Guideline

Mobile Laser Scanning Technical Guideline

March 2023

Queensland Government

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1 Introduction

The popularity of Mobile Laser Scanning (MLS) systems revolve around the rich, accurate and repeatable information that is captured during an MLS project. It is these characteristics which 'add value' past the immediate needs of a project and delivers a wider corporate value than what is achievable with other types of survey techniques.

This document aims to bring consistent terminology and understanding to the MLS capture process for the Department of Transport and Main Roads Queensland and industry. Although not a standard, this Technical Guideline attempts to standardise common terms and methods that are being adopted in industry (and internally), file requirements and naming conventions.

2 Definition of terms

Term	Abbreviation	Definition
Australian Height Datum 1971	AHD71 AHD	Official vertical datum in Australia based on Mean Sea Level from 32 gauges around Australia in 1971.
American Society for Photogrammetry and Remote Sensing	ASPRS	A scientific organisation whose mission is to advance knowledge and improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems, and supporting technologies.
AUSGeoid		AUSGeoid models are used to convert ellipsoidal heights to Australian Height Datum (AHD) and vice versa
Breakline		A Breakline is a barrier string which represents a crease in the topography. No triangles, created in the triangulation process, can have a side that cuts this barrier string.
California Department of Transportation	CALTRANS	Road Authority of California
Clearly Defined Points		A Clearly Defined Point is a distinct point on the ground that can be selected in the Pointcloud with reasonable certainty that the points on the ground are the same as the points in the Pointcloud.
Common Control Points	CCP	Coordinated points used to seamlessly tie two independent data collections together.
Continuously Operating Reference Stations	CORS	Provides GNSS carrier phase and code range measurements in support of 3-dimensional positioning activities.
Data Mine		The process of digitising information from the Project Pointcloud at a time after the capture of the Pointcloud, sometimes much later, when required by some other process than the one that caused the initial capture.
Department of Resources		Authority responsible for Queensland’s land, water and resources.
Ground Control Point	GCP	Coordinated points used to tie a PPC to the PRF more accurately.

Term	Abbreviation	Definition
Geocentric Datum of Australia 1994	GDA94	An ellipsoidal surface expressed as latitudes and longitudes which has its origin at the centre mass (hence the term Geocentric) of the earth. The coordinate datum of the GDA'94 is the Australian Fiducial Network (AFN), which is tied to the International Earth Rotational Reference System (IERS) Terrestrial Reference Frame 1992 (ITRF92), epoch 1994.0.
Geocentric Datum of Australia 2020	GDA2020	GDA2020 is a static datum. It is an ellipsoidal surface expressed as latitudes and longitudes which has its origin at the centre mass of the earth. It is realised from the derived coordinates of the 109 Australian Fiducial Network (AFN) geodetic stations provided in the 2017 Determination of the Recognised Value Standard of Measurement of Position, referenced to the Geodetic Reference Frame 1980 (GRS80) ellipsoid and determined with respect to the International Earth Rotational Reference System (IERS) International Terrestrial Reference Frame 2014 (ITRF2014), epoch 2020.0.
Geo-Referenced Imagery		Imagery captured at the same time as the capture of the single Pointclouds and the principal point is encoded with the location.
Ground and Feature Model	GFM	A digital model of the ground and the features on that ground made-up from coded Breaklines, spot heights, feature strings and feature points.
Global Navigation Satellite System	GNSS	A satellite system that is used to derive geographic location anywhere in the world.
Inter-Governmental Committee on Surveying and Mapping	ICSM	Governmental committee that provides leadership through coordination and cooperation in surveying, mapping and charting.
Inertial Measurement Unit	IMU	An electronic device that measures and reports a body's specific force and angular rate using a combination of accelerometers and gyroscopes.
Minimally Constrained Project Pointcloud	MCPPC	Aligning and combining of individual Pointclouds from multiple passes to a best fit location without the aid of ground targets. The MCPPC is generally aligned to the PRF using GNSS observations only and is represented as a singular Pointcloud with minimal feathering in position and height.
Map Grid of Australia		Cartesian coordinates from a Universal Transverse Mercator projection. The Coordinate Reference System (CRS) has three map projection zones for Queensland and for GDA2020 are expressed as: • GDA2020 / MGA zone 54 • GDA2020 / MGA zone 55 • GDA2020 / MGA zone 56 For GDA94, expressed as: • GDA94 / MGA zone 54 • GDA94 / MGA zone 55 • GDA94 / MGA zone 56

Term	Abbreviation	Definition
Mobile Laser Scanning	MLS	A moving platform that collects Pointclouds using Laser Scanner/s, GNSS instrument/s and other sensors which are combined and mounted on a constantly moving ground based vehicle. Excludes 'stop and go' Terrestrial Laser Scanning.
Mobile Laser Scanning Technical Guideline Checklist	MLS Tech Guide Checklist	Checklist which accompanies the project proposal which provides a summary of the MLS contractors response and also allows the MLS contractor to provide alternative solutions or methods.
Pass		The result of combining multiple runs in the same direction that will produce a singular Pointcloud in a certain direction of travel.
Pointcloud		Data collected by a Mobile Laser Scanner that has been adjusted for position from GNSS location and IMU corrections for each vehicle pass resulting in vertices with x, y, z coordinates and associated properties (e.g. intensity, RGB values). From a single pass only.
Point Data Record Format	PDRF	Forms part of the LAS format definition. Provides information about each single point recorded in the LAS file.
Project Pointcloud	PPC	The MCPPC aligned to the PRF using GCP. The PPC is represented as a singular point cloud with minimal feathering in position and height.
Project Reference Frame	PRF	The Project location as evidenced by the coordinates of the Project Reference Frame Marks.
Project Reference Frame Mark(s)	PRFM	The Survey Control Marks that create the Project Reference Frame. These marks will be fit for purpose and provide a valid coordinate within the PRF.
Project Proposal		Document detailing project scope and specifications that may be used as part of an Invitation to Offer, Survey Brief or Request for Quote.
Permanent Survey Mark	PSM	A uniquely identifiable mark which can be found in the SCDB or a uniquely identifiable mark placed by a Surveyor and submitted to DoR with the required information relating to that mark.
Positional Uncertainty	PU	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark with respect to the defined datum and represents the combined uncertainty of the existing datum realisation and the new control survey.
Red, Green, Blue	RGB	A colour model where red, green, and blue light are added together in various ways to reproduce a broad array of colours. These colours are then used to generate the colouring of the LAS data utilising the imagery taken at the time of capture or aerial imagery.
Relative Uncertainty	RU	The uncertainty between the horizontal and/or vertical coordinates of any two survey control marks.
Run		A single partial collection of raw Pointcloud data that does not fully cover the project length in a certain direction of travel.

Term	Abbreviation	Definition
Shadow / Shadowing		The result of the laser being stopped by an object leaving a void in the Pointcloud.
Special Publication 1	SP1	Document published by ICSM identifying the standard for one, two and three dimensional positioning.
Secondary Project Reference Frame Mark(s)	SPRFM	Marks placed that are stable and have been positioned from PRFMs using GNSS, conventional traversing techniques and/or levelled with a digital level. These marks will be fit for purpose and provide a valid coordinate within the PRF. A detailed report on how these marks have been established is mandatory.
Singular Pointcloud		The result of combining a pass in each direction of travel that covers the entire length and width of the project area.
Survey Control Database	SCDB	A digital record of the state's geodetic survey control information.
Survey Uncertainty	SU	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark relative to the survey in which it was observed and is free from the influence of any imprecision or inaccuracy in the underlying datum realisation.
Department of Transport and Main Roads Queensland	TMR	Road Authority of Queensland
Trajectory		A series of vehicle positions as referenced by the recorded GNSS coordinates of the MLS vehicle whilst Pointcloud data is being captured.
Vehicle Pass		The combination of multiple small Pointclouds collections in the same direction along a road that create a Pointcloud.

3 Mobile Laser Scanning (MLS) Technical Guideline Checklist

The *MLS Technical Guide Checklist* is an integral accompaniment to this Guideline and forms part of all project proposals. The *MLS Technical Guide Checklist* states technical aspects required by Transport and Main Roads and also provides the Offeror the opportunity to detail their method.

For each item where the department has a technical requirement, it will be specified in the TMR column and the Offeror column will be greyed out. If the Offeror proposes an alternative, they will detail that method in the Offeror column. This offer will then be evaluated as non-conforming.

Where the department does not specify a requirement, the TMR column will be greyed out and the Offeror shall detail their method in the Offeror column.

http://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Surveying-support-documents.aspx

4 Safety

The department has a responsibility to ensure the safety of all its employees, including MLS contractors. To minimise risk, the MLS contractor will be requested to submit safety documents at the time of tender so that the department can gather an idea of the safety processes and procedures of potential future contractors.

At the end of the MLS project, all safety documents, which should be signed by all required, will be requested to form part of the final deliverable.

5 Project Reference Frame (PRF)

The department must be confident of re-establishing the Project Reference Frame (PRF) within a suitable precision. This may be for multiple purposes including design, construction or asset management. The practice of locating Project Reference Frame Marks (PRFM) accurately the first time will also minimise issues with future works not fitting with the MLS capture. The department also has an obligation to help strengthen the State's Survey and Mapping Infrastructure.

5.1 PRF requirements

The PRF shall adhere to the *TMR Surveying Standards*.

The coordinates of all PRFMs shall meet the following requirements:

For projects using GDA94 as datum:

Project Datum	
Horizontal	Geocentric Datum Australia (GDA94)
Vertical	Australian Height Datum (AHD71) Ausgeoid09 Version 1.0
Project Projections	
Horizontal	Geocentric Datum of Australia 1994 (GDA94) / Map Grid of Australia (MGA), Zone 54, 55, or 56

For projects using GDA2020 as datum:

Project Datum	
Horizontal	Geocentric Datum Australia (GDA2020)
Vertical	Australian Height Datum (AHD71) Ausgeoid2020
Project Projections	
Horizontal	Geocentric Datum of Australia 2020 (GDA2020) / Map Grid of Australia (MGA), Zone 54, 55, or 56

5.2 PRF marks

At times, the department will supply survey accurate coordinates of the PRFMs from recently completed Global Navigation Satellite System (GNSS), Total Station and/or Digitally Levelled control networks over the project area. Other times, the department will require the MLS contractor to accurately coordinate new PRFMs. The contractor shall adhere to the *TMR Surveying Standards*.

All marks used as PFRMs are to be registered with Department of Resources as Permanent Survey Marks (PSM) and therefore shall meet criteria of a Permanent Survey Mark in relation to type, accessibility and location.

The coordination of new PRFMs shall be derived via Static GNSS observation and least squares network adjustment. Datum Control PSM's adopted as base stations as part of this adjustment will generally have a horizontal PU of <20 mm and be fixed by GNSS. Establishing strong survey accurate connections to surrounding Continuously Operating Reference Stations (CORS) and AHD marks should also be a consideration when selecting or placing Datum Control points for MLS capture.

All PRFMs shall meet or exceed the following for accuracy:

Horizontal	**SU < 15 mm @ 95% CL and PU < 30 mm @ 95% CL** Survey Uncertainty (SU) and Positional Uncertainty (PU) as defined in *Inter-Governmental Committee on Surveying and Mapping's Special Publication 1 v2.2* (ICSM SP1 v2.2).
Vertical	Height uncertainty between PRFMs shall conform to a minimally constrained Global Navigation Satellite Systems (GNSS) loop closure that meets **10 mm + 1 ppm** of the loop distance for all marks. If a digital or automatic level is being used, the misclosure will be as per *TMR Surveying Standards* (i.e. 12 * √k)

Short baselines between PRFM and the vehicle contribute to the best possible positional accuracy outcome (ref: *CALTRANS Terrestrial Laser Scanning Specifications*, June 2018 https://dot.ca.gov/-/media/dot-media/programs/right-of-way/documents/ls-manual/15-surveys-a11y.pdf. The options for spacing PRFMs along the road corridor are shown in the *MLS Technical Guideline Checklist.*

5.3 Secondary Project Reference Frame Marks (SPRFM)

It may not be practical in some instances to use the PFRMs supplied as base stations whilst collecting point cloud information. If this is the case, other SPRFM can be used by the MLS contractor. Additional SPRFMs placed by the MLS contractor shall be fit for purpose with a detailed description in the Survey Report of how this objective has been achieved. The contractor shall adhere to the *TMR Surveying Standards*.

> **Note**: Some points may be controlled horizontally using GNSS, some using terrestrial traversing. Similarly, for heights, some points will be digitally levelled, others using trigonometric heighting or even GNSS.

