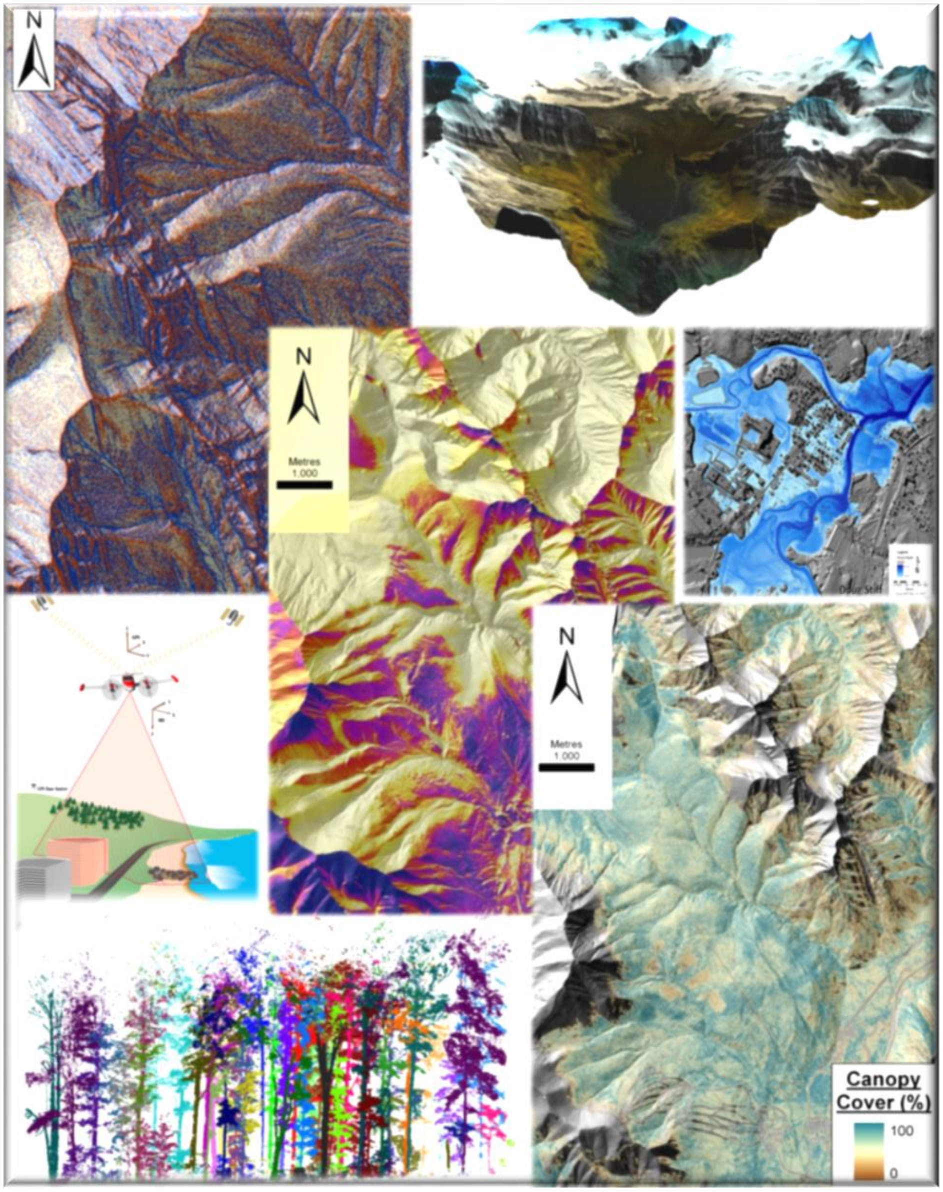
Alberta Airborne LiDAR stakeholder Forum & Questionnaire Report

Forum hosted at the University of Lethbridge, July 8th – 10th, 2013
Questionnaire posted online at www.surveymonkey.com from June to August, 2013



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Executive Summary

The report presents a summary of a questionnaire and a two day forum aimed at better understanding issues of high priority to airborne LiDAR stakeholders in Alberta and ways in which the use and value of LiDAR data holdings could be enhanced. From 62 questionnaire respondents, it was found that three market sectors dominate the Alberta LiDAR stakeholder community (natural resources, environment and energy) with the top three priorities being: i) access to and archival of LiDAR data; ii) development of new applications; and iii) efficient processing workflows. Almost all respondents indicated that they would consider the use of an online LiDAR data portal to support data access and management, while point cloud processing ranked most highly in terms of existing skill shortages and training needs. There was minor sectoral stratification apparent in some of the responses, with the most notable being that industry and government stakeholder groups both singled out error modeling and acquisition guidelines as high priority needs.

During the open discussions on day 2 of the forum, approximately 50 attendees discussed many topics under the headings of 'standards and best practices', 'data centres', 'LiDAR training and certification'. Due to the devastating floods that occurred in Alberta shortly prior to the forum, some discussion points referred the theme of using LiDAR to support flood risk mapping and visualisation. Consequently, this topic was given a dedicated section in the report. Across these four broad themes there were variable amounts of agreement amongst stakeholder groups.

In general, 'standards' was a divisive issue due to the perception that new standards create barriers to entry and stifle innovation. It was agreed, however, that better guidelines tailored to the needs of specific project objectives were necessary both to ensure clients got what they needed and so that service providers better understood that need. Recommendations were made for flexible and adaptable acquisition guideline templates with a decision criteria matrix to aid contract managers in the project specification process. Similarly, discussions were held around accuracy reporting and how desired data quality and accuracy should be related to project needs and not set arbitrarily high. Moreover, a suggestion was made that accuracy and quality attributes should be embedded in the mission planning process to optimise acquisition efficiency and so that service providers can demonstrate to users how a plan meets contract specification. Discussions on 'best practices' led to the most consensus amongst stakeholders. This could be because the three sectors canvassed have distinct areas of activity such that 'best practices' for one will not impact those for another, or because 'best practices' are intrinsically valued and everyone wishes to be on the same page when it comes to the best way to do something. It was clear that stakeholders viewed best practices more as guidelines to help optimise operational, processing or reporting workflows rather than as standards. Of all sectors, government users appeared most in need of best practice guidelines to support efficient data processing and analysis workflows in geosciences, natural resources, environment, policy and potentially permitting or regulatory mapping/site assessment activities.

As with 'standards', certifications was a divisive issue that received limited support, at least in so far as a dedicated LiDAR certification was concerned. The view that the community needs more training, education and outreach for LiDAR-related topics was unanimously supported, however. The concept of broad remote sensing, GIS or geomatics certifications at technical and professional levels that ensured recipients had an appreciation for LiDAR theory, applications and basic procedures was received more favourably. Indeed, such a model is analogous to the successful

American Society of Photogrammetry and Remote Sensing (ASPRS) certification program and could be adapted to be hosted by a Canadian society like the Canadian remote Sensing Society (CRSS).

The concept of developing a 'Data centre' was also generally supported across all stakeholder groups but for different reasons. Industry was cautiously supportive if it could provide a marketing mechanism for small scale high volume sales and as long as data services were embedded to allow end users the ability to create information online as well as access data. The government, academic and industry consultant sectors were supportive given current challenges in identifying what data exist where and then in accessing the data. A divisive element of the associated discussion was that of data licensing and ownership. There were no recommendations to change current models of data licensing, as it became clear overall that the models have successfully transferred large volumes of data from the private sector to the public sector and this is generally seen as beneficial despite licensing restrictions. Nonetheless, it was clear that any data centre serving the needs of Albertans would need to accommodate data licensing models and ensure data security. Overall, it was felt there was a business case for a LiDAR data centre in Alberta (if not Canada) and that it would be most effectively led by industry with arm's length government and academic partnerships to ensure end user needs are considered and to leverage the R&D capabilities of universities.

The topic of LiDAR in support of flood mapping came up several times. For example, it was noted that if a data centre were to embed online services, one such service could be the visualisation of flood water levels and associated recurrence probabilities across areas of interest on the landscape (The National Oceanographic Atmospheric Administration - NOAA - have such an online application for coastal regions around the US: http://www.csc.noaa.gov/slr/viewer/#). Flood risk mapping also came up in terms of being an example where existing engineering survey 'standards' can stifle innovation and progress. Specifically, in the case where contract specifications have precluded the use of LiDAR to support floodplain risk assessments even though such applications of LiDAR have been common practice for several years in parts of the world where such standards have not been a barrier (e.g. the FEMA Flood Insurance Program in the USA). The topic was also discussed as a possible example of a demonstration project between industry, academia and government to illustrate how flood risk modeling / mapping can be aided by LiDAR in the Alberta context.

It was generally felt that all three sectors needed to be engaged in any initiatives towards developing guidelines, best practices, standards, certification, data centres and educational pathways. Indeed, all topics overlap so it is suggested that they be considered in terms of a holistic and organic model of interrelated community needs with varying and sometimes conflicting priorities amongst stakeholder groups. One direct approach is through the development of government needs-driven and research-based projects that aim to develop best practices and guidelines though academic and industry partnerships. Such projects could tackle questions related to application needs but the point is to keep the higher-level integrative needs as an explicit objective. Such projects act as effective training, educational and outreach pathways for students, employees and decision makers. At a strategic level, an impartial institutional entity is needed to provide some oversight to the activities. In terms of generic certifications, it was suggested that the Canadian Remote Sensing Society could play an oversight role. Both government and industry stakeholders held the view that universities should play an oversight role on several of the topics raised. While there are several university experts in Alberta, there is no institutional entity that links them under a common goal of addressing LiDAR stakeholder needs. A recommendation of this report is that such an entity be created. Possible pathways might be through groups like the

Canadian Remote Sensing Society or the Canadian Institute of Geomatics, or using the Campus Alberta Innovates Program model.

Introduction

Alberta has the largest aerial coverage of airborne LiDAR of any province in Canada. The private sector and the provincial government have proactively engaged the technology to support a range of applications in the engineering, environmental, energy and natural resources sectors. The objective of the University of Lethbridge Stakeholder Forum on July 8th and 9th was to explore ways in which the value of airborne LiDAR data holdings could be enhanced for public, private and academic sector stakeholders. Best practices for data processing, portability, archival, reporting, and training were discussed. Following the two-day Forum, was a field trip hosted by Optech Inc. to observe real time data collection and processing of a terrestrial last scanner (ILRIS LR) over the Frank Slide, Alberta. On July 11th and 12th, Drs Hopkinson (U Lethbridge) and Isenburg (rapidlasso GmbH) hosted a two-day hands on workshop to showcase some LiDAR point cloud processing tools.

On day 1 of the University of Lethbridge LiDAR Stakeholder Forum, fourteen experts from a cross section of the LiDAR community gave talks highlighting their activities and perspectives related to contemporary LiDAR operations and applications. The purpose behind hosting such a broad spectrum of talks, was to provide participants a well-rounded context for the panel and breakout discussions on day 2. Following introductory remarks concerning the University of Lethbridge's strategic interest in fostering greater connectivity with the LiDAR stakeholder community from David Hill, Director Centres and Institutes, industry, academic and government speakers presented on the following topics: a brief introduction to LiDAR (Hopkinson, U Lethbridge); new hardware technology developments (Leslar, Optech; Kadatskiy, Riegl); LiDAR operations to support commercial, academic and national monitoring objectives (Maric, Airborne One; Niemann, U Victoria; Ramond, NEON); new efficient data processing/analysis tools (Isenburg, rapidlasso); Research into error modeling, error mapping, and data fusion classifications (Goulden, Dalhousie U; Adda, U New Brunswick; Chasmer, U Lethbridge); Govt Alberta activities and perspectives (White and Patterson, Alberta Environment and Sustainable Resource Development); Federal Govt LiDAR guidelines initiative (Lamothe and Jansen, Natural Resources Canada). Most of the talks can downloaded here:

http://scholar.ulethbridge.ca/hopkinson/announcements/lidar-forum-presentations

A *Survey Monkey* online questionnaire was used to collect registration information for participants of the Forum. In addition, basic demographic and perceptual data were collected to guide some of the discussion points at the Forum. The questionnaire was designed for and distributed primarily to stakeholders in Alberta, Canada but responses were also solicited from a small number of colleagues in the US and UK. Approximately, 70 LiDAR community stakeholders from a range of sectors and experience levels were personally invited to the workshop and to participate in the survey. In total there were 62 responses, with 44 of these coming from the invited respondents and the rest from forwarded emails or the workshop website (http://www.uleth.ca/artsci/lidar). From the 62 respondents, 51 registered to participate in the actual workshop. Ultimately, the flooding that occurred in Alberta in June, 2013 meant some of the registered participants had to cancel (mainly from the Alberta Government). Over the course of the two day Stakeholder Forum, 46 people participated in presentations and group discussions.

The report is divided into two sections: the first presenting a summary of the questionnaire results and the second a summary of the discussion points raised at the forum. The actual questionnaire results are provided in complete and filtered form as a series of pdf attachments. The summary discussion points in part 2 have been compiled from notes collected in real time by Chris Hopkinson, Laura Chasmer (both U Lethbridge) and Nathan Ballard (Govt Alberta). Laura's and Nathan's notes are included at the end as appendices to the main report.

Presentation materials from the Stakeholder Forum and detailed results of the questionnaire are available online at:

http://scholar.ulethbridge.ca/hopkinson/announcements

The original forum agenda and web site are available online (for now) at:

http://www.uleth.ca/artsci/lidar

Part 1: Questionnaire Results

The questionnaire was divided into two sections containing the following questions:

Section 1 (demographics):

1. Will you be attending the University of Lethbridge LiDAR stakeholder forum July 8th & 9th?
2. Please provide your contact details
3. Level of LiDAR experience: None, Novice, Proficient or Expert
4. Sector: Academia, Industry, Government or Other
5. Within which market sector/s or application area/s do you mostly work: Environment, Natural Resources, Emergency Management, Energy, Civil Engineering, Architecture, Planning, Education/training, Other
6. Which type of LiDAR technology or data do you use: None, Airborne (area mapping), Airborne (corridor), Airborne (bathymetric), Mobile, Ground-based, Other
7. Which of the following best describe your LiDAR stakeholder role: Hardware design / manufacture, System sales, Data collection service, Data processing service, End user analysis / modeling, Data purchasing, Policy / guidelines, Other

Section 2 (perspectives):

8. Based on your needs and experience, please prioritize the list below in order of highest (1) to lowest (9 or N/A) importance: Training & certification, RFP/RFQ guidelines, Efficient processing workflows, Error modeling/reporting, Application development, Data access / archival, Data acquisition guidelines, Data delivery reporting
9. Would you consider using an online LiDAR data repository to host, share or manage your data: Yes, No, maybe, N/A
10. In which area/s of your LiDAR workflow are training opportunities most needed? Highest (1), Lowest (8 or N/A): Applications, Sensor operations/processing, Data fusion, Mission planning, Point cloud processing, Raster / GIS modeling, LiDAR theory, Project archival / data management

Results for the above questions (minus attendance and contact details) are summarised after applying the following filters:

1. No filter, all data are summarised (Table 1)
2. By Industry sector (Table 2)
3. By Academic sector (Table 3)
4. By Government sector (Table 4)
5. High proficiency level (proficient or expert) (Table 5)
6. Low proficiency level (novice or no experience) (Table 6)

Question:	Rank		
	1st	**2nd**	**3rd**
3. Experience	Novice (26)	Expert (16)	Proficient (11)
4. Sector	Academia (20)	Industry (19)	Govt (18)
5. Market	Nat Resources (47)	Environment (42)	Energy (16)
6. Technology	Airborne (area) (49)	Airborne (corridor) (19)	None (12)
7. Role	End user (37)	Data proc. Service (26)	Data collection (17)
8. Importance	Data access/archive	New applications	Efficient processing
9. Online data	Yes (29)	Maybe (24)	N/A (8)
10. Training need	Point cloud proc.	Applications	Raster/GIS modeling

Table 1. Summary responses for all data (out of 62 responses, no filter). Only top 3 responses reported

Question:	Rank		
	1st	**2nd**	**3rd**
3. Experience	Expert (9)	Proficient (5)	Novice (4)
5. Market	Nat Resources (14)	Environment (13)	Energy (13)
6. Technology	Airborne (area) (16)	Airborne (corridor) (10)	Mobile (7)
7. Role	Data proc. Service (13)	Data collection (10)	End user (8)
8. Importance	Acquisition guidelines	Efficient processing	Error modeling
9. Online data	Yes (8)	Maybe (8)	No (1)
10. Training need	Point cloud proc.	Sensor ops/proc.	Applications

Table 2. Summary responses for Industry sector data (out of 19 responses). Only top 3 responses reported. Highlighted fields signify trends that are distinct to the Industry sector when compared to all data.

