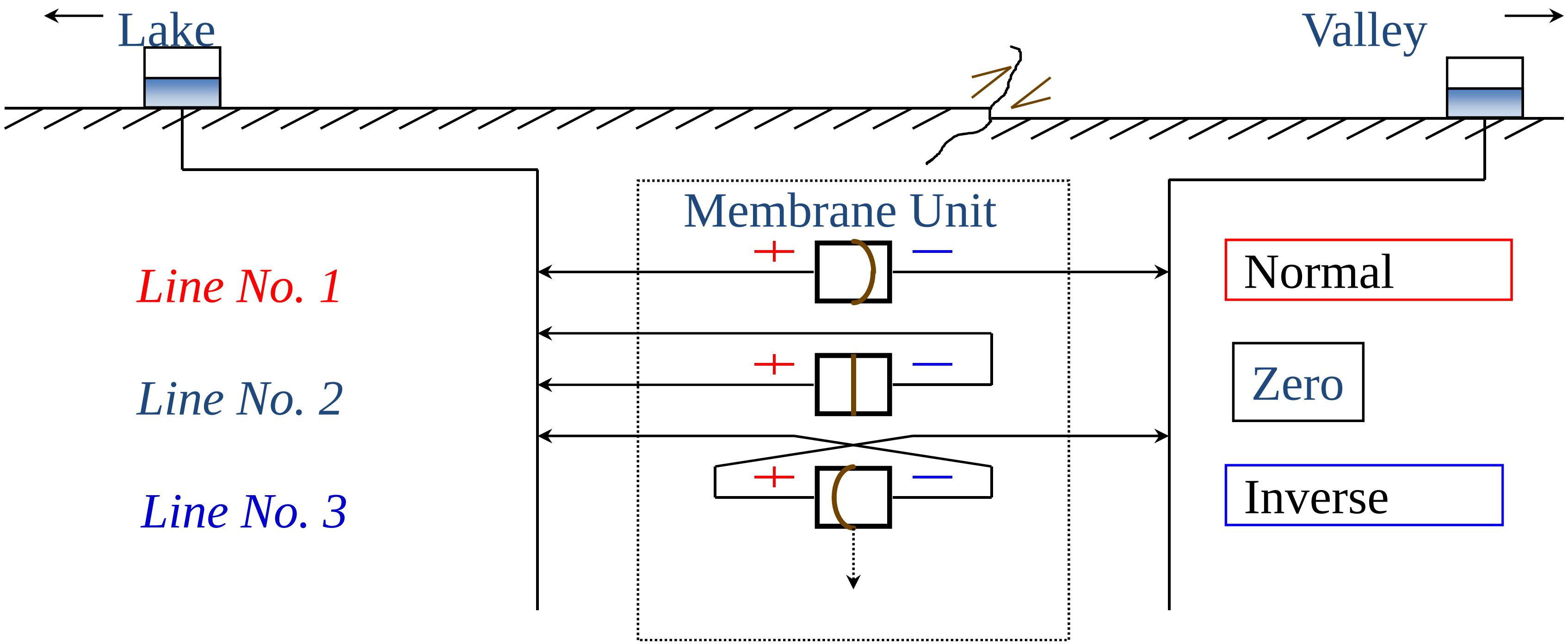
Valley side
vessel

Central Unit
for
several inputs

Lake side
vessel
(adjustable)

HSDM –Differential Pressure System

Measurement setup for calibration process



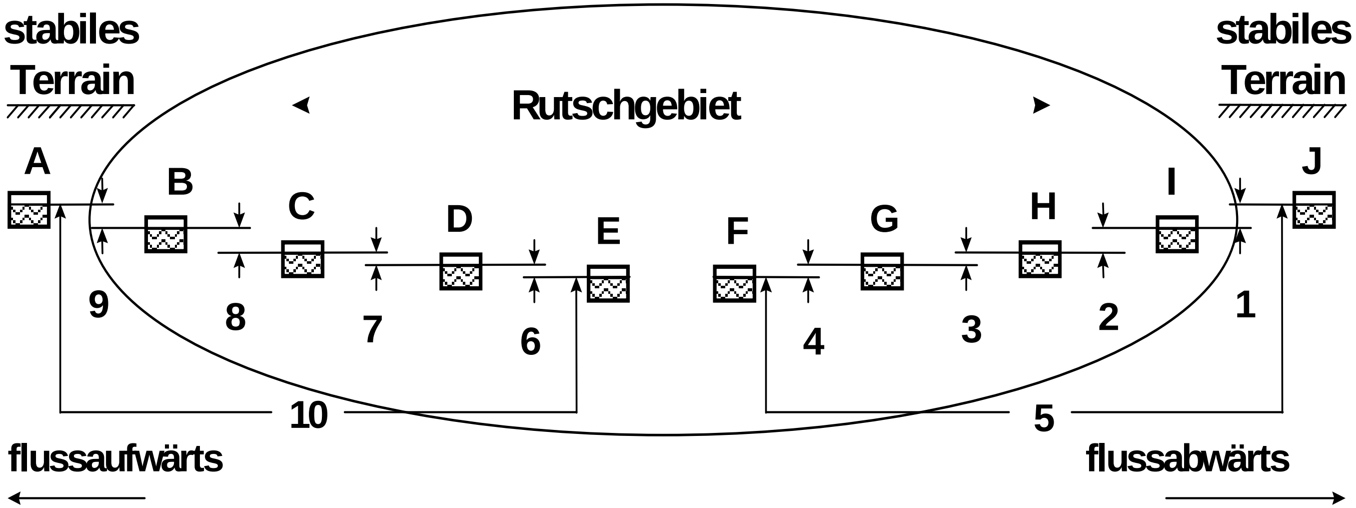
Target: Determination of residual deflection
Determination of long-time-drift of differential-pressure-sensor

