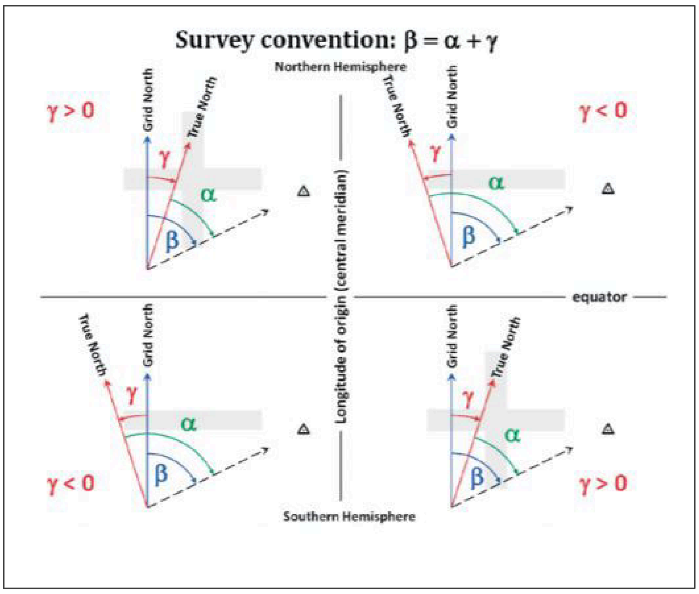
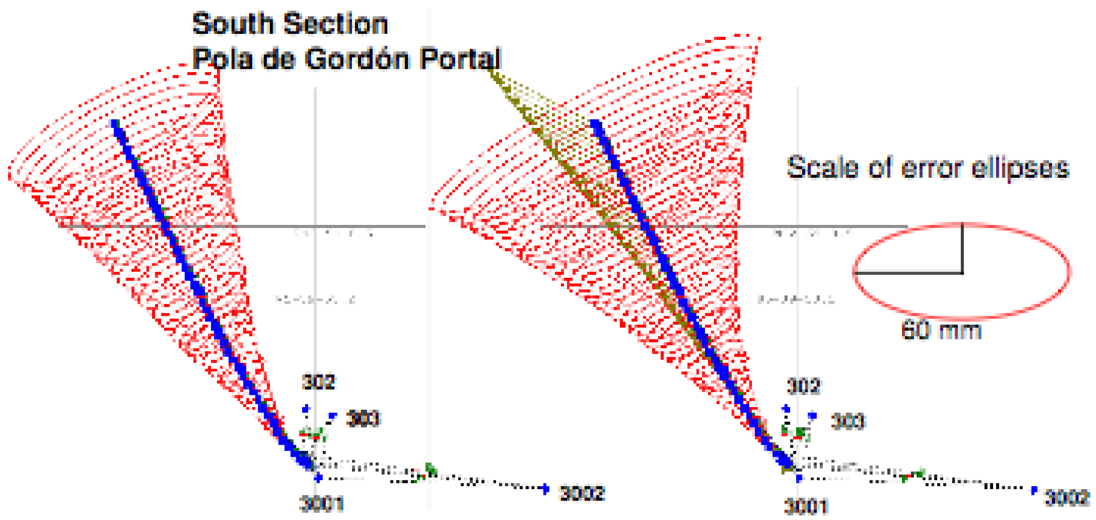
mining & tunnel surveying

- What are the principles of mine surveying?
  - Mine surveying follows standard principles as typical land surveying:
    - Surveying instruments: mitigation of errors & differencing, calibration and testing.
    - Accuracy and precision (accuracy critical, precision slightly less requirements)
    - Coordinate types and conversions
    - Contours, DEMs & TIN, GIS
    - Calculation checks (volume calculations)
    - Atmospheric effects (bending, distance delay)
- What are some legal considerations and role of a mine surveyor?
  - Roles of a mine surveyor include:
    - Set out and prepare plans of workings of a mine (roads)
    - Set out drives adjacent to ore bodies.
    - Survey bore holes to keep them vertical and to map them
    - Maintain statutory mine and safety plans
      - Sparks from electronic measurements in methane areas; optical-mechanical instruments.
    - Exploration Survey management
    - Volume surveys
    - Land, environmental & spatial data management
    - Subsidence, infrastructure monitoring
  - Legal considerations are most state based to assist in the safety and efficiency of mine operations.
    - e.g Surveying Act, Mines Inspection Act, Surveyor General's Guidelines, Coal Mines Regulation Act
- What calculations are done in mining surveying?
  - Area and volume calculations (can be done using laser scanning drones)
    - Dam or open cut: quantities calculated every 2 weeks. Volumes accuracy approximately 1%.
    - Stockpile volume
    - Excavation for road work from road cross sections, tunnels, etc.
  - Orientating
    - Computing join between 2 grid coordinates, gets grid bearing and grid distance
    - Azimuth relates to true bearing: **Azimuth = Grid Bearing - Grid Convergence**.
      - Grid convergence needed.
- What are some of the tools used for mining surveying?
  - Gyro
    - To control accumulation of traverse error (but not on every line, choose a line when the precision is expected to be worse, angles typically are precise)
      - Remember **grid convergence**