Question:	Rank		
	1st	**2nd**	**3rd**
3. Experience	Novice (9)	Expert (4)	None (4)
5. Market	Environment (17)	Nat Resources (14)	Education (10)
6. Technology	Airborne (area) (13)	None (7)	Airborne (corridor) (4)
7. Role	End user (15)	Data proc. Service (7)	Data collection (4)
8. Importance	New applications	Efficient processing	Data access/archive
9. Online data	Yes (11)	Maybe (7)	N/A (2)
10. Training need	Point cloud proc.	Applications	Data fusion

Table 3. Summary responses for Academic sector data (out of 20 responses). Only top 3 responses reported. Highlighted fields signify trends that are distinct to the Academic sector when compared to all data.

Question:	Rank		
	1st	2nd	3rd
3. Experience	Novice (10)	Proficient (3)	None (3)
5. Market	Nat Resources (17)	Environment (9)	Emergency mgmt. (3)
6. Technology	Airborne (area) (17)	Airborne (corridor) (4)	None (2)
7. Role	End user (13)	Policy/guidelines (7)	Data proc. Service (5)
8. Importance	Data access/archive	Acquisition guidelines	Error modeling
9. Online data	Yes (8)	Maybe (7)	N/A (3)
10. Training need	Raster/GIS modeling	Point cloud proc.	Applications

Table 4. Summary responses for Government sector data (out of 18 responses). Only top 3 responses reported. Highlighted fields signify trends that are distinct to the Government sector when compared to all data.

Question:	Rank		
	1st	2nd	3rd
3. Experience	Expert (16)	Proficient (11)	
4. Sector	Industry (14)	Academia (7)	Govt (5)
5. Market	Nat Resources (24)	Environment (18)	Energy (13)
6. Technology	Airborne (area) (27)	Airborne (corridor) (15)	Ground (9)
7. Role	Data proc. Service (17)	End user (16)	Data collection (15)
8. Importance	Error modeling	Acquisition guidelines	Efficient processing
9. Online data	Maybe (13)	Yes (11)	N/A (1)
10. Training need	Point cloud proc.	Applications	Data fusion

Table 5. Summary responses for Proficient/Expert category (out of 27 responses). Only top 3 responses reported. Highlighted fields signify trends that are distinct to the Proficient/Expert category when compared to all data.

Question:	Rank		
	1st	2nd	3rd
3. Experience	Novice (26)	None (9)	
4. Sector	Academia (13)	Govt (13)	Industry (5)
5. Market	Environment (24)	Nat Resources (23)	Education (6)
6. Technology	Airborne (area) (22)	None (11)	Airborne (corridor) (4)
7. Role	End user (21)	Data proc. Service (5)	Policy/guidelines (7)
8. Importance	Data access/archive	New applications	Efficient processing

9. Online data	Yes (18)	Maybe (11)	N/A (5)
10. Training need	Raster/GIS modeling	Point cloud proc.	Applications

Table 6. Summary responses for Novice/No experience category (out of 35 responses). Only top 3 responses reported. Highlighted fields signify trends that are distinct to the Novice/No experience category when compared to all data.

From the stakeholder demographic data collected from all 62 questionnaires presented in Table 1 we find 85% stakeholder respondents were at least novice LiDAR users with some experience working with LiDAR data. An attempt to distribute the questionnaires to a balanced cross section of stakeholders from academia, industry and government is reflected in the numbers of responses from each stakeholder sector: 20, 19 and 18, respectively. The three market sectors that appear to dominate in the Alberta LiDAR stakeholder community are natural resources, environment and energy. This is almost certainly a function of Alberta's geographic situation and economic reliance on oil, gas and forest resources plus the environmental cleanup and monitoring following resource extraction activities. LiDAR DEMs and derivative point cloud products have proven valuable across a broad spectrum of resource inventory, site selection and land surface classification needs to support associated industry planning / operations and regulatory activities. The majority of stakeholders (79%) indicated that they worked with airborne area-based LiDAR mapping, while a much smaller proportion, 30%, also worked in some capacity with airborne corridor data. In third place, 19% of stakeholders indicated that they did not actually work with any LiDAR data; rather their activities would be more strategic / management level or they were very new to the community. 60% of respondents considered themselves end users of LiDAR data or data products while 42% and 27% considered themselves providers of LiDAR processing or collection services, respectively (note: numbers add up to >100% because many stakeholders play dual roles).

In the perception-based data captured from all stakeholder respondents in table 1, we find that the highest priority across the community is effective access to and archival of LiDAR data, with the development of new applications and efficient processing workflows being close second and third priorities. In response to the question whether or not stakeholders would use an online data repository for hosting, sharing and managing data if available, 48% stated yes, 40% maybe while 10% considered the question not applicable to their situation. Only one person stated that they would not use an online data repository if available. Overall, this is a highly affirmative response that indicates a need or an opportunity to develop some kind of online LiDAR library or data warehouse for Albertan LiDAR stakeholders. In answering the question about training, respondents ranked point cloud processing as the area needing most attention, with general applications and Raster / GIS modeling close second and third priorities, respectively.

When filtering the responses according to the three stakeholder sectors, we see generally the same overall response patterns. There are some notable exceptions, however. Of the three stakeholder sectors, it is clear that the industry respondents were the most proficient or experienced with academics second and government respondents third. In terms of market activity, industry respondents were no different from the overall group response but academics and government respondents replaced energy with, respectively, education / training and emergency management as being highly ranked activities in their community. Given the academic objective to teach and the government mandate to serve / protect societal needs, these distinctions are important but unsurprising. The only notable difference in terms of LiDAR technology used across the sectors canvassed, we see that 37% of industry respondents also work with mobile LiDAR technology as well as airborne. Mobile LiDAR is relatively new compared to airborne and it is still in relative infancy with regards to applications and workflow development. Consequently, academic and public sector adoption in this region is behind that of industry. The top three ranking roles that stakeholders play tend to be as end users or as data service providers in some capacity. While rankings differ across sectors (with industry tending towards service provision while academics and government tending towards end users) we see that in the government sector data collection is not ranked highly but policy and guidelines development is. This appears to reflect the public sector need and activity surrounding the development of best practices, RFP (request for proposals) and contract specifications.

Stakeholder perceptions of priority issues demonstrate some interesting differences with sector. The academic sector holds the same three issues of data access / archival, new application development and efficient data processing, as does the wider community. However, industry and government both place the need for acquisition guidelines and error modeling as high ranking priorities. This difference appears to reflect the more applied or operational and contractual aspect of LiDAR data use in industry and government, whereas academics tend to be more concerned with the creation of new knowledge. It is also interesting that the government sector ranks data access / archival as the number one priority whereas as this does not rank highly in industry; instead the development of efficient data processing workflows being ranked more highly. This is perhaps unsurprising, as industry is usually well equipped to handle and store the data they collect, with their primary goal being to move data to clients and do this quickly, accurately and efficiently. There are no notable differences across sectors when it comes to the willingness to use an online data repository if one existed. All sectors responded favourably. Training needs did not differ widely across sectors with all sectors agreeing that point cloud processing and general applications being important. The notable deviation was that in place of raster / GIS modeling, industry ranked operational training (sensor use and processing) more highly. Again, this is unsurprising given industry practitioners are the ones typically doing the sensor installations / calibrations, data collection and processing.

As with the results filtered by sector, the proficiency-filtered responses display little variation from the overall trends. Notable observations are the ground-based LiDAR becomes a high ranking technology used by expert and more proficient LiDAR stakeholders but less so by novices. As with industry and government responses, we see that error modeling and acquisition guidelines are considered highly important to expert stakeholders yet are a low priority for those newer to and less familiar with the community and data use. The 'Education' market and 'policy / guidelines' stakeholder role show up as characteristics of the low proficiency level due to the high number of students and government managers (as opposed to users) in this stratification of the data.

More detailed results from the online survey monkey questionnaire for each of the stratifications presented above are available online in PDF report form at:

http://scholar.ulethbridge.ca/hopkinson/announcements/LiDAR_Forum_Report

Part 2: Open forum discussion sessions

The interactive sessions held on day 2 of the forum were divided into two expert panel discussions and two breakout periods. The objective of the interactive discussions was to open a dialogue on some of the 'hot topics' in the LiDAR stakeholder community and gain some appreciation for how perceptions vary across sectors. In the first panel discussion expert stakeholders from Govt Alberta (White), Govt Canada (Lamothe), service provider industry (Parent), software development sector (Isenburg) and National monitoring operations sector (Ramond) provided some initial thoughts on the needs for data and reporting standards. After each expert presented their views, an open discussion followed. Immediately following the expert panel session was a breakout to address the related topic of sectoral needs for best practices and guidelines. After lunch, an interactive panel discussion ensued on the need for LiDAR data centres that could host, serve, manage LiDAR data and potentially provide online data processing and analysis services. The panelists represented a cross section of stakeholder groups from Govt Alberta (Patterson), Govt Canada (Lamothe), service provider industry (Parent), Academia (Niemann), and the geospatial consulting sector (MacArthur).

The final session of the day was a breakout discussion on the needs for training and certification of LiDAR users and practitioners. Due to the Alberta floods of June 2013 and the realisation in the participant group that flood modeling and mapping was instrumental to the rapid growth of the global LiDAR industry in the late 1990s and early 2000s, it was decided to set aside some time to discussing this topic, also.

The following sub-sections present a summary of the most important discussion points raised in the open forum and are divided according to the primary themes of: Standards and best practices; Data centres; Training and certification; and Flood mapping / modeling. These subsections are further subdivided into industry, academic and government sectoral perspectives, with a general overview at the end. More detailed bullet form notes that were recorded during the actual talks and discussion sessions by Dr. Laura Chasmer (U Lethbridge) and Nathan Ballard (Govt Alberta), are provided at the end of the report as appendices. It is important to clarify that the notes made and the summaries provided here reflect the comments and opinions of some people made in the short time available at the forum. Consequently, the text that follows is not a comprehensive or in depth review either of the topics or the associated stakeholder perceptions.

Standards & best practices

Industry perspectives

While 'standards' in the strictest sense still do not exist for LiDAR systems, acquisition, reporting, data processing, error assessment, there are many guidelines and proposal templates being developed by various agencies to meet their own needs. These guidelines and templates are much more stringent than in the past and reflect the maturation of the community both on the service / hardware and on the end user sides of the stakeholder community. In general, three high level concerns were raised from the industry perspective over the development and implementation of standards and/or guidelines: 1) that they not be overly prescriptive in defining the hardware specs or operational procedures required to meet client data or project needs; 2) that they be transparent, adaptable or frequently updated to accommodate the rapid changes in and evolution of hardware, software and operational procedures; 3) that standards / guidelines developed by one agency to meet their needs not be arbitrarily adopted by another agency without first considering how their needs are unique and how these needs might impact data requirements.

During the discussions, industry stakeholders indicated that clients are frequently unsure of how to specify their LiDAR data requirements in order to address their in house needs. Consequently, it often occurs that data or accuracy requirements are inappropriately specified relative to the task being addressed and this only becomes apparent long after data delivery. This can lead to perceptions of data capabilities being over sold or in clients being overwhelmed with data and unable to use it for the intended purpose. Fortunately, as the community matures, such disconnects between user needs and vendor / hardware capability are becoming less frequent. Guidelines for proposals, reporting and accuracy assessment are generally seen as useful in ensuring clear project specifications and contractual obligations, as long as they are limited to defining outcomes and are limited in terms of prescribing procedures.

Of the LiDAR specs available and commonly used in North America, FEMA, ASPRS and USGS are probably most common and useful in providing general guidelines. Though, it is important to appreciate that each is more or less useful for given client needs and should not be imposed arbitrarily. Clients need to think carefully about their specific needs and educate themselves on LiDAR capabilities / limitations. The vendor typically has only a limited understanding of many client needs and expectations need to be clarified up front. In this sense, standards (in the stricter sense) are seen as positive, as they act to protect both the vendor and the client. Of paramount importance is that accuracy specifications are realistic and attainable, and not set higher than necessary to meet the client's needs. It is often the case that high accuracies are achievable but the disproportionate increase in operational costs to meet high accuracy specifications is not in either the vendor or the client best interest.

Industry participants appeared generally amenable to a Canadian federal government specification for LiDAR acquisitions and reporting. However, the same concerns as outlined above were evident. It was suggested that at the federal level, a template approach that allowed smaller provincial and municipal level agencies to tailor the guideline to their own needs and priorities might be preferable to a guideline containing set specification values.

Public sector perspectives

During the discussion sessions the Govt Alberta LiDAR purchasing guidelines and the NRCan draft airborne LiDAR guidelines received much attention. From a federal perspective the NRCan guidelines are intended to support the creation of a national master standing offer for LiDAR acquisitions, whilst aligning with the National Elevation System. The first draft of the federal guideline initiative was released for review and feedback during the summer of 2012 and at time of writing (September 2013) was not officially published. The Govt Alberta guidelines are intended for in house use only and are considered a living document that will be updated along with advances in technology and procedures.

The second draft of the NRCan guideline is intended to be released late in 2013. The current guideline contains details on planning, operational, processing and reporting elements of a LiDAR project, such as:

- Project planning and contracting
- General survey parameters
- Environmental conditions
- Leaf-on vs Leaf Off
- Coastal applications & low tide
- Nominal Pulse Spacing
- Data voids, flight line configuration, scan angle
- Accuracy requirements
- Metadata
- Reporting specifications

It was clear throughout the discussions that public and private sector stakeholders held differing views about standards and/or guidelines. Government users and managers appeared to unanimously value standards or guidelines that could be used to ensure quality and consistency in delivered data and products. These were viewed as essential elements of the contracting process. However, it was also clear that while there was a realisation that existing guidelines need to be tailored to the needs of the client and kept up to date, this was not always straight forwards within large public sector agencies where there are many end users and as yet unanticipated uses for the data. One opinion was articulated that high data quality products are a priority as any uncertainty in raw data will be propagated and/or amplified in derivative products (e.g. forest/wetland classification and wet areas mapping). In support of this opinion, several government (and other) sector stakeholders felt that data quality and accuracy reporting were where most effort should be directed in establishing guidelines.

An alternative (though not necessarily contradictory) view was that consistency should be the priority in cases where data will be used within a monitoring context. While it is possible to achieve and specify both high quality and data consistency, it is apparent that if either has a significantly higher priority to the other, then this could influence operational collection and/or processing procedures. Indeed, if consistency is favoured over quality, there might be a temptation for guidelines to provide strict specifications and limits on many operational data collection parameters (such as altitude, scan angle, scan rate, PRF, divergence, pulse power, return classifications, waveform digitization) and environmental conditions (time of year, soil moisture, ground cover, foliage density, etc). Tight tolerances specified in an attempt to ensure optimal monitoring conditions, could limit the number of vendors able to meet the specification and was a concern raised by industry stakeholders. It was argued that strict and arbitrary specification of operational parameters and procedures can lead to increased data errors.

Following from an engaging group discussion about sensor parameter influences on data attributes, it was commented that the ideal guidelines would provide a quantification of parameter sensitivity and influence on final data quality properties like density and uncertainty. Such information would aid government sector (and all end user) stakeholders in understanding which data collection and processing components might need to be specified to meet their particular needs. For example, for certain landcovers, terrain types and/or applications, prioritising and establishing a specification for certain parameters (such as altitude, scan angle, flight line overlap) while leaving other parameters to the discretion of the provider may yield optimal results.

The topic of 'best practices' was most prevalent within the government stakeholder group. In both the federal and, in particular, the provincial government communities, LiDAR is being used to support or research a wide range of geosciences applications. However, it is clear that while basic LiDAR data processing is reaching a level of maturity, workflows and tools to support applied geosciences in the public (and consultancy) sector are in their infancy. There are several challenges, including in house skills and software licensing but perhaps of most significance is the lack of standardisation over LiDAR-based geosciences workflows and information creation. Departments often utilise in house routines that are based on easily available tools and skill sets that may differ to another department within the same agency or at different agencies. This creates challenges in terms of information quality, consistency and permanence. Consequently, there appears to be an urgent need to develop and publicise best practices guidelines to meet geosciences workflow needs within Alberta and other national-level jurisdictions.

Academic sector perspectives

Much of the academic perspective on standards and guidelines centred on the need for better understanding and reporting of errors in raw data and derivative products. An interesting discussion concerning trends towards increased point density revealed some disagreement between academic and industry stakeholder perspectives. On the one hand industry (and many end users) appear to view increased point density as a selling point of modern hardware, due to the perceived increase in data quality (ability to discern small features). While on the other, academic research has shown that when increased data density is achieved through increased PRF, it can actually diminish point level accuracy relative to data collected at lower PRF (or increased pulse-level energy). Therefore, while it is true that increased point density will, all being equal, result in better feature definition, it is also possible that if increased density is achieved through increased PRF (as opposed to lower flying height or smaller scan angle) then noise in the point cloud can also increase. It was further argued that given higher PRF returns are closer to the detection threshold than lower PRF returns, a high sampling density might come at the expense of missing some of the finer detail in forest canopy environments. This is counter-intuitive, given higher density will physically sample more of the 3D canopy envelope.