no manipulation of the system after installation ⇨ remote control

Measurement Setup: Slope Movement Münster Basel

Technical data

Range: +/-500 mm
Accuracy: 0.1mm
Max. number of sensors : 12



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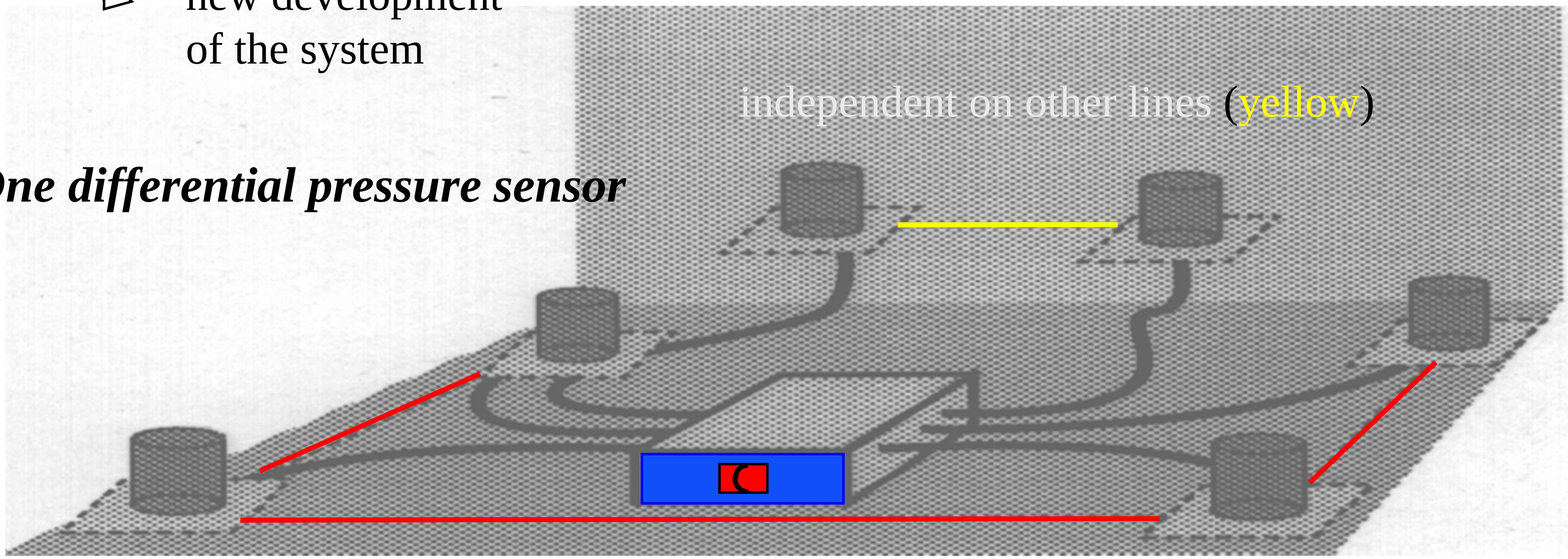
Multiple Lines Measurement Setup

The magnetic switching system integrated in the CPU switches on each measurement container to the difference pressure sensor.

