Elevation Data Product Specification and Description

Source:
Airborne Light Detecting and Ranging (LiDAR)

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1.0	06/03/2015	Brad Fulton	SME project board endorsed document
2.0	28/10/2020	Shawn Ryan and Craig Evans	GDA2020 product changes and DCS updates.

Contents

1. Introduction

This document describes the specifications and deliverables for airborne Light Detection and Ranging (LiDAR) surveys undertaken by DCS Spatial Services (SS).

The LiDAR survey produces a spatially accurate point cloud as the primary product. It may be classified or unclassified and captured at varying point densities and accuracies as described by the Inter-Governmental Committee on Surveying and Mapping (ICSM) Guidelines for Digital Elevation Data (2008). The derived product is a bare earth Digital Elevation Model (DEM).

2. Data Specification and Description

2.1. Point Density

The point density of a LiDAR dataset can vary depending on the purpose of the capture. It is a representation of the laser returns received within a 1x1m grid on a ground surface (e.g. 4pt/m2).

The point density of a tile defines its category level. Refer to **Section 2.6** for further information.

2.2. Accuracy

Vertical Accuracy is assessed by comparing LiDAR point returns against survey check points in bare open ground. It is calculated at the 95 per cent confidence level as a function of the vertical Root Mean Square Error (RMSE). This is undertaken after the standard relative adjustments of the point cloud have taken place. For example, flight line matching.

Horizontal accuracy is checked by comparing the LiDAR intensity data viewed as a Triangular Irregular Network (TIN) surface against existing imagery and known locations. The LiDAR data can be viewed as an intensity image to correctly identify common points. Refer to **Section 2.6** for further information.

2.3. Check Points

Check points are surveyed by connection to the local Survey Control Information Management System (SCIMS) with 'accurate' height (class LD/B or better). Where possible, levelled marks are used to establish the local Australian Height Datum (AHD) in preference to Global Positioning System (GPS) derived heights. Check points are distributed throughout the geographic extent of the LiDAR capture area and are used to provide a best fit by way of a block shift adjustment, or where necessary, a transformation to account for geoid anomalies.

2.4. Point Classification

The LiDAR product is the classified point cloud which contains all points measured during the flight. Initially, every point is allocated to the 'default' class. Automated algorithms and manual processes then attribute the points with a more meaningful classification, such as ground, vegetation, water, building or structures. Refer to **Appendix B** for the Standard Point Classifications.

2.5. Classification Levels

Point cloud information created will have a classification ranking. Refer to **Appendix C** for Spatial Services Classification levels defining completeness and effort.

2.6. Data Specifications

The table below identifies the positional requirements and accuracy associated with the three identified ICSM categories of LiDAR capture.

Feature	Category 1	Category 2	Category 3
General			
Horizontal Datum	GDA2020		
Vertical Datum (Orthometric)	AHD71		
Vertical Datum (Ellipsoidal)	GDA2020		
Projection	MGA Zones 54-57		
Geoid	AUSGeoid2020		
Metadata	ANZLIC Compliant		
Point density			
Point density	Minimum 1 point per square metre	Minimum 1 point per 4 square metre	Less than 1 point per 4 square metre
Accuracy			
Typical use	Modelling of inundation from floods or storm surges in areas of high value assets. Planning of large infrastructure projects	Modelling of inundation from floods or storm surges in areas with minimal infrastructure	Hydrological modelling of large catchment areas, preliminary route assessment and 3D modelling
ICSM Vertical Accuracy 95% confidence (1.96 x RMSE)	+/-0.30 metres on bare open ground (Category 2 & 3 data uses fewer check points to verify accuracy than Category 1 data)		
ICSM Horizontal Accuracy 95% confidence (1.73 x RMSE)	+/-0.80 metres on bare open ground		
Recommended Contour Interval	0.5 metre	1 metre	2 metres
Minimum Grid Cell Size (DEM)	1 metre	2 metres	5 metres
Maximum Tile Size	2km x 2km		
Check Points			
Number of Check Points	Minimum 1 point per 100km2 (equally distributed throughout the job extent).	Minimum 6 per 2500km2	
Check Point Vertical Accuracy	Direct connection to a local SCIMS mark with an accurate AHD height (Class LD/B or better)		
Check Point Horizontal Accuracy	Positional uncertainty better than 0.9m		
Note	*The classified point cloud is retained in ellipsoid height format to allow for future improvements in the vertical datum and accurate nesting of adjacent elevation data*		

3. Deliverables

The range of standard products listed below is designed in consideration for user functionality, storage space and production capacity - minimising redundancy and control costs whilst maintaining the potential to create alternate or value-added products as required.