The point to the above discussion was not that high density through increased PRF is not desirable, rather it was that rules on data density are not straight forwards and specifications should not arbitrarily impose high densities if and when not necessary. OR, that if high point density is required, it might be worth specifying that high density is not to be achieved by operating at the envelope limit for the highest PRF achievable with a given sensor. A more general point on this topic, was that given sensor settings do influence output data properties, then all flight and sensor settings should be reported as part of the standard metadata associated with all surveys. To date, while some vendors do report all survey configuration settings, this is a not a common practice, and is one element that could be addressed in any new standards or guidelines initiatives.

Beyond PRF and data density, there was much discussion from the academic side on the topic of system, terrain and landcover error propagation in general. Two topics stood out as pertinent within the scope of standards and guidelines. The first was a suggestion that detailed error modeling should be part of the survey planning process. To date, mitigating errors at survey planning stage has been based on some simple assumptions and recommendations provided by hardware manufactures OR by the experience of data collection companies. Neither approach is highly scientific and generally means that either: a) errors might exceed expectations in some areas; or b) in order to ensure data meet contract specification, flight and sensor settings are configured to exceed quality expectations by a wide margin. Neither scenario is optimal and may incur delays or unnecessary cost. Therefore, planning a survey with landcover, terrain and system error propagation routines embedded into the process would allow vendors to demonstrate to clients how the survey plan meets contract specification, OR, allow clients a more informed method of defining contract specifications and data reporting deliverables.

The second error-related discussion topic addressed accuracy reporting. Gradually, the community is moving towards a more rigorous expectation for error assessment and reporting. Gone are the days when a few control points collected over a parking lot or runway surface would suffice to demonstrate that data are within contract requirements for RMSE. It is becoming commonplace to stratify data accuracy reporting according to dominant landcover classes and use the terms fundamental, supplemental and consolidated vertical accuracies (FVA, SVA and CVA). Various guidelines (such as USGS) contain details on how such reporting can be presented. It was suggested that as well as stratifying data according to dominant landcovcer types, that further reporting requirements such as slope classes and the spatial representation of the control data relative to the entire project could be added. Understanding the spatial location and representation of control data is important as LiDAR data for a given project could be collected over multiple missions, each with variable levels of accuracy and error components that are independent of landcover. Further elements of data reporting that are not standard but could be are the sensor calibration data and the strip to strip bundle adjustment reports. Both are essential to the data processing workflow and give an indicator as to how well the sensor holds its system calibration and how well aligned the flight lines are. These elements of data processing influence overall accuracy but are a separate and valuable index of overall data quality and so there is value in including them in the data report.

A further academic perspective on the development of standards and guidelines was that specifications should follow from need such that a Boolean approach could be implemented where project needs could be identified and prioritised using a series of logical criteria and operators. Such an approach or tool might be complex to set up given the wide range of applications and sensor types but would make the development of contract specifications simpler and more transparent for end users.

Some general perspectives

- LiDAR was sometimes over sold or incorrectly marketed in the early days
    - There are limitations that need to be better understood by end users
    - Standards / guidelines help end users and data providers communicate needs and capabilities
- Some differing perspectives on priorities between academia, government and industry
    - Even in industry sector, data vendors appear more willing to cautiously embrace standards than hardware manufacturers.

- Standards/guidelines must be constructed to meet the basic needs of immediate and peripheral industries such that innovation is not restricted, while accommodating the potential for long term monitoring.
- Standards must address minimum standard of quality
- Intended purpose for the data must be clearly stated in contract specifications
- University community maintains a watch dog and advisory role
    - Integrity, consistency, quality, error, error propagation, development of best practices

<u>Data Centres</u>

Industry perspectives

Hardware industry appears to have little to say about the topic of data centres. The LiDAR service provider community does see this as a relevant issue, however, as depending on how data centres are implemented, they are perceived as either a threat to sales or an effective marketing, management and client services tool. There are generally two main models by which commercial LiDAR data are collected and distributed: a) contract-based data acquisition; b) proactive population of an in-house data library by a vendor with the expectation of selling data licenses multiple times. The first of these models is more traditional. The second model carries some inherent risk to the vendor but due to the possibility of multiple licensing, sales costs for end users are dramatically reduced compared to the first model. This reduced-cost access to data comes with some limits and restrictions, however. For example, data redistribution and sharing is only permitted under strict licensing terms and, given data in the library were not collected to meet potential library users' needs, the data specification may not be optimal for a given user need.

A perceived risk associated with data centres is that if all data owners (vendors and users) can publicise and share their data within a library, then some future sales could be compromised as users will be inclined to first seek data through the cheaper data centre instead of directly contracting services. Another perceived risk is that if a data centre is online and publicly viewable, then the security of data and ability to manage licensing is out the vendor's control and in the hands of a third party. However, the service industry appears cautiously welcoming of public LiDAR data centres, as if implemented carefully and with a view to meet all stakeholder needs, then they could actually increase data sales and bring down costs for all concerned. A primary mechanism being the ability to distribute small volumes of data over again to a high volume public client base that cannot currently access LiDAR data, which are typically obtained and sold for large project areas.

A challenge identified in 'selling' data licenses to small scale public users was that most small users would not have access to processing and analysis tools. Thus, a further industry perspective was that if data centres are to be successful at marketing data licenses (and thereby receive the full support of data collection companies) was that online portals for data need to more than just serve data. There was general consensus that a data centre would need to at least map out data extents, provide comprehensive metadata and reports, facilitate queries about coverage attributes with user-selected areas and facilitate direct or indirect requests for data. However, these capacities alone appear to be insufficiently compelling to motivate industry buy in. Indeed, such capacity already exists and there are a growing number of such online data portals around the world but most deal almost entirely in public data for which there are no license restrictions. Therefore, it seems the primary barrier to industry adoption and full endorsement of online LiDAR data centres is the ability to implement services that meet client needs. Forestry and oil sector needs (such as well site location or stand inventory parameters) were noted as requiring relatively simple visualisation and data processing steps, and if implementable in an online LiDAR data and services centre then LiDAR vendor buy in would buy-in would be easier to justify.

Some slightly alternative views towards LiDAR data centres were voiced by the geomatics consultancy sector that exists mid-way between data vendors and end users. It was noted that for a large number of consultancy projects where it is believed LiDAR could be of value, a large proportion of project start up time is dedicated simply to identifying what data exist and what it might cost to obtain. Thus, having an online data centre illustrating all data coverage (public and commercial) within a region, and the cost / licensing requirements would result in significant cost and time savings on many consultancy and engineering projects. Furthermore, it was stated that an impediment to LiDAR data usage in many consultancy projects was the cost. Thus, a data centre is seen as a way to, eventually, bring down costs for end users and encourage wider adoption of LiDAR data across a broader range of projects than is typical.

Government perspectives

Federal and provincial government perspectives on data centres were aligned in that it is generally perceived as a common good that all data collections are mapped, archived and documented within a common and accessible online environment that can be viewed by the public. However, there were distinct differences in that federal government prefers an open access approach to data, while the government of Alberta maintains the pragmatic approach that public data ownership would be too costly. Alberta has thus adopted the data licensing model developed by industry and therefore recognizes that an online data centre for such holdings would need to accommodate this data licensing model. Indeed, the draft NRCan federal govt guidelines initiative, which is developed in support of the national elevation system, indicates that open access and data sharing are preferred. It is not clear that nonpublic access data could be supported within a national elevation system data portal but it does appear to be out of scope for the federal government to manage and publicize (i.e. market) private data licenses so there may be some incompatibilities with current licensing models, as adopted in Alberta, and any federal initiative in this regard.

Similarly, the government of Alberta appears unlikely to be in a position to implement and host an online data centre of its holdings given the licensing restrictions over data that it does not own. However, many government Alberta data users indicated internal challenges managing, accessing and sharing their licensed LiDAR data holdings amongst and across departments, and from this perspective an online and public access system could effectively 'outsource' a costly and complex data management task. It was postulated that given the data are licensed anyway and if the licensing were not infringed, then having a third party manage the data on behalf of the public could actually improve access and sharing of data, which would enhance government operational efficiencies. Government sector users were cautiously supportive of embedding services within an online data centre. Supportive because (as outlined above) many geosciences and engineering application workflows still require the development of efficient workflow best practices, so if these tasks could be implemented at the server, this would save time in data transfer, analysis, skills training and possibly software licensing. Cautious because transparency and consistency of workflow procedures are important within a regulatory and permitting framework.

Academic perspectives

Many academic viewpoints mirror those of the government end users and industry data providers, while in some cases there is clear disagreement amongst academics about the rites to access what is perceived to be public data. Indeed, this has been a hot topic both within the meeting discussions and across the community in general. Many academics believe that if public funds were used in obtaining data (whether licensed or owned) then the public (e.g. academic researchers) has the right to access. This was brought up as a general point but also specifically as related to the Alberta data holdings, which are almost entirely comprised of licensed data. To counter this academic opinion, industry and government stakeholders explained that, in the Alberta context, data access was obtained at a fraction of the cost of ownership and industry proactively engaged in library-based data collections with the explicit business model of multiple licensing. Thus, if data became open access as soon as they became the property of a government agency, then initial costs would go up and industry would be unable to support collections over such large areas. Indeed, it was noted by govt Alberta users that if they had to pay commercial costs of ownership, it would be difficult to justify the expenditure in the first place. At some level, it was decided that it was more in the public good to have widespread coverage that could support a wide range of government mapping activities, than a much smaller coverage (if any) that would at best support limited project-based tasks. Licensing appears to be a model that allows government agencies to more effectively map, manage and inform policy over a vast area of land resources, while ensuring commercial activities in this sector are viable and sustained in the long term.

As with the geomatics and environmental consultancy sector, university researchers noted that identifying and obtaining datasets to support research is a time consuming task, and commercial acquisition costs are frequently beyond university professor budgets. Consequently, there was resounding support for the concept of online LiDAR data centres from the academic community; especially if it might enable access to some free datasets and/or bring down costs. The element of online services did not appear to be a priority for those academics already embedded in the community as they would typically have access to resources to work with data. However, more junior, inexperienced students or faculty members not embedded within the geomatics or remote sensing communities, likely would value the addition of analytical or visualization services hosted at the data source.

The importance of metadata and developing a comprehensive set of reporting criteria for any data entered into an online data repository was stressed. It was generally felt that the academic community would maintain an objective position on the critical elements of a data / service centre and would be well positioned to provide input and support to the development of online services that align with best practices whilst informing the development of metadata criteria. Some discussion touched on whether or not such a centre could be hosted by an academic intuition but this was not explored deeply, as most stakeholders appeared to hold the view that this would have the best chance of success if implemented in the private sector. Ultimately, it was felt that the success of any such initiative would be enhanced if it was led by the private sector but coordinated in close cooperation with the public and academic sectors. However, there appeared to be further consensus that the ideal online data centre that is intended to be a repository for 'all' data over a given region should be managed by a neutral third party; i.e. while data vendors should be involved in the process to ensure their licensing and data security requirements (plus any other concerns or needs) are addressed they might not be the most well positioned, resourced or impartial to take on such a task.

LiDAR training and certification

Industry perspectives

All divisions within the industry community (manufacturing, data collection, and consultancy) were in agreement that training opportunities in LiDAR do not typically meet needs and that it can be difficult to identify employees with existing applicable knowledge and skill sets. It was further agreed within the industry sector that standards, guidelines and best practices should inform training and education programs. However, there was no consensus on whether or not certification was beneficial. Questions were raised over whom (which society, institute or government agent) would be the governing body for any general LiDAR-related certification and there was a perception that a certification program might create a barrier to entry (for individuals and companies) where none previously existed.

One area where certification was perceived as potentially beneficial was in terms of individual manufacturer's systems. The data collection / vendor community suggested that there could be value in having individuals trained and certified on the operation, troubleshooting, calibration and initial processing of individual systems given all sensors are not identical. Such a program would most likely need to be offered by manufacturers themselves. While it was not explicitly discussed, the same logic might apply to major software platforms used in LiDAR data processing, modeling and analysis. The value in such certifications would mostly be in terms of: a) identifying suitably qualified job applicants; and b) implementing tailored training programs for new hires that require training that might be difficult for the employer to provide. Industry stakeholders appeared to see this level of certification as largely an industry activity and responsibility. It was suggested that if some form of 'higher level' certification were desired for LiDAR practitioners and users that it should be an extension of an existing society or provincial professional certification program as opposed to a new and dedicated LiDAR certification; i.e. add LiDAR content to existing programs.

While hardware manufacturers and vendors saw value in LiDAR and positioning theory, system operations, calibration and data processing, the consultancy sector valued more the training of applications, such as: natural resources assessment, climate change impacts / adaptation, engineering, data analysis, and even the softer skills of team-based collaboration.

The consultancy sector appeared less supportive of a LiDAR certification initiative; it was considered unnecessary and potentially punitive to experienced LiDAR stakeholders choosing not to certify themselves. However, there was a hint of some implicit incongruence in the negative views held by industry towards certification, as all agreed that enhanced training and educational opportunities were needed and that industry should play a role in influencing the format and content of any curricula. While training / educational courses / programs do not need to lead to any certification, some form of accreditation / certification program is typically required if curriculum content is to be unified across the community and beyond the mandate of the individual entities providing the training or education. Thus, while industry reticence to embrace a new form of certification is understandable some form of course accreditation would provide industry the opportunity to influence curriculum in a direction that meets their needs across a wide range of training and course offerings.

Government perspectives

Government stakeholders voiced a need for education, training and outreach across a hierarchy of responsibility levels. As with industry, there was a clear need for technicians to have hands on skills and in this category, point cloud processing and classification ranked high as subjects where skills were generally lacking. It was suggested that specific software and hardware skills were more in the domain of industry training events than university course offerings. However, it was also indicated that university-led introductory seminars and educational events summarising the range of applications supported by LiDAR would be useful for high level government managers, decision makers and even the general public. Involving university students in government research was viewed as beneficial in terms of transferring skills and knowledge from universities to government while enhancing the LiDAR expertise of potential future government employees.

There was no overall consensus on certification, though some government stakeholders did believe that any form of certification would primarily have to be accepted by industry. A modular form of certification was postulated as a possibility where components could be chosen much like a university program of courses so that the certification could be tailored to the needs of individuals and the sectors they serve. Academic or professional societies were seen as obvious vehicles for the development of certification programs, if one were to be developed.

Academic perspectives

An academic viewpoint expressed in the forum was that universities do not 'train', they 'educate'. This led to further distinction between university education vs college vocational training. While these might be traditional perspectives and roles of universities and colleges, it was clear that some of the non-academic stakeholders did look to universities to provide the students they might one day hire with a combination of relevant skills and knowledge. Something that some felt was not readily available in the typical pool of recent graduates (college or university). Some discussion centred on the kinds of pedagogical pathways that could be implemented in a university setting to meet some of the training and educational needs of public and private sector LiDAR stakeholders. The earlier discussion on standards, guidelines and best practices provided some context, as it was generally felt that any university curriculum with a LiDAR component should consider or be aligned with the standards and best practices of the day. In general, there was agreement across all sectors that academic institutes needed to partner effectively with industry practitioners and government users on the delivery of relevant and useful knowledge (whether it be training or education).

Such partnership is relatively straight forwards and already popular at post graduate level where government users of LiDAR frequently look to universities to assist in the development of new procedures or in addressing management- or policy-related research questions. In the LiDAR community, such partnership is less common with industry due to challenges over scheduling and a more operational focus to in house needs. It was suggested that universities and/or colleges could be more responsive to and supportive of public / private sector partnerships by implementing a broader range of pedagogical pathways towards degrees; i.e. allowing course credit for activities that might be outside the typical class room or lab-based course. The NSERC supported Amethyst remote sensing internship program at the University of Lethbridge was cited as an example that could be adapted to address the goals of greater stakeholder engagement through project-based internships and practicums.

The concept of practicums was raised alongside the possibility of equipment sharing between universities and companies. Industry could transfer knowledge and research capacity to universities, while universities would transfer knowledge and research outcomes back to industry partners and potential future employees. This was considered of value to the academic community because university researchers are often unaware of the operational envelope and limitations of the hardware supporting the LiDAR data they use in teaching and research. Developing such partnerships within the Alberta LiDAR community appeared highly tangible given the critical mass of activity in this region.