β – Grid Brg
α – Azimuth
γ – Grid Convergence

- Gyro lines improve precision (error ellipses); guards against systematic errors (refraction / LoS bending) & gross errors)
- Underground angle observations: gyro obs with a double zig-zag traverse (good results of accuracy and reliability); obs are independent



- Calibration of IMU units for north alignment.
- Micro-tunnelling vertification of pipe-jack alignment from the launch shaft.

- Laser scanning
  - TLS typically more precise than UAS survey
- UAS / UAV: efficient, operations can still continue (e.g Stockpile Volume Estimation)
  - Imaging sensors - cameras
  - Fixed wing vs multirotor (gmat1110)
  - Ground sample distance (i.e spatial resolution)
  - GCPs important (for heights)
  - Better to fly at oblique/near-nadir angles (height is weaker)
  - Digital photogrammetry: automatic tie-point (TPs) extraction
    - Auto Detect TPs -> Match TPs -> measure image coordinates -> register TPs in 2 or more images.

    - using SIFT algorithm to search and match TPs
    - Indirect vs direct georeferencing
  - Products: ortho-mosaic images, 3D point cloud.

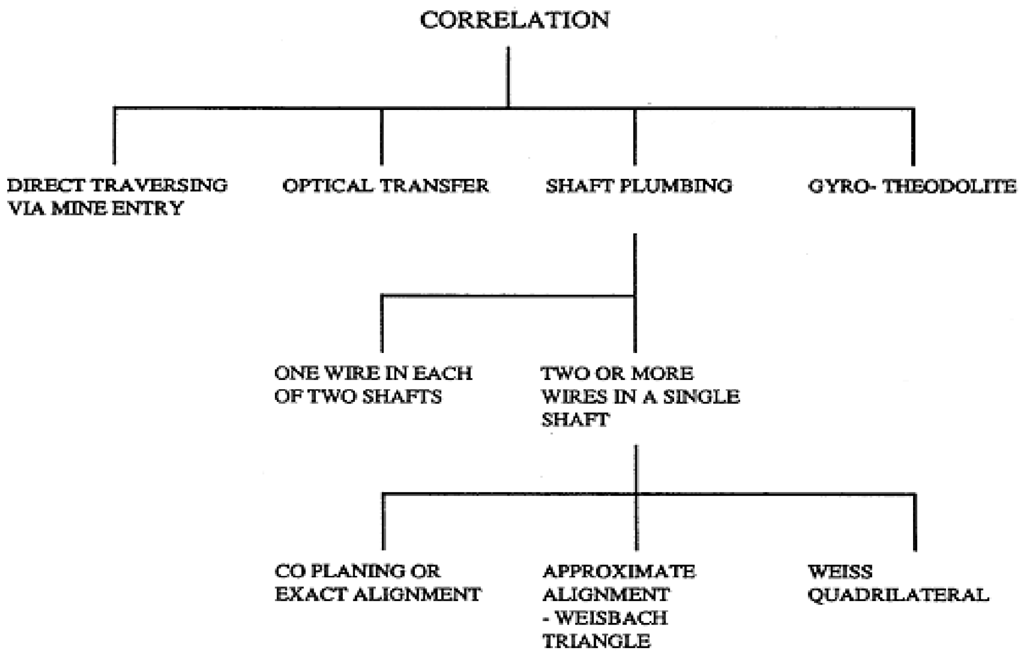
Summary for UAV surveying

The following aspects need to be considered for the best practice of conducting a UAV aerial mapping project.