The information in the Survey Report shall contain metadata detailing the method used in the location of all SPRFMs supplied and the resulting accuracy achieved.

5.4 GNSS processing

All GNSS observations and network adjustment reports (both minimally and fully constrained) shall be submitted to the department for approval. No PRFM coordinates shall be adopted or used until approved by Transport and Main Roads.

The MLS contractor shall ensure that any major differences observed in both the PRFMs and SPRFMs are bought to the attention of the departmental project manager immediately. No processing of data that could be impacted by any potential error in PRFM or SPRFM coordinates shall be undertaken until the differences are resolved to the satisfaction of the departmental project manager.

5.5 Governance

It is the MLS contractor's responsibility to complete a Form 6 accompanied by a sketch of the Permanent Survey Mark (PSM) for all new PRFMs placed. If required, the department can supply Permanent Survey Mark numbers upon request. Completed Form 6's and PSM Maintenance Forms are required to be submitted as part of the project deliverables.

The department has an obligation to help strengthen the State's Survey and Mapping Infrastructure. The department requires that any GNSS data recorded be supplied in either RINEX or TDEF format.

The department will ensure that this supplied information is passed onto the Department of Resources for use in strengthening the Survey Control Database (SCDB) network.

Field observation sheets recording details of each setup shall be supplied to the department as part of the project deliverables.

Images of the receiver setup shall be provided. The requirements for images can be found in the *TMR Surveying Standards* - Observation records.

6 Boresight calibration

Angular misalignment between the measuring axes of the GNSS receiver, Inertial Measuring Unit (IMU), lever arm and laser scanner must be known in order to deliver the best possible Pointcloud. The angular misalignment of the system can be determined by performing calibration procedures.

It is important that a boresight calibration be performed on the system to identify and rectify any angular misalignment between the measuring axes of the IMU and laser scanner.

Boresight calibrations shall occur immediately prior to any MLS capture for the project and be performed again at the end of the project to ensure that the calibration parameters have not changed during the project.

If for any reason the system is disturbed or disassembled and reassembled during the project duration, another boresight calibration shall be performed prior to any further capture.

Depending on the scale of the project, multiple boresight calibrations may have to be performed by the contractor. This should be outlined in the project proposal and/or discussed with the project manager prior to award or mobilisation.

The contractor shall identify how a boresight calibration will be performed in their response.

7 Singular Pointcloud requirements

This part refers only to the raw scanned data adjusted for position from GNSS location and Inertial Measurement Unit corrections for each vehicle pass along a section of road or carriageway.

The Pointcloud from each pass will extend outside the kerbing to the closest limiting factor that will supply a return from the laser (e.g. noise barrier / retaining walls).

If only a single pass is required, the lane to travel in for capture will be identified in the project proposal or by the project manager.

7.1 GNSS Concurrent base station specification

The PRFMs / SPRFMs shall be used to control the position of the Mobile Laser Scanner by processing GNSS baselines using a number of base stations concurrently.

> **Note**: If PRFM / SPRFMs base stations are occupied simultaneously, there is only a redundancy in the GNSS observation at the PRFM / SPRFMs, but generally NO redundancy at the vehicle. Therefore, concurrent base station observations (i.e. 2 or more) only constitute a partially independent GNSS reading.

7.2 GNSS Baseline specification

Short base lines between PFRM and the vehicle contribute to the best possible positional accuracy outcome (ref. *CALTRANS Laser Scanning Specifications*).

The PRFMs / SPRFMs selected as GNSS base stations during Pointcloud capture must ensure that under normal circumstances, no processed baseline from the MLS vehicle exceeds the baseline length (if specified) in the projects' *MLS Technical Guideline Checklist*.

For both the GNSS base station and vehicle, the GNSS measurement frequency shall be set to one second epochs (or less) and all GNSS receivers shall be dual frequency.

7.3 GNSS Baseline processing specification

The method of processing GNSS baselines between the PRFM / SPRFMs base stations and the vehicle shall be detailed in the projects' *MLS Technical Guideline Checklist*.

8 Multiple pass requirements

The department's normal survey practice requires redundancies to achieve confident statistical results. To give a level of redundancy when capturing Pointclouds, a minimum of three passes shall be run on the pavement. Multiple passes over a period of time also allows the GNSS constellation to change significantly thus reducing the effects of multipathing. Multiple passes minimises the effects of shadowing.

On MLS vehicles using multiple scanners to give the multiple aspect coverage in one pass by capturing two or more scans at the one time, these scans do not use independent GNSS constellations. In this case, a minimum of three independent passes are still generally required by the department.

For some projects, it may be appropriate to minimise the number of passes to less than three but requires prior agreement with the department. Extreme caution should be exercised and is NOT a recommended practice.

If the scan of each lane does not fully overlap the adjoining lane, then each lane shall be scanned a minimum of three times.

If there are multi-lanes in any direction, then the most appropriate lane(s) for reducing multipathing and shadowing; whilst also providing maximum coverage should be considered.

It is the contractor's responsibility to ensure that sufficient coverage of the road surface, surrounding road furniture and the terrain has been performed.

Where variation is required due to a project's specific objectives, these requirements may be varied in the project proposal (Request for Quote, Survey Brief, etc.).

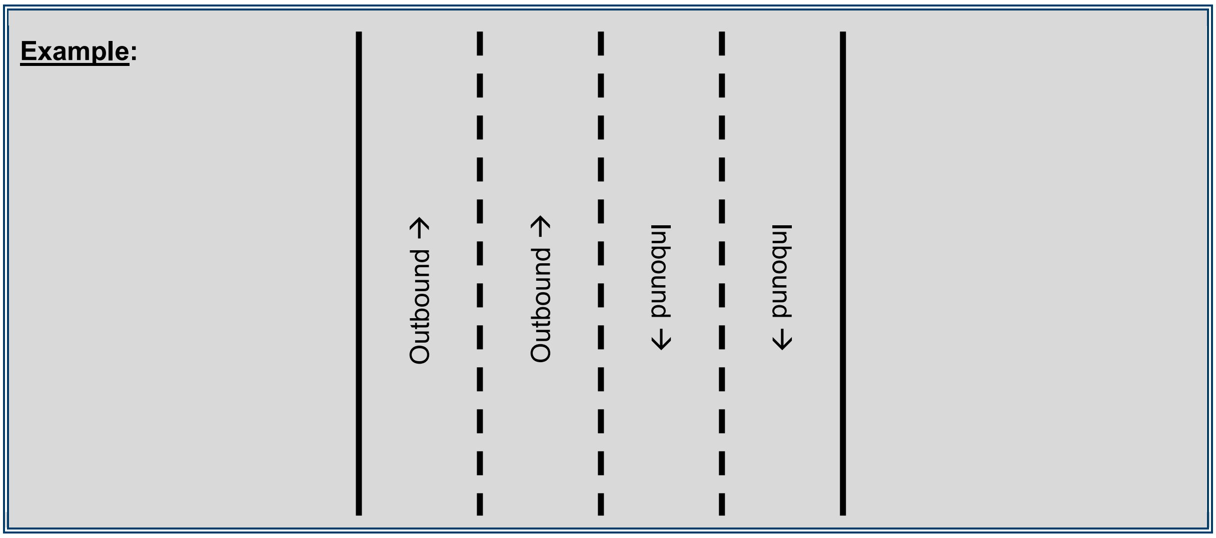
8.1 Carriageway pass requirements

There are multiple carriageway and lane combinations. MLS projects rely on having sufficient data and redundancy collected on each type of combination.

8.1.1 Single carriageway – Multiple lanes

A single pass is required in each direction of travel. A third pass is required in either direction to provide sufficient coverage, density and redundancy in the data collected.

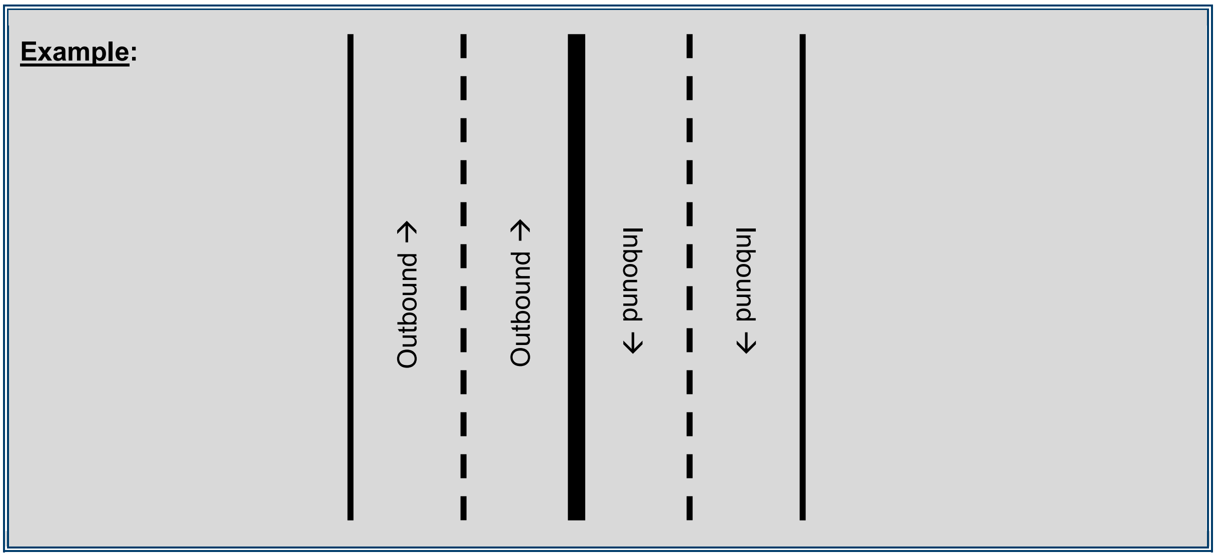
Figure 8.1.1 – Single carriageway – Multiple lanes



8.1.2 Single carriageway – Divided lanes

On occasion, a barrier may divide the lanes of each direction. On single carriageway divided lane roads, if the scans from each direction of travel lane do not fully overlap, each direction of travel lane shall be scanned a minimum of three times.

Figure 8.1.2 – Single carriageway – Divided lanes

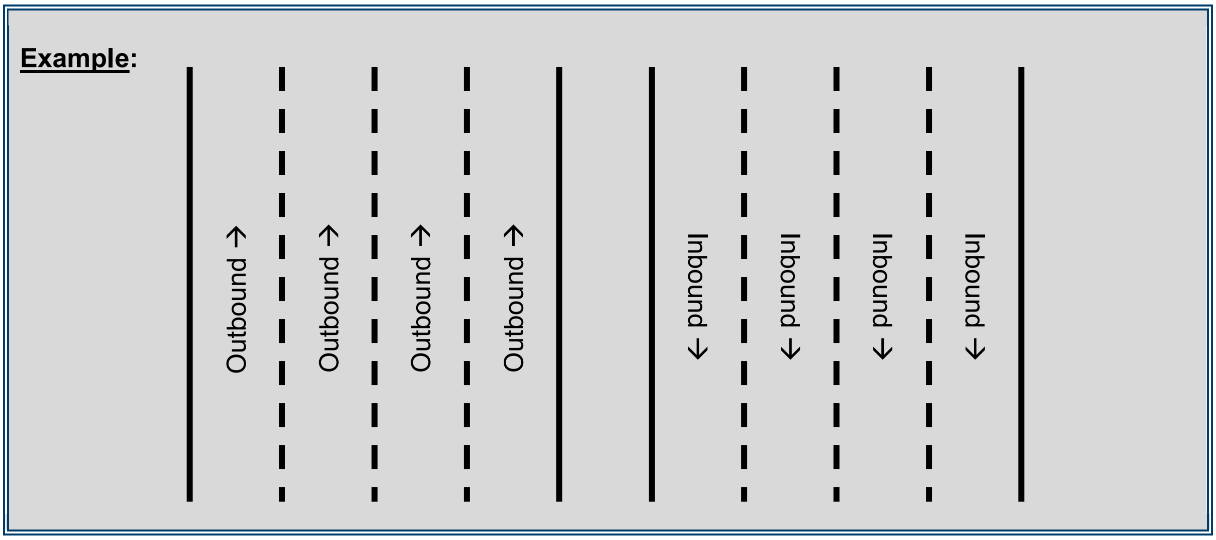


8.1.3 Dual carriageway – Multiple lanes

On dual carriageway multiple lane roads, if the scans from each carriageway do not fully overlap, each carriageway shall be scanned a minimum of three times.

At least one run shall be driven in the left hand through lanes of each carriageway.

