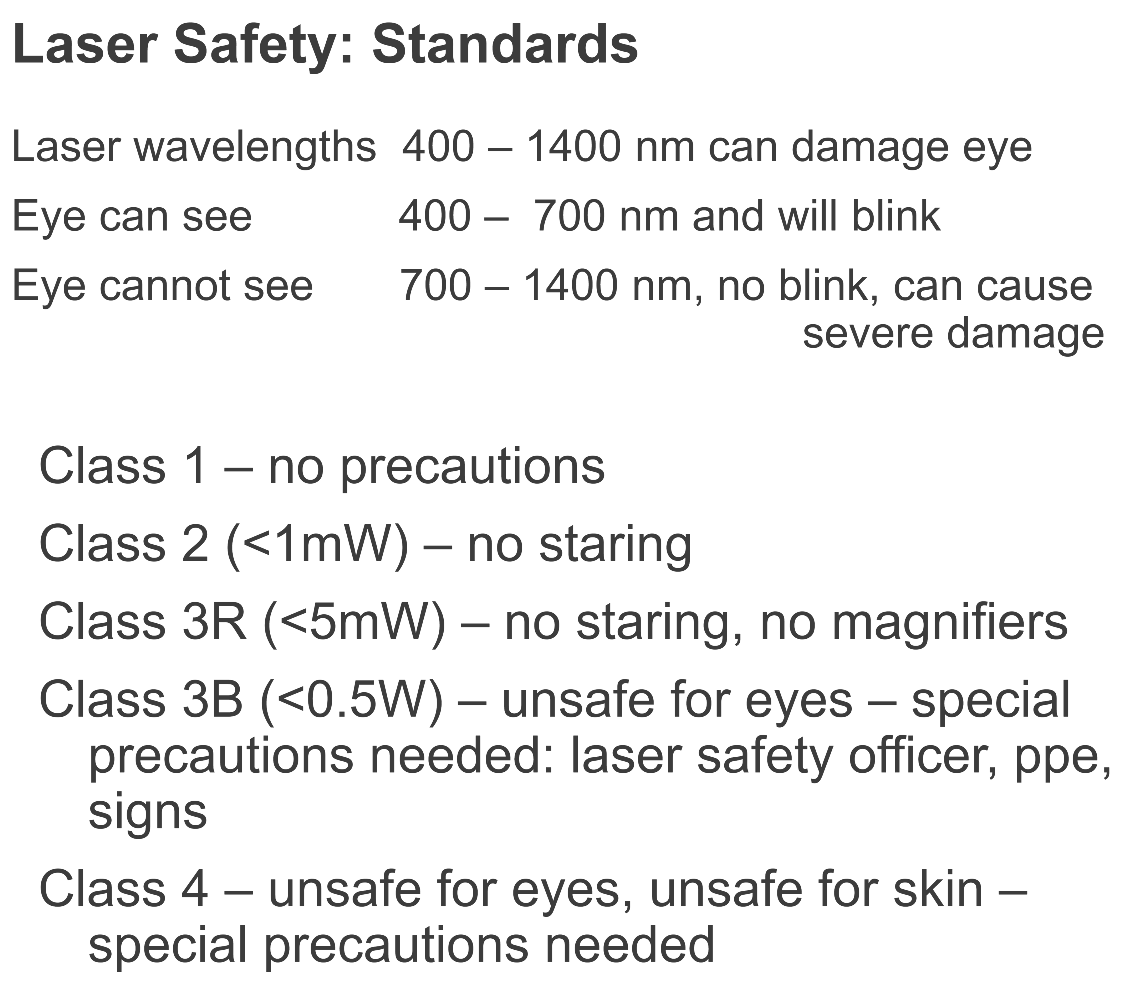
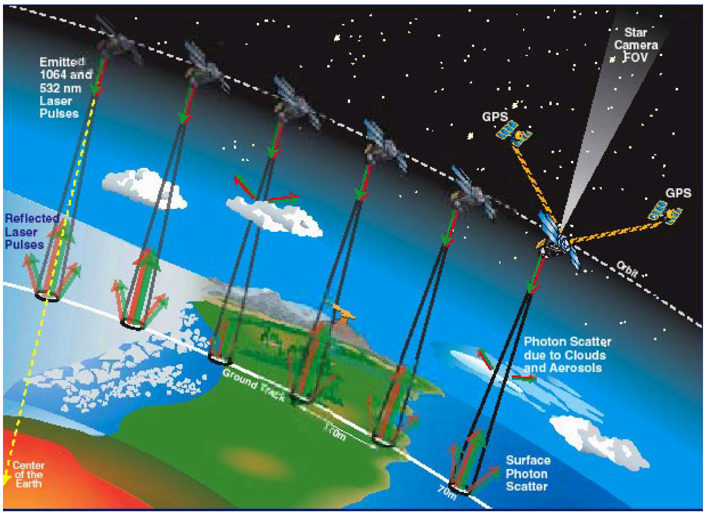
laser scanning