Academics generally held a more positive view of LiDAR certification than industry or government. While it was conceded that the possibility exists for a certification program to create barriers if implemented incorrectly, it was thought that it would bring greater accountability to and support enhanced communications within both vendors and users. It was felt that a certification program that was sensitive to the needs of the public and private sectors could provide some guidance for curriculum and in supporting the design of pedagogical pathways alluded to above. It was noted that the Canadian Remote Sensing Society (CRSS) is in the process of developing generic certification programs and that it might be possible link a LiDAR certification to this initiative or at least embed some LiDAR content into a more general certification. Analogues were drawn to the certification programs of the American Society of Photogrammetry and Remote Sensing (ASPRS) and their LiDAR committee. Academics appeared to prefer that oversight and delivery of a certification program be in the domain of national societies instead of provincial professional bodies. In some ways provincial professional designations may appear more logical as they are analogous to the certifications engineers and surveyors can obtain. However, at this adolescent stage in the evolution of the community, and given the inherent mobility of airborne mapping operations and companies, a national program might make more sense.

Flood mapping / modeling

Due to the topical and sometimes divisive nature of flood mapping and risk assessment (in light of Alberta's devastating recent floods), much of the discussion at the forum moved away from issues central to the LiDAR community. The notes provided below will focus on points directly related to the use of LiDAR in support of flood assessments.

Industry perspectives

It is clear in the industry stakeholder community that the awareness of LiDAR in support of flood modeling, mapping and risk assessment is high. Some frustration was noted that while other jurisdictions around the world have embraced and promoted LiDAR for risk assessment and mitigation, Alberta, and Canada in general, is behind many other countries. Specifically, it was noted that the tendering process for projects containing a flood assessment component has frequently systematically excluded LiDAR as an option due to rigorous specifications for flood plain survey point accuracy. It has frequently occurred that point accuracy specifications have tended to require traditional survey point accuracy at cm-level to support channel and floodplain cross-sections at given distances along the channel. LiDAR point data typically cannot meet such rigorous specifications but it is generally accepted in industry (and in various government jurisdictions around the world) that what LiDAR lacks in point level accuracy is made up in terms of increased data density which allows for better floodplain feature definition in 3D and in facilitating what amounts to almost infinite cross sections. A LiDAR DEM and point cloud model can thus support both model set up (though bathymetric data must be supplemented) and post model flood visualisation at a high resolution. This is well known and highly routine in many locations.

An industry perspective voiced at the forum was that government decision makers needed to be more aware of the data and methods available in tackling such problems so that outdated approaches do not become the default in request for proposal documents. It was felt that the academic community should play a role in 'educating' the public sector in this regard, due to possible perceptions that LiDAR service provider opinions could be based on a desire to 'sell' data. It was suggested that a pilot study comparing traditional survey supported flood modeling and visualisation be compared with LiDAR supported efforts in various Alberta floodplain settings to identify and quantify the merits of each approach and develop a business case for decision makers.

The Geomatics consultancy sector made note that while LiDAR is a very useful tool for flood mapping, modelling and visualisation, it is not the complete answer and, as with traditional ground survey, still relies on many complimentary data types and model simulation procedures. There was a general sense of optimism in this sub sector of the industry stakeholder group that the recent floods in Alberta would alter government approaches to this issue and lead to more activity in the LiDAR sector.

Government perspectives

It was noted that if provincial government floodplain mapping specifications precluded the use of LiDAR, this may have been partly due to limited in house capacity and skills to work with LiDAR and not simply due to a lack of understanding over its merits. Also, while data exist for many areas of potential flood risk in Alberta, many of these lands are in private hands and it is not immediately apparent to decision makers that the data might already exist. This re-raised the concept of data centres as a mechanism to promote data usage in application areas where it is presently under exploited.

Academic perspectives

The academic community welcomed opportunities to work with industry and government on developing LiDAR flood assessment pilot studies in Alberta. It was noted that data collection, processing, analysis and modeling procedures in support of large scale comprehensive flood assessments are inherently multi-disciplinary. Any pilot studies to develop optimal procedures would need to take into account the multi-disciplinary nature of the problem and aim to build suitable teams from appropriate backgrounds while supporting interdisciplinary training and educational pathways.

In terms of research questions that need to be addressed, it was noted that there are many areas of active research in the use of LiDAR to support flood modeling and mapping. Notably, the use of LiDAR point cloud data to support improved parameterisations of floodplain roughness (flow resistance). Further, it was felt more investigation is needed into the propagation of error into water level and flood extent simulations due to DEM and other LiDAR-based derivative model parameters. This was seen as a critical element in convincing government agencies that visualisations and flood model results obtained through LiDAR, compelling as they appear, can be reliable and statistically meaningful. Similarly, it was felt that best practices were needed for such LiDAR-based workflows, as while many of the steps are relatively straightforward, choices need to be made over some data processing and analysis settings that can have implications throughout the remaining workflow. Consequently, without procedural guidelines it is possible that different software environments or analysts could achieve differing model outcomes even when using the same input data.

Discussion and conclusions

It is clear that LiDAR stakeholders in Alberta, Canada and globally represent a diverse multi-sector, multi-disciplinary community that deals with a very wide range of applications. Given profit motivation on the industry side and land use management, regulation and policy development objectives on the public sector stewardship side, it can be challenging to reach consensus on priority needs or in optimal ways to address these needs. After circulating a stakeholder questionnaire, the topics of standards, guidelines, best practices, certifications and data access stood out as requiring further discussion at the following stakeholder forum.

Of the identified ‘hot topics’, ‘best practices’ was found to generate consensus or the least disagreement across stakeholder sectors. It seems all groups felt there was a need to develop best practices for a number of LiDAR application workflows due to the often large number and complexity of the steps in a post processing workflow. A high amount of consensus was also reached in terms of the general need for guidelines, with the government sector most needing them for data acquisition contract specifications or for data quality reporting. However, while industry supported guidelines at a general level, there was a caution that they should not be overly prescriptive, and should focus more on deliverable outcomes than on data collection and processing configuration. There was some disagreement to this view when it came to monitoring applications, where some control over collection parameters could improve consistency of temporal data. In response to concerns over unnecessarily prescriptive contract and project guidelines, and recognition that specific users and applications have differing data needs, it was suggested that acquisition guidelines should be inherently flexible and adaptable and focus on allowing clients to identify priority specifications given their unique needs. A somewhat different view emerged regarding data accuracy reporting, where it was felt that typical reporting approaches generally did not adequately quantify or report on all pertinent elements of data quality. More rigorous approaches were suggested that accounted for uncertainties that varied with location, terrain, landcover, and data quality issues due to calibration, flight line configuration, and sensor settings. Indeed, it was suggested that error modeling could be performed in the pre-survey planning phase to help optimise survey configuration and help ensure contract specifications are met.

The logical next step from guidelines and best practices is to consider standards and certifications. These topics produced the least consensus and generally the highest level of concern amongst stakeholder groups. On the one hand, it was recognised that standards provide a solid basis for contracts, guidelines, best practices, legal accountability while also very useful in guiding education / training curricula. This connection to training and education produces a logical tie to certification, which was welcomed by some (though not all) in the academic and government sectors. Industry was generally the weariest overall, considering standards and certifications as sometimes serving the agendas of a minority while posing potential barriers to entry that could even stifle innovation and hold up progress. An example that was discussed at some length in the forum related to the recent floods in Alberta.

It was observed that a challenge associated with standards and certification is that they need to be constantly updated otherwise innovation can be stifled and the latest technologies and methods (which may provide better outcomes than traditional approaches) can be labelled non-standard and therefore considered unreliable, untested or outside contract scope. This appears to have happened in Alberta where despite the use of LiDAR to support floodplain risk assessment around the world (e.g. the FEMA flood insurance program in the US) Govt Alberta floodplain mapping contracts are reported to have used engineering ground survey criteria that were 'standard' in the early '90s. The associated engineering standards and best practices appear not to have kept up with global trends and thus even though LiDAR might enhance flood risk mapping results, it has at times been excluded on the grounds of point level accuracy, even though data densities and feature details are orders of magnitude greater than possible with traditional survey. This appears to be an example where adhering to outdated but familiar 'standard' or 'best practice' procedures could result in inferior project outcomes when compared to non-standard (in the local jurisdictional context) but more up-to-date approaches. A related but almost 'counter' concern is that if the public sector supports and adopts new LiDAR standards and certifications (a sector that is still evolving rapidly) then progress could be halted prematurely.

Less resistance was apparent over the concept of generic certifications that were not LiDAR specific but perhaps contained LiDAR elements. The concept of broad ranging remote sensing, GIS or Geomatics certifications at technical and professional levels that ensured recipients had an appreciation for LiDAR theory, applications and basic procedures was received more favourably. Indeed, such a model is analogous to the successful American Society of Photogrammetry and Remote Sensing (ASPRS) certification program and could be adapted to be hosted by a Canadian society like the Canadian remote Sensing Society (CRSS).

The topic area leading to the most debate, and that recurred across all discussion themes, was of data access, ownership and licensing. Alberta's proactive stance on data licensing (i.e. industry model and government adoption) has led to Alberta having the most LiDAR coverage of any Province in Canada. This has resulted in the innovative use of LiDAR in support of a wide range of mapping applications in resource mapping with the potential to support some permitting approval, regulatory and policy development processes. However, despite these benefits (both to industry and government) there was recognition amongst all stakeholders that data access in general was problematic. Some academics, for example, believed that if public sector funds were used to acquire data then the data should be freely available to the public. This opinion was countered based on the premise that for the government to have full rights of ownership, the data would have cost substantially more and nowhere near the current level of coverage could have been obtained. Moreover, even if the data could be shared freely, this would lead to another more technical and costly problem of managing the process of sharing meta- and actual data.

The idea of developing a LiDAR data centre in Alberta generally received support across all stakeholder groups. It was felt that from the industry perspective a data centre could act both to market data availability to existing and new markets, while allowing potential landowners, developers, consultants and government users a 'one stop shop' library environment to assess all that exists within the region. Furthermore, an efficient cloud based data server system could provide a default enterprise data management system for large scale users like government agencies. Such a model would effectively outsource the LiDAR data management process that many in the government community voiced as an existing challenge. Indeed, it was suggested that an external data management portal may even improve the accessibility of data for some government departments. Needless to say the academic viewpoint on this was supportive as anything that communicates and eases data access to support research and teaching has to benefit the processes of research, knowledge generation and transfer.

However, while the implementation of an online LiDAR data centre was generally perceived as having many benefits to all stakeholder groups, some challenges were identified that require serious consideration. Primary amongst them being who would implement a data centre and, given data licensing compromises a high proportion of the LiDAR sales in Alberta, how are the rights of data owners/licensees protected? There were no simple answers to these fundamental questions but it was clear a data centre would only obtain all stakeholder support (especially industry providers) if the existing licensing sales structure could be supported in a secure manner. It also seemed clear that neither provincial nor federal government would be in a position to implement and operate a data centre if it were to act as a mechanism to sell data licenses for the private sector. Moreover, despite the attractive possibility of higher sales volumes from small scale users, it was generally agreed that simply serving metadata and actual data is of limited use to many small scale 'would be' users, as they would typically not have the tools or knowhow to exploit the data even for simple visualisation and mapping tasks.

Both the industry vendor and consultant sectors agreed that the success of a data centre would be much enhanced if data services were embedded to support a range of online visualisation and data modeling capabilities that would add value to the data. It was also generally felt amongst members at the forum that a commercial LiDAR centre owned and operated in the private sector would have the best chance of success and meeting all stakeholder needs. This would not preclude the possibility of some free access to data or derivative products but a business model is needed that demonstrates there is a commercially viable model that can be sustained on brokering data licenses and potential services. It was also suggested that a portal could be managed through subscriptions or in terms of providing an enterprise data management solution for 'big' users like the Government of Alberta. Therefore, while real challenges were identified, a number of creative and widely beneficial solutions were quickly identified. Next steps appear to be the development of a specific request for information from LiDAR stakeholders to better understand market needs and to support the development of a business case. It was felt that while industry is likely best positioned to lead such an initiative, chances of success will be enhanced through an industry, academic, government consortium approach that addresses commercial interests, technical research and end user priorities.

Multi-sector partnerships like this were considered important in addressing all the needs-based discussions hosted at the forum. In addition to the data centre model discussed above, it was generally felt that all three sectors needed to be engaged in any initiatives towards developing guidelines, best practices, standards, certification and educational pathways. Indeed, all topics overlap to some degree so a suggestion stemming from the questionnaires and forum is that these topics not be considered in isolation or from the perspective of individual stakeholders. Rather as a holistic and organic model of interrelated community needs with varying and sometimes conflicting priorities amongst stakeholder groups. A front lines approach to achieving this goal is through the development of government needs-driven research-based projects that aim to develop LiDAR workflow best practices and guidelines though academic and industry partnerships. Such projects could tackle distinct research-based questions related to seemingly unrelated application needs but the point is to keep the higher-level integrative needs as an explicit objective while engaging all sectors simultaneously. Moreover, such projects act as effective training, educational and outreach pathways for students, employees and decision makers. At a strategic level, it is believed some form of impartial institutional entity is needed to provide some oversight to the activities. At least in terms of certification, it was suggested that the Canadian Remote Sensing Society could play such an oversight role. Both government and industry stakeholders held the view that universities should play an oversight role on many of the topics raised. Currently, however, while there are several university professor experts in Alberta, there is no institutional-type entity that explicitly links them under a common goal of addressing LiDAR stakeholder needs in Alberta and Canada. A recommendation of this report is that such an entity be created. Possible pathways to the formation of such a group are through existing societies like the newly independent Canadian Remote Sensing Society or the Canadian Institute of Geomatics, or perhaps using the Campus Alberta Innovates Program model, which aims to foster closer research and teaching connections between pan Alberta university professors.

Appendices

Appendix 1. Forum notes collected by Nathan Ballard, Government of Alberta.

Monday, July 8th,

1. Introductory Comments - 9:00 AM - Chris Hopkinson

- Housekeeping
    - Online resources, including presentation pdf's will be made available following the conference
- LiDAR Cost benefit analysis: Sugarbaker, Snyder & Maune; Presented at 2012 ILMF, Denver
    - Dollar benefits of top 10 BUs in USA
    - Dewberry (US Geological Survey)
    - 1.18 B$/yr in current benefits
        - ~13B$/yr potential benefits
- Data formats / Uses
    - Point clouds
    - IR image (comment: underutilized)
    - Surface models
    - 3D structure
- Primary application: DEMs
- ALS Technology
    - decimeter accuracy DEM
    - Buildings & infrastructure visible
    - 3D vegetation structure
    - Components
        - Differential GPS
        - Inertial Measurement Unit
        - Electro-optical LiDAR system
            - r = (c*t) / 2
        - Scanner
        - Aircraft platform & offsets
        - Computer processing
    - Single pulse emitted, multiple return capability (multiple surfaces encountered, multiple returns recoded) - (?backscatter?)
    - Biomass mapping can be achieved by developing statistical descriptions of return times

2. An overview of Optech's LiDAR mapping technologies - Mike Leslar, Optech Inc. Vaughn Ontario

- LiDAR & Camera Sensor Solutions
    - Ground-based static
        - < 1 cm accuracy achievable
        - CMS: Cavity Monitoring system
            - underground mining - 3D scan of tunnels
        - ILRIS: Intelligent Laser Ranging and Imaging System
            - 1800 - 3000 m range
            - Open-pit mining, geology, forestry, etc.
                - rock face scans (mass movement/rockfall detection)
                    - e.g. 2 km distance for measurement
            -
        - Applications
            - Cavity Monitoring Systems
                - tunnel monitoring (safety applications)
                - monitoring and volume calculation
    - Ground-based Mobile

        - Lynx Mobile Mapper
            - engineering & transportation application
            - vehicle mounted
                - accuracy +/- 5 cm
                - 200 m range
    - Airborne LiDAR
        - Orion series C/M/H (Low/Mid/High altitudes)
            - fast, low altitude scanner
            - used in close range
        - Pegasus
            - 2 lasers working at different frequencies
            - longer range systems
            - relatively dense point clouds
        - CZMIL
            - bathymetry - aquatic environments
            -
    - Airborne Cameras
        - CS/CM/CF/CC-R series cameras
        - Integration with multispectral
    - Special Projects

3. <u>Riegl LMS-Q780 Long Range, Full waveform Airborne LiDAR scanner case study - Vladimir Kadatskiy, Riegl USA</u>

- Mountain mapping
    - Requirements
        - High point density
        - High accuracy
        - High efficiency
    - Challenges
        - Extreme relief
        - Eye safety (high powered laser)
        - Uniform point spacing
        - Complete coverage
- Rocky Mountain Case Study
    - Riegl LMS Q780 was used
        - 266 k measurements per second
        - full waveform system with unlimited number of target echoes
        - Range performance: scalable with power settings from 6-100%
            - Maximum altitude 11,000 ft
        - 25 mm resolution
        - up to 10 simultaneous pulses in the air
            - Proprietary pulse modulation minimizes ambiguity and resulting data gaps stemming from simultaneous pulses
        - Project Area Ouray, Rocky Mountains
            - Measurements at altitudes greater than 16,000 ft were captured successfully
                - 0.6 pts / m^2 resolution
    - Conclusion: Reigl system is capable of mapping mountainous terrain accurately
        - Advantages of pulse modulation include the ability to expand the zone of data collection and minimize data gaps
    - Future technologies in the pipeline
        - LMS-Q1560 (modeled for between 20-60% reflectivity)
            - 2 laser channels
            - single multifacet polygon mirror
            - pulse frequencies of 800 kHz
            - integrated secondary IR scanner

        - 14 degree offset from center for each laser, in opposite directions
            - allows for a uniform point clouds and can map from several angles simultaneously (e.g. all 4 sides of a building).

