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Developing Internal Data Quality Metrics for Lidar: A USGS-ASPRS Research Effort

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Outline

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  - Rigorous Calibration
- Concluding Remarks

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Introduction

- Lidar data have become the primary means of 3D mapping
- Quality standards transform Lidar point cloud from pretty visualization to metric data
- Quality control and assurance processes are not consistently applied
  - Does not mean current processes are incorrect
  - Inconsistent in reporting quality of calibration/boresight of Lidar system
- With large projects such as 3DEP on the anvil, consistent geometric quality assessment methods for procurement purposes needed

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ASPRS Lidar Cal/Val Working Group

- ASPRS Airborne Lidar Committee has formed a working group of:
  - Industry - Instrument Manufacturers, Data providers, and Data users
  - Government (USGS, NGS/NOAA, US Army corps, NGA, etc.)
  - Academia (Ohio State, University of Calgary, Purdue, etc.)
- Develop and publish guidelines on assessing geometric accuracy of Lidar data
  - Relative (Internal) Quality Control Processes and Report
  - Absolute (external) Quality Control Processes and Report
  - Recommended Quality Assurance Guidelines

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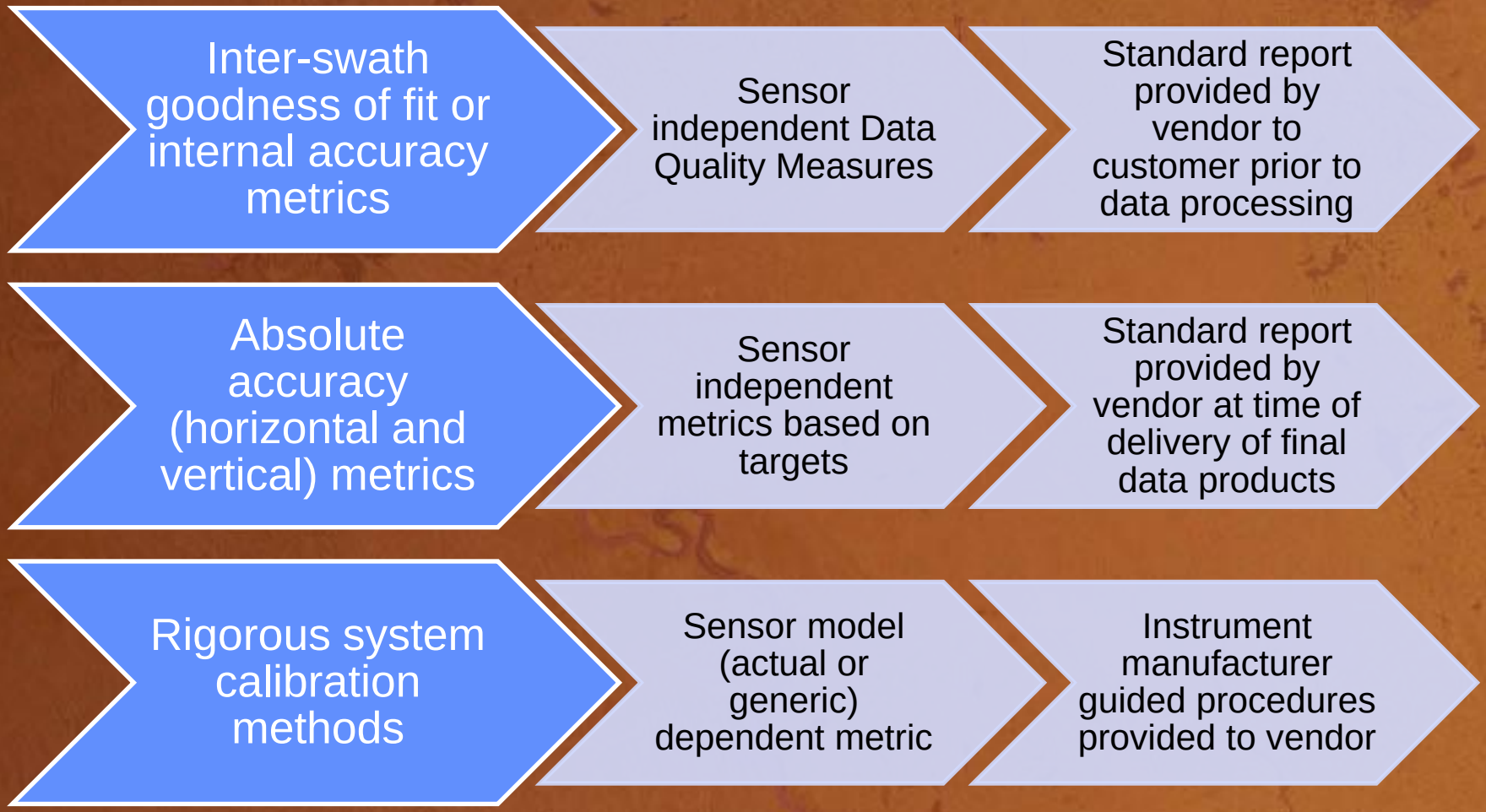
Framework for Guidelines Document