- What is laser scanning (LS)? What are some technical specifications of specific laser scanners?
  - Essentially a high-speed RTS with reflectorless EDM (D1.2 Laser Scanning, p.4)
  - Technical specs: D1.2 Laser Scanning, p.21
    - Range (m)
    - Pts/sec
    - Precision: (angular ("), range (mm), 3D point (mm)
    - Scan resolution (mm)
    - Battery life, data storage capacity, weights
    - Time for scan: finer scan is longer
    - Features
      - Colourised point clouds
      - Data acquisition control (controlling elevation, azimuth)
      - Registration type
  - Different scanners have different advantages (speed, pts/sec, range, ambient conditions)
- What risks come with using laser scanners?
  - If the laser is able to be seen by the naked eye. (Class 3R = reflectorless, classifications may be different in other countries.):



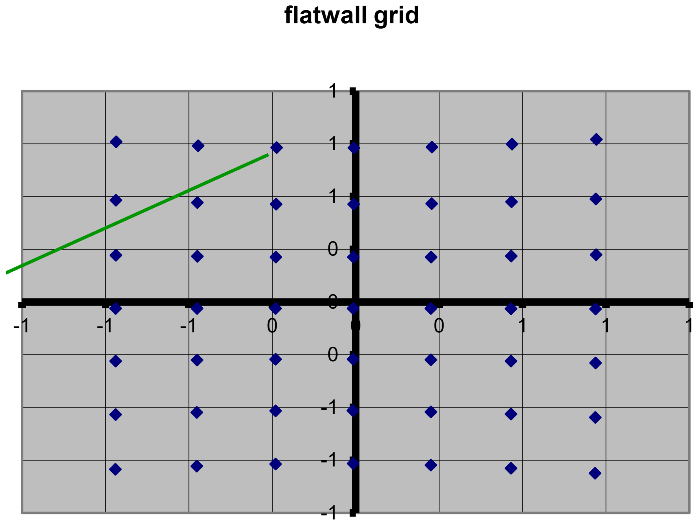
- What are the different types of laser scanning?
  - **Airborne**

- Laser scanner is mounted in an aircraft and emits a laser beam which is reflected off the ground surface.
  - Elevation of scanned surface can be determine by signal time-of-flight.
- Requires accurate info of orientation and position of aircraft during flight.
  - GPS for position,
  - IMU - Inertial Measurement Unit for pitch, yaw and roll in order to position LIDAR measurements on ground level.
    - Number of obs/second to consider (high-rate of obs vs low rate of GNSS; needs a timed link)
- Targets need higher contrast.
- Real-time updates via telemetry.
- **Intensity** (how much light is reflected back) also an important observable. NIR radiation from laser scanners affected by:
  - Range: power of signal, surface reflectance, sensitivity of instrument
  - Surface type: diffuse reflection more effective than specular reflection as better chance of return reflectance.
  - Angle of incidence.
- Multiple return lasers (top of foliage vs bare earth; DEM, DSM, forest heights, carbon accounting)
- UAV LiDAR vs Plane Lidar
  - Quick to process for UAV (i.e drones)
  - Lower height, increase in accuracy, denser point cloud.
    - Higher chance to pass through tree and vegetation. Minimum point to take as the terrain level.
  - Greater height, greater coverage
  - 10 pts/m^2 (Plane) vs 100-1000 pts/m^3 (UAV)
- **Satellite** laser scanning:
  - Geoscience Laser Altimeter System (GLAS, ICESat)



