INFOEX™ 3.0—ADVANCING THE DATA ANALYSIS CAPABILITIES OF CANADA'S DIVERSE AVALANCHE COMMUNITY

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ABSTRACT: The Canadian Avalanche Association's Industry Information Exchange (InfoEx) is a daily exchange of technical snow, weather, avalanche and terrain information among subscribers from all types of avalanche safety operations in Canada. In addition to providing a platform for a candid and timely exchange of observations and assessments to enhance the decision-making context for subscribers, InfoEx is also a data cornerstone for the production of public avalanche bulletins by Avalanche Canada.

Historically, InfoEx consisted of daily static, multi-page text reports, initially distributed by fax, later by email and an online portal. Increased information volume and subscriber growth, however, made the text format increasingly inefficient and cumbersome as a risk management tool in a time-pressured environment. In 2012, TECTERRA provided funding to completely redesign InfoEx's infrastructure and turning it into an explicit geospatial data system. TECTERRA's investment created a positive, but formidable challenge. This paper describes the principles and design choices taken to create a flexible, expandable InfoEx system that supports the diverse needs of the community, and elaborates on the lessons learned from the community's transition to new technologies.

KEYWORDS: Information exchange, operational recordkeeping, software design, mapping, visualization, decision-making

1. INTRODUCTION

The Industry Information Exchange (InfoEx) of the Canadian Avalanche Association (CAA) is a daily exchange of technical snow, weather, avalanche and terrain information among subscribers from all types of avalanche safety operations in Canada (CAA, 2014), including backcountry guiding operations, ski areas, highway and railway avalanche safety operations, avalanche safety consultancies, individual guides and others. The confidential exchange began in 1991 in response to a BC Coroner Service's recommendation following a commercial avalanche fatality. InfoEx serves as a platform for a candid and timely exchange of critical observations and assessments to enhance the decision-making context for subscribers. All subscribers are expected to regularly contribute observations and assessments during their operating season. Subscribers also require a professional CAA member on staff to ensure submissions are compliant with the Canadian Observation Guidelines and Recoding Standards (OGRS: CAA, 2007). In addition to the direct benefit to subscribers, InfoEx also acts as a data cornerstone for Avalanche Canada (AC), enabling forecasters to produce public avalanche bulletins. InfoEx is therefore an indispensible component of avalanche risk management in Canada.

Since its inception, the CAA, in service of the InfoEx subscriber community, has managed InfoEx. Annual subscriptions are required for each main avalanche safety decision node. The number of subscribers has grown steadily through the years. There are currently roughly 130 safety operations contributing to InfoEx during the peak winter months.

The technological foundation of InfoEx has also evolved continuously. Initially, daily submissions of observations and assessments to the CAA were done by fax machine (InfoEx 1.0). A technician at the CAA manually compiled the submitted information nightly into a standard report (Bay and Dennis, 1994), which was circulated to subscribers via fax. In the second half of the 1990s, email

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slowly replaced the fax machine, both for data submission and report distribution, but reports were still compiled manually. In 2003, the CAA recognized that a more modern information management strategy was required to meet the increasing data needs of the community (Atkins *et al*., 2004). This led to the development of InfoEx 2.0, which consisted of the first operational InfoEx database, SnoInfo (a Windows application for data submission) and the first iteration of CAAML, an XML standard for the electronic exchange of avalanche safety information (www.caaml.org). This system allowed the automatic creation of InfoEx reports without the help of a technician and the distribution of the information via an online portal. Reports remained limited to a static daily compilation of observations and assessments presented in text format with standard tables and free-form comments. Continuous subscriber growth and increase in information volume made this text format increasingly inefficient and cumbersome as a risk management tool.

In 2012, TECTERRA—a provincially and federally funded non-for-profit agency that invests in the development and commercialization of geomatics technology (www.tecterra.com)—approached AC and the CAA to discuss how their programs could support avalanche safety in Canada. It became quickly apparent that an overhaul of InfoEx infrastructure would be tremendously beneficial for the entire Canadian avalanche community. While increased data exchange and analysis capabilities would directly enhance safety within the professional community, this development would also have a positive impact on public avalanche safety by creating a more advanced data stream for the creation of the public avalanche bulletins by AC. The generous support of TECTERRA created an unique opportunity to redesign InfoEx from the ground up and turn it into an explicitly geospatial data system. The development project was initiated in the fall of 2012. After a full year of requirements gathering, designing, developing and testing, the new system, InfoEx 3.0, was launched for operational use on December 1, 2013.