4. A service provider perspective on airborne LiDAR operations and industry trends
- Martin Maric, Airborne Imaging Inc (Division of Clean Harbors) , Calgary, AB

- Largest privately owned LiDAR library in North America
    - 1m DEM and point cloud in .LAS
    - 1.25-2 pts per m
    - 650,000 km^2 in Canada & USA
- LiDAR Industry in Canada
    - LiDAR is now perceived as proven and established
    - systems and system providers have improved substantially
    - year 2000 - 4 (maybe 5) companies in Canada with LiDAR sensors
        - In 2013: 14 companies
        - > 95% of systems are sold "off the shelf"
    - Reliability has improved substantially since 2000
        - Reliance on proprietary technology and in-house expertise
    - ASPRS-Radar
        - wanted **standards** for LiDAR
            - Established .LAS format
            - FEMA created guidelines
            - **USGS** - more stringent standards used throughout North America today
    - Systems available with 8-- KHz and growing
    - MPIA - multiple pulses in the air simultaneously
    - High point densities
    - Software
        - Still very Digital elevation model driven
        - More and more clients experimenting with the point cloud
        - Desktop hardware has improve dramatically
        - Software costs can be prohibitive
    - End user drivers
        - cost
        - accuracy
        - Density requirements for penetrating canopy to improve the supplemental vertical accuracy
        - Better density in mountain flying
        - Better definition of urban structure
        - Creating vectors from LiDAR? Lidargrammetry
    - Standards are needed
        - Canada does not have set standards
        - Standards protect the end user and the service provider
        - define clear, realistic accuracy expectations
    - Q&A
        - Where are there opportunities to do more with the data? (e.g. application areas)
            - Data is underutilized. Flood modeling is an area which could be improved. There are unrealistic expectations for data accuracy. There are advantages to increased area coverage as opposed to point-to-point accuracy. FEMA standards are likely adequate for most purposes.

5. Development and operation of an academically-oriented programme to acquire, process and deliver airborne multi-sensor remotely sensed data - Dr. Olaf Niemann, Geography U of Victoria, BC Hyperspectral and Lidar Research Group

- Provide data to academia, government and industry (2005)

- Challenge: to develop a capability to collect and provide research quality airborne remotely sensed data to interested users.
    - at a reasonable cost
    - complimentary data capability (e.g. Hyperspectral)
    - Partnership with Terra Remote Sensing Inc.
- Introduction
    - LiDAR = form
    - Hyperspectral = functioning
        - maximum flexibility as opposed to multispectral
        - better definition of the reflectance spectrum
            - measuring vs. detecting
    - Ground support resources in addition to airborne
        - see online materials for specifics
- Data Quality is Priority
    - Ultimate quality of the work depends on starting with data acquisition and calibration
        - spatial calibration is time consuming but well worth the effort
        - Developed a processing environment that exploits the various datasets
        - Based on the integration of data in all aspects of processing
        - Tools built in-house
    - Successes (BC and Northern AB):
        - wetlands mapping
        - forest structure / commercial inventory applications
        - vegetation health
        - site monitoring
    - Wetlands Characterization and Mapping
        - Functional relationship between water and veg structure
        - extract relevant information from remotely sensed data restricted to 2-dimensions
            - nonparametric procedures
        - Boreal
            - completed projects near Lac La Biche
                - 2m hyperspectral
                - soil moisture / drainage
                - canopy height
            - Landscape classification is very accurate relative to published resources
        - Horn River, BC
            - high resolution: address traficability
            - lower resolution: drainage connectivity
            - upscale from 2 m to 20 m
                - major forest species mapped to a high degree of accuracy
                - isolated major wetlands/paleo drainage
        - Northern Alberta
            - Apply processing framework to industrial sites
    - Forested Environments
        - Tree tops/crowns outlines, as defined by LiDAR data; and
        - <2 m hyperspectral data
        - modeling is based on canopy structure
            - LiDAR predictions of productivity not perfect but show promise
            - Individual tree classification by species and biomass species
            - biomass calculations of individual tree stems
        - Metrics for Leaf Area Indexes and Tree health developed
            - Indications of Stress
                - Spectral signatures for stress show promise
        - Industrial Site Auditing and Monitoring
            - vegetation mapping
            - hydrocarbon spill detection

            - drilling fluid leakage
- Challenges:
    - Funding
    - Cultural differences between academia, government and industry
    - Personnel
        - revolving door

6. LiDAR onboard the NEON (National Ecological Oservatory Network) airborne observatory platform - Dr. Tanya Raymond, Systems engineer, Airborne Observation Platform, national Ecological Monitoring Program, boulder, CO, USA

- NEON
    - Funded by the national Science Foundation
    - A continental-scale ecological observatory
    - drivers and responses of ecological change
    - experimental infrastructure for other experiments
    - develop educational resources
    - Project timeline (30 years)
        - data collection to begin ~2017
    - Grand challenge:
        - to enable understanding and forecasting of the impacts of climate change, land use change and invasive species on continental-scale ecology
        - by providing infrastructure to support research, education..
            - biogeochemistry etc...
- Investigation strategy
    - 20 domains that Divide the USA and Peuerto Rico
    - 3 sites per domain
        - core site
        - relocatable site
        - aquatic site
    - 60 sites throughout the united states and puerto rico
        - Sample each site onece per year for 30 years
- Observation Platforms
    - Aquatic Observation Systems (AO/IS)
    - Airborne Observation (AOP)
    - Terrestrial observations (TOS)
    - Terrestrial Instrument Systems (TIS)
- LiDAR is one piece of a larger puzzle
- Unique features of NEON
    - NEON is Continental in scope
    - Timeframe (30 years)
    - Integrated Observations (standardized instrumentation, procedures and protocol)
        - representative sampling across replicated gradients
    - Collaborative scientific enterprise (free open access to public)
- Airborne Observation Platform
    - Jet Propulsion Laboratory provided Imaging Spectrometer
        - Optech D-8900 camera
        - Optech ALTM Gemini
    - The lowdown: a combination of Hyperspectral Imaging, Gemini Waveform LiDAR, Optech RGB Digital Camera
    - Concept of Operations
        - 3 identical payloads
        - 3 aircraft
        - March-October flights continuously annually
        - 1 aircraft west USA, 1 east, 1 opportunistic (fires, floods. etc.)
    - Scientific staff to conduct ground measurements for calibration of imagery

- LiDAR and Hyperspectral flight parameters are matched as much as possible
    - e.g. footprint diameter etc...
- Optimizing LiDAR Parameters
    - playing with configurations
        - wide vs narrow divergence
    - parameter sets will depend on multiple factors
        - Single segment vs multiple segment waveforms?
        - Trigger threshold values?
- High Park Fire, CO with CSU and Others
    - Fire burned 350 km^2 in Colorado
        - State of the landscape
        - Conditions prior to the fire
        - fire severity and pattern affect
        - What parameters are best to capture “snags”?
            - 5 different parameter sets
- Overview of NEON
    - RAW (L0)
        - raw data
        - ancillary data
    - Calibrated (L1)
        - Radiometric, orthorectified, atmospheric correction, etc.
    - Derived (L2/L3)
        - Science data products and native and lower resolutions
            - Biodiversity
                - Biogeochemistry
                - Land use
                - Bioclimate
                    - Leaf area index
        - Calibrated Discrete and Waveform LiDAR Data
- Integration with non-airborne platform data
    - Ground based spectral collections (Harvard University)
            - spectral library?
        - Rochester institute of technology - Ground Sampling
        - Boston University / U of Massachusetts - Ground Sampling
    - HyspIRI satellite (60,000 ft) integration being investigated.
- American Geophysical Union Meeting 2013 Session B069

7. <u>Efficient LiDAR Processing with LAStools - Dr. Martin Isenburg, rapidlasso GmbH, Germany</u>

- LAStools - efficient processing of Massive LiDAR data
- Elsewhere
    - Europe
        - First to use LiDAR on a large scale
            - Many areas are below sea level
                - e.g. Netherlands
                    - First national coverage ~1969
                    - High demand for precision
                    - LiDAR Points vs DTM Raster
                        - users are far more familiar with grids
    - Asia
        - Flooding
            - Philippines
                - DREAM LiDAR Project
                    - Acquire 3D elevation with sufficient resolution to create an Elevation Model and produce flood maps for major river systems

            - develop capacity
            - +/- 20 cm vertical accuracy
            - 33% of Philippines landmass
    - Generating Billion Point TINs
        - input streaming TIN from triangulator
            - generate Raster DEM from Mass Points via TIN
        - impractical to store LiDAR in ASCII format
    - LAStools
        - started in January 2007
        - commercialized in 2010
        - strengths are the data processing tools
        - toolbox interface for ArcGIS
        - Workflow
            - ground points
                - height points
                    - classified points
    - Free LiDAR
        - Land Survey of Finland
        - Danish
    - Full waveform

8. LiDAR system and terrain error modelling - Tristan Goulden, Ph.D. student (ABD), Dept. of Process Engineering & Applied Science, Dalhousie U, Halifax

- Error
    - Trust of data quality
    - Risk assessments
    - Mission planning capabilities
    - Majority of DEM users do not consider error
- Sources of Error
    - hardware components
        - GPS
        - Inertial Measurement Unit
        - Laser Ranger
        - Laser Scanner
    - Slope
    - divergence, etc...
- Empirically observed RMS error
    - Huising and Pereira (1998)
    - Hyyppa et al (2005)
    - Errors up to 70 cm
- Error modeling
    - Ussyshkin and Smith (2006) - Performance analysis of ALTM 3100EA: Instrument specifications and accuracy of LiDAR data
- Error modelling results
    - 3D ellipsoid describing the space which containts the point with statistical confidence
- Hardware errors
    - Direct georeferenceing of LiDAR
        - each component contains error
    - GPS error
        - satellite availability/geometry
        - atmospheric interference
    - Laser scanner
        - angular error
        - manufacture of angular encoder, etc...

    - GPS error: H: 3-5 cm V: 5-10 cm
    - IMU error: ...
- Recall basic Propagation of error calculations
- Error increases with scan angle
    - scan angle errors increase with flight elevation
        - implications for mission planning
- Terrain related errors
    - Beam divergence
        - Peak power occurs along beam centreline
        - Radial distance from beam centerline vs % irradiance follows a normal distribution on flat ground.
        - Incidence angle
            - "smeared footprints" can occur on sloped areas
            - Ideally, pulse will contact perpendicular to terrain
    - Predicting slope based error
        - Koppe's formula
            - horizontal error (hardware componence)
            - vertical error
        - Propagate error based on terrain slope
            - combine hardware errors with a terrain model
            - etc...
    - LiDAR DEM error
        - Predictable errors can arise due to scanlines (on survey)
    - Conclusions
        - Manufacturer accuracy specification and quality assurance procedures prove sensor was operating correctly, not necessarily an estimate of error across the survey area.

9. <u>User-side Analysis of the Effects of Airborne LiDAR uncertainties on mapping applications - Patrick Adda, Ph.D student (ABD), Dept geomatics Engineering, U of New Brunswick, Fredrickton</u>

- Evolution of positioning
    - a single error model is not appropriate for all
- Why user-side error analysis
    - accurate spatial information
    - ID blunders from acquired LiDAR data
    - Field blunders while validating LiDAR point clouds
- Start with specifications
    - Different applications, different accuracy requirements
    - Plan allowable error
        - Manufacturer's uncertainty budget + Uncertainty effects
            - user defined Total uncertainty Budget
                - Specifications met / not met/ over-specified / under-specified
                - Recall the propagation of error
                - Understand the limitations of the data!
- Checkpatching Approach
    - Field validation of accuracy
        - by Merrett Survey Partnership, UK,
        - etc...
    - Checkpoints should be 3x more accurate than LiDAR data
        - find differences between ground truth data and LiDAR
- Lessons Learned
    - The vendor is typical suspect for erroneous data
        - flight errors
    - Digital Terrain Models contain elevation errors
        - In practice, flood mapping accuracy can be compromised
    - Obstructions increase RMSE error.

        - Data capture process
        - survey tools and methods
        - limiting technology
        - etc...

<u>10. A hierarchichal LiDAR data fusion classification of land cover types in Alberta and the NorthWest Territories - Dr. Laura Chasmer, Wilfrid Laurier University & U of Lethbridge, AB</u>

- Problem
    - accurate classification of rapidly changing landcover to quantify changes affect ecosystems
    - Background
        - Historical Land cover change due to permafrost thaw in NWT
            - Bog/Fen CO2 emissions
                - implications for carbon flux
            - Scotty Creek NWT - discontinuous permafrost (rapidly changing)
            - Utikuma Regional Study Area - heterogeneous upland/peatland complex
        - Accurate Change detection
            - critical to accuracy of rates of change
            - confusion matrices do not provide 'accuracy'
        - Improve accuracy of Land Surface Models
            - increased errors due to inaccuracy of inputs
        - Human Disturbance
            - Linear features
        - Policy and Planning
- Objectives
    - Design a decision tree fusion classification
        - LiDAR Data (airborne)
            - Topography
                - Statistical separation and based on radial association (from DEMS)
            - texture
                - Plan curvature, rate of change in terrain
            - vegetation structure
                - iterative low-pass filter (mean)
        - Worldview2
            - single intensity
            - SVI
            - Speckle
        - Decision tree classification is more accurate when ground truthed
        - Confusion matrix overestimated the accuracy of unsupervised classification
    - See ppt for specifics of how well individual decision criteria worked...
    - Spectral data introduced uncertainty in some cases
    - An example from Slave Lake, AB was provided - Land cover classifications
- Differences in Discharge rates were found between Fusion and Parallel-piped methods of classification
    - differences of up to 23%
    - Discharge significantly influenced by area
- The importance of a good land cover classification
    - Scotty Creek Discontinuous Permafrost
    - Spectral classification: 2x greater plateau area than DT Fusion
    - SC = overestimate thaw-related discharge from plateaus
    - Suggests that increases in modeled discharge due to plateau haw may be lower than previously anticipated.

11. <u>Overview of the projects undertaken by the Government of Alberta involving iterative low-pass filter (mean) and other remote sensing techniques - Dr. Barry White & Dr. Shane Patterson, ESRD, GOA, Edmonton</u>

Innovation supporting continuous improvement in environmental and economic performance

- Wet areas mapping:
  - Useful in planning
    - watershed.for.unb.ca/TRAIL
    - TRAIL TOOL - recreational trail planning tool
  - Contaminant spill containment scenarios
  - Value chain optimization
    - connecting standing volume to world market
    - assessing milling opportunities at the forest estate level
  - Landscape prediction of vegetation community types
    - invasive species management, site classification and strategic investments in silviculture
- Moving Forward
      - enhanced LiDAR-related innovation within Alberta to increase home-grown solutions
      - need to focus on developing LiDAR tools
- Earth Observation & Remote Sensing Technologies
  - Finding new applications for existing data resources.
    - Energy, forestry, linear developments
      - Contamination issues, 20-50 year flood mitigation
    - Equivalent Land Capability
      - Natural regeneration
        - Landform design
          - Geotechnical stability
          - natural appearance
        - Watershed development
          - Water extent
          - wetlands/peatlands
    - Canada Centre for Remote Sensing
    - Monitoring Procedures for Reclamation in AB
      - University of Lethbridge
  - Summary
    - EO/RS tools represent transformational technologies that would assist in environmental policy, monitoring and regulatory programs
    - Need to continue building integrated and collaborative partnerships and approaches
    - Continued investment in innovation tied directly to "strategic needs"
    - Need to be mindful that "mare can be worse"
    - Avoid becoming "needlessly complex"

Q&A:

Q: Has Alberta gotten to the point where they are using multiple layers of LiDAR data (e.g. change detection, etc.)?
A: The impetus has been on getting complete coverage of the province. Only limited areas have 2 timeframes of LiDAR coverage. Most of the data is from ca 2008.
Chris Hopkins: University community has access to multi-temporal datasets, in combination with GOA's...