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Inter Swath Accuracy: DQMs

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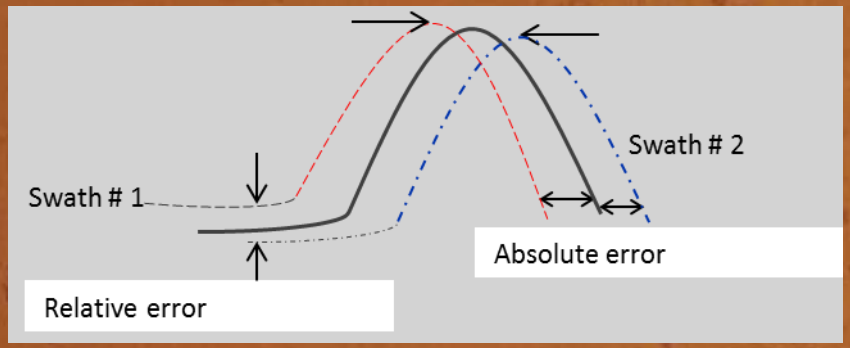
Inter Swath Accuracy: Why?

- Quality of calibration manifests most clearly in overlapping regions of adjacent swaths
- Importance of well calibrated instrument cannot be overstated
- A consistent quantifiable process to check the quality of calibration is needed
- DQMs quantify the inter-swath goodness of fit in a consistent manner



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Internal accuracy: DQMs

- Three Data Quality Measures to represent inter swath accuracy of data

Nature of surface	Examples	Data Quality Measures (DQMs)/Goodness of fit measures	Units
Natural surfaces	Ground surface, i.e. not trees, chimneys, electric lines etc.	Point to natural surface distance	Meters
		Point to surface vertical distance	Meters
Man-made surfaces	Roof planes	Centroid of one plane to the conjugate plane	Meters
	Roof edges	Centroid of one line segment to the conjugate line segment	Meters

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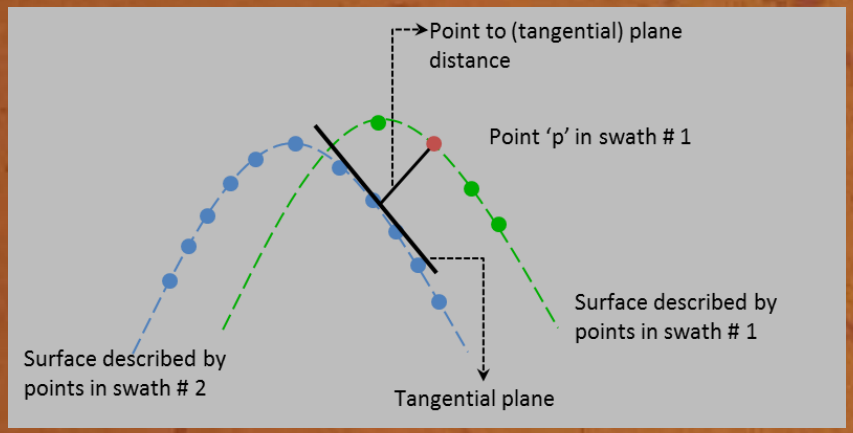
DQM over Natural Surfaces: Point to Tangential Plane Distance