- **Terrestrial**: has a tripod mounted device and measures flight time of emitted radiation to produce a point cloud of 1000s of points.
  - Most precise, mid-range, expensive, specialist, different grades
  - Data can be edited to produce 3D maps

- Useful for structural monitoring and high definition surveying
- Different grades include
  - Survey grade: dual-axis compensators, centring (OP, laser), long range
  - High productivity: fast scanning, medium range, onboard registration,
  - Imaging: shorter range, user friendly, registration.
- Grid spacing of scanning/measuring surfaces by sampling.



- **Mobile**: platform mounted rotates to produce a point cloud of millions of points
  - Advantages in saving costs from traffic control and increase in safety, fast and high productivity & definition; big data but expensive.
  - Requires several components, like GNSS, IMU, odometers and digital cameras.
- **Handheld**: Lightweight, easy to manoeuvre, but less accurate and closer range
  - Uses SLAM technology (Simultaneous Localisation and Mapping), an algorithmic approach to mapping.
    - Works by determining the pose (position and orientation of an object, LiDAR + IMU) to define the reference frame.
    - Tracking errors introduced when the area lacks distinct features to localise
    - Handheld can show **drift**. Important to work in **loops** enabling the SLAM algorithm to recognise features and minimise drift and move slower than the scanning speed.
    - Faster, but less accurate.

- What are some examples of laser scanners?
  - Riegl VZ-600l, C5, Leica RTC360, BLK360, Zeb Revo, ranging from survey grade with RTK connection & georeferenced non-survey grade/hand-held
    - Some sacrifice range for point rate or speed or vice versa

Instrument	Zebedee	Zeb Revo	Leica C10	Leica BLK360
	 Figure 3	 Figure 4	 Figure 5	 Figure 6
Type	Mobile (GeoSLAM)	Mobile (GeoSLAM)	Terrestrial	Terrestrial
Year	2013	2014	2009	2017
Price				
Range	30m, 15m outside	30m, 15m outside	300m	60m
Accuracy	15mm (increases significantly on long scans)	15mm (increases significantly on long scans)	4mm @ 1-50m	6mm @ 10m
Scanning Rate	40kHz	43.2kHz	50kHz	<360kHz
Field of View	N/A	270°H, 360° V	360°H, 270°H,	360°H x 300°V
Photorealistic	No	No	Yes	Yes
Weight	Very light	Very light	Heavy	Very light
Time required to scan/10	4	4	10	5

Comparing Scanners

Different scanners used for different tasks.

BLK360 – lightweight but quite good resolution – shorter range

C10 – longer range, higher fidelity and precision – good for the Altar

Zeb Revo – lower quality but manoeuvrable. Good for fill-in.

Georeference on MGA/ AHD

- What certain projects can be done with laser scanners (main advantages)?
  - Instructure mapping and modelling (old bridges) for maintenance, repair or refurbishment
  - Mining for stockpile modelling and volume determination; contouring and DEM; volume calculation.
  - Deformation monitoring.
  - Law enforcment: road traffice accident mapping
  - Cave mapping
- What calibration and errors need to be considered in laser scanners?
  - Test configurations for calibration: ISO standards (17123): 4 targets, 2 instrument stations, sensitivity of the test procedure.
    - Or even through EDM multi-pillar baselines.
  - Error sources include:
    - Partial reflections from multiple surfaces (i.e wire mesh): going through the wire, two surfaces
    - Edge of an object: the wider the beam, the bigger the error, centre point slightly offset from corner.
    - Ghosting / multipath: scanning through glass/water, some go through and measure objects behind wall. Sunlight effect.
    - Atmospheric (distance and bending effects)
    - 'Bright' objects causing incorrect distance.
    - Applying scale factors?
- What is registration in laser scanning?
  - The process of combining different point clouds from different scans (mathematical least-squares). Types:
    - Target-based: 5-common targets to reference, all on different heights, numbering also important, strong geometry.

