Meeting LiDAR industry and end-user needs: best practice guidelines, skills training and efficient project design

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Abstract

At last year's ILMF meeting, three key issues facing the industry were noted: i) recruitment; ii) training; iii) development of standards and best practices. In 2004, the Applied Geomatics Research Group embarked on a market research project to evaluate LiDAR industry training needs. The findings from this study were implemented in the curriculum at the Centre of Geographic Sciences in 2006 and published in the May, 2007 edition of *Photogrammetric Engineering and Remote Sensing*. The training provided at COGS is offered to students within the geomatics post-graduate advanced diploma program. During this course, students are introduced to theory, operations, data processing and applications of LiDAR. Any students wishing to continue and develop their 'hands-on' skills may continue at AGRG, NSCC through a six month internship or as a M.Sc. student in Applied Geomatics, hosted jointly with Acadia University. At AGRG we own and operate an ALTM3100C system enabling students/interns the opportunity to play an active role in our international research projects and thus gain 'real world' LiDAR experience. Regarding standards and best practices, the American Society of Photogrammetry and Remote Sensing LiDAR Committee is developing data standards, operational guidelines and a handbook to promote efficient application of techniques. Of equal importance, is the objective of enabling service providers and endusers to communicate their technical capabilities and application needs. It is anticipated that by providing authoritative guidelines on best practices and data standards, that the forthcoming handbook will become a reference of choice for project design and RFP development.

Background

While high resolution airborne LiDAR topographic mapping technology and services have been commercially viable and available around the world since the mid 90's (Flood and Gutelius, 1997), there are still many challenges faced by both providers and consumers that can impact the operational effectiveness and value of commercial LiDAR projects. Some of these challenges are simply a function of continually evolving technologies and the inevitable game of 'catch up' that the market must play, while others relate to an imbalance between demand and supply. Some service providers might argue that there is little to no imbalance between the market demand for LiDAR data and the industry capability to meet it. Indeed, a rapid increase in the availability of LiDAR sensors in the market place has been observed and growth is predicted to continue (TMSI, 2005). Hard statistics on actual market 'need' are more difficult to quantify but the number of public RFPs (request for proposals) for LiDAR work has grown substantially in recent years and the ASPRS 10 year remote sensing industry forecast suggests that the need for high resolution and accuracy technologies like LiDAR currently exceeds use (Mondello et al. 2008). Regardless of any real or perceived mismatch between the supply of and need for LiDAR data products, the imbalance we are concerned with here is the high demand for LiDAR knowledge and expertise compared to a very limited supply of trained and knowledgeable practitioners.

Specifically, we can refer to a number of examples: a) the growing need for LiDAR operators and data processing technicians within the service sector; b) the need for end user GIS technicians with LiDAR data manipulation and quality control skills (and, of course, the tools to allow them to do this!); c) the need for end user project managers to be sufficiently well informed that they can develop LiDAR project RFPs; and d) the need to reduce ambiguity in data collection and reporting procedures by adopting consistent and repeatable procedures across the entire community. In all of these examples, there is either a 'knowledge' or a 'skills' deficit that the community needs to address. This deficit is nothing new and is to be expected in the early years of a relatively new and highly successful technology like LiDAR. Perhaps another way to frame this is to suggest that as a community, the commercial elements of 'technology' transfer are slightly ahead of the associated 'knowledge' transfer. To support this opinion, I could cite many examples of LiDAR data collection projects where enduser expectations were not quite met for one reason or another. In almost all cases, the inability to meet the expectation can be traced back to one of the knowledge or experience gaps listed above.

Such imbalances, therefore, are typically addressed using traditional knowledge transfer mechanisms of education, training and consultancy. There are many obvious public knowledge transfer routes and the presentations and workshops provided at the ILMF (International LiDAR Mapping Forum) are excellent examples. There are also the various ASPRS (American Society for Photogrammetry and Remote Sensing) and ISPRS (International Society for Photogrammetry and Remote Sensing) conferences, workshop series and committees that do a great job of ensuring that advances in the sciences, technologies and applications are communicated within the community. However, excellent as these forums are, they can never engage all enduser LiDAR project decision makers and practitioners, and they tend not to provide an effective vehicle for the skills training of technicians. Post secondary education is a standard path to appropriate knowledge and experience for a high proportion of geomatics personnel. However, in the case of LiDAR, the technology tends to be sufficiently expensive that only a very few academics at universities and colleges actually have the technical and operational experience necessary to effectively educate and train future LiDAR users. Consequently, much of what needs to be known by many LiDAR stakeholders (enduser or service provider) is often learned 'on the job' (Hopkinson et al, 2007).