- Ideally, conjugate features in both swaths should be coincident
  - Any departure from ideal is a measure of discrepancy
- Select a point from one swath and determine its neighbors in swath # 2.
- Fit a plane to the neighbor points
- Determine distance of point ‘p’ to this plane.



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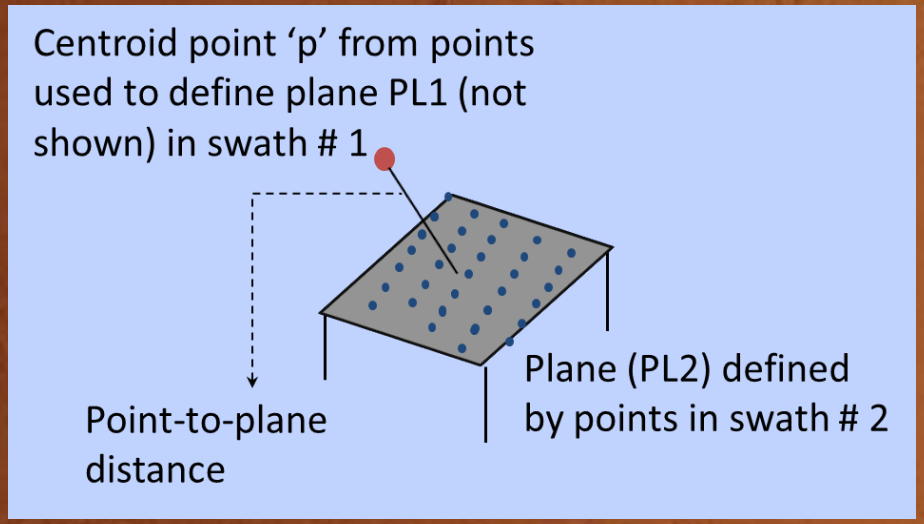
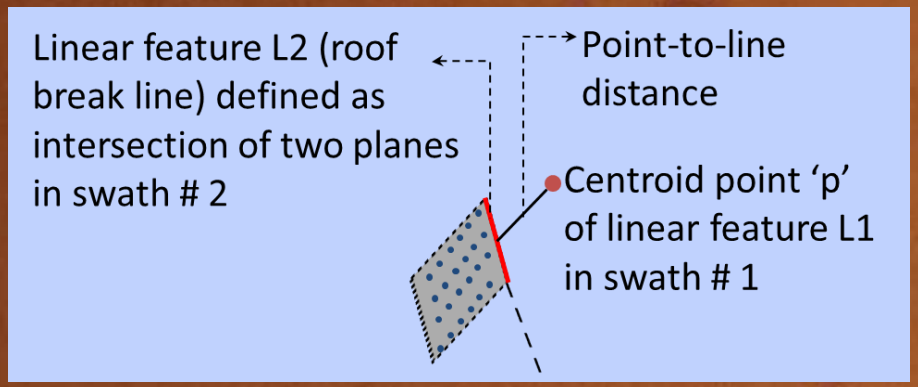
DQM over Man-Made Surfaces: Point to Planar and Linear Features Distance



DQM over planar surfaces: Man-made planar features (e.g. roof planes) can be extracted and used for measuring the inter-swath goodness of fit.



DQM over man-made linear features: Linear features (e.g. roof edges), can also be used for measuring discrepancy between adjacent swaths.