Figure 8.1.3 Dual carriageway – Multiple lanes



8.2 Poor GNSS environments

It is the responsibility of the MLS contractor to increase the number of passes or implement other strategies in poor GNSS environments. These areas shall be reported to the project manager and noted in the survey report to explain what measures had been implemented to ensure the required accuracies of the project have been met.

8.3 Data overlap

Horizontal or vertical steps in the delivered point cloud are unacceptable. These steps may occur where the project contains roads that are intersecting, or runs have been stopped or started on a road. At these locations, Common Control Points (CCP) must be applied to ensure a consistent and comprehensive Pointcloud is delivered.

In a situation where the current project intersects with an older MLS project that must be matched into, the project proposal will provide relevant details and data required to ensure a seamless match of both sets of data. This may include specifying the required overlap of data if any. Sufficient survey control from the older project, which may include PRFM and/or SPRFM marks which shall be used for control, will be provided by the department to the MLS contractor.

9 MLS Variables

Generally speaking, environmental factors; colouring; shadowing; Pointcloud density and Pointcloud patterns all affect the quality of the delivered Pointcloud. Due to the wide variety of MLS hardware manufacturers and suppliers, the ability to customise hardware configurations and the methods used to collect information, it is becoming increasingly difficult to generate specifications that cover all aspects of all systems. It is the intention of this guideline to allow each MLS contractor to supply sufficient information about their hardware and methods so that the department can make an informed decision about their suitability. The delivered Pointcloud needs to be of sufficient quality so that identification of features at the desired accuracy can be achieved.

Environmental factors, colouring, shadowing, pattern and density will all need to form part of the MLS contractor's submission. This information should be submitted under the following headings:

- Environmental factors
- Pointcloud colourisation
- Shadow mitigation, and
- Density and Pattern diagrams (these diagrams can be theoretical).

9.1 Environmental factors

Different hardware will respond to different environmental conditions in different ways. For example, wet surfaces affect the ability of laser systems to get a return pulse. Rain, standing water and even a heavy dew will all have an effect on the quality of the Pointcloud captured. The MLS contractor shall identify the environmental conditions (heat, rain, dust, etc.) that cause degradation to the Pointcloud for their particular MLS system. A suitable methodology shall be presented with each project that mitigates each of these factors.

9.2 Pointcloud colourisation

Pointclouds can be coloured using a number of different techniques. Below are the two common methods of colourising Pointcloud data.

9.2.1 RGB colouring

Pointclouds can be coloured with Red Green Blue (RGB) values that have been assigned to individual points within the Pointcloud from imagery.

The imagery used to colour Pointclouds can be either the imagery that was captured at the time collection or by aerial imagery. The contractor should consider which type of imagery would be best suited and clearly identify which imagery will be used in the project proposal.

9.2.2 Intensity return colouring

The most common Pointcloud colourisation is to use an intensity value derived from the strength of the return signal to the laser scanner. This will provide a greyscale colourisation derived by the intensity.

Different systems use different Bit sizes to record this data (2, 4, 8, 16, etc.). This causes additional work on behalf of the department to derive and record the intensity colour ranges from different providers.

To alleviate this, the department requires the intensity of the laser returns to be standardised / normalised. All delivered intensity coloured Pointcloud data shall adhere to the 16 Bit colour range, from 0 (black) to 65535 (white).

Providing the department with the range of these values adds more understanding of the delivered Pointcloud, especially in relation to future Data Mining activities.

Factors such as normalisation of the intensity value to correct for distance from the scanner are not well communicated at present.

9.3 Shadow mitigation

Shadowing due to blocking of the emitted laser rays means that some of the features in the capture area will be obscured. This can occur from sources such as; vegetation cover, steep side slopes, pedestrians and other traffic on the carriageway.

> **Note**: If there is a problem with parked vehicles in urban areas, then consideration should be given to scanning at night when parked vehicles may be absent or completing additional passes to rectify these issues. This is to be identified in the tender proposal and/or discussed with the assigned project manager.

With rotating multi-sensor lasers, the shadowing is reduced by the forward motion of the MLS vehicle combined with the rotation of the multi-sensors giving multiple intersections of the scan lines. If oscillating single-sensor lasers are used in combination on a MLS vehicle, the alignment of the side scanners may be such that the scanning is performed oblique to the direction of travel of the MLS vehicle. Opposing scans will still pick-up points behind obstructions even if one scan is obstructed.

While some MLS systems have fixed alignment of the component lasers, all endeavours must be made to eliminate the effects of shadowing by adopting a suitable operational methodology in capture. This method shall be explained in detail in the MLS contractor's proposal.

9.4 Density and pattern

9.4.1 Density

Some systems are capable of collecting over a million points per second whilst others only a fraction of this. Vehicle speed will also be a major factor affecting the final point density.

The department requires the density of the delivered Pointcloud to be sufficient so that points, lines and surfaces meet the accuracy requirements specified.

9.4.2 Pattern

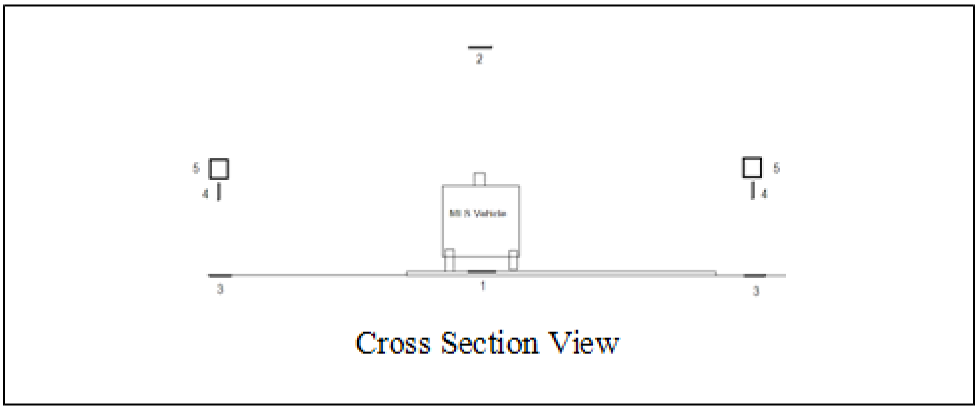
Point cloud patterns vary widely with each having certain advantages / disadvantages. Some systems have the flexibility to allow aspect changes, while others are fixed to a set position.

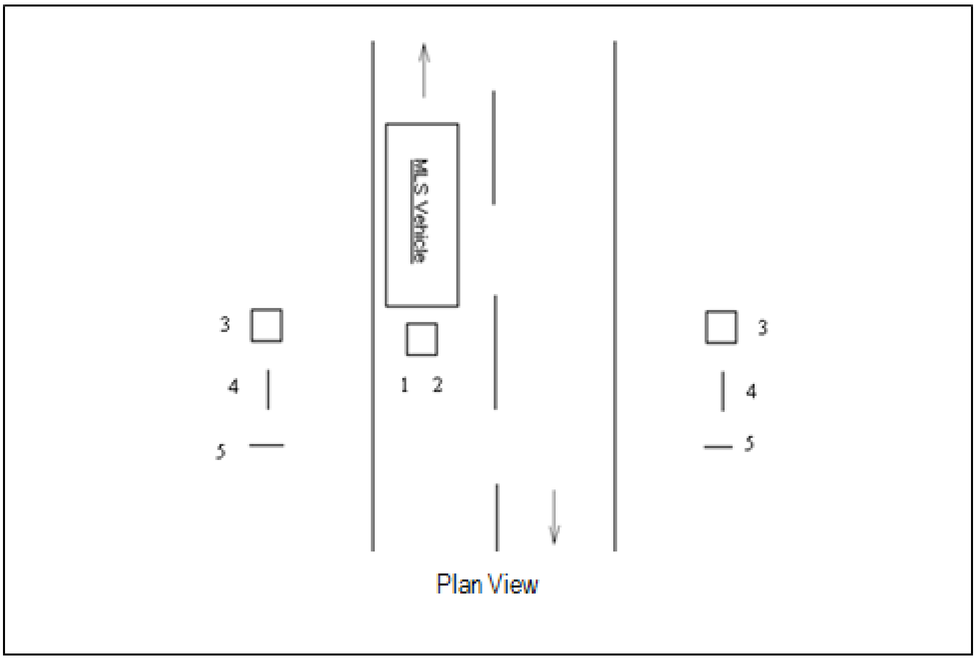
9.4.3 Density and pattern diagrams

The contractor is to supply the department with diagrams, either a theoretical plot or an example LAS file, showing the Pointcloud density and pattern (at 80 km/h) in the direction of travel on a 1 m square surface that is:

1. Horizontal and directly under the scanner head at the approximate height of the road.
2. Horizontal and at 5 m directly above the scanner head.
3. Horizontal and at 15 m left and right of the scanner head at the approximate height of the road surface.
4. Vertical at 15 m left and right of the scanner head at the same height as the scanner head and parallel to the direction of travel.
5. Vertical at 15 m left and right of the scanner head at the same height as the scanner head and perpendicular to the direction of travel.

Figure 9.4.3(a) – Pointcloud pattern and density diagram requirements





A few examples of density and Pointcloud patterns are provided below:

Figure 9.4.3(b) – Oblique scans from rotating single-sensor scanner

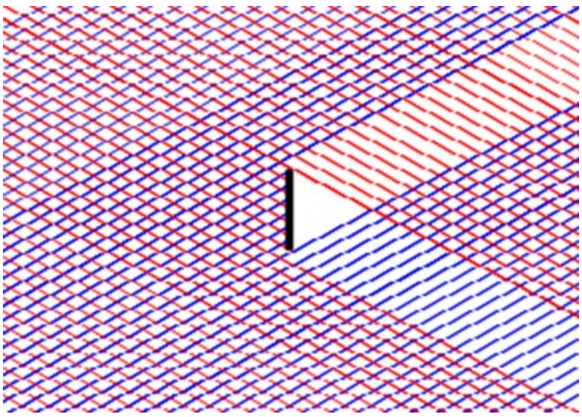


Figure 9.4.3(c) – Rotating multi-sensor laser

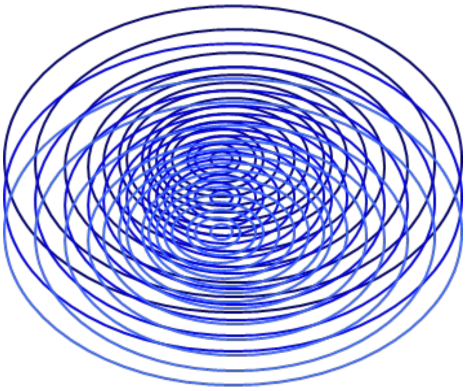
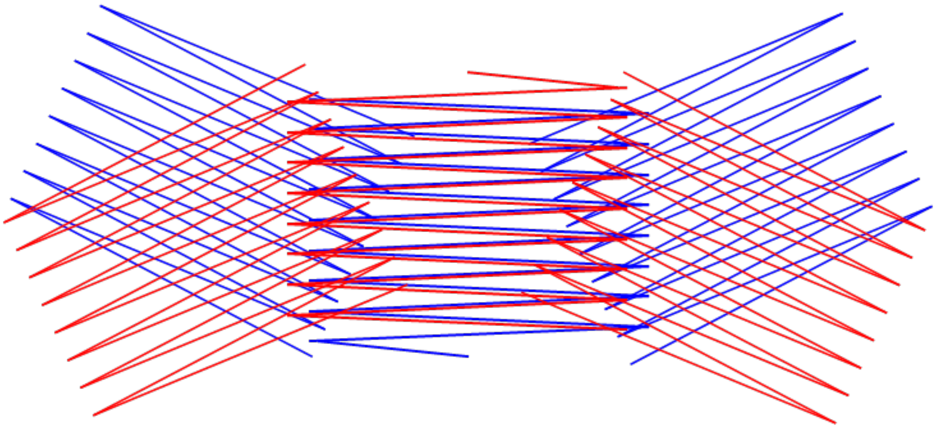


Figure 9.4.3(d) – Several oscillating single-sensor lasers



Note 1: Multiple scans can achieve a higher overall density of points, but if there are any issues with aligning multiple Pointcloud scans together, the definition of features can become a problem if the point density is not high enough in each individual scan. Therefore, all density diagrams above shall be prepared for a single Pointcloud pass only.

Note 2: If multiple scanning configurations are proposed for a project, then multiple diagrams representing each configuration will be required.

Note 3: Supplying a single Pointcloud (LAS file) so that Transport and Main Roads can do the assessment of density and pattern is an option with prior agreement from the department. Details such as configuration name and vehicle speed will need to be supplied.