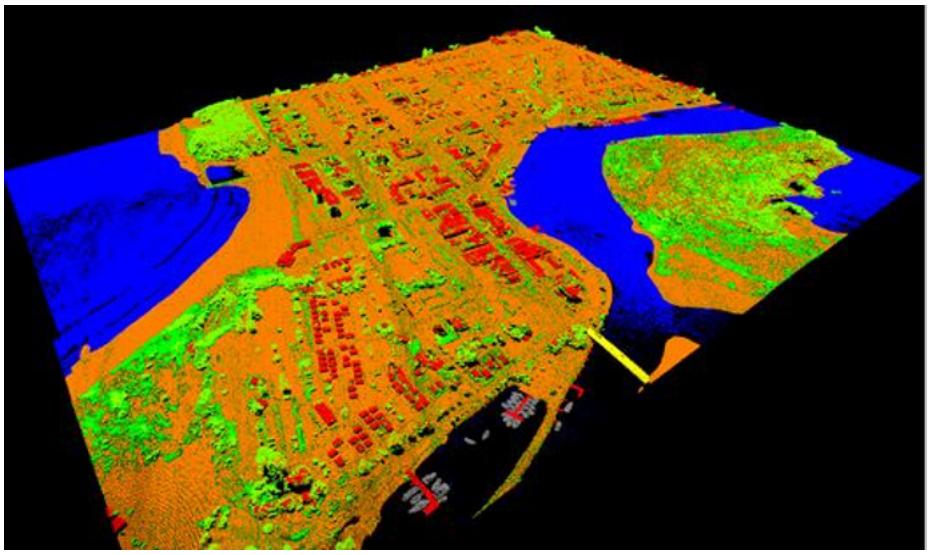
Product	File Format	Description	Category		
Primary Products			**1**	**2**	**3**
Classified Point Cloud	ASPRS LAS v1.4 (PDRF 6)	Attributed in accordance with designated classification level; 2km x 2km tiles	✔	✔	✔
Derived Products: Digital Elevation Models (DEMs)					
DEM	Cloud Optimised GeoTIFF	1 metre resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles	✔		
DEM	Cloud Optimised GeoTIFF	2 metres resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles		✔	
DEM	Cloud Optimised GeoTIFF	5 metres resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles			✔
Supporting Products					
Metadata	HTML	ANZLIC Compliant	✔	✔	✔

4. Product Details

4.1. Point Cloud

Point cloud data products apply to all capture categories. Every point captured is supplied within a 2x2 km tile in LAS 1.4 (PDRF 6) format. Points that are deemed 'overlap' are flagged as Overlap with their classification value retained. Ground points that are deemed 'key points' are flagged as Key Points with their classification value retained.

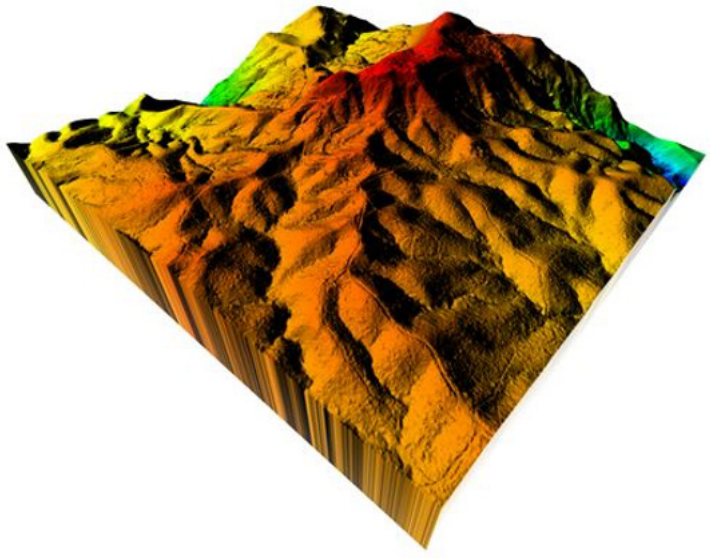
Refer to **Appendix A** for product known issues and anomalies. Refer to **Appendix B** for point cloud classification details.