- ❖ Accuracy depends on GSD
- ❖ Optimal $\sigma_{xy} = \pm 1$ GSD; $\sigma_z = \pm 1.5$ GSD
- ❖ 70% ≤ Image overlaps ≤ 90%
- ❖ Number of GCPs ≥ 5
- ❖ GCP survey @ RTK ≥ 30 epochs (best with bipod)
- ❖ Oblique Images improve accuracy significantly
- ❖ Time of the day = light cloudy or mid-day (less shadow)
- ❖ Large elevation variation = oblique images + variable flight H
- ❖ Use a gimbal to stabilise camera (reduce vibration blur)
- ❖ Slow ground speed (reduce motion blur)
- ❖ High resolution optical sensor (small GSD)
- ❖ Leaf shutter lens (avoid rolling shutter effects)
- ❖ High quality camera (less sensor or lens distortion)

  - GIS in mines: inputting UAV data, laser scanning data to be visualised (3D representation)
    - Query and overlay analyses,
    - Hydrology: surface and underground flows, pollution tracking, soil erosion potential.
    - Customer analysis
    - Enables the modelling of mine features and ventilation, mine development design,
      - Shooting seismic images to map the subsurface and identify deposits.
  - GPS at mine sites
    - Detail and stakeout: antenna on pole
    - Blast hole drills: mount antenna on drill mast, instead of stake out, location, guidance, depth
    - Earthmoving machines: plan & profiles, bench or road, shovels, loaders, dozers, graders
    - Haul trucks
  - Remote sensing for DTMs, structural geology overlays
- What coordinate systems are used in mine surveying?
  - Legislated requirements, Australian mines use MGA coordinates
  - Current maps and plans based on MGA2020
    - Involves scale factors (coordinates and distance)
      - Grid dist = Ground dist & CSF.
    - Transformations and conversions
  - Connected to SCIMS, correlation needs to be Class D.

        - Verticality surveys; marks on the roof/ribs (walls); optical and laser plummets for plumbing down.
- How are EDM baselines used in mining?
    - Mine baseline, gives orientation, verification, not calibration.
    - Also used for calibration gyros. Comparison (above ground) with azimuth on a 'known' baseline.
        - Calibrate on gyro on surface, re-calibrate after and check for any drifts.
- How can surface surveys be correlated with underground surveys? Why is it important?
    - Correlation is the establishment of the true relationship between underground and surface surveys.
        - the MGA coords of at least one UG point and grid bearing of one UG baseline must be determined

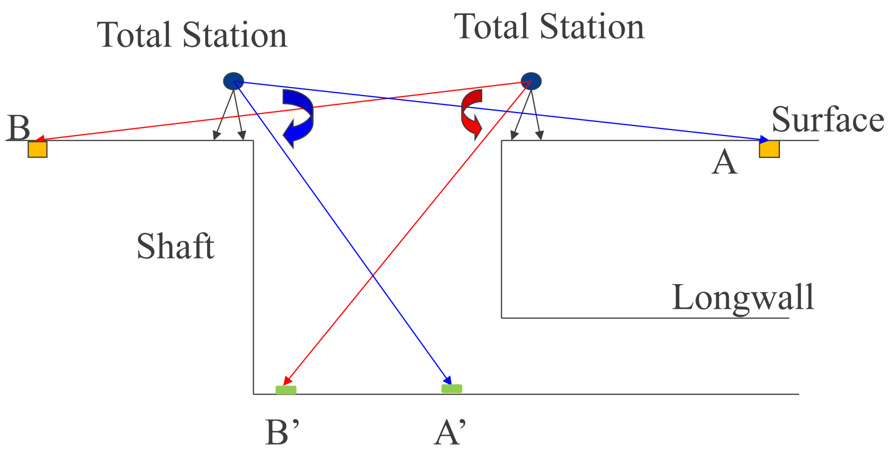


    - Options include:
        - If there is a "walk in" entry, direct traversing is useful. For tunnels, either in a
            - Zig-zag pattern
            - Braced quad method
        - Shaft plumbing
            - One shaft, two wires: short lines, easy to propagate error.
            - Two shafts, one wire: when doing an underground traverse and 2 shafts are used, **assume** a bearing, carry bearings, close traverse, and swing the bearing.
                - Better accuracy than one shaft and even gyro.
                - Error much smaller as baselines is usually several hundred meters.
        - Gyro can be done for both, but typically for shafts.
            - Done independently of the shaft plumbing.
    - **Transfer of azimuths** relies on good survey control, permanent marks and baselines established.
        - Control surveys with stations in walls better for more redundancy.