        - Cloud-based: combining overlapping point clouds visually (by eye), check residuals, automatically by algorithm.
            - correspondence, transformation, optimisation techniques, feature-based techniques, end-to-end (deep learning)
        - Traversing: only for survey grade laser scanners
            - Longer distance between setups
            - Direct georeferencing
- How is the data processed and in what format?
    - Data formats include
        - .nav or RIMEX = GPS & IMU
        - .ldr = Angle and range
        - .e57 = 3d imaging data
        - .las = 3d point cloud data
    - Loosely coupled processing with IMU measurements.
    - Workflow, file compatibility a large issue. Need to work different software (Leica Infinity, LiDAR360, etc.) with different file types.

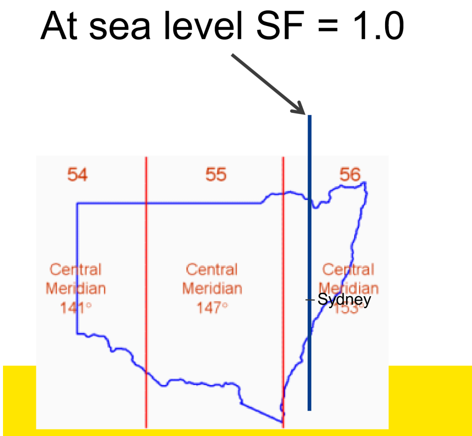
File Types and Compatibility

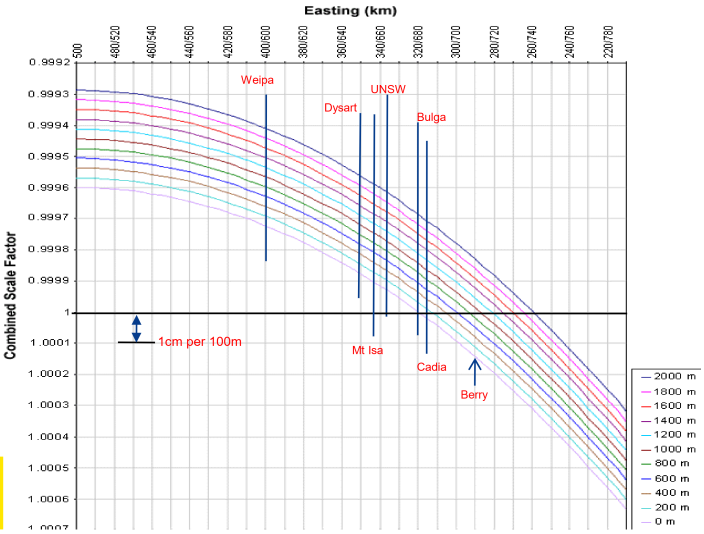
Scanner	Output File Types
Leica C5	E57, PTG, RCP, LAS
Zeb Revo	LAZ, LAS, PLY, TXT, E57
BLK360	E57, PTG, RCP, LAS
BLK2Go	E57, PTG, RCP, LAS
RTC360	E57, PTG, RCP, LAS
LiGrip H120	LAS, PLY, LiData

Software	Inputs	Outputs
Leica Cyclone REGISTER 360+	E57, PTG, RCP, LAS	E57, PTG, RCP, LAS
Lidar 360*	LiData, LAS, LAZ, PLY, E57, PCD	LAS, LAZ, TXT, PLY, ASC, NEU, XYZ, PTS, CSV
GEOSLAM Connect	GEOSLAM, LAZ	E57, LAS, LAZ, PLY, TXT
Faro Scene 3D	FLS, E57, PTZ, PTX, LAS, LAZ	CPE, E57, VRML, DXF, FLS, PTS, RCS, LAS, POD