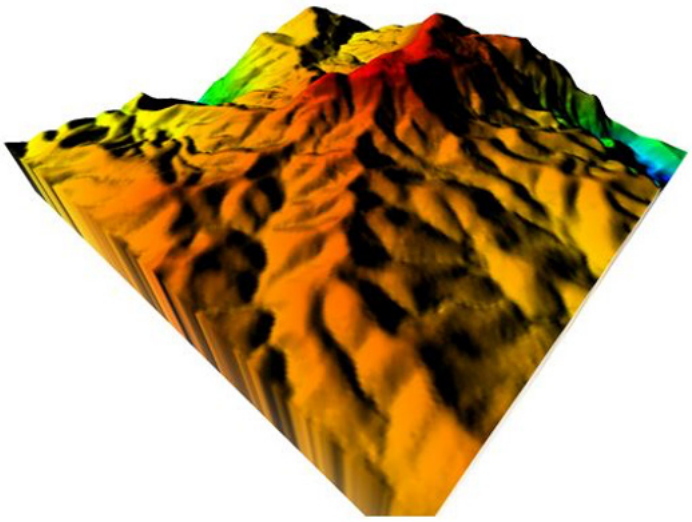
Level 3 classified point cloud

4.2. Digital Elevation Model (DEM)

The bare earth DEM is derived from point cloud data. The data is not hydrologically enforced (break lines) or hydrologically conditioned (identification and analysis of sinks). It is anticipated stakeholders will become involved in value-adding activities to produce other applications and specific products such as hydrologically sound data.



One metre bare earth digital elevation model



Five metre bare earth digital elevation model

4.3. Metadata

A single metadata statement (html) is provided for each tile.

4.4. Products Filename Convention

The table below is the filename convention used.

	Mapsheet Name	YYYY	MM-	SG#-	CL-	DAT_	eee	nnnn_	zz_	wwww_	hhhh	_res	_Metadata
	Mapsheet name	Year of capture	Month of capture	Sensor generated from (LID) followed by ICSM cat (1,2 or 3)	Classification level	Datum (ELL, AHD)	Easting value south-west corner of tile	Northing value south-west corner of data tile	Map grid zone	Tile width in whole kilometres	Tile height in whole kilometres	Resolution or posting in metres	Metadata
Product Type													
Point Cloud	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Example	Kempsey202004-LID1-C3-AHD_3106640_56_0002_0002.las												
DEM	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
Example	Kempsey202004-LID1-AHD_3106640_56_0002_0002_1m.tif												
LAS Metadata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Example	Kempsey202004-LID1-C3-AHD_3106640_56_0002_0002_Metadata.html												
DEM Metadata	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Example	Kempsey202004-LID1-AHD_3106640_56_0002_0002_1m_Metadata.html												

5. Appendix A

5.1. Product Known Issues and Anomalies

5.1.1. Anomaly: DEM Triangulation Interpolation (DEM)

Interpolation lines can be seen across the waterway in areas where the DEM is created using a triangulation process. Where ground points are not available during the TIN process across adjoining tiles holes may be present within a DEM.