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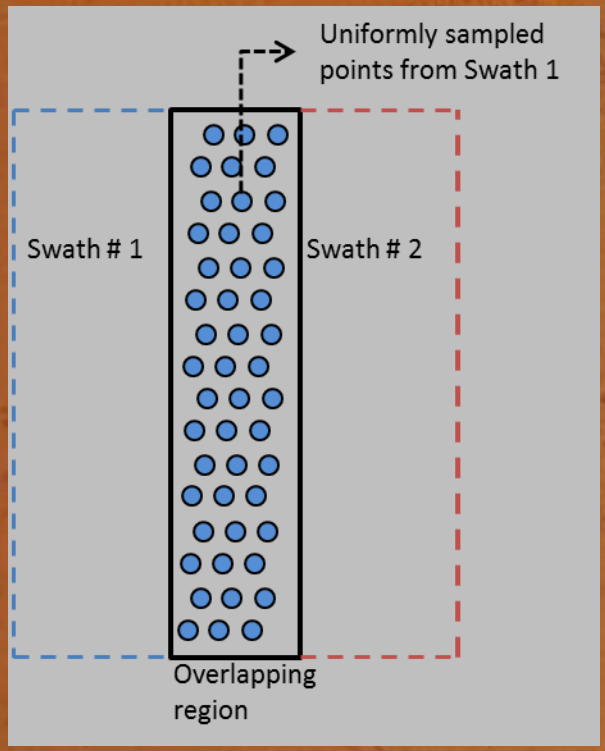
DQM over Natural Surfaces Research Software

- US Geological Survey has funded prototyping a research level implementation for the Working Group
- The prototype works on adjacent and multiple swaths
- Uniformly samples point in overlapping region
- Determines DQM for each sample



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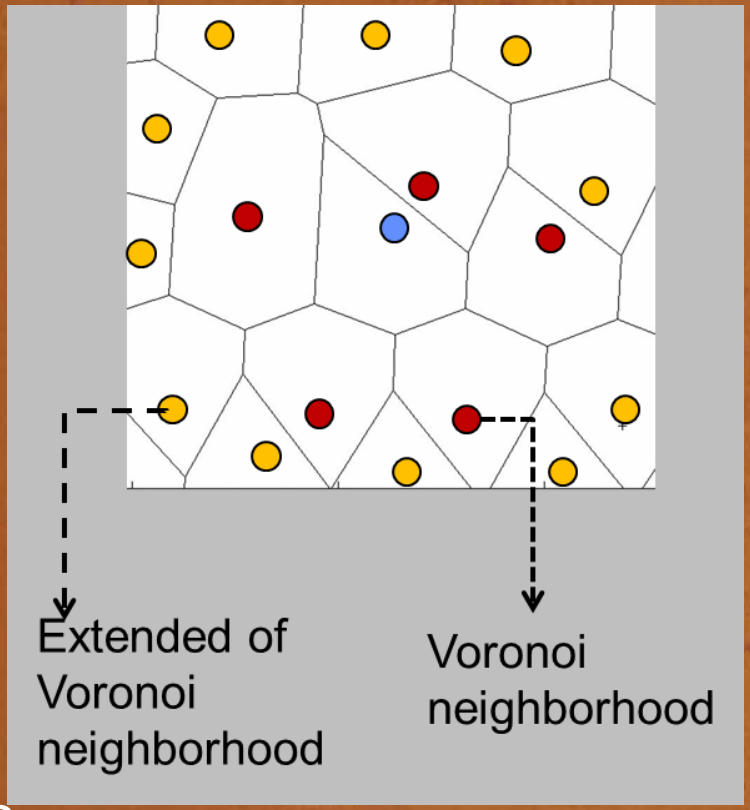
DQM over natural surfaces implementation

- Determine neighbors for each sample point
  - Voronoi Neighbors
  - Extended Voronoi neighbors
  - Nearest Neighbors
- Determine Planar parameters using Eigen analysis
  - Eigen values give RMSE of planar fit
  - Eigen vector give planar equation
  - Many linear algebra packages available (e.g. Eigen)
- Determine Point to Plane Distance
  - Displacement vectors, Normal vectors, etc.