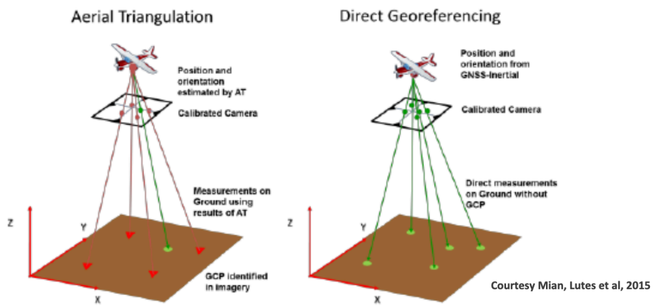
- What is geo-referencing?
    - Indirect georeferencing, involves **estimating** the position and orientation of laser scanner and identifying the ground measurements based on **overlapping** imagery, (i.e centre of targets or using coordinates derived from features)
        - Requires GCPs/targets
        - Involves post-processing

- Time-consuming
- Achieves higher accuracy in height.
- Scale factor may potentially need to be considered? MGA CSF based on "sea level" (height above ellipsoid) & Easting (distance away from Central meridian (CM = 0.9996)), Grid dist = Ground dist * CSF)





- Direct georeferencing involves using known position and orientation from GNSS RTK-IMU or traversing pre-surveyed marks.
  - Real-time
  - GNSS-IMUs
  - Faster field time.
  - Comparable height accuracy.



UAV – Unmanned Aerial Vehicle or
RPA – Remotely Piloted Aircraft
CASA – Civil Aviation Safety Authority (Australia)
GSD – Ground Sample Distance
GCP – Ground Control Point
AGL – Above Ground Level
AT – Aerial Triangulation (Georeferencing using GCPs)
IMU – Inertial Measurement Unit
SOC – Standard Operating Conditions
DSM – Digital Surface Model
DEM – Digital Elevation Model (basically a DTM)
DTM – Digital Terrain Model (bare earth)
KML – Keyhole Markup Language (for Google Earth)

- What is SIFT and SfM?

        - Scale-Invariant Feature Transform: detects unique matching features and tries to match them together
        - SfM: Structure from Motion: combination of SIFT and computer vision algorithms to create 3D surface models and point clouds.
        - These are typically used in photogrammetry.
        - Others include SIFT, SfM (more with photogrammetry)
    - What modelling software exists to process and display laser scanning data?
        - In order to make deliverables client-friendly, software can display laser scanned models in 3D without specialised software.
            - e.g Leica TruView Desktop and Live, Unreal Engine, QTM, Faro Webshare.
    - What should be considered when using a laser scanner for quality assurance?
        - Consider (along with the main project design surveying):
            - Scanner tech specs (**range, set angle, scan speed, point density, accuracy**) and whether overlap or scan surface can influence quality
                - Has the instrument been calibrated before?
            - Type of registration (target, cloud, or traverse?)
            - Consider potential error sources? Data voids due to: occlusion, wet surfaces, vegetation, glass (ghosting effect); noise from moving objects.
                - Determine any field work errors (bumped targets, incorrect target heights, inaccurate identification of target centre, incorrect numbering)
                - Target stability (tripods, stick-on, geometry, angle of incidence, overlap)
            - Should you geo-reference? What form of georeferencing should be undertaken (indirect or direct, through resection, local coordinates of MGA/AHD)?
            - Accuracy of resultant coordinates of targets and modelled surfaces (overlap, strength?
            - Presenting the results. Leica TruView?
        - Do quality checks, like:
            - Measure with TS, tape of disto:
                - Strings along well-defined surfaces
                - B/W scan targets
                - Height benchmarks
            - Overlay strings on unified point cloud and check manually.
            - Compare point clouds from different instruments/scans using software (e.g CloudCompare)