Q: Where is AB going with emergency management within the context of LiDAR.
A: Wet areas mapping was largely a response to pine beetle infestations.
Bob Sleep: LiDAR purchases have substantially aided forward planning.

12. <u>Canadian Federal Government LiDAR guidelines - Philippe Lamothe and Darren Jansen, Natural Resources Canada, Ottawa, ON</u>

- Elevation and LiDAR Activities at NRCan
- Caveat: For this presentation "standards" = "Guidelines" - Standards have not yet been approved.
- Overview
  - National Elevation Project
    - A popular geospatial data theme

- Limited data and products
- etc.
- Data Portal (http://geogratis.gc.ca/site/extraction)
    - Derivatives
- Open architechture point cloud
- Canadian Airborne LiDAR Acquisition Guidelines
    - Objectives
        - Create a standard for the National Elevation System
        - Support planning
        - Support the creation of national master Standing Offer (NMSO) for LiDAR acquisitions
                - prearranged contracts with set pricing structures
    - Summer 2012 0 First Draft of Federal guidelines
        - Major feedback themes
            - Clarity from the perspective of users/providers
            - Who has which roles & responsibilities
        - Summer 2013 - Second Draft (soon) Feedback requested on:
            - Sectional breakdown
                - Project Planning and Contracting
                - Genreal LiDAR Survey
                - etc...
            - Environmental Conditions
                - Snow/cloud/etc.
                - Leaf-on / Leaf Off
            - Coastal Applications & Low Tide
            - Nominal Pulse Spacing
                - Low (1 pulse / 2 M^2)
                - standard
                - high (2 pulses/m^2)
            - Data voids & Flight Lines
                - scan angle
                - spacial accuracy requirements
                - data voids
            - Data Ownership model
                - Feds are commitment to an open data policy
            - Point cloud classification
                - levels of accuracy requirements
                    - e.g.:
                        - ground
                        - low veg
                        - etc...
            - Metadata
            - Project planning and Reporting Specifications
    - GeoHash Tree and LiDAR
        - global, hierarchical, variable-sized cell structure
        - A dataware housing structure: see ppt for more details
        - Take home message: Open-source structure...
    - Pointcloud: http://github.com/pramsey/... (see ppt for URLs)

Tuesday, July 9, 2013

1. <u>Panel discussion: The need for reporting standards.</u>

Panel Members: Philippe Lamothe (NRCAN), Dr. Martin Isenburg (rapidlasso), Barry White (ESRD), Jocelyn Parent (Airborne Imaging), Tanya Ramond (NEON)

- Barry White
    - LiDAR acquisitions must be of sufficient quality to promote adequate vegetation inventories (Forestry, Wetland, etc.). A failure to meet this basic standard would result in the propagation of errors throughout management frameworks.
    - Guidelines are important, however care must be taken not to stifle innovation
    - How does error propagation effect specific parameters of LiDAR?
        - Bob Sleep: LiDAR is simply another tool in the toolbox for end users. LiDAR may have been oversold early in its adoption. LiDAR produces excellent DEMs, however it is most useful in combination with other products. Negative perceptions may still linger stemming from early sales tactics.
        - Chris Hopkinson: ...early proponents of LiDAR may have sold LiDAR as the "answer to the Universe," however, the industry has matured and hopefully perceptions will as well.
- Patrick Adda: ... LiDAR guidelines should have a lifecycle in order to keep up with changes in technology.
- Barry White: (essentially agreed and stated that this is the model that Alberta Uses)

Isenburg: Standards are wonderful, but you need standards for how to make standards. LAS 1.3 is a good example. LAS 1-1.2 were excellent. Starting with 1.3 there were problems, however the standards were not developed within a transparent environment. Standards must be developed within a transparent environment.

- Full waveform data format: example: proposed by Leica for their tools. Was unopposed in the (closed) standards discussions. This wound up within the LAS standards even though the needs of other users (non-Leica) are not met.
- discussion group (http://www.pulsewaves.org)
    - Reiterated the need for an "open, transparent, and updatable standards development environment"

- UK: The open and transparent model needs a champion (with integrity), otherwise this model will be unsuccessful.
- Bruce MacArthur: The pace of change will likely render standards obsolete very quickly.
- Isenburg: pulsewaves.org will allow both data sharing and collaborative standard development.
- Bob Sleep: The continuous updating of standards may cause the obsolescence and require governments to continuously build business cases to keep up.
- Isenburg: LAS is central to the framework (an orthogonal standard), and the file formats would become obsolete.

Philippe Lamothe: NRCan is in the process of developing federal data reporting guidelines. What do users want to see in reporting? What elements are missing? how do providers currently interact with standards that currently exist? How does industry encourage their use?

- Bob Sleep: Developing a set of guidelines that would meet the end result we wanted. People within the industry are very receptive to sharing and providing information for standards development.
- UK3: A one size fits all standard is likely unworkable. Different applications may require different nuances in the data. (e.g. bare earth is best attained with leaf-off imagery).

Chris Hopkinson: Suggested a "template" approach, where specific metadata is required, but no hard boundaries are placed on how that information is recorded.

Tanya Ramond: NEON requires very standardized and consistent approach.

- NEON is a national scale LiDAR project, which is unique. NEON may provide an opportunity to set standards that others would adopt.
- Standards need lifecycles, but further, standards should really be instrument specific.
- Points per m^2 does nothing to inform the strength of the laser being used (photons hitting the ground). pts/m^2 is not specific enough for standards reporting.
- Chris Hopkinson: reiterated the importance of Tanya's comments.
- Philippe Lamothe: Examples in Quebec
- Vladimir (Reigl): Saying the LiDAR was not accurate enough is not specific enough. An analysis of the systems used to collect the LiDAR and training of providers should also be examined.
    - A stronger laser is not the solution in all cases. In some cases higher repetition rates will provide better data.
- Chris: All else being equal, higher rep rates can result in a decrease in the positional accuracy.
- Vladimir: The performance of the system is highly dependent on the reflectivity of the surface being analyzed.
- Tanya: Instrument parameters and landscape characteristics do need to be addressed in the planning phase. There is software available for modeling the effects of these variables.

Jocelyn Parent (Airborne Imaging): Most clients buying LiDAR do not know exactly what we want, so they refer to USGS specs. The USGS specs are designed to meet the needs of the USGS, not everyone. If we put specs together, they should meet only the base requirements (a minimum standard of quality). This would allow for flexibility in the design of data capture and processing. Comprehensive standards would drive up the cost of data acquisition.

Vertical accuracy standards should be specific to ground points.
Hard-coded number standards would likely be a mistake.
Prefer a minimum standard onto which bells and whistles can be added.
Formats should not be specified, to avoid making specifications too restrictive

- Bret Purdy: Development of standards is much more difficult than developing guidelines. More professional judgement is required when working with guidelines. Standards are easier to work with, but they do not necessarily result in better products as much of the professional judgement is sidelined.

2. Breakout Discussion

Chris Hopkinson's introduction of the discussion

Project Areas

- Mission specifications
  - survey area
  - Timing
  - Data requirements
- Survey planning
  - configuration
  - route planning
- Airborne operations
  - logistical challenges
  - calibrations, etc.
- Ground support
  - Primary duties of the ground crew:
    - set up base stations
    - collect calibration/validation data
    - Process data
    - client interaction
- System calibration
- Data Integration
- Data output
  - datums/projections
  - file formats
  - Raw info (GPS, scan angle, etc)
  - File size / tile extents
  - derivative features
- Data Quality Concepts
  - Data quality
  - Absolute accuracy
  - Relative accuracy
  - Precision
- Accuracy classes
  - Fundamental vertical accuracy
    - accuracy in open and typically flat 'hard surfaced areas'
  - supplemental vertical accuracy
    - a range of land surface classes
  - consolidated vertical accuracy
- Nominal Point Spacing
- Data storage, formats & management

    - data management is likely the most important of the 3.
- Understanding Data Size
    - Increasing data density increases the file sizes
- Analysis Workflows
    - Many user specific needs
    - limited off the shelf software
    - Converting point clouds into decision-ready info can be complex
    - Many packages needed = high investment in skills & software
    - Etc...

Breakout discussion points

Academic perspective

- What are the goals for standards and best practice guidelines?
    - Integrity and consistency of data
    - Accessibility
    - Processing thread metadata standards incorporated. Adequate documentation of data manipulations
        - Data lineage, adequate documentation
            - Sensor information and referencing system information
        - File formats
        - Discrete or waveform

- Who should set the standards & best practices?
    - All sectors should be represented:
        - Academic incentives include data accuracy and consistency.
            - Vested interests include: data for Publications and new research,
        - Standardize the methodology for measurement of accuracy
        - Academics associations should provide support and research

- What role can Universities play?
    - Publication and scrutiny of data quality & manipulation techniques
    - Support through research

Data providers perspective

- Goals
    - brief specifications to avoid limiting the technologies
        - Federal Government should set the standards but remain adaptable
        - Universities should provide training and processing
            - in-depth theory provided
            - fundamental knowledge basics
        - Industry should provide certification for specific products, proprietary processes, etc.
    - Ground control best practices should be outlined

End-user perspective

- Transparency in the development of standards
    - include a diverse group of users and developers
- Specific enough to be useful, but general enough to not stifle innovation
- State clearly the intended purpose of the standard
- Universities: Provide training of standards
    - watch dog role, assessing unintended consequences of standards

Natural Resources perspective

- Multi-level standard approach (National --> Provincial --> Jurisdiction / Industry)
- Parameter sensitivity specifications
    - implications
        - applications

        - errors
- Universities' role:
    - Development of new methodologies
    - Determining the sources of error and error propagation
    - Developing risk profiles

Environment Perspective
- Develop a Stakeholder process
    - Then allow industry to develop standards & business cases that meets stakeholder needs
- Stakeholders define the outcome, Industry prescribes solutions
    - Co-Operative / user Groups
- Universities' role
    - Determine the current state of technology
    - Determine best available technology that is economically achievable
    - Define the limitations of the technology (objective watch-dog role)
    - Developing LiDAR applications
        - context specific

Government Perspective
- Develop agnostic datasets
- Data fusion standards
- Universities' role:
    - develop an end-use matrix for guidelines
    - Define specifications
    - Proof of concept
    - seminars
    - education and outreach
    - become an active participant

<u>3. Panel Discussion: Data Repositories</u>

Panel members: Shane Patterson (GOA), Olaf Neimann (U of Victoria), Bruce MacArthur (Tesera Systems), Dr. Martin Isenburg (rapidlasso), Jocelyn Parent (Airborne Imaging), Philippe Lamothe (NRCan)

- Topics:
    - LiDAR data exists for growing area is in Canada, but no easy access exists for end users
    - Limits data sharing within & accross institutions
    - Missed project opportunities
- Data access and archival was rated as the most important on average priorities (from forum attendee survey)
- Survey respondents were 89% supportive regarding the use of a hypothetical online LiDAR data repository
- Challenges
    - data size
    - 3rd party software or in-house development
    - Licensing
    - Funding sources
    - Commercial or public model...
- Discussion questions
    - Do we want or need a LiDAR data centre?
    - What form should it take
    - What services should it provide?
    - Where should the data sit?

Martin Isenburg:

- What is already available?
    - www.laszip.org - a list of free and lossless LiDAR data sources
        - several examples internal to that site were shown
- Jocelyn: It would be nice to know the full geographical extent of existing data, regardless of the vendor or organization that owns it.
    - A 3rd party should operated the data centre if it is a collective effort, or done in-house for private effort.
- Chris Hopkinson: A collective site might be an effective way to market existing data.

Bruce MacArthur: Service provider performing data analytics.
- Finding data is the most challenging aspect of analytical services
    - Many product libraries are not searchable spatially
    - Finding datasets can comprise 25-70% of the workload in analytics
- Many different business models exist, different parties could find common ground through the development of a data portal
- Much of the data is firewalled, many opportunities exist for industry growth and employment if LiDAR was made more accessible.

Olaf Niemann: Academic perspective - open access would be fantastic
- Datacenters would allow for consistent metadata and source tracking procedures
- Government Agencies should be helpful in setting these up due to the costs
    - Non-profits and Universities do not have enough funding to pull it off, that leaves government

Philippe Lamothe: Federal Government Perspective
- Federal government is in the process of building a National Elevation System data centre with support for LiDAR.
    - However, what constitutes LiDAR data?
        - Point clouds are difficulty
            - software availability
            - software usability
        - Similarities to the development of GIS
    - Data Centre should:
        - Provide access & discovery
        - core functionality
        - Wherever possible - open geospatial data
- Questions
    - what impediments are there for data sharing from the perspective of clients & providers? Data ownership? Sensitivity of the data?
- Chris Hopkinson: The large proportion of the data out there is licensed to some degree.
- Philippe: were developing this portal on faith that data providers will share their data.
- UK: A solution may be that the index is provided on the site, but a dual model be adopted: 1) open source data; 2) Proprietary data for sale
- Chris: A logical concept it is, but If the Canadian government hosts data indexes online, does that constitute advertising and therefore a conflict of interest?
- Philippe: Yes
- Isenburg: A way around that is to provide a low resolution dataset, with information directing users towards more dtailed datasets available.
- Bruce:?Merks? Might be another avenue. They have contracts available for...
- Chris: Would the federal government be willing to host information for which they are not responsible, with a disclaimer.
- Philippe: Crowd-sourcing is an avenue we could explore
- Patrick Abba: Will it ever be possible for Canada to make data freely available.
- Martin Maric: The problem is that our government is not spending the money to acquire the data outright, in which case they would be freely available to distribute it.
- Patrick Abba: Would it not be a better use of taxpayer money to distribute the data and reap the benefits of innovation?

- Chris: (playing devil's advocate) In defense of Alberta's model, the licenses for the data were obtained at a much cheaper cost, which it can be argued that it might be a better use of taxpayers dollars.
- Mike Leslar (Optech): Liability is also an issue, liability comes with data ownership and distribution.
- Bob Sleep: The $20 M we spent licensing the data has paid dividends in savings and planning. However, if we had approached managers with the price tag it would cost to purchase the data, we never would have acquired it.
- Bev Wilson: data subscriptions...

Shane Patterson: GOA perspective
- How can we bring stakeholders together in a framework where multiple users can use LiDAR data
- Business cases must be considered, both businesses and government are stakeholders in the process
- How can LiDAR data be shared, but also GOA requires updated data on a regular basis.
- Chris: What happens to the derivative products?
- Shane: Value added products are shareable. Data sharing agreements must be attained to share raw data with researchers.
- Bob Sleep: If there are derivative datasets, we are able to share and distribute them
- Patrick Abba: Could government / private partnerships be used to purchase and distribute full provincial coverages?
- Shane: This is one potential avenue to purchase the data. This is one of the main ideas behind bringing the various stakeholder groups together to collectively fund the acquisition.

4. Breakout Session

LiDAR Training & Flood Modeling Example

Opening Comments: Chris Hopkinson
- Community needs
    - Communication
    - Training
    - Applied Research
- Software platforms
    - Data providers
    - End-users
    - Different software packages for each
        - somewhat inefficient to use several software packages within a single workflow
    - Training
        - where to focus training time
            - point cloud processing (data providers seem to use these more)
            - raster training (end users seem to prefer)
            - how do we divide training time?
    - Enduser experience & resources
        - steep learning curve for point cloud processing
        - how much training investment is required
    - Training options (knowledge transfer)
        - vendor-specific seminars/workshops
        - conference workshops
        - lectures/coursework
        - Internships/practicums (most bang for the buck)
        - Graduate theses
        - Conferences & publications
        - Research-based field training
    - The C-CLEAR example
        - Canadian Consortium LiDAR Enviro Apps Research
        - Offshoot of Optech's in-house research & client demonstrations
        - several ad hoc projects 2000-2003 with NRCAN, Env Can, WLU, Queens, Western
        - C-CLEAR partnered on a CFI proposal in 2003 to acquired LiDAR equipment
        - 2004-2011 C-CLEAR operated out of AGRG using ALTM 3100C & ILRIS 3D

- Essentially a University outreach to the federal government
  - federal government was involved in the planning process
- Examples of training/outreach needs
  - Most C-CLEAR support for forestry & hydrology applied research
    - biomass modeling / land surface classification
    - Watersheds / flood modeling / visualization
  - Gradual acceptance of LiDAR for forest resource inventory
  - Occasional perceiption that LiDAR cannot suppor accurate flood modeling
  - Sometimes a change in approach is needed - new methods need to be proven, standardized and trained

Breakout discussion points

Academic perspective

- Q: What are education / training / outreach priorities?
- A: Universities do not train, they educate!
  - Universities should focus on theoretical aspects and foster critical thinking. Colleges and training institutes (e.g. NAIT/SAIT) are for training.
  - Universities should prioritize the understanding of the data, how it is derived and how it is applied. This is consistent with the need to maintain quality and consistency in the data.
  - Outreach: Foster critical thinking among the LiDAR community.
    - Pursue Pilot projects with various stakeholder groups (e.g. Garry Oak Society)

- Q: Do we need certification programs?
- A: Not the academic communities responsibility, this responsibility is best left to the professional societies.
  - LiDAR community is a large, eclectic group with diverse needs.
  - It is a contentious issue whether a certification program is even necessary. There was no consensus among the group.
    - Pros: degree of accountability
      - level of expectations are (in theory) met by the contractor
    - Cons: Meaningless barrier to entry into the industry
      - needlessly prohibitive
      - deterrent to entry into the field
- Q: If so, who should accredit & deliver training; i.e. set curriculum?
- A: CRSS or industry groups that represent diverse interests should deliver industry specific training
  - Any training towards certification should be distinct from University training and curriculums
  - Given much data exist, what are the barriers to implementing an Alberta-wide LiDAR flood risk assessment?
    - Data accessibility and data ownership, period!
      - Therefore costs.
    - Liability: Data quality may be an issue due to liabilities that arise because of error in value aded products
    - Data of sufficient quality is essential to generating accurate flood risk assessments.