In this paper, we will address some of the above challenges with examples of solutions by referring to: a) the 'LiDAR Industry Best Practices' initiative of the ASPRS LiDAR subcommittee; b) The LiDAR project "proof of concept" research activities developed at the Applied Geomatics Research Group (AGRG) through the Canadian Consortium for LiDAR Environmental Applications Research (C-CLEAR) model; and c) The variety of tailored classroom, workshop and 'hands on' LiDAR training opportunities offered at the Nova Scotia Community College (NSCC) by the AGRG to both endusers and service providers.

ASPRS LiDAR Best Practices Initiatives

The ASPRS was founded in 1934 and its mission is:

> *to advance knowledge & improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems (GIS), & supporting technologies.*

The increasing use of airborne LiDAR technology during the mid to late 90s led to a growing appreciation within ASPRS of a need to establish consistent and professional practices. For example, while some state or provincial government agencies had started to develop their own requirements for LiDAR data acquisition protocols and accuracy assessment, there was little consistency in the approaches being advocated. Further, certain application domain agencies (e.g. FEMA – Federal Emergency Management Agency) provide somewhat rigorous guidance related to their specific needs (e.g. flood insurance maps) but these guidelines cannot always be easily transferred to different applications domains (e.g. highway design, urban development or forestry). This lack of universally applicable procedural guidance on LiDAR data collection and delivery can make communication between vendors and endusers complex and open to misunderstanding. In 1999, the ASPRS LiDAR Sub Committee (ASPRS LC) of the Photogrammetric Applications Division (PAD) was set up to address the need for more widely applicable guidelines and standards. The objectives of the Committee are to:

- Promote greater adoption of LiDAR technology.
- Provide guidance and recommendations for the professional practice of LiDAR mapping.
- Address the need for best practices and common guidelines for the proper planning, implementation, data processing and QA/QC of LiDAR data products.
- Assist in establishing common data exchange formats, sensor calibration routines, uniform data analysis and accuracy assessments across the industry.
- Provide ASPRS members a voice in the adoption and future development of the technology.
- Draft a LiDAR manual outlining ASPRS endorsed best practices to be used as a source of reference both for service providers and end users.

The web site of the Committee can be found at:

http://www.asprs.org/society/committees/LiDAR/

The ASPRS LiDAR Committee has a voluntary membership of over 100 stakeholders from industry, government and academia. Currently, industry members from the manufacturing and service provision sector make up the greatest proportion so the internal expertise on issues related to technology, operations, data processing and quality control is of a high calibre. The committee holds official meetings two times per year; once at the annual ASPRS conference and once at the Fall meeting. In the intervening time, committee members generate and review materials relating to the best practices guidelines. Guidelines on accuracy reporting that have already undergone internal committee review and acceptance are available on the website as are some of the materials currently under review.

The ASPRS LC is working with other divisions and committees within ASPRS on issues peripherally connected to LiDAR. For example, we are collaborating with the ASPRS standards committee on making the ASPRS LAS binary LiDAR exchange format a more widely accepted standard data format. We also review the materials of other committees to ensure that the interests of LiDAR community stakeholders are represented. A current example would be our membership review of the ASPRS draft guidelines for procurement of professional aerial imagery, photogrammetry, LiDAR and related remote sensor-based geospatial mapping services (ASPRS procurement guidelines committee, 2008). In addition to working internally on ASPRS related initiatives, the LiDAR Committee collaborates closely with government agencies on issues of mutual interest. For example, the Committee is working with and assisting LiDAR stakeholders within the USGS and NOAA on initiatives such as developing a unified approach to national LiDAR data collection (e.g. Stoker et al. 2008) and setting up national sensor calibration sites.

By providing guidance on the provision of consistent, high quality LiDAR project design and data collection services, and promoting the use of a common data exchange format, the LiDAR Committee is actively helping service provider and enduser stakeholders improve their workflows and, more importantly, communicate their needs and capabilities more effectively with one another.