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DQM Test Plan

- The goal of the testing process is to test the efficiency and validity of DQMs as indicators of the inter swath goodness of fit
- The Working Group recognizes that the DQMs are departure from practice
- A comprehensive test plan has been prepared and distributed to volunteer data providers
  - Currently, this tool is being tested on different data sets, collected under different conditions, instruments, and by different vendors
- Peer reviewed publication of results of test

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DQM Test Plan

- Data re-generated after errors are introduced to nominal boresight values
- Volunteer data providers distributed a table with three sets of errors to be introduced to the nominal parameter values
- The errors introduced to the boresight parameters vary depending on discussions with data providers

ΔX (m)	ΔY (m)	ΔZ (m)	Δω (seconds)	Δϕ (seconds)	Δκ (seconds)	Mirror angle scale (unit less)	Range errors (meters)
-0.13	0.7	.17	17”	-18”	72”	0.13	0.7
-0.15	-0.14	0.05	11”	106”	5”	0.15	-0.14
-0.04	0.07	0.08	71”	129”	66”	0.04	0.07

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DQM Test Plan

- The output generated will be analyzed to obtain summary estimates of errors in different data sets.
- Analysis will be followed with discussions with the ASPRS Cal/Val Working Group members on representing results
  - Geoscience Australia represents them as matrix.

RMSE	624	625	626	723	724	725
624		0.052512		0.088273	0.076865	0.057583
625	0.052512		0.041458	0.042303	0.057077	0.044703
626		0.041458		0.068512	0.040003	0.032112
723	0.088273	0.042303	0.068512		0.036485	
724	0.076865	0.057077	0.040003	0.036485		0.044831
725	0.057583	0.044703	0.032112		0.044831	

- Analysis will help correctly quantify the quality of data for procurement and scientific applications.

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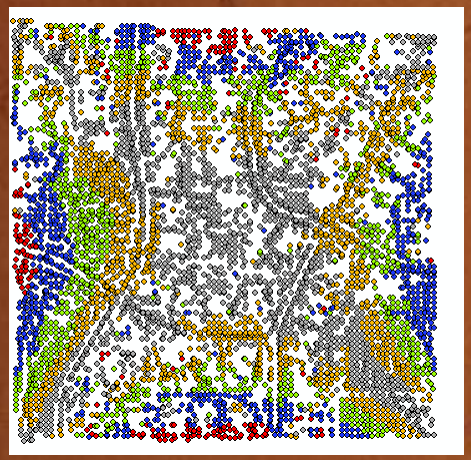
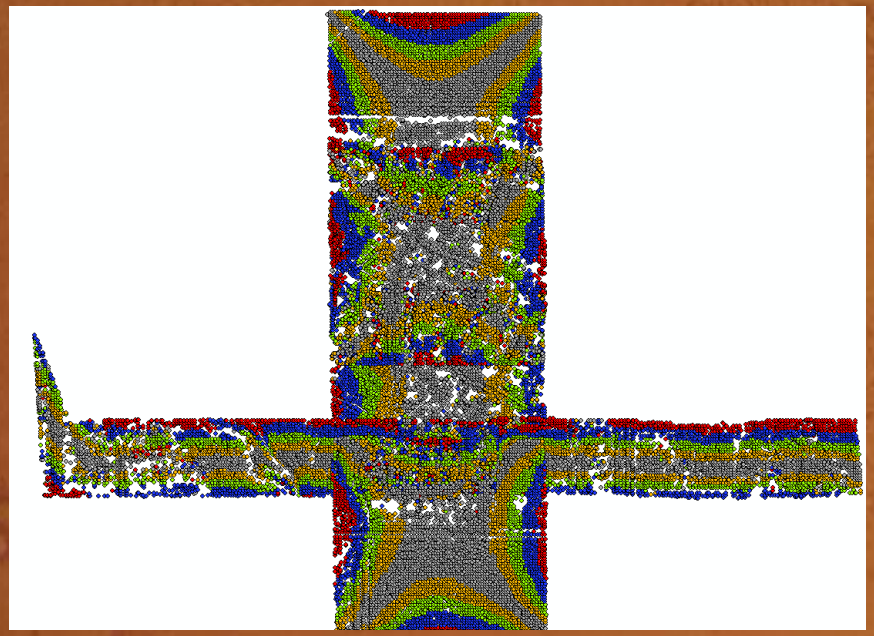
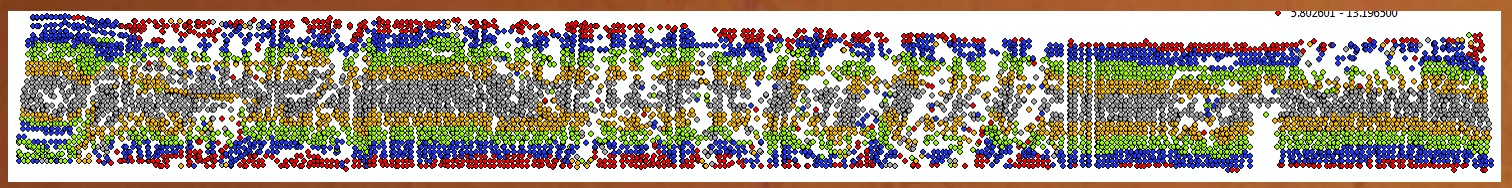
Some preliminary analysis