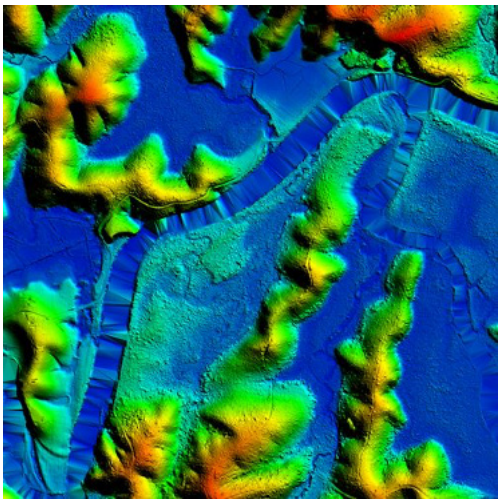


Image of triangulation issue in waterway

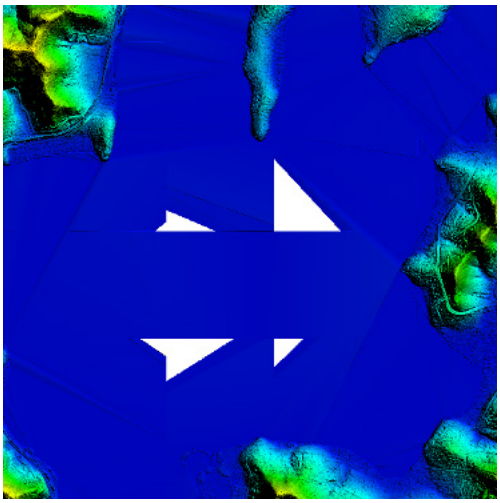
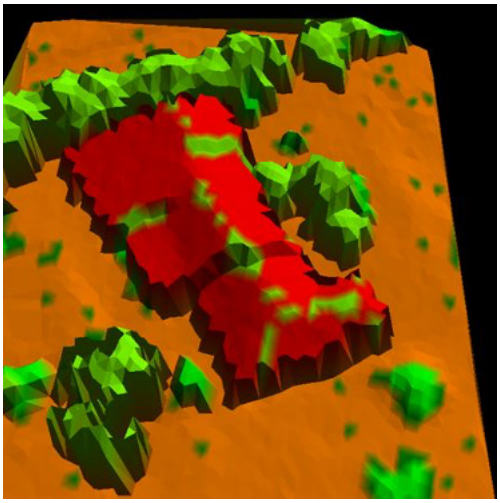


Image of missing data

5.1.2. Anomaly: Vegetation in Buildings (Point Cloud)

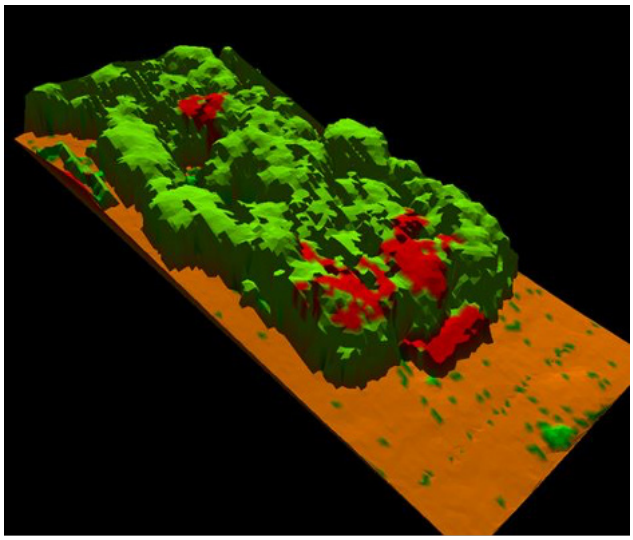
Parts of buildings may remain in a vegetation class after automatic classification, this is not rectified by manual C3 classification check.



Misclassified vegetation and buildings parts

5.1.3. Anomaly: Building Points in Vegetation (Point Cloud)

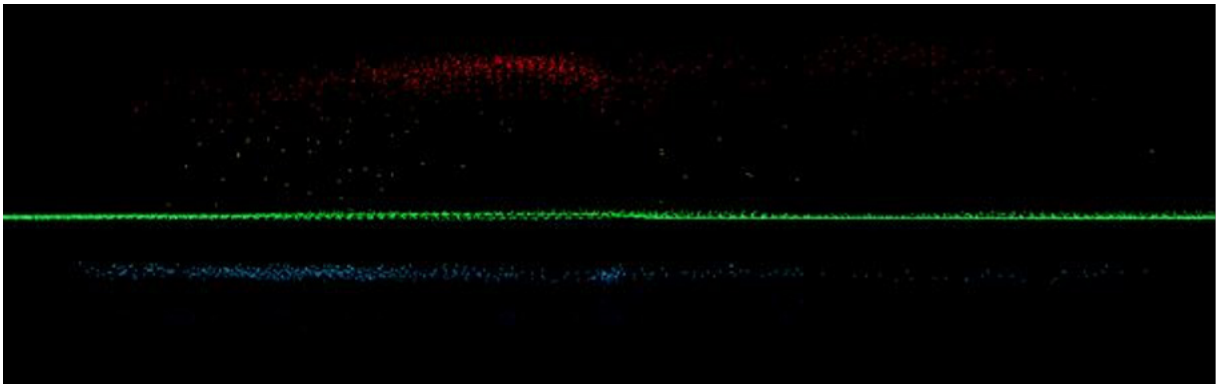
Linear surfaces in tree canopies may be classified as building due to the automated building classification process, this is not rectified by manual C3 classification check.