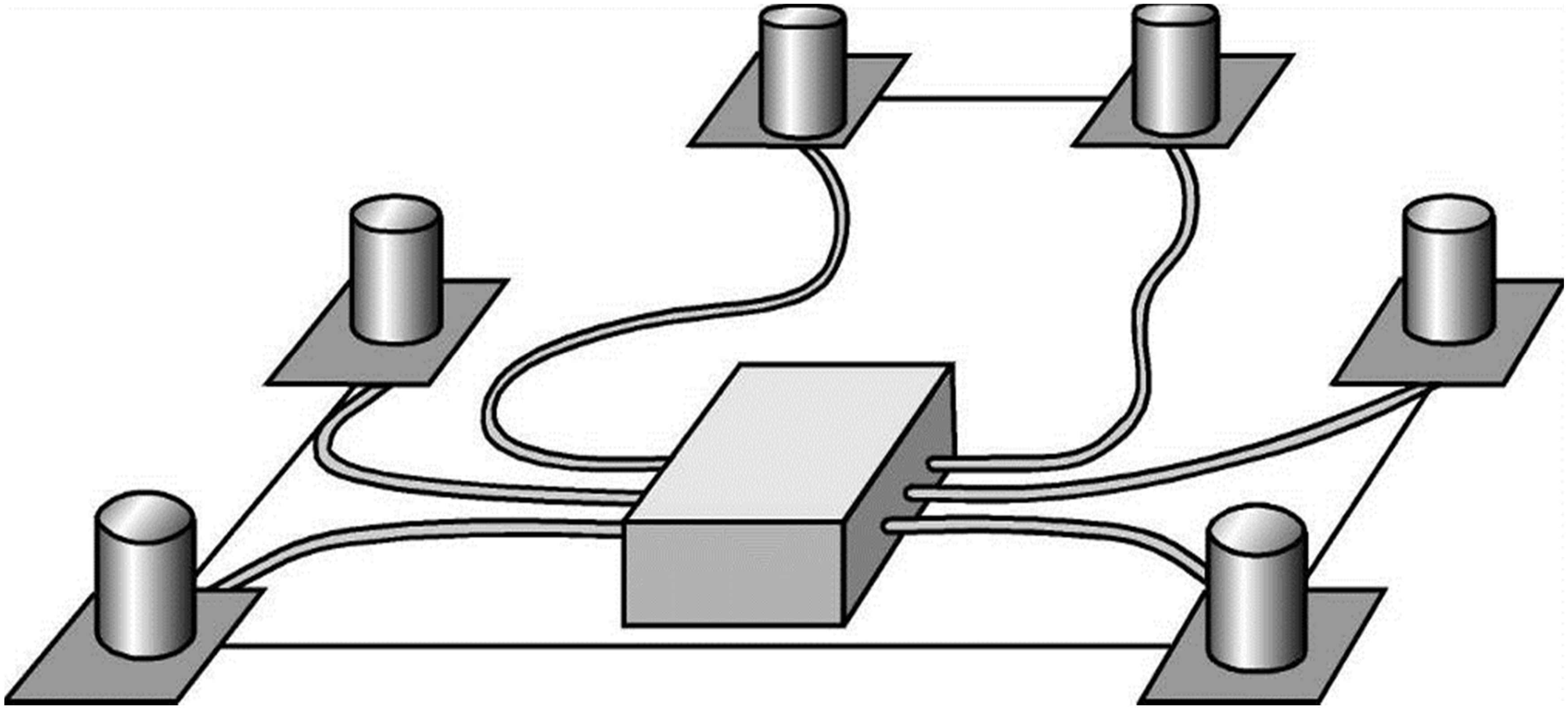
multiple measurement lines

new development
of the system



dependent on other lines (red)

Hydrostatic Measurement Method LAS (Large Area Settlement)



3D Measurement Systems

GPS/GLONASS

Vector Measurement Systems

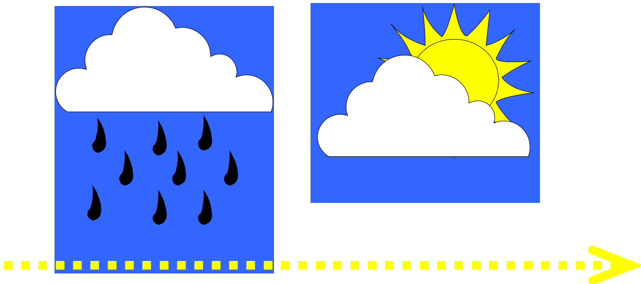
- Total Stations/Tacheometers/Lasertracker

Total Stations (eg. Trimble VX Spatial Station)

- Example: Trimble VX Spatial Station
  - Similar to Trimble S8 (except Fine Lock)
  - Accuracy: distance 3 mm + 2 ppm, angle 0.3 mgon (1“)
  - Robotic operation (one man operable)
  - Scanning functionality
    - range < 150 m, speed typical 5 Pts/s, minimum point spacing mm,
      3D point accuracy 10 mm @ ≤150 m
  - Integrated camera
    - 2048 x 1536 pixels, video stream 5fps

Ortho image station concourse Zurich Mainstation, captured with Trimble VX. Source: terra vermessungen ag

Stochastic and systematic Effects



Instruments

- Deviations of the instrument (internal)
- Temperature influences
- Torsion of the instrument
- Pollution of the lenses

Line of sight

- Meteo (Pressure, Temperature, Humidity)
- Refraction (-> HZ, V)
- Optical Elements in the line of sight

Target

- Alignment of the Prism
- Pollution of Prism
- Stability of the pillar
- Expansions from temperature