10 Imagery capture

Geo-Referenced Imagery shall be acquired over the project area at the same time as the capture of the Pointcloud/s as a record of the project area at the time of Pointcloud capture. Image capture at a different time does not meet this requirement as Site conditions may have changed (e.g. a work crew with traffic control are digging up a section of road when the Pointcloud is captured but have left the site when the images are captured). There may be times when an exception can be made with the prior agreement of the department (e.g. Pointclouds captured at night to minimise shadowing caused by vehicles). This is to be discussed with and approved by the project manager prior to any capture.

When the MCPPC or PPC is made-up of multiple Pointclouds, only those passes that give a new image area are required to be imaged.

> **Note:** If a lane is run multiple times, only one of the passes needs to capture the imagery unless there is part of the project area that has not been captured previously.

The imagery shall cover the entire length and width of the project. Images shall be delivered on a per road basis. If there are separate sections along the same road that are required, imagery is only required in the areas identified in the project proposal. The imagery shall be indexed so that it can be cross-referenced to a coordinate or supplied with specific software that has the functionality to 'go to' a coordinate, with prior agreement from the department. Naming conventions can be found in Appendix G.

The contractor is to avoid early morning and late afternoon where under and over exposure of photos is likely to be an issue (8am to 4pm is usually ideal). The contractor is to a make a considered effort to ensure that imagery is not captured in wet conditions. The MLS contractor is responsible for ensuring all images are of acceptable quality. Acceptance of imagery will be based on the completeness and quality of the images supplied. Images that are under or over exposed, blurry, distorted by water on the camera lens or not fit for purpose will be rejected and the MLS contractor will be asked to resupply the imagery.

Care should be taken in the imagery capture to ensure that both sides of signs that are double sided are captured.

Geo-Referenced Imagery captured may be used:

- To provide a visual aid at a particular location.
- To assist with using the Ground and Feature Model for design and asset management purposes (the multi-aspect imagery can be interrogated to assess the condition of the terrain and features in the Ground and Feature Model (GFM) and help in the interpretation of the model at particular locations).
- To assist with the 'Data Mining' of the Minimally Constrained Project Pointcloud (MCPPC) or the Project Pointcloud (PPC) when future digitising is required (Since 'Data Mining' can occur sometime after the capture of the Pointclouds, the imagery will also assist with an estimation of the relevance of the data for any use).
- As a record of the project area at the time of capture, and
- For colourisation of the Pointcloud.

As different projects have different requirements for imagery, the projects' *MLS Technical Guideline Checklist* may specify the distance between successive image capture locations. Similarly, the *MLS Technical Guideline Checklist* may specify the required resolution of each image captured.

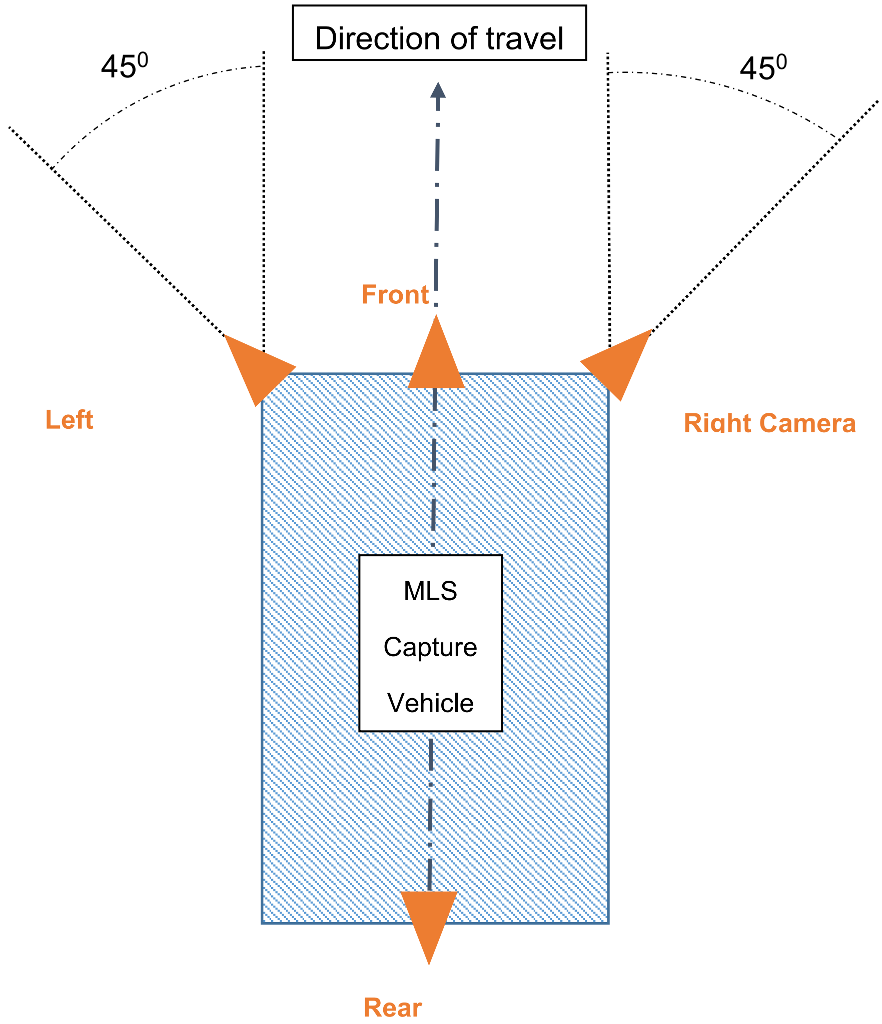
> **Note 1:** When tendering it may be a requirement for the tenderer to supply example imagery to show the coverage, format and quality that will be delivered.

> **<u>Note 2:</u>** Colourisation of the Pointcloud using the imagery may affect the amount of imagery that needs to be collected. For example, imagery may need to be collected on all passes at very short intervals for successful Pointcloud colourisation to occur.

Geo-Referenced Imagery shall be supplied in a file format agreeable to the department and as outlined in the project proposal. To date the accepted file format for geo-referenced spherical imagery is stream PGR. All other imagery shall be supplied geo-referenced in .JPG format with an index to allow cross-referencing to a coordinate. Panoramic JPG imagery is unacceptable.

An example setup for multi camera vehicle setups is shown in the diagram below. Cameras should be setup to ensure some overlap between the resultant images from Left and Front cameras; and Front and Right cameras.

Figure 10 – Multi camera vehicle setup



11 Requirements for combining multiple Pointcloud passes into a Minimally Constrained Project Pointcloud (MCPPC)

The Minimally Constrained Project Pointcloud (MCPPC) shall cover the entire carriageway in both directions and shall extend to the closest limiting factor that will supply a return from the laser (e.g. Noise Barrier).

In some instances when high accuracy information is not required at the time of Pointcloud capture, a GNSS only solution is the most appropriate capture technique. This may be the case where asset information is the primary objective of the MLS capture. A GNSS only solution will help minimise the initial cost of survey control, but still may have sufficient rigour around the collected data to post control it at a later date should a more accurate survey need arise.

11.1 Pointcloud consistency

Variations in the raw individual Pointclouds, the MCPPC and the PPC representing the same features will give an indication of the consistency of the MLS system and calibration. The magnitude of the variation can be displayed in various forms to give an indication of the uncertainty that has been achieved.

11.2 Horizontal survey uncertainty

The MLS contractor will be required to place or locate check points throughout the project area to ensure that the MCPPC fits horizontally to the PRF. The MLS contractor shall generate a report showing the compliance of the MCPPC to the PRF. This will be done by tabulating the vector shift of each check point from the coordinates derived from the MCPPC and the coordinates of the check points as positioned using independent means.

Appendix A and F explain this process in more detail.

11.3 Horizontal relative uncertainty

The MLS contractor will be required to establish check sites throughout the project area to ensure that the MCPPC fits horizontally within itself. The MLS contractor shall generate tabulated reports showing this compliance. Within sliding windows of up to 200 m, the distances between Clearly Defined Points in the MCPPC must agree with independently measured distances between those same two points.

Appendix B and F explain this process in more detail.

11.4 Vertical survey uncertainty

The MLS contractor will be required to place or locate check points on hard surfaces throughout the project area to ensure that the MCPPC fits vertically to the Project Reference Frame. The MLS contractor shall generate reports showing this compliance. This will be done by tabulating the difference in height between the MCPPC, and an independently derived height for that same Clearly Defined Point.

Appendix C and F explain this process in more detail.

11.5 Vertical relative uncertainty

The MLS contractor will be required to establish check sites throughout the project area to ensure that the MCPPC fits vertically within itself. The MLS contractor shall generate reports showing this compliance. This will be done by tabulating, within sliding windows of up to 200 m that the height differences, on hard surfaces, between Clearly Defined Points in the MCPPC agree with independently measured height differences between those same two points.

Appendix D and F explain this process in more detail.

11.6 Vertical longsections

Quality assurance string (QQ) shall be digitised from the MCPPC. The QQ longsection string is a defined feature that is also used for other purposes.

In the following road situations, this QQ string shall be located along:

Two-way traffic	The linemarking separating opposing traffic (i.e. the centreline).
One-way traffic	The linemarking representing the right hand side of the right hand lane. (A QQ string is required for each opposing carriageway for dual carriageways).

Note: If the road is not line-marked then the centre of the pavement, defined as the mean of the edges of pavement, shall be used as the quality string.

This quality string shall be coded as QQ00. This is a quality assurance string coded QQ with an identifier of 00 (zero zero). The project may include multiple separate QQ00 strings that cover single carriageways, dual carriageway situations and side roads.

Vertical longsection QQ strings shall have a valid height determined by the average of the thickness of the PPC or MCPPC at the vertices location. Each vertex is to be no more than 10 m apart along the string and shall cover the entire length of the project including side roads. The department requires a file containing all QQ00 strings in .12daz format.

The department also requires files containing heights from each individual raw Pointcloud on the horizontal position of the vertices of the Quality String (QQ00). These strings are to be coded as QQ with the subsequent identifier number reflecting the raw Pointcloud pass numbers detailed in the table in Section 11.8.4.1.

Example: Raw Pointcloud Pass 1 (LAS 1.2 Classification: 21) would be coded QQ21 (two one), Pass 2 (LAS: 22) would be coded QQ22 (two two).

The project may include multiple individual strings with the same code (e.g. Pass 1 for each section of the project). These QQ strings are to be provided in .12daz format.

11.7 Useful range

The useful range of different MLS systems will vary. Some systems have long range scanners that can easily measure more than 200 m from the scanner head, while others are significantly shorter range. The accuracy of the scanner at close, medium and long ranges also varies with distance due to angular and distance measuring accuracies. The quality of the IMU in the MLS system will also have an influence on how far from the scanner head a Pointcloud remains useful. Similarly, the quality of the GNSS observations will impact on the useful range. Even though a Pointcloud may extend to 200 m from the scanner head, in most cases the part of the point cloud that meets the accuracy specified by the project will be considerably less than that distance.

Hence, the department requires a statement that defines the useful range of the MCPPC making reference to the project uncertainties and the width covered. This statement will be based on calculations and the experience of the MLS contractor. Further it will be based on the GNSS, IMU and scanner accuracy specifications and procedures adopted.

Example: A useful range statement is provided by the MLS contractor stating 'The MCPPC supplied meets or exceeds the accuracy requirements for this project between the edges of pavement.' In this example, it means that for any Clearly Defined Points collected during the project that fall between the edges of pavement, the resulting positions and heights of those points are within the project accuracy requirements specified.

Note: It is common practice that laser scanners measure in plane distances. The requirements for most departmental projects are that the MCPPC be delivered as MGA coordinates. Therefore, there is the potential for errors in the distance measured from the scanner head of up to 40 mm / 100 m due entirely to Point Scale Factor. It is important that this is considered when the MLS contractor makes their 'useful range' statements, particularly in relation to the horizontal components.

11.8 Pointcloud (MCPPC) cleansing, thinning and classification

11.8.1 Cleansing

During the capture of the Pointclouds, erroneous points may be captured from other sources that are moving, generally other road vehicles. Care should be taken to remove the influence of these erroneous points when aligning multiple Pointclouds together and later when defining the road surface and other features in the GFM. The final Pointcloud can be cleansed of these points for final delivery.

If the decision is taken to cleanse the MCPPC of erroneous data, care must be exercised to ensure that valid features in the apparently erroneous data are not deleted. It is recommended that data is not deleted but pushed to other files or classified in such a way so that it can be separated from the clean data. Care should be taken as removal of non-erroneous data during a cleansing process may result in the MLS contractor having to re-supply datasets.