Misclassified vegetation and buildings parts

5.1.4. Anomaly: Spurious Points (Point Cloud)

Spurious points that may be present over water caused from the intense reflection of the laser along with excessive solar glare.



Depiction of excessive reflection error

6. Appendix B

6.1. Standard Point Cloud Classification

Standard Point Classes (derived from the LAS 1.4 specifications and ASPRS guidelines) are:

Number	Point class	Description
1	Unclassified	Unclassified
2	Ground	Bare ground
3	Low Vegetation	0 – 0.3m (essentially sensor 'noise')
4	Medium Vegetation	0.3 – 2m
5	High Vegetation	2m >
6	Building	Buildings, sheds, silos, wharfs, jetties etc.
7	Low Point/Noise	Spurious low point returns (not useable)
9	Water	Any point in water
17	Bridge Deck	Any bridge or overpass
18	High Point/Noise	Spurious high point returns (not usable)

6.2. Classification Flags

Classification flags are used to indicate special characteristics associated with the point. The bit definitions are:

Bit	Field Name	Description
1	Key-point	If set, this point is considered to be a model key-point and thus generally should not be withheld in a thinning algorithm.
3	Overlap	If set, this point is within the overlap region of two or more swaths or takes. If used, all points in the overlap region must have this bit set. Note that "primary" data in an overlap region may then be identified by using a combination of Point Source ID and Overlap bit.

7. Appendix C

7.1. Spatial Services Classification Levels

Level	Description
0	**Undefined** All points allocated classes 0 (unclassified) or 1 (default) by LiDAR processing software with no classification algorithms applied.
1	**Automated Classification** Data is subjected to automated algorithms which, as a minimum, will classify the points into classes 2 (ground), 3-5 (vegetation), 6 (building/structures) and 7 (low points and noise).
2	**Ground Anomaly Removal** Level 1 classified data is further enhanced by the removal of significant anomalies which remain in the ground class (2). Typically, this editing will re-classify points into class 7 (low points/noise) or class 18 (high points/ noise). The overall intent here is to create a ground surface suitable for orthorectification of imagery, with a minimum of effort.
3	**Manual Ground Correction** Significant (usually manual) effort is required here to ensure that only actual ground points are assigned class 2. Typically, this editing will both remove and add points to the ground class derived using the automated algorithms. Any points observed in water are to be re-classified into class 9, and other features which may require special attention include dense or low vegetation, rocky outcrops/boulders, contour/levee banks, wood/rubbish piles and islands. Ideally, to assist with the creation of hydrologically sound data, 'bridge-like' structures will be identified at this level and classified accordingly. This manual task is best undertaken with reference to associated imagery.
4	**Full Classification** All data is classified according the specified classes in Appendix B. Development of a hydrologically conditioned DEM will generally require this level of classification to properly identify buildings and other man-made structures which are likely to have an impact on water flow.

8. Appendix D

8.1. Glossary of Terms

Definitions are taken from ICSM National Elevation Guidelines where possible. Asterisk (*) indicates that the definition is derived from alternate sources.