C-CLEAR and AGRG LiDAR Project Collaborations

The Canadian Consortium for LiDAR Environmental Applications Research (C-CLEAR www.c-clear.ca) was established shortly after the ASPRS LiDAR Committee in 2000, and for very similar reasons. The C-CLEAR activity was initiated at Optech Incorporated (world leading LiDAR sensor manufacturer) as a means of partnering with government and academic research groups to evaluate LiDAR technology in environments or situations where it was not yet proven or to develop new applications that were not considered commercially viable. For example, glacier water resource mapping (Hopkinson et al. 2001; Hopkinson and Demuth, 2006), wetland vegetation mapping (Töyrä et al. 2003; Hopkinson et al. 2005), and snowpack water resource mapping (Hopkinson et al. 2001; Hopkinson et al. 2004) were some of the natural resources assessment applications tested. C-CLEAR quickly proved to be a successful vehicle for LiDAR technology evaluation and application development and by 2002 had moved its base of operations to the Department of Geography at Queen’s University in Kingston, Ontario. Following a successful hardware acquisition proposal partnership with the Applied Geomatics Research Group (AGRG http://agrg.cogs.nscc.ca) at the Nova Scotia Community College, C-CLEAR moved again in 2004 to take advantage of direct access to Airborne Laser Terrain Mapper (ALTM) 3100C and ILRIS3D sensors.

While technology testing and application development were the primary objectives of C-CLEAR, it soon became apparent that perhaps the greatest community benefit realised through C-CLEAR and AGRG collaborative LiDAR research activities was knowledge transfer to the enduser project partners. We have partnered with several university, government and private sector researchers across Canada, the US and Europe and facilitated access to over 200 LiDAR datasets for use in graduate student theses and other applied research projects (see LiDAR metadata inventory: http://agrg.cogs.nscc.ca/projects/LiDAR_Metadata). Aside from access to data, however, we have also worked with our partners to assist them in developing their LiDAR project RFPs or in evaluating commercial tenders once they come in (Note: AGRG does not take on non-research oriented commercial data acquisitions).

By working with AGRG, many of our government partners have learned that LiDAR can meet their needs and more importantly, they have gained the confidence to initiate their own commercial projects. Two recent examples from our own backyard in Atlantic Canada are Halifax Regional Municipality (HRM) and New Brunswick Emergency Measures Organisation (NB EMO). In 2005, AGRG partnered with HRM to collect a small pilot dataset over the urban core of Halifax. At that time HRM staff were aware that LiDAR would help them in their coastal adaptation planning and urban design projects but had no internal experience with LiDAR project design or data handling. Through multiple small research collaborations and ‘show and tell’ presentations, HRM gained the confidence to initiate a commercial LiDAR acquisition over most of the Municipality (> 1000 km^2). AGRG assisted with the RFP design and review process and once the data were in hand, AGRG continued to assist HRM with advice on data manipulation procedures. The NB EMO project was similar in that the project partners knew LiDAR could help them with flood level prediction on the St John River but had no internal expertise on such techniques. In 2007, AGRG partnered with NB EMO and the University of New Brunswick to perform a LiDAR flood risk mapping exercise over a portion of the river flood plain. One Year later, NB EMO commissioned a commercial data provider to fly the rest of the flood plain. The C-CLEAR model of LiDAR project proof of concept has directly led to an increase in the comfort level of potential endusers to the point where they are willing to embark on commercial projects. C-CLEAR and AGRG have therefore had a direct impact in reducing the perceived risk of adoption and opening up marginal LiDAR markets for industry.

Further afield, C-CLEAR has assisted Natural Resources Canada develop both glacier mass balance (Hopkinson and Demuth, 2006) and forest resource monitoring (e.g. Hopkinson et al. 2008) strategies, while also working with provincial water resources agencies and private sector survey companies on developing snowpack monitoring techniques in forested and mountainous watersheds. None of these natural resources assessment techniques are quite at the point of commercial adoption by the Federal or Provincial Governments but we consider this a work in progress as it takes a long time to change large scale resource monitoring practices. However, these initiatives demonstrate that LiDAR is not limited to topographic base mapping and there is the potential in the near future for it to be adopted as a monitoring tool (see various chapters in the *Hydroscan* book outlining a number of potential monitoring and assessment techniques in the water resources community: Hopkinson et al. (eds), 2008). Once these monitoring applications are considered economically viable, they will provide a steady source of reliable income for service providers. C-CLEAR's and AGRG's role in these projects is to assist the enduser community in developing the work flows necessary to extract the required information and in evaluating the commercial viability relative to existing monitoring techniques (e.g. Hopkinson et al. 2004).