11.8.2 Thinning

When multiple Pointclouds are joined to give an excessively dense MCPPC, it may be that some thinning process is used on the MCPPC to bring the density back to more manageable sizes. For example, thinning the MCPPC on the pavement surface.

If a thinning process is used, care must be taken that ground points remain in the MCPPC and the resultant density of the MCPPC will be greater than that of a single Pointcloud pass.

11.8.3 Gridding

To be developed. Regular grid of points to represent the road surface instead of entire Pointcloud data.

11.8.4 Classification

The department may require the PPC or MCPPC LAS data to be classified. Depending on the project, the ASPRS LAS classification may be required for point class with the determination of the point class derived by different Pointcloud classification levels.

Similarly, the department may require data to be classified in other point classes which would be stipulated in the project proposal.

11.8.4.1 Pointcloud point classification

Once individual point clouds are combined as a PPC or MCPPC, the department will require the points to be classified in a certain manner. This may be either the ASPRS point class or by a departmental defined class.

For most departmental MLS projects, it becomes difficult to differentiate between individual Pointcloud passes. Therefore, each individual Pointcloud in the PPC or MCPPC is to be classified or identified in such a way so it can be differentiated from the other individual Pointclouds.

Each individual Pointcloud inside the delivered LAS file will be named as shown in the table below. In Version 1.2 of the LAS file format, classification levels 13 to 31 are reserved for future ASPRS definition, the department will utilise these point classes to identify the required Pointcloud pass. The following table outlines the classification regime:

Individual Pointcloud Pass	LAS 1.2 Classification
1	21
2	22
3	23
4+	24+

11.8.4.2 Pointcloud classification levels

At times the department may need to have the collected data classified into ASPRS Pointcloud point classes. Depending on the project's requirements, the classification level of the data may require greater manual input to ensure point classes have been met as opposed to automatic processes. This will be outlined in the project proposal.

Classification levels are defined below:

Pointcloud Classification Level	Description	Definition	Required Point Classification Accuracy
Level 0	Unclassified	No point classification required	N/A
Level 1	Automated and Semi-Automated	Batch processing of Pointcloud data to attain ASPRS LAS classifications of 2 to 9	95%
Level 2	Ground surface improvement	Level 1 data further processed either manually or automatically to remove anomalies in the data and improve the point classification of 2, 3, 4, 5, 7 & 9	98%
Level 3	Ground Correction	Data further improved from Level 2 to ensure that only actual ground points are in point classification 2	99%
Level 4	Detailed Classification and Correction	Data improved from Level 3 to ensure that points in every point classification are in fact the relevant feature in the classification	99%

11.8.5 LAS Point data record format

The department will require LAS files to have a specific Point Data Record Format. The PDRF will depend on the version of LAS file requested for the project deliverable.

The PDRF will be consistent with the published ASPRS LAS file format standards.

11.9 Cloud to cloud matching

To be developed. Matching multiple clouds to one another in Horizontal and Vertical to get a best fit result.

12 Adjusting Pointclouds to the Project Reference Frame (PRF) using Ground Control Points (GCP) to create a Project Pointcloud (PPC)

For applications where high accuracy is required, the MLS contractor will generally require ground control points (e.g. a point, a series of points, a target, linemarking, etc.) to meet the accuracy required. These targets will be used to align the MCPPC with greater accuracy to the PRF to create the PPC.

The major source of error in an MLS project is expected to be in the vertical component. The captured data must be aligned vertically to the local PRF so that when the information is used, it can be used confidently knowing that the local topography and PPC are coincident. That is the existing ground, the PPC and the digital GFM must be consistent with the PRF.

Appendix E explains the targeting process in more detail.

If the MLS contractor deems that additional targets are required to meet accuracy requirements in areas of poor GNSS reception, it will be the responsibility of the MLS contractor to place these extra marks.

The PPC is to cover the entire carriageway in both directions and is to extend to the closest limiting factor that will supply a return to the laser (e.g. Noise Barrier).

12.1 PPC consistency

Variations in the PPC representing the same features will give an indication of the consistency of the MLS system and calibration. The magnitude of the variation can be displayed in various forms to give an indication of the accuracy that has been achieved.

Horizontal Survey Uncertainty

Refer to Clause 11.2 and replace all references to MCPPC with PPC.

Horizontal Relative Uncertainty

Refer to Clause 11.3 and replace all references to MCPPC with PPC.

Vertical Survey Uncertainty

Refer to Clause 11.4 and replace all references to MCPPC with PPC.

Vertical Relative Uncertainty

Refer to Clause 11.5 and replace all references to MCPPC with PPC.

Vertical - Longsections

Refer to Clause 11.6 and replace all references to MCPPC with PPC.

Useful Range

Refer to Clause 11.7 and replace all references to MCPPC with PPC.

Project Pointcloud Cleansing, Thinning and Classification

Refer to Clause 11.8 and replace all references to MCPPC with PPC.

13 Ground and feature model requirements

13.1 Background

The PPC (or MCPPC if no PPC exists) will be used as the source to digitise a Ground and Feature Model (GFM). This GFM may be used to model the road surface, the general formation shape and any observed road furniture.

The department's coding convention as set out in *TMR Surveying Standards* shall be adopted.

All points and strings shall be coded as per the *TMR Surveying Standards Schedule 1, Codes, Linestyles and Examples*, with particular attention paid to the situational examples provided.

The GFM shall be delivered in .12daz format.

> Link to the *TMR Surveying Standards* http://tmr.qld.gov.au/business-industry/Technical-standards-publications/Surveying-standards.aspx

13.2 General

If points are digitised from a PPC (or MCPPC) into a GFM, the horizontal and vertical positions of those points are deemed to meet the Horizontal and Vertical Locational and Relative Uncertainties of the project. This assumption is made based on the close relationship between the extracted information (GFM) and the data source (PPC or MCPPC). It also ensures that meticulous digitising and accurate extraction algorithms are being used in the GFM generation process.

If the MLS contractor:

- proposes to use lower accuracy algorithms
- is working with a point cloud with a low point density or Pointcloud patterns not suited to the extraction task, and/or
- proposes to speed up GFM creation by relaxing care and attention when digitising

then, the accuracy loss between the PPC (or MCPPC) and GFM must be quantified. To do this, a new set of uncertainties will be supplied to reflect the accuracy loss between PPC (or MCPPC) and GFM. These values are to be supplied in addition to the uncertainties of the PPC (or MCPPC).

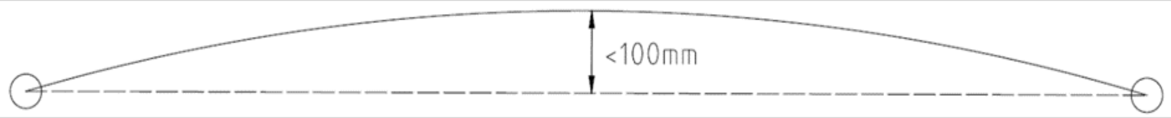
> **Note:** If there are areas where the contractor has not achieved the uncertainties specified in the brief, the MLS contractor shall identify these areas in the Survey Report so that a negotiation can occur around final payment.

To better understand the likely quality of the digitising processes used by individual MLS contractors, the department requires the contractor to outline the methods that will be used to create the GFM. The projects' *MLS Technical Guideline Checklist* will be used to provide the department a summary of the proposed processes.

For 95% of any check points chosen on a non breakline detail feature in the MCPP, the perpendicular distance between it and the line segment representing it in the GFM must be less than 100 mm.

Figure 13.2 – Chord to arc tolerance

Example: Line Marking



13.3 Terrain

Generally, the extents of the GFM extraction area will be supplied as part of the project proposal and will be larger than what would be practicable to obtain from the PPC (or MCPPC if there is no PPC). Extraction of the terrain surface off the pavement is generally required within the extraction extents particularly where the grass is mowed or where the operator has confidence that the ground surface is being represented (i.e. when there is no grass on the terrain surface). If there are trees or high grass that provides a false representation of the terrain, these areas do not require terrain extraction, but should be identified in the survey report and by uniquely identified closed Boundary (BY) polygons in the digital GFM created.

Special note shall be taken in relation to stringing conventions to ensure the creation of a valid Triangular Irregular Network (TIN) to define the road terrain surface.

Note: Only codes in the SURVEY DTM model are used for producing the TIN.

Points digitised on the pavement and kerb / barriers have a defined extraction interval (see Section 13.4 and 13.6) that will ensure that the TIN created will be representative of the surface, i.e., there will be minimal interpolation if the default parameters are adopted.

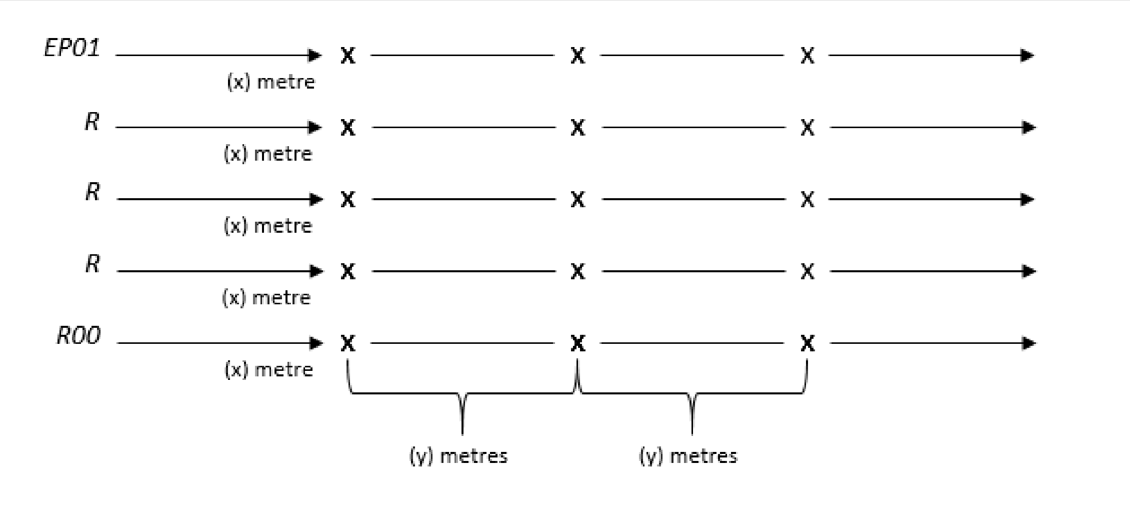
For 95% of all differences between a terrain point interpolated height, as determined from the TIN, and its independently levelled value, must not be greater than that shown in the GFM TIN Interpolated Accuracy requirements in the projects' MLS Technical Guide Checklist.

13.4 Pavement extraction

A control line (QQ00) will have already been digitised as part of the vertical longsection check performed. All QQ00 are to be duplicated as RC00 but with a longitudinal point every (y) metres. This control line will be the reference for the pavement definition. The pavement shall be represented by a series of longitudinal breaklines. These breaklines are to be coded as R (Pavement surface) and are to be created parallel to the control line (RC00) every (x) metres across the pavement to within 300 mm of the edge of pavement (EP string) or kerb lip (KL string). All these Breaklines shall have a valid height every (y) metres along the string within the extraction extents. (x) and (y) will be detailed in the projects' MLS Technical Guide Checklist.

__Figure 13.4 – Pavement extraction requirements__

Example: Pavement Extraction



13.5 Linemarking strings

The linemarking on the pavement within the extraction extents shall be digitised with a valid height. QQ00 strings may be duplicated as an appropriately coded linemarking string.

Note: Linemarking is not used to create the TIN. It is only to show where the linemarking exists on the road. As such it is only needed to be located at changes in type of line, changes in direction and with points close enough to give a reasonable approximation of curves. The points on linemarking strings will not need to be located every (y) metres, only enough to indicate their true horizontal position (see Figure 13.2).

13.6 Barrier device strings

Any barrier devices within the extraction extents such as median kerbs, kerb and channel, concrete barriers, guardrails, fences along the median, wire rope barriers etc. shall be digitised.

The kerb and channel within the extraction extents shall be digitised as KL (Kerb Lip), KI (Kerb Invert) and KT (Kerb Top) strings.

All these Breaklines are to have a valid height at least every 5 m along the string. It is recommended that manual digitising is performed to ensure compliance with horizontal, vertical and GFM TIN interpolated accuracies.

The *TMR Surveying Standards, Schedule 1 Codes, Linestyles and Examples* has situational examples on how to locate this information.