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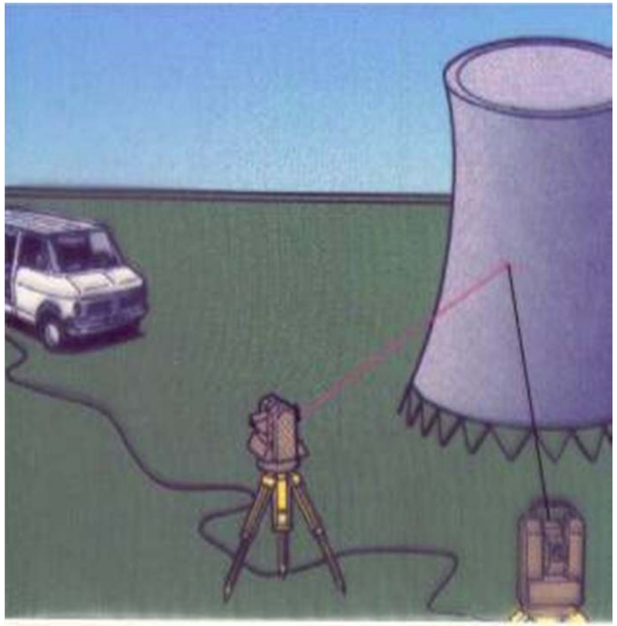
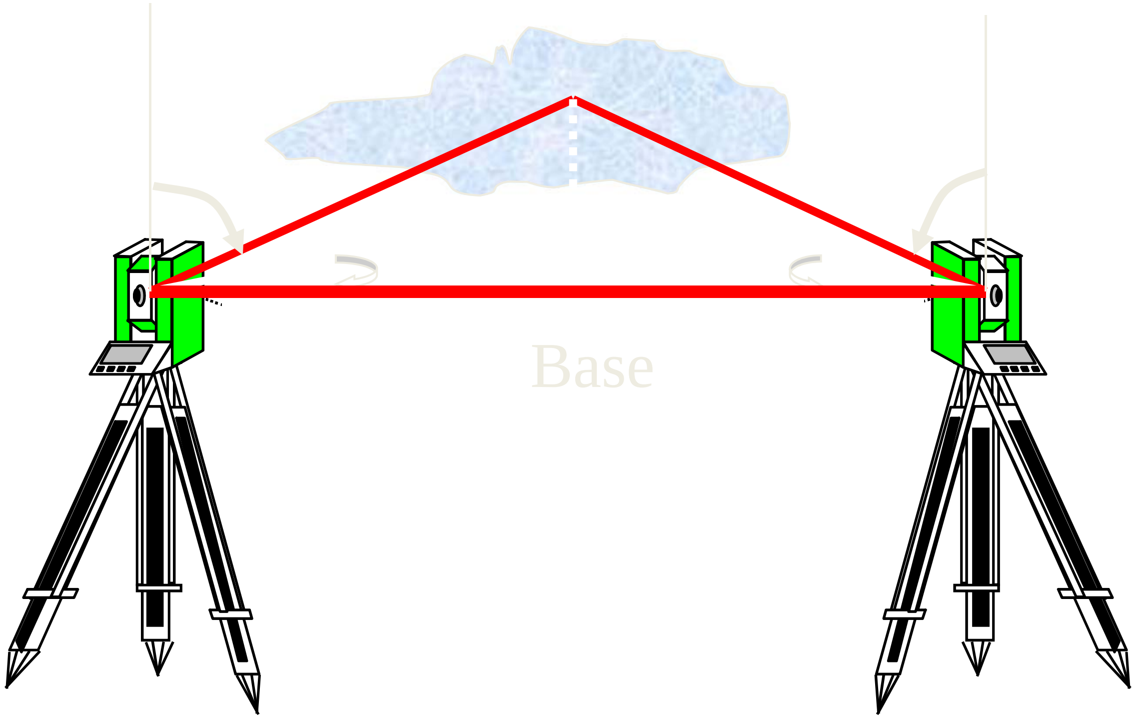
Influences of Glass

Leipzig City Tunnel

Motorized Theodolites/Videotheodolites

- Videotheodolites (Intzersection Method)
- Motorised tacheometer (vector measurement)
- Motorised tacheometer (contactless, scanning method)





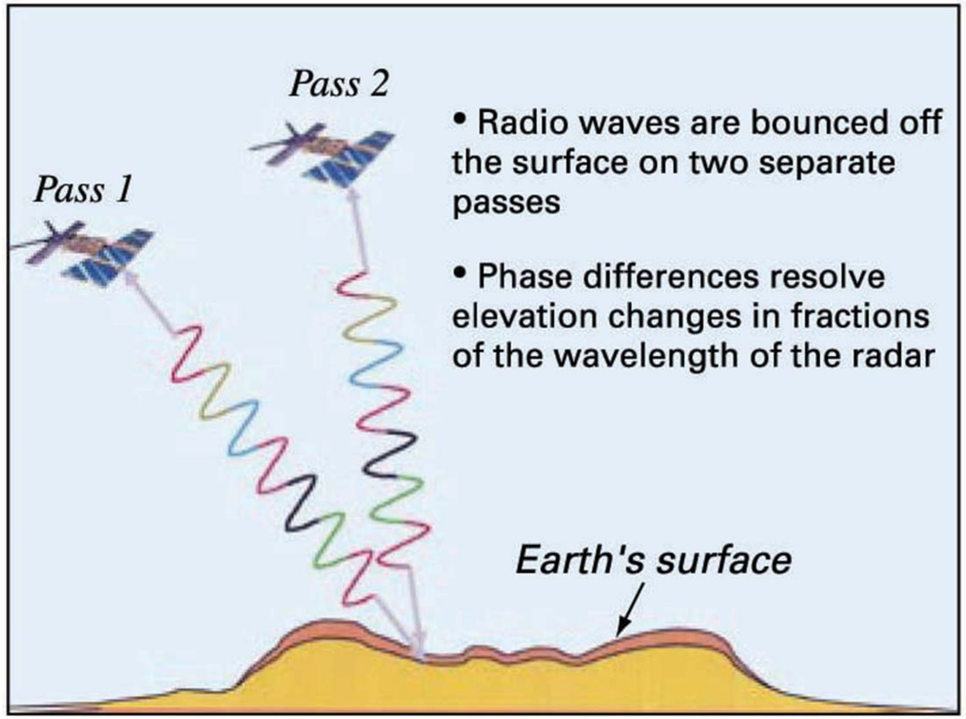
Intersection geometry influence
as in Photogrammetry