Given AGRG has been supported through federal research funds, this operational model is one of non-profit cost-recovery. Consequently, our research partners do not purchase LiDAR data rather it is licensed such that NSCC retains ownership of the data while the partner is granted perpetual access to the data with exclusivity for a period of two years following data delivery. This model ensures that data do not get 'lost' and can be made available for future projects.

To qualify for a C-CLEAR survey, a potential research partner is requested to demonstrate the following:

a) The survey requested is for research purposes;
b) The data will not be used for commercial purposes;
c) The study area should not normally take more than a single day to survey;
d) The partner should demonstrate that an equivalent survey would not otherwise be possible if commercial vendors were used (e.g. prohibitive cost, insufficient knowledge in the field of research or lack or availability);
e) There will be AGRG collaboration (student or otherwise) on papers and presentations directly resulting from the C-CLEAR supported project.

Each year AGRG conducts a series of back-to-back research survey missions across Canada, the US and more recently as far afield as Peru. During the summer of 2008, we coordinated several LiDAR missions over Andean Glaciers in Tropical Peru one month and then the following month we were mapping Arctic coastal areas near the Canada / US border. As with most C-CLEAR missions, both projects required the collaboration of several partners from multiple institutions. We endeavour to involve our academic and government partners in as much of the logistical planning, aerial and ground data acquisition and post-processing as we possibly can. This level of 'client' participation in the LiDAR project workflow ensures a level of outreach and knowledge transfer to the end user community that cannot be matched in commercial LiDAR contracts or traditional university, conference or workshop education. C-CLEAR started out as an applications R&D vehicle but its major benefit to the community has been its 'hands on' educational outreach role in raising confidence in the service provider and 'fringe' enduser community.

AGRG and C-CLEAR LiDAR Training Mechanisms

The Applied Geomatics Research Group (AGRG) evolved out of research and educational activities at the NSCC's Centre of Geographic Sciences (COGS) in 2000. With financial support from the Canada Foundation for Innovation, AGRG research projects utilizing LiDAR and other geomatics datasets were initiated in the Annapolis Valley of Nova Scotia, Canada. Since then, AGRG research has expanded to include global partners from the private, academic and government sectors and it has inherited the C-CLEAR initiative. As part of the Province-Wide Nova Scotia Community College we are also acknowledged leaders in educating vocational advanced diploma students in the art and science of geomatics research. Through partnerships with a number of Maritime Universities, our research faculty members are actively engaged in post graduate supervision of several LiDAR thesis projects at the Masters and Ph.D. levels. In addition to academic diploma- and degree-level programs and courses, other LiDAR training mechanisms offered by the AGRG to outside partners are short-term practicums, industry internships, an annual LiDAR 'Summer Institute', targeted workshops, conference seminars and 'hands on' project partnerships (see above). A crucial element of AGRG's training capability is that in addition to extensive in-house GIS, Remote Sensing and CAD computing software resources we own and operate all of our own ground and aerial survey equipment (including 4 x Leica survey GPS units, a total station, ALTM 3100C, ILRIS3D, Rollei Digital Camera). Our students and interns are able to utilize this equipment for an in depth hands on learning experience.

These educational and training mechanisms have evolved with our growing experience but of note is that in 2004, AGRG (in collaboration with ASPRS LC members) embarked on a LiDAR training needs market research project (the results of which were published in *PE&RS*: Hopkinson et al. 2007). Two questionnaires were sent out to over 600 members of the international LiDAR academic research and commercial mapping community, and a LiDAR research and training workshop was hosted in Halifax, Canada. The purpose of the questionnaires and the workshop was to better understand the status of, and needs for training within the LiDAR community so that AGRG could tailor its educational and research activities to better meet the needs of the community. The list of questions is provided below:

1) How many years have you been actively involved with LiDAR: a) 0; b) 0-1; c) 1- 5; d) 5-10; e) 10+
2) Is it difficult to find candidates with LiDAR experience to fill LiDAR related positions in your profession?
3) Do you believe there is a need for independent LiDAR training?
4) Are you aware of any LiDAR training that was offered in the past or is currently available?
5) Do you conduct your own LiDAR training?
6) If YES to (4 or 5), what is the format of the training: a) Academic LiDAR program, b) LiDAR component in academic program; c) service provider training; d) manufacturer training; e) independent training program; f) conference seminars and workshops?
7) Who do you think most needs or would be the biggest user of LiDAR training: a) University researchers and students; b) Government researchers; c) Commercial service providers; d) Commercial end-users?
8) What do you think should be the priority topics for a LiDAR training program: a) Principles of LiDAR; b) Mission planning and project management; c) Field operations; d) LiDAR data processing and calibration; e) End-user applications; f) Sensor fusion?
9) In your opinion, which is more important when designing a LiDAR training program: a) Maximizing theoretical content; b) Maximizing practical 'hands on' opportunities; c) Maximizing opportunities for attendance; d) Minimizing participant costs?
10) What do you think is an appropriate entry qualification for a LiDAR training program: a) No qualification; b) High school diploma; c) Relevant industry experience; d) Relevant post secondary diploma; e) Bachelors degree?
11) Based on your opinion of the needs for LiDAR training what do you think would be an appropriate duration: a) Half a day or less; b) One day; c) One day to one week; d) One week to one month; e) A single term or semester; f) One year; g) Greater than one year?

12) Based on your opinion of the needs for LiDAR training, what do you think would be the most appropriate format: a) Customized training at site of client; b) 'Boiler plate' (fixed curriculum) training at site of training institution; c) Degree program; d) LiDAR course within an academic degree program; e) Vocational diploma/advanced diploma training?

We do not have space to discuss all the findings of the LiDAR training needs assessment here but a summary of the responses for question 2 to 5 and 7 to 12 are provided below in Table 1 and Figure 1, respectively. The full analysis is presented in Hopkinson et al. (2007).

Question			**Stratified responses**					
	All responses		Academic		Government		Industry	
	Yes	No	Yes	No	Yes	No	Yes	No
2 - Is it difficult to find experienced personnel? (36)	75%	25%	86%	14%	60%	40%	71%	29%
3 - Is there a need for independent training? (54)	92%	8%	84%	16%	100%	0%	100%	0%
4 - Are you aware of any LiDAR training? (71)	54%	46%	58%	42%	40%	60%	71%	29%
5 - Do you conduct LiDAR training? (71)	51%	49%	44%	56%	30%	70%	68%	32%

Table 1. Yes/No responses for questions 2 to 5 in the questionnaire. Responses of 'don't know' and 'maybe' have been considered neutral and not presented in the analysis. (Number in brackets denotes actual number of Yes/No responses).

Most questionnaire respondents that expressed any opinion suggested that it is difficult to find appropriately qualified or experienced personnel to fill LiDAR positions (75%), and this observation demonstrated little stratification across sectors (60% government to 86% academic). Also in agreement across all three sectors was the finding that the majority of respondents agreed there was a need for independent LiDAR training (92%). In answering questions 4 and 5, a little over half indicated that they were aware of or performed some kind of LiDAR training themselves, whether it be in house training of staff, open to students and/or the public, or for paying clients. However, there was a slight stratification suggesting that the industry community is most active in (68%) and more aware of (71%) training opportunities, while government respondents demonstrated the least activity (30%) or awareness (40%).

In response to the question "*who most needs or would be the biggest user of LiDAR training?*" (question 7) the cumulative responses for the four options (commercial end users, service providers, academics or government) demonstrated no clear ranking with the share of the vote ranging from 20% for government to 28% for endusers (Figure 1). However, when the results were stratified, it was clear that respondents from each sector tended to believe they most needed training; with 48% of government respondents believing that government employees would most benefit from LiDAR training, 38% of academics believing they would most benefit, while 41% and 36% of industry respondents believing that commercial endusers and service providers, respectively, would most benefit. This does not necessarily suggest that members of each sector believe that they have the least amount of training but rather relative to other sectors they think they need it the most. These results corroborate earlier findings and indicate that there is a shortage of training opportunities across the entire LiDAR community.