13.7 Road signage

Any observable road signs within the extraction extents shall be digitised. Care should be taken in the imagery capture to ensure that both sides of signs that are double sided are captured. Comments that identify the type of sign or a summary of the words that appear on the sign shall be recorded on these points in the digital GFM. When delivered, the comment should be attached to the point feature or line string as vertex text.

13.8 Features and services

Any identifiable features and services that can be confidently located within the extraction extents are to be located, e.g. street lights, noise barriers, large signs, variable message signs, gantries, pits, gully traps, manholes, edges of concrete etc.

13.9 Structures

Bridge overpasses shall have basic bridge strings extracted:

The purpose of extraction is to provide an envelope that represents the available width and height. The basic strings should consist of the following:

- A Soffit string (SF) at the entry and exit to each overpass.
- Additional Soffit Strings (SF) if there is another soffit under the bridge that affects clearance.
- Abutment Strings (HT and HB).
- Headstock Top and Bottom Strings (HT and HB).
- Pier Top and Bottom Strings (BE).
- Centre of Columns or Piles (PBPC and PBPP) [and a diameter if applicable], and
- Any concrete protection or other feature that will limit clearance (i.e. concrete barriers, stone pitching, rock cutting, etc.).

14 QA, reporting and delivery

A number of reports shall be prepared that outline the results of the MLS operation. These should include but not limited to the following documentation:

a) MLS system reports – Component calibration, alignment and self-tests.

b) A Trajectory string for flight line by way of a 12daz string attributed with RMSE values on each vertex (which represents the RTK position epoch) during capture.

c) Statement on how the IMU (and wheel encoder if fitted) observations are applied during times of degraded, lost, or obstructed GNSS signal reception.

d) If a multi-laser system is used, evidence of how the scans from each scanner join.

e) A 12D Model file of the vertical longsections (where appropriate) of each individual Pointcloud, MCPPC and PPC taken along the quality string QQ00.

f) Reports on the horizontal and vertical compliance of the MCPPC, PPC and individual Pointclouds to the PRF.

g) A Survey Report shall be prepared outlining the successful completion of the project and any problems that have been encountered along the way. On projects with staged delivery, a Survey Report will form part of the deliverables for each stage.

A statement describing how any new PRFMs / SPRFMs have been coordinated and levelled shall be outlined in the Survey Report.

Example: SPRFMs Numbered 1234-2345 have been located using GNSS techniques pursuant to meet or exceed SU and PU < 60 mm and levelled using a digital level from the adjacent PRFMs.

If there are areas where the contractor has not achieved the accuracy specified, the MLS contractor shall identify these areas in the Survey Report so that a negotiation can occur around final payment.

The Survey Report shall be signed by the person responsible for the survey. This person shall be a Surveyor (G2) as defined in the *TMR Surveying Standards*.

If there is a requirement for the MLS contractor to place or register Permanent Survey Marks for a MLS project, the Surveyor shall meet the criteria of C3 as defined in the *TMR Surveying Standards*.

For a summary of the deliverables, file naming and formats required for successful delivery of Mobile Laser Scanning information, refer to Appendix G.

Appendix A – Horizontal survey uncertainty

For 95% of points, the length of the vector between:

a) the coordinates of a Clearly Defined Point in the MCPPC, PPC or GFM, and

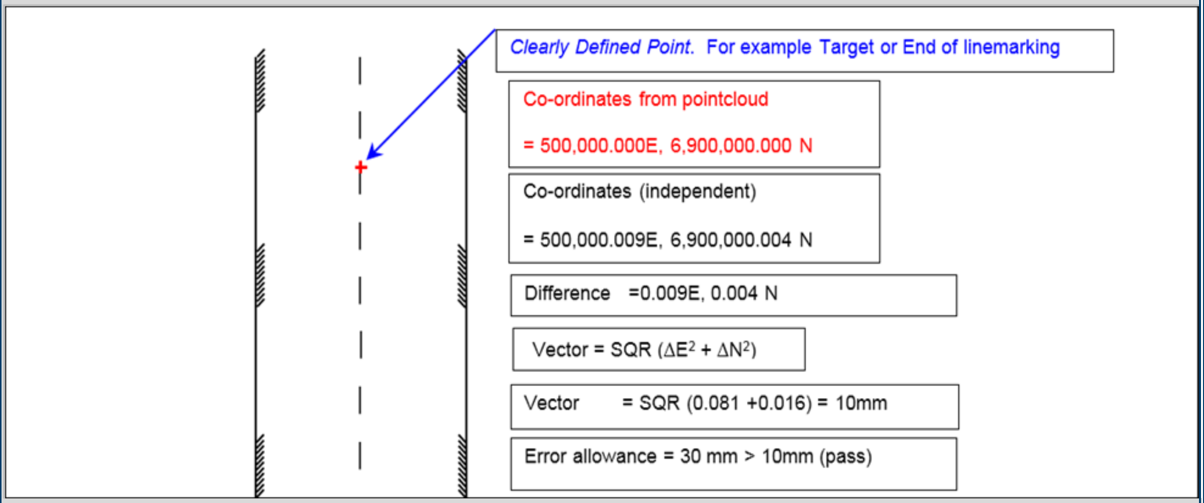
b) the coordinates of that same Clearly Defined Point derived by independent means

must be less than (x) mm {(x) will be specified in the projects' *MLS Technical Guideline Checklist*}.

This process is provided as a means to check the absolute horizontal positioning during processing and can be used by independent auditors to check the supplied data for horizontal fit to the PRF.

These marks are to be located and coded as PQAP in the field.

For example if error allowance (x) = 30 mm.



There is always a trade-off between checking everything and not checking anything. For each project, this balance may be different, and the *MLS Technical Guideline Checklist* provides the flexibility to customise the distance between successive check point locations (in the context of this document, check points and check sites are defined in Appendix F).

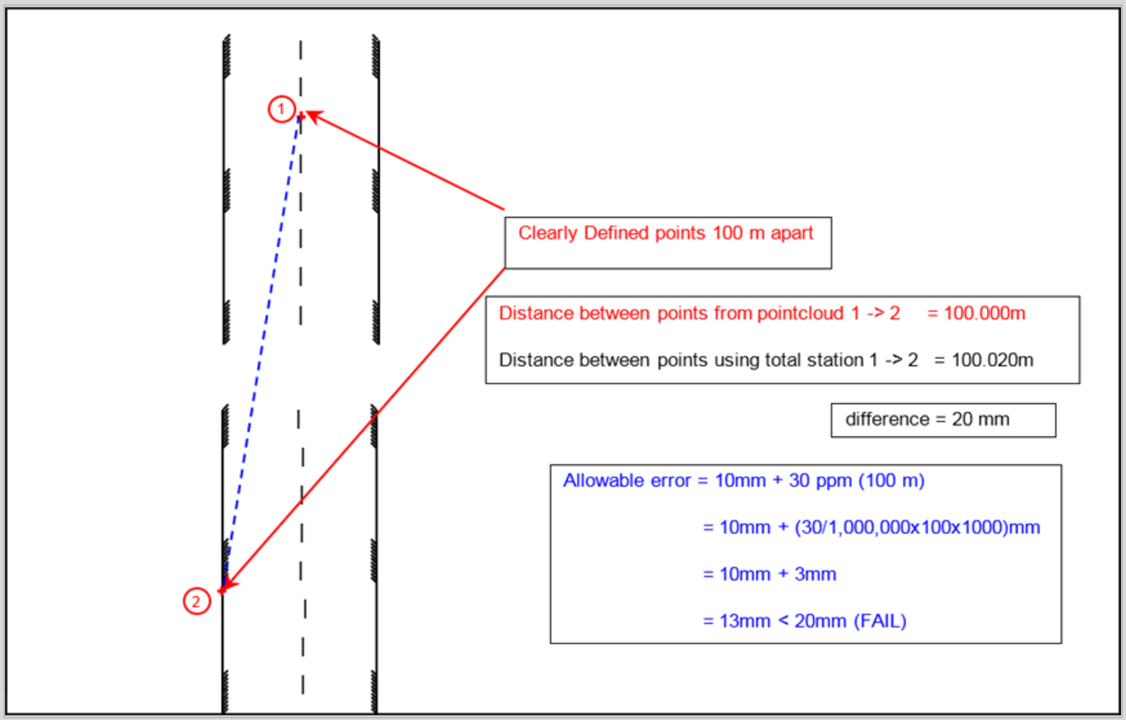
Appendix B – Horizontal relative uncertainty

Within a sliding window of up to 200 m, 95% of all distance differences between Clearly Defined Points in the MCPPC, PPC or GFM must agree with independently measured distance differences between those same two points by (y) mm + (yy) ppm of the distance between the points as defined in the GFM section of the projects' *MLS Technical Guideline Checklist*. Even over shorter distances the same formula can be used to check the information provided as the (yy) parts-per-million (ppm) over short distances becomes negligible and the formula effectively becomes (y) mm.

These marks are to be located and coded as PQAP in the field.

For example, the relative distance difference between two points in the PPC have been measured by total station and the difference in distance is compared using (y) mm + (yy) ppm of the distance between them.

If (y) = 10 mm and (yy) = 30 ppm.



There is always a trade-off between checking everything and not checking anything. For each project, this balance may be different, and the *MLS Technical Guideline Checklist* provides the flexibility to customise the distance between successive check site locations (in the context of this document, check points and check sites are defined in Appendix F).

Appendix C – Vertical survey uncertainty

For 95% of all points (on hard surfaces) tested, the difference in height between the MCPPC, PPC or GFM and an independently derived height for that same Clearly Defined Point must be less than (z) millimetres. The *MLS Technical Guideline Checklist* provides categories for Vertical Survey Uncertainties and Check Site Spacing's.

These marks are to be located and coded as QQls and QQxs in the field.

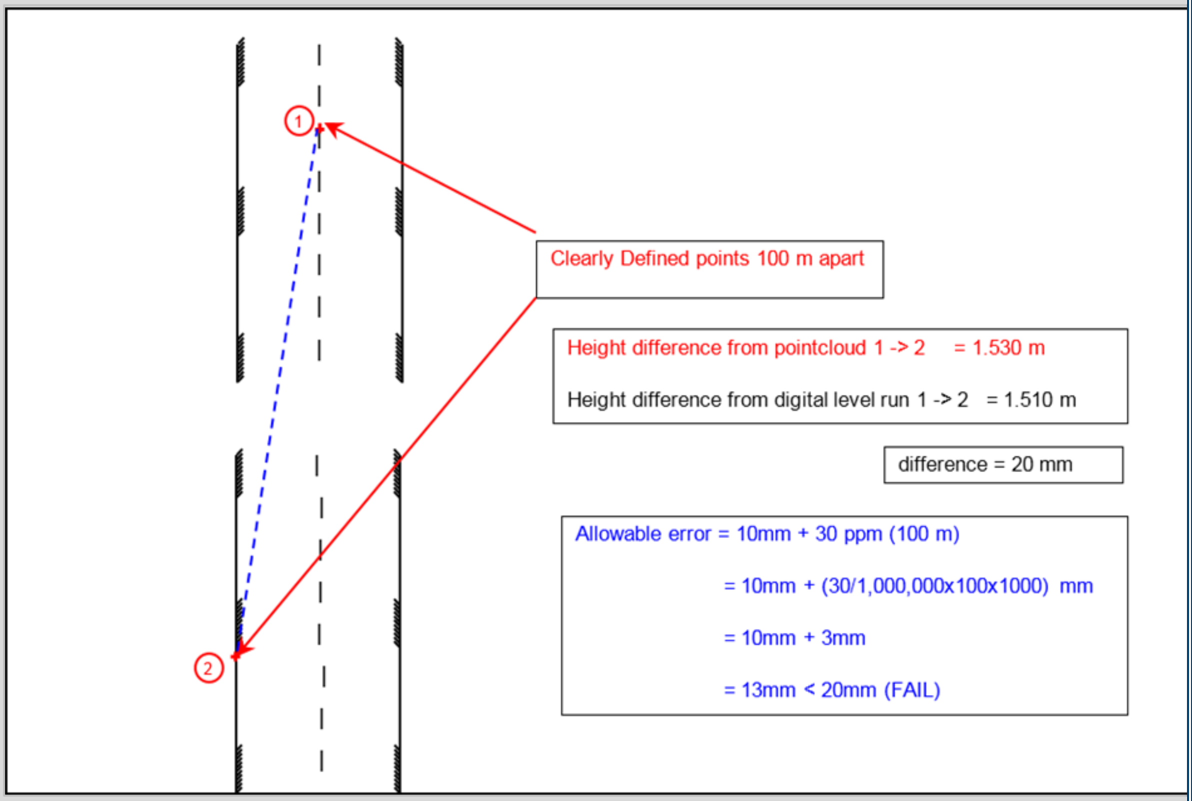
There is always a trade-off between checking everything and not checking anything. For each project, this balance may be different, and the *MLS Technical Guideline Checklist* provides the flexibility to customise the distance between successive check site locations (in the context of this document, check points and check sites are defined in Appendix F).