- Inclined road entrances easier to obtain azimuth via traversing
- Vertical shafts more challenging; either by shaft plumbing, shaft levelling or gyro azimuth (auto-collimators, laser devices)
    - This is conducted either by:
        - Optical:
            - Not suited for deep shafts.

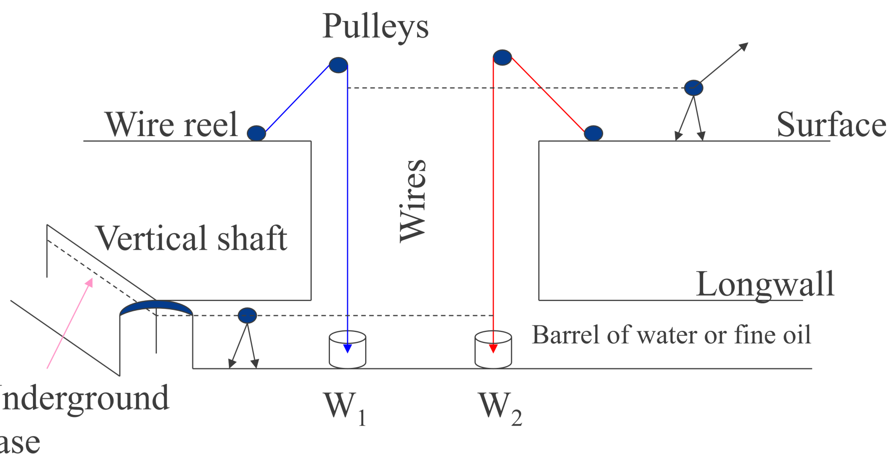
Optical method

Not for narrow deep shafts



- Mechanical method
    - Water/fine oil used to prevent swaying.

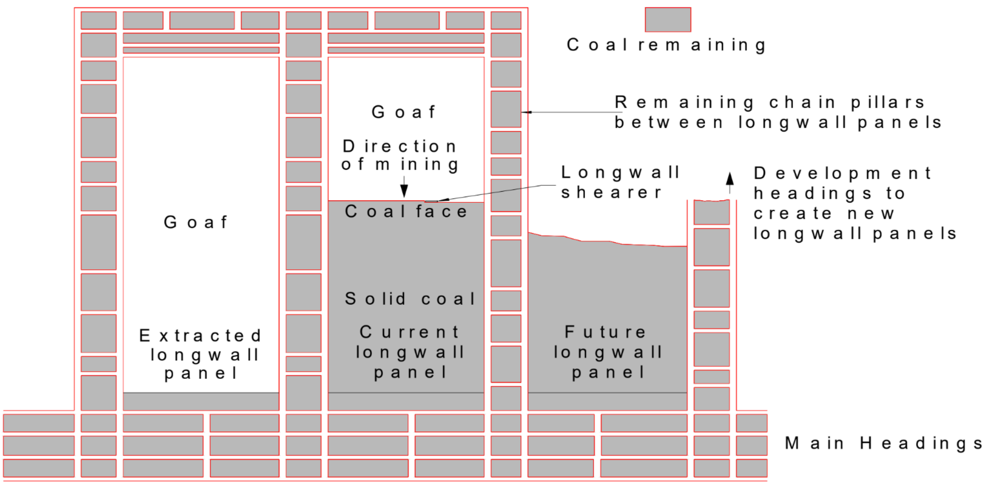
Mechanical method



- Checks include Weisbach triangle.

- **Transfer of heights:** typically in shafts.
    - Levelling: targets at top and bottom of shaft; pentagonal objective prism
    - Steel band: band fixed above surface; tension corrections
        - Levelling and tape:
        - Total station transfer; wide shaft, shallower tunnel
        - Using EDM: setup at the bottom of shaft
            - Applying atmospheric correction: yes
            - Applying CSF: no, strictly horizontal

- Correlation is crucial for:
  - To predict surface subsidence or damage (may cause sinking, monitoring by **satellite remote sensing (InSAR) comparing to levelling**)
    - Differential InSAR (DInSAR): highly cost effective for monitoring displacements of ground surface.
      - One colour band = one wavelength, measure how much has sunk at pixel level.
    - Assists in deformation monitoring,
    - Depth of cover, overlying strata properties, seam thickness, utilities.
  - To know where to bore a hole or reach a collapsed tunnel for rescue or ventilation (longwall coal mining)
    - Ensure verticality in shafts
  - To ensure excavation within legal boundaries.
    - Above ground surveys for construction of open cut mines. Knowing mine lease boundaries.
- What mine rehabilitation practices happen?
- What are some ethics in mine surveying?
- What are some considerations for longwall mining surveying?
  - Typical layout of long-wall mining involve:
    - Four headings, two for ventilation, two for transportation.
    - Shearer moves across coal face, roof held up by hydraulic beams.