Responses to question 8 suggest that "LiDAR applications" is an important topic. However, stratifying these results by sector indicates that although government and academic enduser respondents hold this opinion, members of industry tend to place at least as much importance on the more practical options of data processing, project management and sensor operations. This stratification likely mirrors the common LiDAR activities within each sector. Government and academic researchers tend to be more concerned with the application of data to a specific question or problem, while the industry sector is more concerned with operational aspects of the technology and data collection. Of most significance, is that these results demonstrate that the actual training needs of each sector are different.

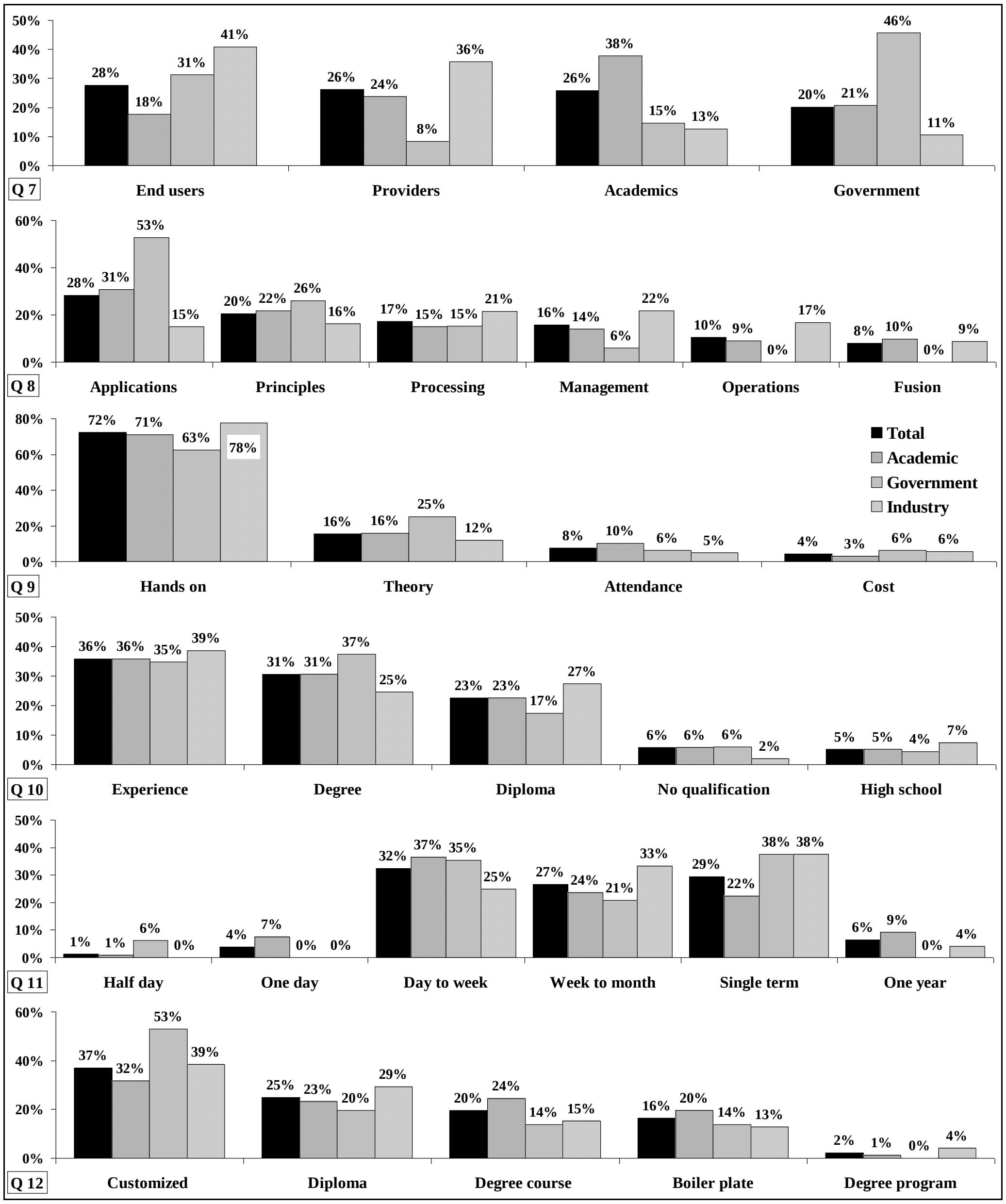

Figure 1. Summary of responses to AGRG questions 7 to 12, stratified by respondent sector: 7) Greatest need for LiDAR training? 8) Priority topics? 9) Most important when designing a training program? 10) Appropriate entry qualification? 11) Appropriate duration? 12) Most appropriate format.