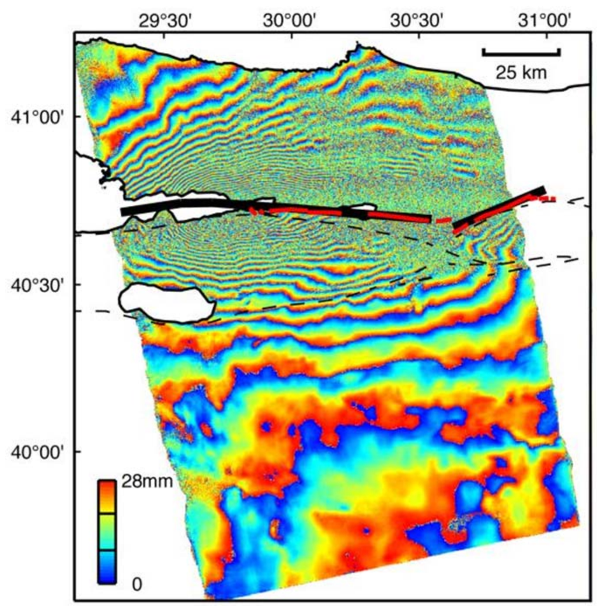
Radio Interferometry

Interferometric synthetic aperture radar, also abbreviated **InSAR**

- Uses radar (SAR) images to generate maps of surface deformation
- Uses differences in the phase of the wares returning to the satellite or aircraft
- Can potentially measure centimetre-scale changes

Application: monitoring of subsidence and structural stability





Interferogram produces using ERS-2 Data spanning the Izmit earthquacke, (NASA/JPL)

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Metrology Overview

Overview: Geodetic Metrology Methods

Metrology methods	***Geometric information***	***Resolution***	***Advantages***	***Disadvantages***
Levelling	***Changes of the local z-coordinate;***	***1/100 mm***	***Simple; perpendicular relation independent of object***	***No automation with optical levels, refraction influence***
Hydrostatic height measurement	***Relative changes of the local z-coordinate***	***1/100 mm***	***No refraction influence, permanent***	***Time intensive installation, problem of coupling, influence of temperature***
Distance measuring 5-2000 m	***Distance, change of distance***	***1/10 mm***	***Permanent; reflectorless for suitable surfaces and angles***	***Just one distance; refraction influence***
Distance measuring 0-5 m ***Invar bars,- wires*** ***Fiberoptical sensors***	***Change of distance***	***< 1/100 mm***	***Permanent; no refraction influence***	***Change of direction only, problem of coupling, just one distance***

Overview: Geodetic Metrology Methods

Metrology methods	*Geometric information*	*Resolution*	*Advantages*	*Disadvantages*
Tilt meter Inclinometer Borehole-Inclinometer	*Rotation around x- or y-axis*	*< 1“* *(0.3 mgon)*	*Permanent, perpendicular relation*	*Problem of coupling*
Vector measuring Total station Electronic tacheometer	*Direction- and distance changes → local 3D-coordinates*	*<1 mgon*	*Independent of superior systems; „Real-time“- analysis, simple target points (reflectors, reflex foils)*	*Refraction; needs reference points*
Laser Scanning Microwave-Interferometry Photogrammetry	*Pointcloud-→ Surface models*	*1-3 cm* *1 mm*	*Reflectorless Measurements* *High sampling rate*	*Depends on the Surface parameteres,* *postprocessing*
3D-coordiantes designation GPS (differential phase measuring)	*Global 3D-coordinates in WGS84-system*	*1 mm x,y* *3 mm z*	*„Real-time“ – analysis possible with fix-installation*	*Free sight to satellites, transformation of parameters necessary for linking with other data*

Overview: Geodetic Metrology Methods

Metrology methods	*Geometric information*	*Resolution*	*Advantages*	*Disadvantages*
Gyroscop **Azimuth finding systems**	***Direction related to the Rotation axis of the Earth***	***1,3 mgon***	***Related to a physical Direction***	***Temperature*** ***Drifts***
Inertial Navigation Systems	***Position, Rotations***	***dm***	***Independent from reference points***	***Temperature Drifts complicated calibration***
Plumbing **- optical plumbing** **- mechanical plumbing**	***Transfer of Local vertical***	***1:500***	***Related to a physical value***	***Refraction (optical)***
Alignment **-Optical alignement** **- Mechanical alignment**	***Deviation of a line***	***0,01 mm***		***Refraction (optical)***

Overview: Geodetic Metrology Methods for Slope Instabilities

Metrology methods	***Geometric information***	***Resolution***	***Advantages***	***Disadvantages***
Gyroscop **Azimuth finding systems**	***Direction related to the Rotation axis of the Earth***	***1,3 mgon***	***Related to a physical Direction***	***Temperature*** ***Drifts***
Inertial Navigation Systems	***Position, Rotations***	***dm***	***Independent from reference points***	***Temperature Drifts complicated calibration***
Radar Interferometry	***Interferometric pattern***	***mm***	***High resolution***	***Surface properties*** ***Does not work on vegetated surfaces***

Engineering Geodesy…

Remember:

- Engineering geodesy consists of more than just use total stations and/or GNSS

- Use your creativity to solve a specific problem

- Think about all the geomatics disciplines
  - Photogrammetry
  - Remote Sensing
  - Geodesy
  - GIS
  - ...