Government perspective

Q: What are education / training / outreach priorities?
A: there is a need for training

- Methodologies for LiDAR surveys
- Management aspects
- Intro to LiDAR (seminar / webinar) technology training short-course
  - decision-makers / project managers

Q: Do we need certification programs?
A: Depends on the job market. No consensus. Both pros and cons among the group.

- Would require industry acceptance.

Q: If so, who should accredit & deliver training; i.e. set curriculum?
A: CRSS, other groups

- Possibly a modular online accreditation
- Industry related practicums
- Develop co-op programs in partnership with Universities

Data Provider Perspective

Q: What are education / training / outreach priorities?

A: Onus should fall on the manufacturers to provide training for specific work flows

Q: Do we need certification programs?

A: Certification programs are probably not necessary

- The LiDAR community is not yet large enough
    - extra university courses may be beneficial to applicants because it shows interest and initiative

Q: If so, who should accredit & deliver training; i.e. set curriculum?

A: it would be an additional barrier to entry into the industry

Q: Given much data exist, what are the barriers to implementing an Alberta-wide LiDAR flood risk assessment?

A: Traditional approaches of using cross sections may offer higher accuracy point to point, however LiDAR fills in the blanks in between

- Barriers include convincing decision makers that the dataset is beneficial
- Data accessibility is an issue

EndUsers' Perspective

Q: What are education / training / outreach priorities?

A: Focus on interdisciplinary aspects of LiDAR data uses

- e.g. engineering & meterologists, analytics,
- climate change adaptation
- Collaborative skills

Q: Do we need certification programs?

A: Not necessary

Q: If so, who should accredit & deliver training; i.e. set curriculum?

- no answer given

Q: Given much data exist, what are the barriers to implementing an Alberta-wide LiDAR flood risk assessment?

A: Likely to become increasingly political

- finger-pointing
- shifting of responsibilities between levels of government and private interests
- Public discussion is arising due to recent flooding in Alberta
    - technical barriers still exists
    - recent events may open access to funding

Environment perspective

Q: What are education / training / outreach priorities?

A: Data handling issues and troubleshooting

- practical aspects of LiDAR
- internal training
    - undergrad
    - virtual master's programs
    - faculty of extension
- Combination of other datasets

Q: Do we need certification programs?

A: There are professional organizations that already exist

Q: If so, who should accredit & deliver training; i.e. set curriculum?

A: LiDAR could be included in one of the existing professional certification programs

- generic vs. thematic
- provincial vs national?

Q: Given much data exist, what are the barriers to implementing an Alberta-wide LiDAR flood risk assessment?

A: Political (both internal and external) interests

- Reports might be shelved without further action, because it is not a priority of the day
    - Perceived as a valuable tool to supplement existing methodologies and surveys
- Pilot projects are needed to demonstrate the technology

- Build business cases

Closing comments:

Chris Hopkinson:
- Shared report will be drafted on the forum proceedings
- Stakeholder needs
    - diverse range of opinions
    - dynamic guidelines are temporally sensitive given the rate of change in technology
    - LiDAR community is very interdisciplinary
    - Open/licensing issues remain a barrier to the development of data centers
        - no solutions were reached, but there were many relevant points raised
    - "Training" vs "principles" approach to education
        - "training" may be too specific and pigeon-hole academic curriculums
- Request for Information proposals may be generated
    - may create the opportunity to get very targeted answers

Appendix 2. Open discussion notes collected by Dr.Laura Chasmer, University of Lethbridge.

'Standards' Panel discussion:

Barry White: Promotes lidar within the government. Have purchased 1 million ha of lidar data every year since 2007/2008. Alberta's wet areas mapping video on YouTube. Boreal forest, very busy, huge challenges due to many uses, and variability. Very flat landscape and also very wet. At least 50% of it are wetlands.

Lidar acquisitions must be adequate for mapping land surface features. Important for sustainability, including conservation, wetlands, etc. Also recognize the importance of planning for flood mitigation, and how lidar can be used for this. Recognised that when you proceed with lidar data, you need to get it right the first time, e.g. you can only get the money once. They did have a workshop when they first started this, and they did develop a set of guidelines for data acquisition. It was a very well established process. Guidelines are critical, but you also don't want to stifle innovation. Technology is moving forward, and so they do want to also move forward, but these new developments must also meet the previous guidelines (so that datasets are comparable and produce the same results). One of the questions that they have is better understanding the error propagation, and how that influences their data products, errors, etc. The other issue that they have is that there is still confusion about the use of lidar. For example, someone might say that they have lidar data and that it didn't work for them, but then this misperception will go through a group and will give it a bad name, when in fact the people didn't actually have lidar data, but did have a data product that might not have been the best thing.

Bob Sleep: Lidar is a tool, it won't solve all of your problems, but you can get a lot of information from it. It needs to be used in such a way that it is a tool, but not expected that it will answer all of your problems. Some of these perceptions may linger…

Tristan: speaking on error propagation – Errors are still very problematic, and there have been simple tools created, but there is still a lot more room for discussions on that.

Chris: There are certain guidelines that address accuracy specs. Whether they meet GoA's specs, that may or may not be the case…

Bob Sleep: GoA do have some specs…

Chris: Did ASPRS allude to error propagation in their guidelines?

Tristan: This has been tossed around, but currently there are other things that are more pressing. It occasionally is brought up, but it is often tossed to the wayside.

Patrick: May be more interest by end users. Reiterates what Barry White says with regards to movement forward of Technology, without stifling it.

Martin's perspectives: Standards are very good, but also need a standard on how to define a standard. E.g. if you look at LAS format, he got involved in injecting transparency on next generation of the standard. The people who defined the standard were a bunch of guys who worked with industry. LAS 1.0, 1.1, etc. were very good. And then came 1.3 some strange things happened, where things weren't as transparent. Since people are coming from large industry, they aren't necessarily coming from the best view of the users, but rather from the viewpoint of what will help their company. When LAS1.4 came along, there was no transparency. Comments were basically ignored by big companies. There is still no transparency in the process. Hopes that there will be some open discussion on line.

In the meantime he felt the need for a new lidar format that supports full waveform. There was only support by Leica to support their full waveform. They proposed it a couple of times, and it became a standard, but this isn't very useful because it doesn't address the other vendors needs. There are proprietary formats of the vendors, theres the sorted pulse data library (a working format), and the GeoLAS format. You can't currently share full waveform data because the formats all vary. Martin created some open source code to process full waveform data using a free reference implementation.

Starting in Dec 2011, he started to develop new versions of the full waveform reader. He emailed everyone who could possibly use the "pulsewaves.org" website. He got funding from ARA and Riegle Compatable with ASPRS LAS format, GPS time connects pulses and returns. He was never tied to any one vendor. Always very open and transparent standards where anyone can discuss. There is no secrecy. This is very important to make a standard credible and accepted within the community.

Chris: Are there situations where completely open standards are not the best way to go?

?: Need champions who will keep it open and spend time on them…

Bruce: this conversation is happening in many domains that happen simultaneously (e.g. standards created by ESRI, who often try to promote their view of the world). Challenge we have is that data and technology are evolving, and the pace of it is outpacing the setting of the standards. So by the time the standards are created, the technology/data have already changed. This is tough. Interfacing with the different players becomes really challenging.

Chris: Standard has the potential to stifle innovation?

Bruce: Pace of tech change and data innovation and all dynamics associated with new formats is just going to increase.

Chris/Bruce: data wars. Different companies competing for their standards to be used.

Martin: Full waveform example is almost opposite – very slow. There were 5-6 different waveform formats. Spend 3-4 months trying to figure out how to just open the data. PulseWave is ahead of the curve because it will allow people to open up a variety of data types.

Bob Sleep: When you have +20 million $ investment, need to have new business cases to start a new standard. How do they integrate it with the older standard? For the province of Alberta, this is a big challenge.

Martin: Varies depending on whether you are using discrete vs. waveform.

Phillippe Vermothe perspectives: Lidar data and reporting standards. They call it guidelines. Not yet standards. They find it important to foster a strong relationship between users and data providers. NRCAN put out guidelines, didn't reach everyone, but there wa considerable feedback. There wasn't much input from commercial clients. All respondents were interested. Amongst the respondents, most stated the same things, but there were things that people disagreed on.Most important, how to report and what to report. What do you want to see in reporting. What elements have you found to be missing, lacking or unnecessary? As a client or provider, how do you interact with standards that currently exist? Are you aware of them? Using them? Recommending them? As an industry, how do we encourage their use?

Bob Sleep: When they started this 6 years ago, they just spoke with people from industry and academia to figureout how to set the guidelines. Hamin Habib, Chris Hopkinson, and others to tap into. If you are setting guidelines, there are lots of people in industry and academia who will contribute.

?: There are cases where not all standards will work. E.g. different objectives will have different standards. How do you define these? E.g. if someone wants a v. good dem of ground, then it is critical that we fly with leaf off. Or if you are flying transmission lines, if you are going over areas with crops, that can be a major problem because there are far fewer returns from the ground. So I am not sure if there can be one standard for everything.

Chris: When we worked on NS guidelines, there were many stakeholders and users of the data for different reasons. Use a Boolean definition depending on the application. Was one slide yesterday (Philipe) where there were varying needs. Some needs can meet a large number of specs, but a Boolean approach is outthere but very difficult to implement.

Patrick: Need to have some guidelines, but not for everyond, but at least at a minimum where most people could use them. Datums matter. Everyone else has them, so we should too.

Chris: often don't have a minimum, but there is a template which is a guideline with blank spaces. That is very useful because it states what are most important. E.g. you don't have any numbers because what is true today won't necessarily be true tomorrow.

Tanya: If they focus on NEON, need to develop a finite set of parameters to enable site and year comparisons, otherwise this hampers the useability of the data. Can also increase errors if you are trying to standardize the higher level data products, especially if they weren't acquired during the same conditions. Make 3 different sets of parameters/standards for all of their data acquisitions. Of course, constrained because they are also doing data fusion with a spectrometer. They have a unique set of parameters that may not be as applicable to another user who is doing some other kind of project. If the NEON project from a lidar stand point is a national scale lidar project – there are no others. USGS has standards, but they haven't done full national studies. This would be a case study for lidar on a full national scale. This could be a starting point. E.g. could use NEON data standards. Standards need life cycles, and are really instrument specific also. Although they want to make payloads identicle, they will need to upgrade their instrumentation, and this needs to be considered. Once question that she has: People are used to thinking about points per m2, but she wanted to take this to another level. Pts/m2 just tells you about your coverage, but it doesn't tell you about the strength of the laser pulse (e.g. the photons reflected). This will change from year to year.

Chris: There is a tendency to have higher and higher PRF, but it usually means lower accuracy returns. Doesn't necessarily contain more information. So there should be guidelines.

Phillipe: Tenders for companies that had v. good point densities but terrible accuracies. Need to meet the required accuracies. This is in a guideline.

Vladimir: A lot of service providers try to be very competitive, they don't really do everything the best way. Therefore poor data has been delivered, but not necessarily connected to the higher rep rate. Also need to consider how the data are collected. Is it better to have higher PRF within canopy? He has looked at forestry for a bit, but it really does depend on species. If higher PRF, will paint the full canopy, so greater chance that pulses will get through the canopy. Less power, but more points will get through the canopy due to probability.

Chris: What Vladimir is saying is true up to a point, but this does require some guideline. But if you are flying at 200 kHz, you need to adjust the flying height. When you are close to the operational limit, this is where you get a lot of degradation. As you go from 33 to 100 kHz, the accuracy decrease with all else being equal. This is propagated even more in forested environment. You don't see much of these things in the guidelines documentation. You often don't see this is because every sensor is different. So these don't always work the same way, and sensors and surveys are slightly different each time. There are some physics behind the laser pulse interaction with the ground. Need to do a better job of quantifying these things.

Vladimir: Also must consider the reflectivity of the surface. There should be a scale as to performance over highly reflected vs. non reflective surfaces. Should always be conservative. Not very good to push the limits of the system, to save money.

Chris: Applications need to be environment specific.

Tanya: There are tools out there DERSID ray tracing software, which takes into account instrument parameters, and will allow you to put in geography and topography of the scene, with reflectivity properties for the scenes, detailed models. This will give people a better idea of what to expect (e.g. laser energy and incidence angle).

Chris: big picture, NEON has slightly different needs than more generic perspectives. They are getting into more academic uses, so they will have very specific needs. There is an area of the user community that will need to get into that.

Neville: Sometimes what you are looking for wrt accuracy isn't necessarily in the las file. They also provide a GPS report. What is more accurate? Your lidar or your base station?

Bruce: Have different hardware, specs, sensors, needs. Need research and development that interfaces between these that will allow the manufacturers to identify good, bad, ugly datasets for specific applications. Program just fills in a matrix that states where the sensor works and where it doesn't (but perhaps not necessarily the data??).

Jocelyn Parent perspectives: As a data provider, lots of unknown or not clarified expectations. Often they don't specify accuracy, point spacing, etc. Canada should have their own standards. This would protect the data providers and the purchasers. He is more familiar with USGS specs. First time buyers often don't really know what they need. So they will turn to USGS specs. The downside is that the USGS are the ones paying for this, and they want that the data are the same using different providers. They have specs to meet their own needs. What we have been talking about is to have more loose (blanks) specs so that these aren't hard coded. If we put specs together, these should be loose. E.g. check boxes. When they sell data, people don't specify building classifications, water classifications, etc. These do drive up the costs.

Vertical accuracies, need to have the proper lingo. Some folks think RMS, some 90%, etc. Needs to be clear. This would remove the ambiguities. Also some expectations are on flat surfaces, and some are on the entire dataset. 30cm on the measured points by USGS is best. Not on derivative products. This gives you an idea of the accuracy on the point cloud itself. Also depends on what you are after – to put out a number, things have changed. Also drives up the price.

Classification: Minimum classification, but if you want the full classification (e.g. bridges, water, building…) more expensive. Should have a minimum standard. Classificaiton accuracy is touchy. People will say 98% of the points need to be in the proper class, but how do you quantify this? E.g. prove to me that 98% of points are properly classified. But it is really difficult to prove.

Thinks there should be some guidelines. Formats not specified, with a list of formats that you could have. Not make it too restrictive.

Brent: Different data management process, where different RFPs start to put in different specs. With his experience with guidelines. Development of standards is so much more difficult with guidelines. Still not approved because there was a paragraph with a standard in there. More importantly, between standards and guidelines, there is more professional judgement required when you work with guidelines. You need to work with the community to develop the best guidelines. So all stake holders become more informed when you use guidelines. But when you use standards, it is much simpler but you don't necessarily get the best product (because you aren't as informed).

Chris: Before guidelines were available, the element of having the end user become educated by the vendor, was difficult because the vendor wouldn't necessarily know how to best address what the end unser needed. Sometime the end user didn't really specify clearly, andso the vendor would specify what was needed, and then several months later, the end user may not have what they needed, exactly.

Need to have objective guidance for both the users and the vendors, with no underlying push/objective.

Section 2: Which sectors most need lidar procedural best practices and what are they?

What are the priorities for standards and best practice guidelines?

Stake holders – what are we trying to measure on the landscape, and then it is up to the industry to discuss what should be used.

What is the exact problem, and what are the capabilities of the lidar system that is being used.

If the user wants to have a specific analysis, the combination of products that can be acquired should be examined. Integration of other datasets.

Need to understand the limitations of what lidar can't do.

As a policy maker, how do you manage and process hyperspectral data – it is still experimental. How do we integrate these things? What do you need on the ground? If you are using that data to fill a regulatory role.