Appendix D – Vertical relative uncertainty

Within a sliding window of up to 200 m, 95% of all height differences(on hard surfaces) between Clearly Defined Points in the MCPPC, PPC or GFM must agree with independently measured height differences between those same two points by (zz) mm + (zzz) ppm of the distance between the points. Over short distances the same formula can be used to check the information provided as the (zzz) parts-per-million (ppm) over that short distance becomes negligible and the formula essentially becomes (zz) mm.

These marks are to be located and coded as QQIs and QQxs in the field.

For example, the relative height difference between two points in the MCPPC has been levelled by digital level and the difference is compared using (zz) mm + (zzz) ppm of the distance between them. If (zz) = 10 mm and (zzz) = 30 ppm.



There is always a trade-off between checking everything and not checking anything. For each project, this balance may be different, and the *MLS Technical Guideline Checklist* provides the flexibility to customise the distance between successive check site locations (in the context of this document, check points and check sites are defined in Appendix F).

Appendix E – Ground control points

The target size, shape, placement regime and configuration are required as part of the MLS Contractors Proposal. The spacing of these targets will depend on the MLS system components and methodology chosen by the MLS contractor.

To accurately position ground control points, they will be located by independent means and evidenced by using PRFMs or SPRFMs as datum.

Height is to be determined by an average of two independent level runs evidenced by a PRFM or SPRFM.

The ground control points shall be coded as PGCP see *TMR Surveying Standards* and must be delivered in .12daz file format.

These targets will generally be objects that are permanent in nature and can be accurately identified and positioned from within the PPC and by conventional total station, GNSS and/or digital levelling.

In addition to the requirements for ground control points spacing as specified in the projects' MLS Technical Guide Checklist, a ground control point must be placed adjacent to the start and end of the project.

Additionally, a ground control point shall be placed at all intersections of state controlled (main) roads within the project area. This requirement will allow accurate matching of future MLS on adjacent main roads and extensions to existing MLS.

> **Note:** To better understand the usefulness of these targets it requires an underlying understanding of the quality and accuracy of the PRFMs and SPRFMs. Thus, the requirement to outline the methodology used in the location of all survey control points in the survey report.

Appendix F – Check Sites and points

Check Sites

The intention of all the check sites is to gather an understanding of the accuracies achieved in areas of both good and poor GNSS coverage as well as close to and half way between PRFMs.

Generally, the spacing of the check sites will be outlined in the *MLS Technical Guide Checklist*. However, the project proposal may outline requirements for additional check sites or to have check sites in specific locations.

The MLS contractor does not have to perform both horizontal and vertical checks on the same check site, but it will be more time efficient and economically viable to do so.

Horizontal

Sites will generally be spaced evenly throughout the project as defined in the *MLS Technical Guide Checklist*.

At each site the MLS contractor will locate a total of at least 10 points within each defined section. Each PQAP point will be at least 10 m from any other PQAP point.

These checks of Clearly Defined Points shall be independently located, and the methodology detailed in the projects' *MLS Technical Guide Checklist*.

Vertical

Sites will generally be spaced evenly throughout the project as defined in the *MLS Technical Guide Checklist*.

At each site the MLS contractor shall locate both longitudinal and cross sectional QQ strings.

The Longitudinal QQ string shall be coded as QQ with an identifier of 'ls' (QQls).

The cross sectional QQ strings shall be coded as QQ with an identifier of 'xs' (QQxs).

These checks of shall be independently located and the methodology detailed in the projects' *MLS Technical Guide Checklist*.

Check Points

Horizontal Survey and Relative Uncertainty Check Points

To check the horizontal survey and relative uncertainties, Clearly Defined Points will be located by independent means as PQAP points. These points will generally be objects that can be accurately identified and positioned from within a PPC (or MCPPC) and by conventional total station or GNSS reading.

Some possible examples of objects that are Clearly Defined Points are:

- corners of concrete (bridge abutments, culverts, etc.)
- centres of light poles or posts
- ends of line marking strings

- guardrail posts, and
- targets that have been specifically placed for this purpose.

In each case, a comment should be attached to the PQAP point that unambiguously describes the point located.

Vertical Survey and Relative Uncertainty Check Points

To check the horizontal survey and relative uncertainties, height quality checks will take the form of QQ strings.

Longitudinal QQ String (QQls)

The longitudinal QQ strings will be a length of approximately 70 m with valid points at approximately 10 m intervals longitudinally along carriageway edge-lines.

Cross Sectional QQ Strings (QQxs)

At each check site, a minimum of two cross sectional QQ string are to be located. These strings are to be no more than 30 m apart and will have valid points:

- sufficient to define the road surface where there is obvious rutting OR equally spaced across each travel lane with at least two valid points in each lane, and
- on the linemarking.

Note: To better understand the usefulness of all of these checks, it requires an underlying understanding of the quality and accuracy of the PRFMs and SPRFMs. Thus, the requirement to outline the methodology used in the location of all survey control points in the survey report.

Appendix G – Summary of deliverables, file naming and file formats

Project and Subsidiary Project Reference Frame

All observations, reductions and reports that relate to any new or existing PFRM or SPRFMs shall be delivered to the department. These should generally take the form of a 12D Model .12daz file, or PDF files or similar as agreed by the department.

GNSS Field Observation Records

Any records taken in the field such as GNSS observation log sheets, images / photographs (as evidence of measurement readings) and any other information that is relevant to processing shall be supplied to the department.

Delivery shall be as a .pdf file ordered such that all information relating to a particular PRFM or SPRFM is together.

Example: Log sheets and images for PSM12345 followed by log sheet and images for PSM54321 in same pdf file.

All GNSS field record data files to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable		FOBS
3	Date	YYYYMM	201403
5	Horizontal projection with appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56 or GDA2020_MGA56
5	Accepted format	Portable Document Format file	pdf
	Example:	MR123456_FOBS_201403_GDA94_MGA56.pdf	

GNSS Processed Data

The department requires that processed GNSS data be supplied in either RINEX (v4.0) (.14o) or TDEF (.asc) format.

All GNSS data shall be compiled by the MLS contractor and compressed into a single zipped folder and supplied to the department.

The GNSS recorded data files to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	GNSS recorded data files	GNSS
3	Date	YYYYMM	201403
4	Horizontal projection with appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56 or GDA2020_MGA56
5	Accepted format	Compressed Zipped file	zip
			rar
			7z
Example:		MR123456_GNSS_201403_GDA94_MGA56.zip	

GNSS Processing Reports

The department requires that:

- minimally constrained adjustment
- constrained adjustment, and
- loop closure.

GNSS processing reports are supplied in PDF format.

The GNSS report files to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	GNSS Processing Reports	GNSS
3	Type of report	Minimally constrained	MC
		Constrained	CA
		Loop Closure	LP
4	Date	YYYYMM	201403
5	Horizontal projection with appropriate zone	Horizontal coordinate projection of project datum	GDA94_MGA56 or GDA2020_MGA56
6	Accepted format	Portable Document Format file	pdf
Example:		MR123456_GNSS_MC_201403_GDA94_MGA56.pdf MR123456_GNSS_CA_201403_GDA94_MGA56.pdf MR123456_GNSS_LP_201403_GDA94_MGA56.pdf	

Conventional Survey Traverse

There may be instances where the contractor may utilise conventional surveying methods to locate PRFMs or SPRFMs. The department requires the traverse reduction and adjustment reports to be supplied in ASCII text or PDF file format.

The Traverse Reduction and Adjustment Report files to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Traverse Reduction	TRRE
		Traverse Adjustment	TRAD
3	Date	YYYYMM	201403
4	Horizontal projection with appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56 or GDA2020_MGA56
5	Accepted format	Portable Document Format file	pdf
		ASCII text file	txt
Example:		MR123456_TRRE _201403_GDA94_MGA56.pdf MR123456_TRAD _201403_GDA94_MGA56.pdf	

Height Reduction

An average of two independent level runs are to be used to determine final heights on all marks placed by conventional surveying methods.

The department requires tabulated results of the two independent level runs showing:

- height datum
- each level run, and
- the average height adopted on each mark.

The Level Reduction Report file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Height Reductions	LVL
3	Date	YYYYMM	201403
4	Horizontal projection with appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	Portable Document Format file	pdf
		ASCII text file	txt
Example:		MR123456_LVL _201403_GDA94_MGA56.pdf	

Final Coordinates

The department requires final coordinates of the PRF and SPRF be supplied in 12d Model .12daz format as well as a comma separated or tabulated in a PDF file.

The Project Reference or Subsidiary Project Reference Frame files to be delivered shall have the following naming convention:

<table>
<tr><th colspan="2">Field</th><th>Explanation</th><th>Example</th></tr>
<tr><td>1</td><td>Fieldbook</td><td>The fieldbook number</td><td>MR123456</td></tr>
<tr><td>2</td><td>Description of deliverable</td><td>Subsidiary or Project Reference Frame Marks</td><td>PRFM</td></tr>
<tr><td>3</td><td>Date</td><td>YYYYMM</td><td>201403</td></tr>
<tr><td>4</td><td>Horizontal projection with appropriate zone number</td><td>Horizontal coordinate projection of project datum</td><td>GDA94_MGA56</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Accepted format</td><td>12d archive file</td><td>12daz</td></tr>
<tr><td>ASCII Comma Separated Text file</td><td>csv</td></tr>
<tr><td>Portable Document Format file</td><td>pdf</td></tr>
<tr><td colspan="3">Example:</td><td>MR123456_PRFM_201403_GDA94_MGA56.12daz
MR123456_PRFM_201403_GDA94_MGA56.csv
MR123456_SPRFM_201403_GDA94_MGA56.12daz
MR123456_SPRFM_201403_GDA94_MGA56.csv</td></tr>
</table>

Governance

The department has an obligation to help strengthen the State's Survey and Mapping Infrastructure.

All Form 6 and PSM Maintenance Forms shall be completed by the MLS contractor. These forms are to be compressed into a zipped folder and supplied to the department.

The Governance folder to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Governance	GOV
3	Date	YYYYMM	201403
4	Accepted format	Compressed Zipped file	zip
			rar
			7z
Example:		MR123456_GOV_201403.zip MR123456_GOV_201403.rar MR123456_GOV_201403.7z	

Ground Control Points

The MLS contractor may have to place Ground Control Points to assist in achieving high vertical and horizontal accuracies.

The department requires coordinates of the GCPs be supplied in 12d Model .12daz format as well as a csv file or tabulated in a PDF file.

The Ground Control Point file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Ground Control Target	GCT
3	Date	YYYYMM	201403
4	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
		ASCII Comma Separated Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_GCT_201403_GDA94_MGA56.12daz MR123456_GCT_201403_GDA94_MGA56.csv	

Common Control Point

The MLS contractor may have to place Common Control Point (CCP) to assist in seamlessly merging two independent collections of data (overlap).

The department requires coordinates of the CCP be supplied in 12d Model .12daz format as well as a csv file or tabulated in a PDF file.

The Common Control Point file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Common Control Point	CCT
3	Date	YYYYMM	201403
4	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
		ASCII Comma Separated Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_CCT_201403_GDA94_MGA56.12daz MR123456_CCT_201403_GDA94_MGA56.csv MR123456_CCT_201403_GDA94_MGA56.pdf	

Boresight Calibration

The department requires files containing all Boresight Calibration information.

The Boresight Calibration files to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Boresight Calibration	BORE
3	Boresight identifier	Number in sequence of boresights performed	1
			2
4	Date	YYYYMM	201403
5	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Portable Document Format file	pdf
	Example:	MR123456_BORE_2_201403_GDA94_MGA56.pdf	

Trajectory Strings

Knowing where the vehicle has travelled during capture may assist with identifying any issues with coverage or GNSS solution. The department requires a GNSS trace file of the vehicle's trajectory during capture.

These strings are to identify:

- the x, y, z position of the trajectory at the given epoch
- the flight number
- Pointcloud pass number trajectory relates to (LAS classification number if available)
- date captured
- start and end time
- Reference Station used to determine the position
- RSME value at each position's epoch, and
- PDOP at each epoch.