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Beaconing, Centering Systems, Reference Points

- Different systems (more or less) available, each has ist own advantages and drawbacks
  - Wild/Leica
  - Kern
  - Zeiss

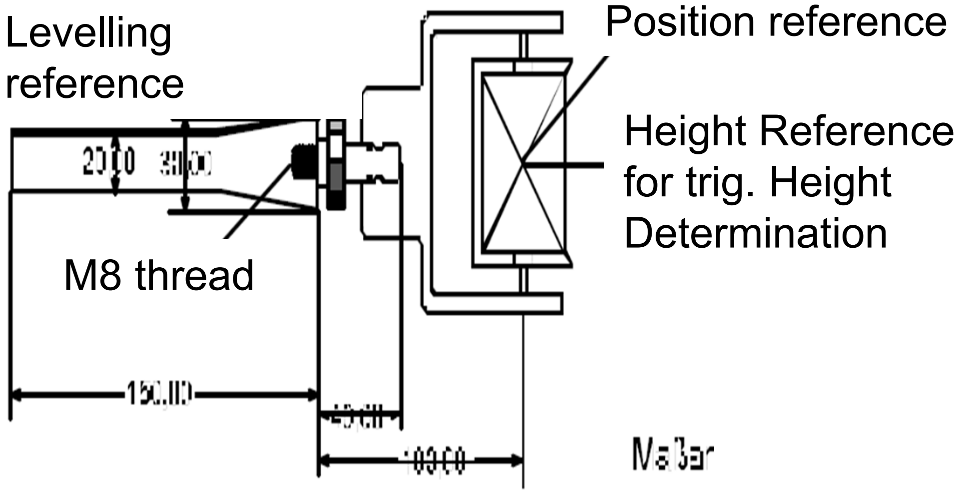
Wild/Leica centering system.
Source: www.geodirekt.de

Kern centering system.
Source: www.swisstopo.ch

Zeiss centering system (Zeiss-Zapfensystem).
Source: www.geodirekt.de

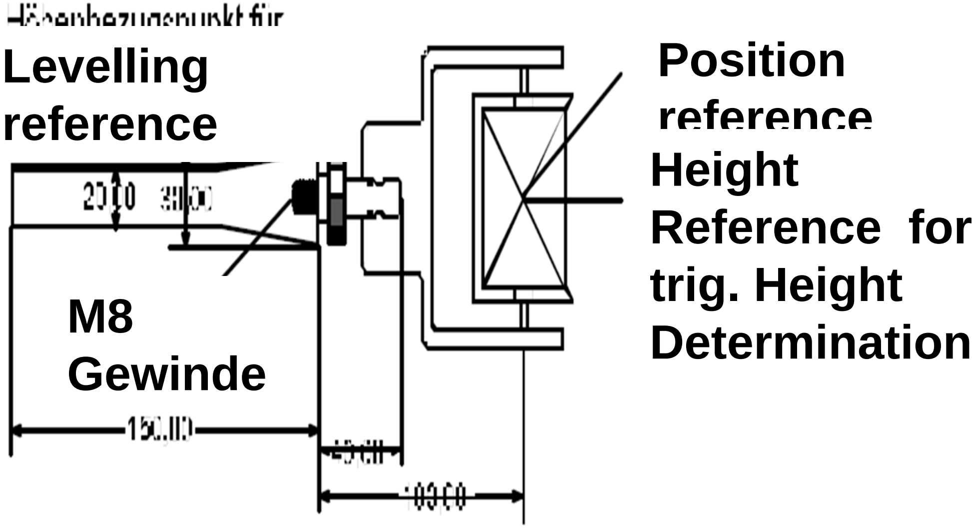
- SBB Bolts
- mounting systems for monitoring purposes