Despite a general lack of appropriate skill sets in the employment market for sensor operators and data processors, the relatively small size and moderate growth of the industry, and a tendency for employees to be trained ‘in house’ or by sensor manufacturers, means that the need for training of personnel on the front lines of the service provider sector is limited. Needs are strongest in the enduser communities at the project initiation and data delivery to manipulation stages of a project. To increase confidence in the technology and data, the enduser community needs to be made more aware of the technology and applications so that they know better how to: 1) specify a LiDAR data collection RFP; and 2) turn raw data into the application information that they require. Some data collection companies do provide these types of educational services to their potential or existing clients. However, with a growing and competitive industry and an ever-expanding end user community, the possibility for perceived conflict of interest indicates there is a need for independent educational facilities to bring LiDAR into mainstream curriculum. With only a few academic facilities worldwide owning and operating their own scanning LiDAR sensors, there is a clear challenge in bringing all aspects of project design, sensor operations and data manipulation to a widely available curriculum.

It is assumed that although specific training needs differ across the LiDAR community, in terms of volume the enduser community's need is at least an order of magnitude greater than in the service provider sector. Regarding training priorities, there appears to be some clear stratification between the needs of endusers and service providers. In general, practical experience and 'hands on' training methods were considered more useful for those entering into LiDAR related employment but this perception was not shared by academics. Also, results indicated that 'enduser applications' were the priority topic in the enduser academic and government communities, while in the LiDAR industry, training priorities were related to more technical and operational topics such as 'data processing' and 'project management'.

In response to the training needs and some of the potential solutions identified in this study, the AGRG offers a suite of training programs ranging from short seminars to multiple day workshops to project-based internships and advanced diploma training that meet the requirements of the LiDAR community. Building on over ten years of 'hands on' experience in LiDAR and GPS survey operations, geomatics higher education, and applied LiDAR research, AGRG is using its airborne and ground based LiDAR technologies and range of software tools to provide comprehensive training opportunities to those in either the service provider or enduser communities. For example, during 2008 AGRG faculty are: a) supervising several MSc LiDAR thesis projects; b) offering a vocational post graduate advanced diploma course entitled "LiDAR theory to operations"; c) offering several advanced diploma directed studies LiDAR research projects; d) presenting several day-long conference and community LiDAR workshops; e) hosting a week-long 'hands on' LiDAR Summer Training Institute at our facility in Nova Scotia (see Figure 2 for an example outline); f) offering the opportunity for internships with our private sector partners; g) offering short term 'in house' practicums to our academic and government research partners; h) encouraging our research partners to be involved in collaborative LiDAR project logistics at all stages of the work flow. We have found that this mix of educational and training offerings is able to meet almost all LiDAR training and educational needs from RFP development and review to project design to mission planning to sensor operations to data processing to information extraction to application development.

Module	AGRG Summer Institute proposed modular format	
1	Course introduction & applications overview Principles of LiDAR Laser ranging Scanning DGPS IMU	1 day
2	Available instruments Topographic Bathymetric Terrestrial Ground based LiDAR demo	1 day
3	Industry guidelines & data formats	1 day
4	LiDAR operations Mission planning Installation & operations	2 days inc. field trip
5	Data processing Data integration Sensor calibration Data manipulation and validation	2 days

Figure 2. AGRG one week LiDAR summer Institute training example.

Conclusion

ASPRS, AGRG and the C-CLEAR model each address slightly different facets of the knowledge transfer needs within the LiDAR community. ASPRS is developing industry best practice guidelines; C-CLEAR provides a particular model for collaborative LiDAR applications R&D; and AGRG offers a broad spectrum of research-based pedagocical pathways to LiDAR knowledge. We have made much progress in merging the C-CLEAR and AGRG models. The next steps in meeting the education and training needs of the LiDAR community will be in further developing curriculum around the professional industry best practice guidelines and data standards initiatives of ASPRS and other national / international societies and agencies. To this end, the ASPRS LiDAR handbook should prove an invaluable resource for LiDAR curriculum development and in continuing to close the knowledge gap and improve the flow of communication between data providers and endusers.

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