Each trajectory string shall be coded as NS and have a unique identifier which directly relates to the flight line number (e.g. NS09).

The Trajectory Strings file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Trajectory Strings	TRAJ
3	Flight Number	Flight / Pass number	1
4	Date	YYYYMM	201403
5	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Keyhole Markup Language file	kml or kmz
		12d archive file	12daz
		ASCII Comma Separated Text file	csv
		ESRI Shape File	shp
	Example:	MR123456_TRAJ_3_201403_GDA94_MGA56.12daz	

Geo-Referenced Imagery

Geo-Referenced Imagery shall be supplied in a file format agreeable to the department and as outlined in the project proposal. To date the accepted file format for geo-referenced spherical imagery is stream .PGR. All other imagery shall be supplied in .JPG format with an index to allow cross-referencing to a coordinate (as per Section 10 Imagery Capture).

Imagery shall be delivered on a per road basis with each individual road requiring a unique file identifier. All side roads shall be delivered as separate files with unique file identifiers.

Imagery shall at least meet the maximum specified 'Imagery photo-point capture intervals' in the *MLS Technical Guideline Checklist*.

Geo-Referenced Imagery – Spherical

All Geo-Referenced Imagery (Spherical) folders to be delivered shall have the following naming convention:

Field		Explanation	Example	
1	Fieldbook	The fieldbook number	MR123456	
2	Description of deliverable	Geo-Referenced Imagery	IMG	
3	Carriageway	State Controlled Roads carriageway identifier	Direction of Gazettal Chainage	2
			Against the direction of Gazettal Chainage	3
4	Date	YYYYMM	201403	
5	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56	
6	Accepted format	360 degree spherical imagery file (stream)	pgr	
Example:		MR123456_IMG_3_201403_GDA94_MGA56.pgr		

Geo-Referenced Imagery (Multi Camera)

All Geo-Referenced Imagery (Multi Camera) files to be delivered shall have the following naming convention:

<table>
<tr><th colspan="2">Field</th><th>Explanation</th><th colspan="2">Example</th></tr>
<tr><td>1</td><td>Fieldbook</td><td>The fieldbook number</td><td colspan="2">MR123456</td></tr>
<tr><td>2</td><td>Description of deliverable</td><td>Geo-Referenced Imagery (Multi Camera)</td><td colspan="2">IMG</td></tr>
<tr><td>3</td><td>Project Number</td><td>Contract number of the project</td><td colspan="2">TMRGT1310</td></tr>
<tr><td>4</td><td>Date</td><td>YYYYMM</td><td colspan="2">201403</td></tr>
<tr><td rowspan="4">5</td><td rowspan="4">Camera Identifier</td><td rowspan="4">Camera position on vehicle (See Figure 10)</td><td>Front Camera</td><td>1</td></tr>
<tr><td>Left Camera</td><td>2</td></tr>
<tr><td>Right Camera</td><td>3</td></tr>
<tr><td>Rear Camera</td><td>4</td></tr>
<tr><td>6</td><td>Easting</td><td>Easting of where image was taken</td><td colspan="2">488400</td></tr>
<tr><td>7</td><td>Northing</td><td>Northing of where image was taken</td><td colspan="2">6945950</td></tr>
<tr><td>8</td><td>Accepted format</td><td>Joint Photographic Expert Group file</td><td colspan="2">jpg
jpeg</td></tr>
<tr><td colspan="5">Example: MR123456_IMG_201403_GDA94_MGA56_1_488400_6945950.jpg</td></tr>
</table>

Vertical Longsections

The department requires separate files in .12daz format containing the QQ00 from the MCPPC (or PPC), and NS strings from Individual Pointclouds.

Vertical longsection QQ00 strings shall have a valid height no more than 10 m apart along the string and shall cover the entire length of the project including side roads.

The NS strings are to be an exact copy of the QQ00 strings but with the heights derived from the individual Pointclouds and identified by the pass number.

The Longsection file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Longsection	LONG
3	Date	YYYYMM	201403
4	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
	Example:	MR123456_LONG_201403_GDA94_MGA56.12daz	

Quality Assurance

To ensure that positional and relative accuracies have been achieved, the department requires quality assurance checks to be made on the data.

All Quality Assurance checks made throughout the project are to be delivered to the department as evidence of meeting required accuracies.

Survey and Relative Uncertainty

A 12d Archive file which consists both the horizontal (PQAP) and vertical (QQ strings) independently located in the field, is a mandatory deliverable requirement.

The QA file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Survey and Relative Uncertainty	QA
3	Date	YYYYMM	201403
4	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d Archive file	12daz
Example: MR123456_QA _201403_GDA94_MGA56.12daz			

Horizontal QA

The department requires a digital file tabulating the positional displacement and relative differences between clearly defined points surveyed in the field (PQAP) and the same clearly defined points in the Pointcloud.

The Horizontal QA file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Horizontal QA	QA
3	Type of check	Reference frame check	HZ
4	Date	YYYYMM	201403
5	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Excel Spreadsheet	xlsx
		ASCII Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_QA_HZ_201403_GDA94_MGA56.xlsx MR123456_QA_HZ_201403_GDA94_MGA56.csv MR123456_QA_HZ_201403_GDA94_MGA56.pdf	

Vertical QA

The department requires a file tabulating the positional and relative height differences between clearly defined points surveyed in the field (QQ strings) and the same clearly defined points in the Pointcloud. These QQ strings are to be located at check sites. The spacing of the check sites is outlined in the *MLS Technical Guide Checklist*.

The Vertical QA file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Vertical QA	QA
3	Type of check	Reference frame check	VT
4	Date	YYYYMM	201403
5	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Excel Spreadsheet	xlsx
		ASCII Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_QA_VT_201403_GDA94_MGA56.xlsx MR123456_QA_VT_201403_GDA94_MGA56.csv MR123456_QA_VT_201403_GDA94_MGA56.pdf	

Ground Control Targets

The department requires a digital file tabulating the positional displacements between the GCP surveyed in the field (PGCP) and the same clearly defined points in the Pointcloud.

The Ground Control Target file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Ground Control Targets	QA
3	Type of check	Ground Control Target	GCT
4	Date	YYYYMM	201403
5	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Excel Spreadsheet	xlsx
		ASCII Comma Separated Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_QA_GCT_201403_GDA94_MGA56.xlsx MR123456_QA_GCT_201403_GDA94_MGA56.csv MR123456_QA_GCT_201403_GDA94_MGA56.pdf	

Common Control Point

The department requires a digital file tabulating the positional displacements between the CCP surveyed in the field (PGCP) and the same clearly defined points in the Pointcloud.

The Ground Control Target file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Common Control Point	QA
3	Type of check	Common Control Target	CCT
4	Date	YYYYMM	201403
5	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Excel Spreadsheet	xlsx
		ASCII Comma Separated Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_QA_CCT_201403_GDA94_MGA56.xlsx MR123456_QA_CCT_201403_GDA94_MGA56.csv MR123456_QA_CCT_201403_GDA94_MGA56.pdf	

Ground and Feature Model

The department requires a digital file tabulating the vertical and positional displacements between the Horizontal and Vertical QA checks surveyed in the field (PQAP and QQ strings) and the Ground and Feature model.

Horizontal checks are to compare the position of features located in the field and the position of the same feature located as part of the GFM.

Vertical checks are to be compared to the TIN generated by the strings extracted to use as the surface definition for the project.

The Ground and Feature Model QA file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Ground and Feature Model	QA
3	Type of check	Ground and Feature	GFM
4	Date	YYYYMM	201403
5	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
6	Accepted format	Excel Spreadsheet	xlsx
		ASCII Comma Separated Text file	csv
		Portable Document Format file	pdf
	Example:	MR123456_QA_GFM_201403_GDA94_MGA56.xlsx MR123456_QA_GFM_201403_GDA94_MGA56.csv MR123456_QA_GFM_201403_GDA94_MGA56.pdf	

Pointclouds (PPC or MCPPC)

Tile Layout File

A tile layout file consisting of a series of closed polygons which represent the extent of each individual LAS file shall be delivered. The preferred format for these files are MapInfo .TAB file or 12d Model .12daz file formats.

The tile layout file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Tile Layout File	GRID
3	Date	YYYYMM	201403
4	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
		MapInfo TAB file	TAB
	Example:	MR123456_GRID_201403_GDA94_MGA56.12daz MR123456_GRID_201403_GDA94_MGA56.Tab	

Pointcloud Extents File

A single closed polygon representing the extents of the Pointcloud data within the tile layout is to be delivered.

The LAS extents file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Pointcloud Extents File	EXT
3	Date	YYYYMM	201403
4	Horizontal projection and appropriate zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
		MapInfo TAB file	TAB
	Example:	MR123456_EXT_201403_GDA94_MGA56.12daz MR123456_EXT_ 201403_GDA94_MGA56.Tab	

Pointcloud Files

Pointclouds should be blocked into individual 1 km tiles based on the MGA coordinate system. Tiles are not to exceed 4GB in size or contain more than 100 million points. Where a 1 km tile exceeds these parameters, this tile must be blocked into smaller individual square grid tiles.

All Pointcloud files shall be delivered in LAS format and to a precision of three decimal places in each point's easting, northing and height.

The version of LAS will be outlined in the *MLS Technical Guide Checklist*. All LAS files to be delivered shall have the following naming convention:

		Fieldbook_Type_ClassificationLevel_Date_Block where:
FieldBook -		the Fieldbook number e.g. MR102058
Type -		the type of file
		e.g. PPC for Project Pointcloud
Classification Level -		
	C0 -	None
	C1 -	Automated and Semi-Automated Classification
	C2 -	Ground Surface Improvement
	C3 -	Ground Correction
	C4 -	Detailed Classification and Correction
(Refer https://www.icsm.gov.au/sites/default/files/2017-03/LIDAR_Specifications_and_Tender.pdf)		
Date -		the date of capture / production in year / month format
		e.g. YYYYMM
Block -		DDDD_MGAZZ_EEEEEE_NNNNNNN where:-
DDDDDDD -		the Datum used
MGAZZ -		the MGA Zone number
EEEEEE		The easting coordinates of the south-west corner of the data grid block
1km tile		501000
500m tile		501500
50m tile		501550
NNNNNNN		The northing coordinate of the south-west corner of the data grid block
1km tile		6901000
500m tile		6901500
50m tile		6901550

The naming convention for these files is to be:

e.g. MR102058_PPC_C1_202102_GDA2020_MGA56_560000_6800000.las

Ground and Feature Model

The delivered Ground and Feature Model shall be coded according to the *TMR Surveying Standards* and in 12D Model .12daz file format unless otherwise stated in the project proposal.

The Ground and Feature Model file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Ground and Feature Model	GFM
3	Date	YYYYMM	201403
4	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	12d archive file	12daz
		Example:	MR123456_GFM_201403_GDA94_MGA56.12daz

Safety

The department has a responsibility to ensure safe work practices were used and adhered to throughout the duration of the project. The department requires copies of all signed safety forms from the MLS contractor.

This includes but limited to all:

- Safe Work Method Statements
- Risk Assessments
- Daily Pre-Start Meetings records, and
- any other safety document related to the project.

The safety documents are to be scanned and supplied as one digital file and shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Safety	SAFE
3	Date	YYYYMM	201403
4	Horizontal projection and relevant zone number	Horizontal coordinate projection of project datum	GDA94_MGA56
5	Accepted format	Portable Document File	pdf
Example:		MR123456_SAFE_201403_GDA94_MGA56.pdf	

Survey Report

The department requires a Survey Report to accompany each delivery stage of a project.

The Survey Report shall be signed by the person employed by the MLS contractor talking responsibility for the data. This person should be a Surveyor as defined in the *TMR Surveying Standards*.

The Survey Report shall address but not limited to the following:

- Scope
- Datum information
- Boresight Calibration details
- Issues during capture and how they were overcome
- Processing details of all data
- Ground and Feature Model extraction
- Issues during processing and how they were overcome
- Quality Assurance processes and results of accuracies achieved
- Deliverables, and
- Signed statement of required accuracies achieved by person taking responsibility for data.

The Survey Report file to be delivered shall have the following naming convention:

Field		Explanation	Example
1	Fieldbook	The fieldbook number	MR123456
2	Description of deliverable	Survey Report	SURV
3	Delivery Identifier	Stage of Delivery	ST1
			ST2
		Final	FIN
4	Date	YYYYMM	201403
5	Accepted format	Portable Document File	pdf
	Example:	MR123456_SURV_FIN_201403.pdf MR123456_SURV_ST2_201403.pdf MR123456_SURV_FIN_201403.pdf	