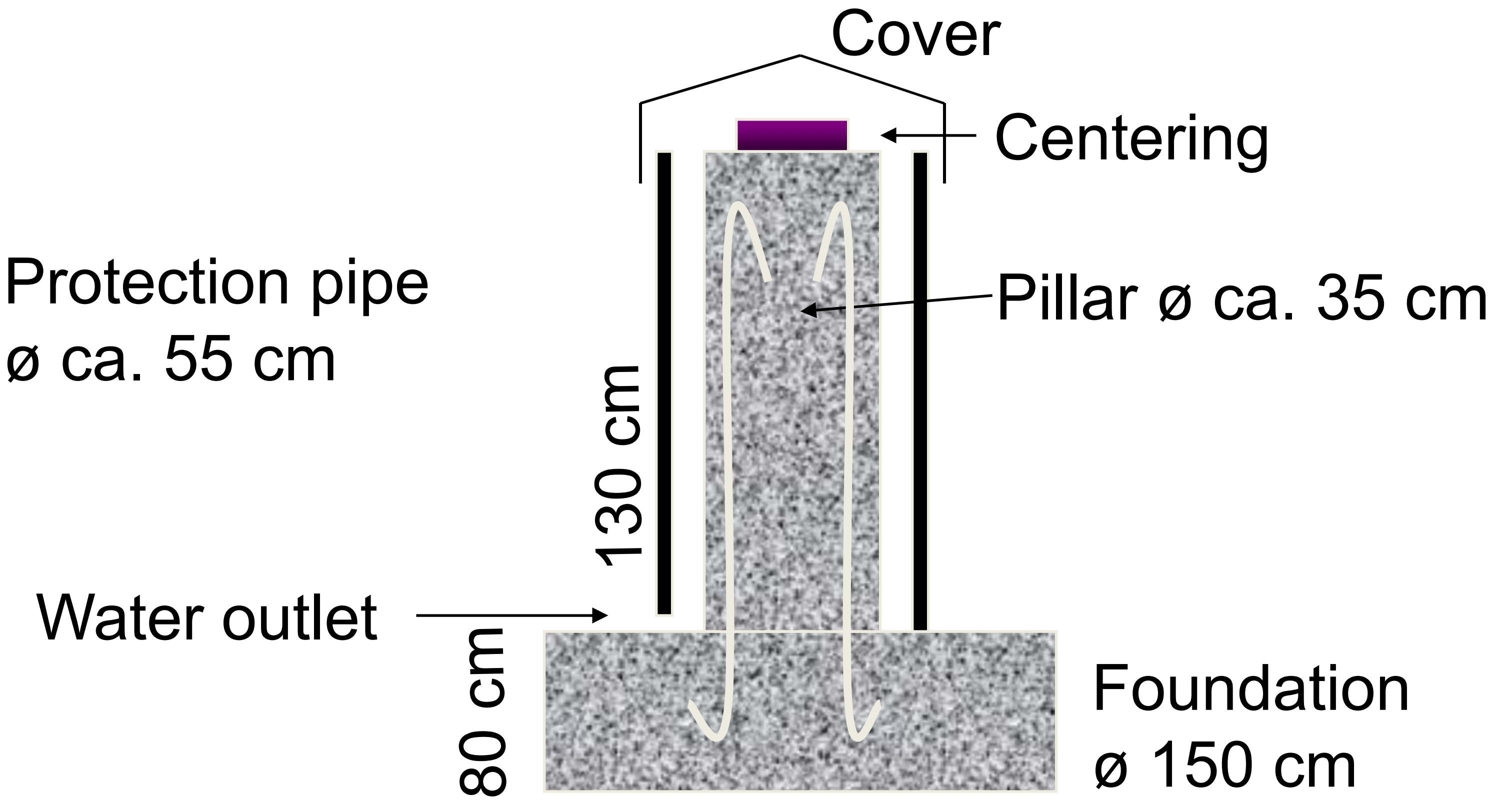
Typical mounting „L-supporter“ for monitoring.
Source: www.goecke.de



SBB Bolts.
Source: unkown

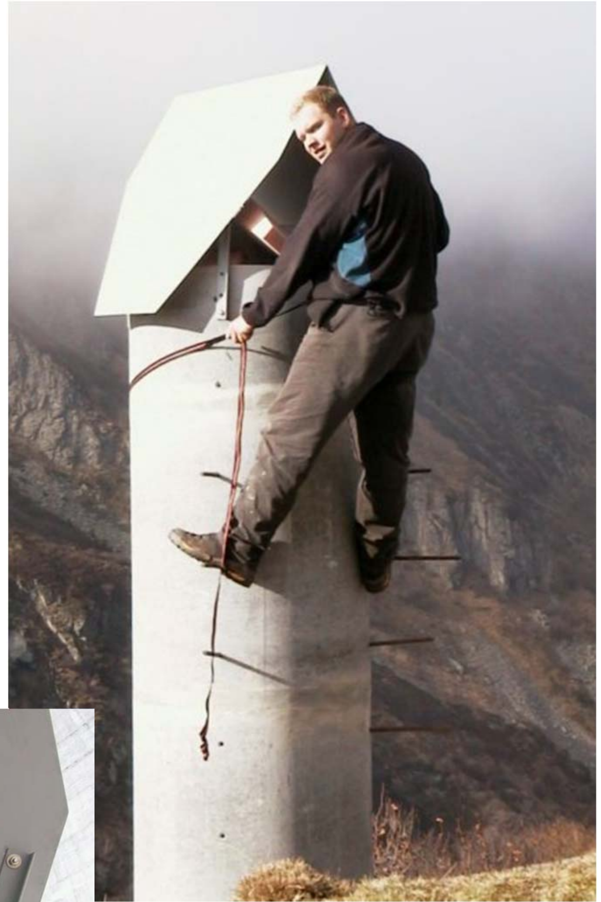
SBB Bolts


Levelling reference
Position reference
Height Reference for trig. Height Determination
M8 Gewinde