  - Instruments to use:
    - Sparks from electronic instruments in methane areas
    - Optical-mechanical?
    - Gyro theodolites?
  - Location of control survey marks?
    - without accurate positioning, accidents occur due to wrong geodetic **datums**
  - Short time frame for surveys? During lunch or maintenance days.
  - Monitoring for subsidence after coal has been removed and roof collapsed?
- What are some of the issues/considerations with underground tunnelling?
  - Influence of internal refraction can cause errors on horizontal angle

    - Prevented by zig-zag traverses with frequent gyro-theodolite azimuths or establishing traverse close to the centre line.
    - Checked with gyro azimuth observations.
  - Losing azimuth accuracy on curves due to short backsights and centring errors. (constrained centring)
  - **Motorised Total stations** reads to prisms mounted on roadheader
    - Alignment of tunnel boring machine using sensors that locate position of boring head
    - Can also be used for remote monitoring and deformation monitoring.
  - **Tunnel profiling**: Can be done using laser scanners, reflectorless EDM, robotic total stations to obtain 3D as built data of tunnel to compare with design tunnel profile.
    - Data processing is done to filter out non-relevant points, orientated by a target-based registration, and then a best fit cylinder is created.

Tunnel Surveys

- Surface Control Networks
  - GPS
  - Terrestrial Survey
- Azimuth Transfer
  - by Co-planing, Weisbach, Braced Quad Method
  - Plumb Lines
  - Optical or Laser Plummets
- Heights transfer
  - by Vertical EDM
  - by Tapes
- Subsurface Traversing
  - Conventional Total Station Methods
  - Gyro-theodolite Observations
- Deflection of the vertical -> Gyro

- What is involved in mine monitoring surveys?
  - Various tools can be used for monitoring; although line of sight becomes an issue.

Surveying methods for monitoring

Simple crack distances

Levelling

Total Station – Theodolite + EDM – robotic?

Laser scanning – terrestrial or aerial

GPS

UAV (drones)

Radar

DinSAR - satellite Radar

+ geotech monitoring, extensometers etc

- What is involved in petroleum mapping
  - Gravity magnetics, well data, Ziegler maps, subsurface grids to be put in GIS data.
  - Other geomatic services.
  - Seismiology; tomography, defining geological features (faults, dykes, sills)
  - Field operations
  - Satellite imagery and DTMs (InSAR)
  - Monitoring oil/gas extraction induced subsidence
  - Drilling at the wrong spot due to different datums
- What are some considerations for open cut surveying?
  - Haul road design: road that is driven up to drop deposits, dependent on:
    - Ample passing width,
    - Good sight distances for safety
    - Long radius, super-elevated curves
    - Lowest adverse grades engineering to the haul truck's optimum capability (even less than 1 in 9)
    - Regular maintenance
  - EDM baseline calibration; mines have their own baseline (shouldn't be undercut)
    - Could check for azimuth and check for gyros.
  - Marking out no-go zones, susceptible to rockfalls; deformation monitoring
    - Line of sight could be an issue (dust, long distances)
  - Setting out
    - For where to put explosives
  - Mapping/monitoring.
    - UAVs used extensively: mine ops less interrupted; cheap, highly productive, regular
    - Conventional detail survey methods + GNSS used for infill or checking
    - Locata: limited sky coverage in open-cut mine to the north; GNSS augmentation.

            - Creating a local GNSS network in broadcasting a GNSS signal.
                - Can be relied on fleet management.
            - Benefits for fleet management:
                - better machine guidance
                - safety, efficiency.
    - Quantity surveys
    - Underground "sea-level" corrections
        - A false "mine" height, correctly slightly different from normal "sea-level" correction to get ellipsoidal distance
- What is ground-penetrating radar?
    - Mapping underground services. GP8800 GPR.
    - Dependent on dielectric constant: ratio of permittivity of substance to free space
        - impacts penetration of radar
    - Interpretation is required.