Government doesn't necessarily understand the questions that they should be asking. They are really good on the forestry side, but what other information can be extracted. For example, with flooding, you may not have as good accuracy, but you are getting spatial coverage.

Who should set the standards and BPs?

Having open guidelines where there is an understanding between the service provider and the user. E.g. if you have specific needs, then the survey would be parameterised in different ways.

What would trigger something to be reflown? E.g. the area of flooding.

How do we mesh datasets? Old vs. new?

Who should set the standards? It would depend on the user. For example researchers want really highly accurate data, while government want greater range of applicability.

What Role can universities play?

Could the university be in a position to create a Boolean software package that would 'pick' out the specs according to the survey/application requested.

Do an assessment of the technologies that are out there now. If technologies are constantly changing, how do we mesh old vs. new datasets. Eg. Optech flying lidar over Vivian and still do.

The different universities have different areas where they have done a lot of work. Look at the technology reviews – how do you apply lidar to other areas? E.g. native grasslands? Where are there other applications, and where are there limitations?

What others said on the break out group discussion:

1. Data Integrity/consistency, lineage, processing, accuracy. Reporting to who?

Data format/version/type

CRSS, PEand RS

University testing and developing standards. Universities can test these things.

2. Data providers:

   Also in terms of priorities, what kind of accuracy and quality. Should be a very brief spec, with a lot of options. Was too much for the user to set up their own specs and standards.

   Specs should be set up by the fed government, but adaptable to other agencies.

   Universities role would be for training in lidar, specialised courses specific to lidar, also certification in partnership with industry. E.g. in Thermography FLIR will certify operators. Could universities work with industry to certify students? Industry: should do more indepth theory on lidar in courses. For certification, it would be more system dependent. Universities as trainers. The fundamental knowledge provided by the universities should be taught, but then once the person graduates and gets a job in industry, usually that person will be further trained to use the instrumentation. Then they can get their certification for processing, operation, etc. Chris: universities not so much in business of training, but colleges are in training role?

3. Geomatics users:

   Transparency in the process in developing of standards. Standards should be narrow enough to be useful, but generic enough not to stifle innovation.

   Priorities should be to have a clear definition as to what the standard is intended for. E.g. use of USGS standards without understanding the application. Specs seem to concentrate a lot on the lidar portion of it, but there should be mention of the full geodetic survey, which could also increase inaccuracies. (e.g. state how it should be done, but doesn't have to sign off by a certified surveyer). Bob – there are geodetic surveyers out there who are not land surveyers.

   Should include a diverse group of users, stake holders, and providers.

Universities to play a role in training. Guidelines and standards be discussed in the curriculum.

Universities could also be independent watchdogs of the standards, to see if there are any unintended or undesired effects. (e.g. run scenarios?)

4. Natural Resources users:

Who should set – Provincially recognised ones that exceed the national standard, and then companies can exceed this even further (e.g. hierarchical). E.g. milestones for each level. Inclusive process that includes academics, industry, govt.

Determine the parameters that impact the end users. Identifying the criteria that are most important (error propagation) and then looking at the risk of each one. E.g. the sensitivity of certain setings and how these play out in the resulting product.

Uni – New methodologies, role in error propagation, look at training component, Risk profiles (e.g. sensitivity analysis of errors).

5. Environment:

What is it on the landscape that needs to be examined. And let industry figure out how we can meet these needs. (e.g. what methods will be used to meet that outcome). What are the capabilities of the system being used. Is there a national/provincial/industry standard that could be used. For example, province may need lower resolution vs. industry which may need higher res. There would be a co-operative users group that could be consulted. (e.g. Puget sound?)

What is required to request a new dataset to be flown? There may be a provincial cooperative or stake holders that might be interested in more data to be acquired. Several may want to look into this?

Universities – we have varying degrees of technologies out there, how do we compare and mesh the datasets. How do the data need to be modified to be able to use this with future/existing datasets?

Look up table approach – Also universities should look into the limitations of the lidar data. Universities may be more honest than industry? There needs to be standards on who can use that data when providing information (e.g. watchdog). Requires objectivity.

Applications – what other applications are out there? How do Alberta work with the universities to develop new applications? What can we extract? How can we continue to build a business case to continue to collect more data? How do we move data forward, and how do we build on it?

6. Government:

When you are defining standards, create an agnostic dataset – this outlines the basics of what a good lidar dataset is. From that point, you add on top what is required from a good dataset for the specific application.

Universities - A matrix could be used that will allow people to do a check off that will let them know how they will alter the specs and the standards for a certain application.

Lidar Apps. Research into test projects and proof of concept.

Seminars for users. Education, the present state of lidar.

For managers, so that they have an idea of what lidar is.

Also need to be an active stakeholder and part of the lidar community (not just sitting back and do lidar research).

When fusing lidar and hyperspectral, what is the impact when you are flying it? How do you make it fit together well? Data fusion standards.

2nd Part: Lidar data centres, do we need them?

Data centers panel discussion:

Do we want or need a lidar data centre?

What form should it take?

What services should it provide?

Who should implement/maintain it?

Martin:

LASzip.org – maintains a list of publically available lidar data.

Grafcan → Allows you to download lidar for very cheap (1 euro per tile).

Open topography one of the best tools out there for downloading lidar data.

Jocelyn:

If there was a repository that people could access, whatever was available would need to address hurdles along the way. Would be good to have a third party (neutral) group that take the lead. Finds it difficult to organize purchase options, perhaps. There are many third companies around. Actual access to data is important, but so is metadata.

Chris – if we were to decide that there was no system that could disseminate data, it might be better to have data requests. Lots of different ways that things can be done.

Bruce:

From Tessera, they do data analysis, part of the largest challenge is actually finding data for a client. One of the first tasks they typically have is to start searching for what is out there. Not all tools are spatial, so it makes it more difficult. Not always easily searchable. Hard to find comparable datasets – that can be 50 to 70% of the time taken.

There are also a lot of different business models. Public and private sectors could come together to make it more easy to find.

Also, when you are training, building systems, etc. this is part of another system. Huge potential to create Centres of Excellence, so long as more data could be accessed to create more products. Firewalls are also difficult to get past. Opportunity to be more creative. More products would make lidar data more popular as well. By being connected we can enable each other.

Olaf:

All in favour of open access. Free data is great. Like the idea of data centres because we can then have some control over data and metadata. USGS has been distributing data for a while, and have nice models doing this. Government should be the organization to host the data. Universities can't afford to do it. Private industry shouldn't really do it either, without the expectation of a business model. Remainng sectors would be either not for profit or government.

Phil:

NRCAN has direct interest in national data centres. What is a lidar data centre? What are lidar data? Point clouds difficult to work with. Majority of clients are using derived data products, a few using classified points, and almost no one using point clouds. Should share the point clouds as opposed to the derived data products, but also provide the data products.

Data should be open access with minimal level of functionality for working with the data.

Questions: What impediments are there for data sharing from the perspective of the clients and providers? Data ownership? Sensitivity of data?

From the perspective of providers and clients, does open sharing and/or lidar data centres cause concern or excitement?

Point of the national framework is to have a data mining structure. Should have open data and also point to private owners of lidar data.

Chris – but isn't there a conflict of interest of the government 'selling' certain providers over others?

Martin – having a recognised platform to hold lidar data.

Bruce – the data holding could point people to opportunities that are out there.

Chris – Owner posts their own data, where you have your own account. You can host any info on the community GIS. Vendors can post their own metadata. That way anyone can put their data on there.

Patrick –

Martin Meric - We don't have the money to fly huge areas for something like the USGS so that they can put it online.

Patrick – data has been obtained using tax payers money so should be online.

Chris – But the data have been acquired for far less.

Patrick –

Martin – Chris worked on data for Halifax, contracted to acquire data, now data are freely available.

Chris – Making comparisons with the US is not fair – more population…

Mike Leslar – Vendor who collects the data has to make sure that data meets accuracy….

Chris – would like all data to be free, but we have to deal with what is going on right now. How do we work for the betterment of society.

Bob Sleep – We have spent $20 million and it has paid off for public policy, etc. This wouldn't have worked if they went to Airborne Imaging to have them acquire data.

Barb – GoA decided that they wanted to acquire this data, and they will give it to ____ to distribute. If things are going to change, it has to be done by…. Publish and subscribe. Create a data subscription so that you know when changes are made, etc. after new data are published.

Shane perspectives:

One of the discussions at the provincial level, they currently have the geodiscover portal. Discussion on cooperatives, how do we show the added benefits of lidar data to other groups in the government (e.g. gravel). Trying to promote value added information in other applications. Need to also provide survey companies the assurances that they will continue to provide data in the future.

There might be a certain amount of the data that will be available, but it won't be the high resolution data. Lidar data is a great tool, but also want updated data. There is a business cost…

Chris – Province has been working with data that have licences. What happens to the derivative products? Are they available?

Shane – Value added product can be shared, (data sharing agreement with the people who have worked on it), but won't give away raw data. They will give out data if there is a partnership with them. Companies will do business because it will save them money and for regulatory reasons. We can't tell them what technology to use.

Bob Sleep – can share forest metric information with the partner. It is a result of the analysis to produce this…

Chris – if I was a small woodlot owner, could I send a request to you?

Bob – Yes, you could if it was available.

Chris – This adds real value, because if there are derivatives that can be shared, then this would be good to have in a portal.

Bob – can also share the DEM, but if people want raw data, they have to go to AI or Northwest.

Patrick – So can we get data right away? Could the government share data if they bought it out right and for the same price (e.g. If a $1 million was given, could it be sold?)

Shane – this is what the cooperative would do, if everyone is looking at the same data, then it would be easier to put together policy (?)

Martin M – Condition that it is our data, but we are making it free to distribute.

Patrick – Anyone could have access, = more use.

Part 3: What are the training and or certification needs of the lidar community?

How do you train the full workflow? Best way to learn is experience…

What are the priorities for education and training? Should we spend time on urban infrastructure? Forestry? Transmission lines??

- Learning about the problems that are associated with the data. Troubleshooting data is really important.
- Use lidar for research but they don't actually teach lidar.
- How do you fuse different datasets and how do you teach. A masters in remote sensing is important.
- Internal training within companies – internships. Amethyst co-op program and for industry to step into a training program at the university. FActulty extension at U of C and U of A that re-trains industry, etc.

Do we need certification programs? Do the universities have a role to play? Should it be vendors? Societies?

- Remote sensing for forestry – e.g. practicing remote sensing as part of your job. Can cross your discipline (do you have the authority to cross this product?)
- Have to come from a university that has a professional qualifications to teach their students with those designations.
- In other designations, there are two levels: one can be education based and one can be more experience based.
- Society and government should provide the designation.
- Perhaps should be a remote sensing body that can be used to generate training opportunities as well as the professional designation, or can partner with governemtn for certification.

If so, who should accredit and deliver training? Ie. Set curriculum?

-

Given that much data exist, what are the barriers to implementing an Alberta-wide lidar flood risk assessment? (However, much of that data doesn't exist in areas that were flooded – data acquisition needs to be part of the discussion).

- In April 2008, 1500 ducks landed on a tailings pond and died. There is now a directive, but AESRD already worked on it for two years before this happened. So they knew that there was a problem, but as soon as there is a problem, they are now being reactive.
- Now have much broader public interest.
- Data – province doesn't own the data for Calgary. Have there been general major basins that have been flown? Lidar over cities – need to access private data. What does the city of Calgary have?
- Who would do the analysis? The province would do this (emergency). AESRD have done some flood risk hazard work. Environment has the mandate to do the risk assessment, but SRD have the licence for the data. Now they have merged.
- Also people within the flood risk group who are comfortable with survey data, but not necessarily lidar data. They are relying on manually surveying cross sections, so there is internal pushback because they are slow to adopt new technology/procedures.
- Look at the technologies that are out there - $340 million to do a flood risk assessment of the province, but now over $10 billion in damage.

Breakout Group Discussion

1. Government:

   Felt that there is a need for education, training, outreach. Private industry need to train on software, so perhaps if the universities could train on point cloud processing, classification, etc. then private industry would have a pool of skilled employees.

   Survey geomatics could also be taught within that. What does it take to do a proper lidar survey (e.g. geodesy). Also geomatics. Also a 1 day intro to lidar (seminar) or a webinar would be good for managers, project leaders, etc. so that the general public/industry/government could get a general overview. Might be good for decision makers, etc. but not too technical. Some applications, etc. (end to end but fairly high level – Chris's intro to lidar – a foundation so that people can understand what comes next, plus the application).

   Certification – not really sure how they should go about doing this. Should a lidar tech be certified? What is industry looking for? Government?
   Chris – can create the certification and then people in gov't can adopt it, or if we know that people need these skills, we can put these within a certification. CRSS could play a role as a certification body like ASPRS.

   Modular form of certification on line would be good. They might need that to go to another job, etc. it gives them accreditation.

   Chris – society is a voluntary society – is challenging to put time and effort into something that will take time to implement, monitor and may take some money too. Perhaps the society can be a bit hands off. E.g. perhaps there is a way for someone else to do the delivery

   Bob Sleep – perhaps the society could watch those that have the certifications.

   Martin M - Course should have industry related practicums where industry might do the training, equipment loans, answer trouble-shooting type questions. Need industry connectivity.

   Olaf – society could set up co-op programs for students to work in industry. In many cases, coop students have become future hires. Terra has picked up a number of UVic students.

   Chris - AMETHYST program have also benefitted from this. Industry wanted to work with AGRG because they needed skilled labour.

   Olaf – enthusiasm from students because they realise that industry is interested in them. Feds used to hire tonnes of students, but not anymore.

   Chris – called AGRG an internship, and they would work in the lab and with a government partner.

Shane – hire interns and coop students from engineering, but would definitely look outside of that. Gives students an opportunity to get involved in policy.

Chris – a lot of the programs who do mentorship are engineering. A lot of survey isn't in geography, but the lidar community crosses over a lot of different boundaries. Need to also think more about traditional engineering pathways.

Shane – want to develop programs beyond engineering. Govt is not the desired hiring body of engineers. So he would rather have the top RS students because then you will get good products.

Brett – AMETHYST program, different create programme, what is the legacy when NSERC runs out? Land reclamation project is one area that there isn't a create programme. Would be good to create a Create programme that allows students to insert themselves into industry.

Chris – had the model of working with industry and government so that we can train and they could get the students for slightly less. In theory, it should be sustainable by the end, but need partners to buy into that model.

Brett – opportunities for people in the community to come back into the institution for re-training. There are course based masters programs in forestry or agriculture already. This means that they don't get a masters → Workforce coming back to the university.

Chris – hard to create new programs – need people to champion it. Need to convince the higher levels from the university, but also need to hear from industry and government (push from both ends).

2. Data Providers

Fundamentals already there, there could be more into lidar, but not to a really great extent. Most initial data processing is linked to proprietary software. Manufacturers of lidar could do the training.

Don't need certification programs (perhaps for lidar) – no governing body to oversee this. Lidar is too young, perhaps. A certification shows that a person has interest in lidar, so that is ok. If someone has an extra course or two, then that would be better, probably.

Barriers to flood risk assessment – there are some traditional methods, and those who use them need to be convinced that this is the way to go. Perhaps the 15 cm accuracy is more accurate, but there is so much more information in the middle (wide area coverage). Lidar also provides much better relative accuracy. Need to convince decision makers. Should check the two methods. Other barriers include data accessibility, work more with it and convince decision makers.

3. Geomatics users

Barriers – will become increasingly political. Will have lots of shifting of responsibility between municipal, provincial, federal and private around floodplain. Who's job is it?

Brent sees it as the opposite – thinks that this will be very much of interest and will get over those political barriers.

Martin M – opens up a whole can of worms as to who decided that they could build on there in the first place. Insurance, etc. devalueing of land on floodplain.

Chris – likely less barriers now than there used to be, perhaps. But still technical barriers. Maybe we can do something now

Bob S – will likely be more funding available for this type of project because of the high profile of the flooding.

Training – Interdiciplinary – engineering, building codes, infrastructure, adaption to climate change initiative. Covers multiple aspects of things that people have been talking about (I think that he is still talking about flooding…)

Chris – do we need to identify more interdisciplinary approaches?

Bruce – yes, between engineers, meteorologists, etc. probabilities.

Chris – multi-disciplinary students. Need to reach out to other departments to fully exploit these datasets. How do the universities respond to that?

Bruce – there are models, but not within institutions, necessarily. This is the tip of the iceberg.

Chris – a lot more lateral flexibility, but we are still a graduate of a particular program.

Bruce – training in interdisciplinary teams. Most teams work with people over a variety of disciplines. The more familiarity and training they have, the more able they are able to contribute. That is a skill.

Chris – a lot of students are reticient to be involved in team projects because the world works that way.

Certification - No

4. Natural Resources combined with Environment (see above).