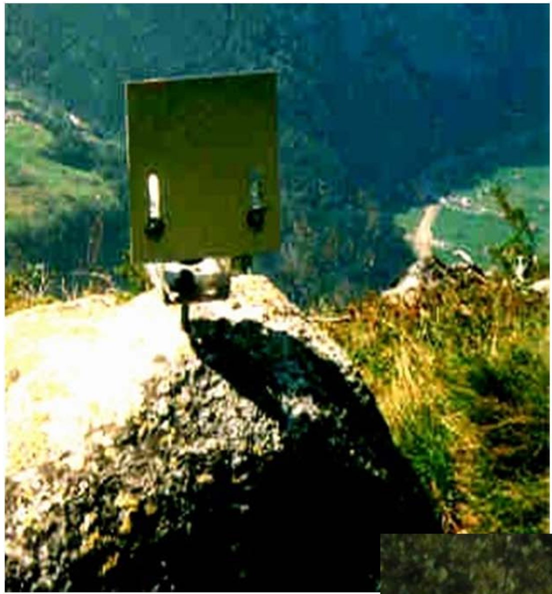

Cover
Centering
Protection pipe
ø ca. 55 cm
Pillar ø ca. 35 cm
130 cm
Water outlet
80 cm
Foundation
ø 150 cm

Observation Pillars

Double shell concrete pillar



Reflector Mounting (?)



Support for Total Stations

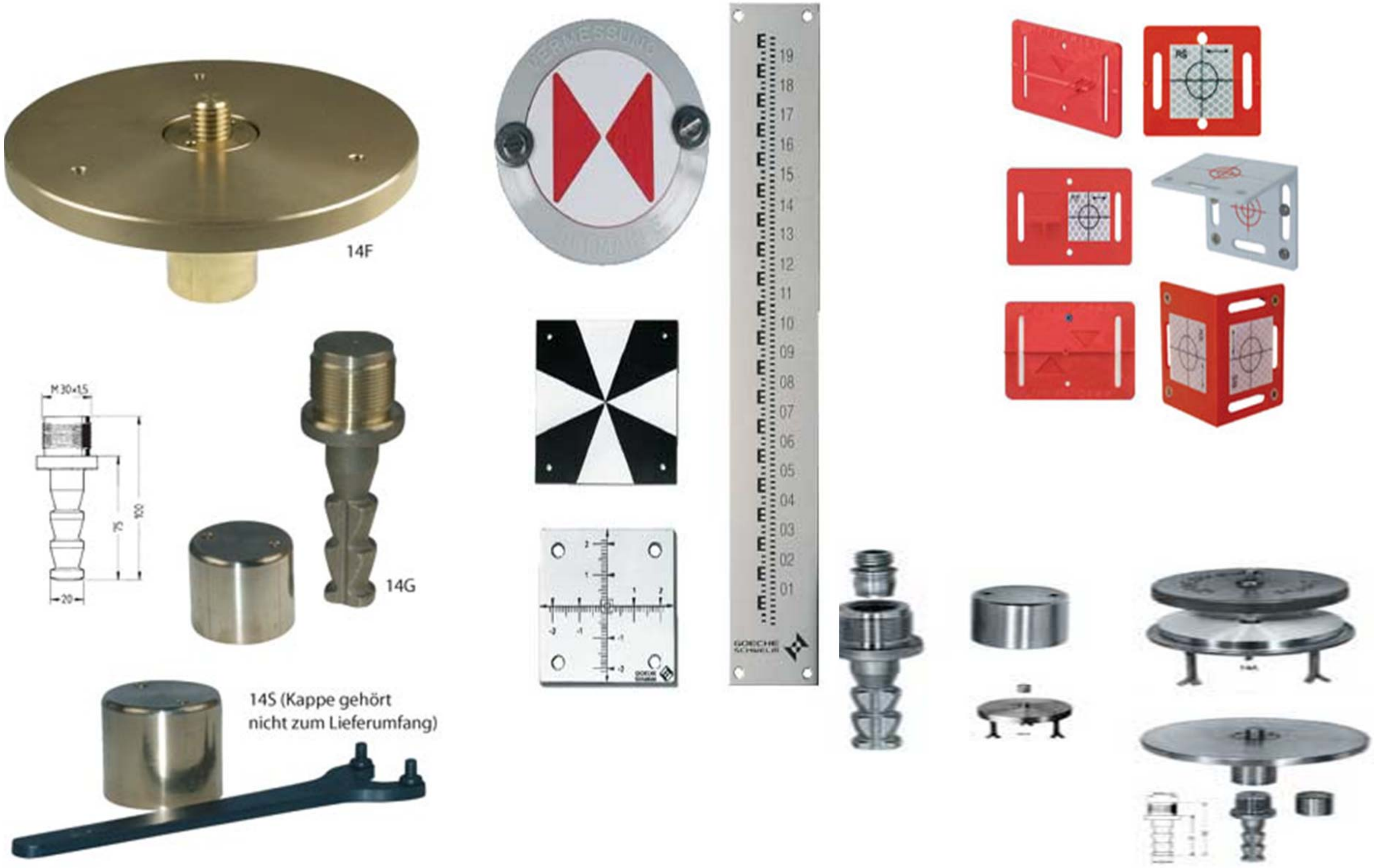
Console with total station,
Mt. Terri Project.
Source: Stephan Schütz

System „Goecke".

Losatec mounting system in Gotthard Basetunnel near Faido.
Source: Stephan Schütz

Prisms

Targets


14F
M 30×1,5
14G
14S (Kappe gehört
nicht zum Lieferumfang)
VERMESSUNG
19
18
17
16
15
14
13
12
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03
02
01