Term	Definition
Accuracy	The closeness of an estimated (for example, measured or computed) value to a standard or accepted [true] value of a particular quantity. Note: Because the true value is not known, but only estimated, the accuracy of the measured quantity is also unknown. Therefore, accuracy of coordinate information can only be estimated
Artefacts	Buildings, trees, towers, telephone poles or other elevated features that should be removed when depicting a Digital Elevation Model (DEM) of the bare-earth terrain. Artefacts are not just limited to real features that need to be removed. They also include unintentional by-products of the production process, such as stripes in manually profiled DEM's. Any feature, whether man-made or system-made, that unintentionally exists in a digital elevation model
Australian Height Datum (AHD71)	Established in 1971 as a National datum for elevations based on observed mean sea level around the Australian coast line. Determined on the Australian mainland by an adjustment of a national levelling network constrained to mean sea level from continuous tidal observations over a period of 3 years at 30 tide gauges. AHD (Tasmania) was re-established in 1983 by adjusting the Tasmanian levelling network to mean sea level determined from one year of tidal observations at 2 tide gauges
Breakline	Linear features that describe a change in the smoothness or continuity of the surface
Check point	A point in the sample used to estimate the positional accuracy of the dataset against an independent source of higher accuracy
Classification*	Refers to the class membership of a LiDAR point return. All points begin as 'default', i.e. have no classification and are then allocated a meaningful value (i.e. ground, vegetation, building, etc.) by either automated or manual methods or a mix of both
Digital Elevation Model (DEM)*	Specifies elevations of the terrain (bare earth z-values) void of vegetation and manmade features. May incorporate a range of data models such as mass point, Triangular Irregular Network, grid or contours and may also include breaklines to better represent discontinuous features thereby improving the overall quality of the DEM
Elevation	Height above a specific vertical reference datum
Geocentric Datum of Australia 2020 (GDA2020)*	GDA2020 is defined by the International Terrestrial Reference Frame (ITRF) at epoch 1st January 2020
Hydrological/drainage enforcement	The removal of elevations from the tops of selected drainage structures (bridges and culverts) in a DEM, Triangular Irregular Network or topographic dataset to depict the terrain under those structures
ICSM	Inter-Governmental Committee on Surveying and Mapping

Intensity*	The intensity of the laser pulse return from the LiDAR instrument. This relates to the brightness of the object struck by the infrared laser pulse. It can generate an image which averages the intensity of all laser returns into a regular grid
Interpolation	The estimation of z-values at a point with x, y coordinates based on the known z-values of surrounding points
Key Points (model key points)*	Also referred to as 'thinned ground points'. A sample of the full (classified) point cloud representing bare earth elevations are flagged as Key Points. The point thinning factor is set during processing, with the accuracy of the flagged dataset within ±15cm of the full point cloud
LAS	A standard LiDAR file format, defined by the American Society of Photogrammetry and Remote Sensing (ASPRS). LAS defines, amongst other things, mandatory data fields and point categories. This includes mandatory metadata documentation. See full description at www.lasformat.org/
Light Detection and Ranging (LiDAR)	Light Detection and Ranging (LiDAR). A technology that determines distance to a surface using laser pulses. Distance is computed by measuring the time delay between transmission and detection of the reflected signal. Also referred to Airborne Laser Scanning (ALS) and Airborne Laser Bathymetry (ALB)
Overlap*	Refers to the common coverage between two overlapping flight runs in an aerial LiDAR survey. Overlapping points are removed (re-classified) during processing as points measured towards the extreme of the laser swath (in the case of an oscillating scanner) contain a large amount of data noise
Point Cloud*	Set of irregularly spaced points derived from LiDAR survey, each with an X, Y, Z value. Depending on the level of processing, points may also have a classification value, i.e. ground, vegetation, etc.
Point Density*	The number of points contained within a grid square of given size. Usually expressed as points per square metre, i.e. the number of points contained in a 1m x 1m grid
Primary Data	Elevation data that has been corrected using Global Positioning System and Inertial Measurement Unit data is calibrated against test points on the ground. Includes LiDAR returns in LAS format
Root Mean Square Error (RMSE)	The square root of the mean of squared errors for a sample
Survey Control Information Management System (SCIMS)	All datasets related to the Survey Control Network
Triangular Irregular Network (TIN)	A set of adjacent, non-overlapping triangles computed from irregularly spaced points with xyz coordinates. The data structure may be based on point, line and polygon data interpreted as mass points and breaklines. The TIN stores the topological relationship between triangles and their adjacent neighbours