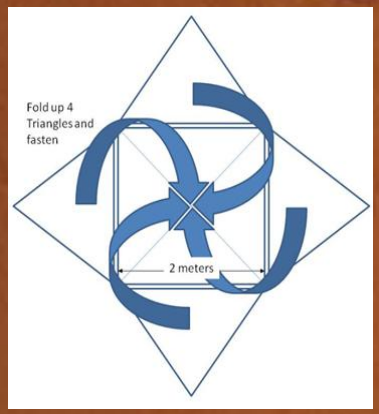


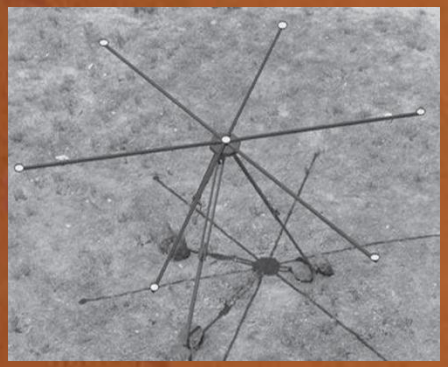




External Quality: Absolute Accuracy

- Targets are not new to the geospatial industry
- Used in conventional surveying, photogrammetry and also microwave/SAR based mapping.
- A few examples are shown





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Discussions on Rigorous Calibration

- Discussions have favored the use of rigorous sensor model based calibration approaches
- Rigorous calibration approach is robust and automated
  - Resulting data are consistent with each other and with external control.
- These approaches use proprietary sensor models
  - Software and procedures suggested by instrument manufacturers may be used for lidar system calibration
- Generic sensor model based calibration
  - ULEM, Semi Rigorous

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Concluding Remarks

- Prototype research software that implements DQMs has been developed.
- Currently, DQM algorithms are being tested and results analyzed by ASPRS volunteers.
- The ASPRS Guidelines on Geometric Quality of Lidar Data will incorporate the results of the analysis.
- It is expected that this USGS led ASPRS research will result in an across-the-board improvement in the quality of lidar data.
- The new DQMs will provide the geospatial community with the capability to procure and acquire lidar data of high and quantifiable accuracy.

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