The purpose of this paper is to explain the features of InfoEx 3.0 that aim to address the diverse needs of Canada's avalanche community. We also share lessons learned during the development process, the training phase and the first winter of operational use. We conclude the paper with an outlook on future developments.

2. DEVELOPMENT APPROACH

While the overall objective of the project was clear from the beginning—to develop a focused, intuitive and user-friendly application for efficiently entering observations and viewing InfoEx reports— the devil is in the details. To ensure that that InfoEx 3.0 would meet the needs of the InfoEx user community, we commenced with an extensive user consultation phase consisting of many interviews and on site visits with subscribers. This process aimed to gain a better understanding of the existing operational avalanche forecasting and data management practices with an eye on how to best integrate a revitalized InfoEx into these environments.

We used an *Agile* software development approach (agilemanifesto.org) for this project. Agile is an iterative development approach that fosters close collaboration between end users and developers by focusing on the frequent delivery of working software for hands-on testing. Agile allows end users to continuously familiarize themselves with the emerging system and fine-tune requirements if needed. To streamline the interaction with the InfoEx user community, we formed a User Acceptance Committee (UAC) consisting of influential InfoEx subscribers representing all industry segments. The UAC participated in regular video conference calls where the development team demonstrated the latest advancements. In addition, UAC members were able to use a test site to explore new functionality as it might be used in their operations. These interactions allowed for critical feedback that was fed into the design and coding processes. This Agile feedback loop was repeated several times during the development phase.

To facilitate the transition to InfoEx 3.0 and ready subscribers for the operational season, we conducted a series of hands-on half-day training seminars in central mountain communities in Western Canada. We offered workshop content via online webinars and YouTube recordings to subscribers in more remote locations. In total, we trained more than 250 individuals prior to the start of the season. We also developed extensive online documentation of the InfoEx system with step-by-step descriptions of the available functionality.

During the operating season, feedback on software bugs and general system quality was collected with an online ticketing system, allowing developers to continuously improve the system throughout the operating season. Software updates were deployed weekly.

3. SUBSCRIBER NEED & FUNDAMENTAL REQUIREMENTS

User consultation resulted in an extensive list of system requirements, captured in so-called *user stories*. Below, we will discuss the most important lessons learned about the Canadian avalanche community during this phase of the project. The highlighted characteristics represent the top-level system requirements that fundamentally shaped the design of InfoEx 3.0.

3.1 Reliability and security

Daily InfoEx reports play a critical role in avalanche risk management routines of subscribers. Subscribers must reliably access InfoEx reports whenever needed.

Confidentiality is the foundation for the frank and timely exchange of critical observations and assessments (e.g., incidents) in InfoEx. An intuitive and effective user management is therefore critical for the success of the InfoEx application.

Requirement - Reliability and data security are top priorities for the new InfoEx system.

3.2 Platform independence

Macs and mobile devices are increasingly prevalent in the Canadian avalanche community. The Windows-based data submission application SnoInfo had become a significant barrier to InfoEx participation.

Requirement - InfoEx must be accessible on as many device configurations as possible.

3.3 Limited connectivity

Many functions of modern software require continuous connectivity, but remote InfoEx subscribers commonly experience limited and/or intermittent Internet connectivity. Despite investment in satellite Internet systems, connectivity challenges remain.

Requirement - InfoEx should not to be slowed down or interrupted by limited Internet connectivity.

The remoteness and limited connectivity of many InfoEx subscribers also means that developments for mobile devices are of limited interest in the first phase of this project.

3.4 Highly diverse users community

The InfoEx subscriber community includes all types of avalanche safety operations (e.g., backcountry guiding, ski resorts, highway and railway safety operations, etc.). While there are many similarities in the avalanche forecasting processes among these industry segments, each has its own nuances. Even within industry segments, operational procedures related to data management and InfoEx often differ from operation to operation reflecting the uniqueness of their operating environments.

Requirement - InfoEx should adapt to existing operational avalanche forecasting practices of subscribers.

3.5 Operational recordkeeping challenges

The days of avalanche professionals are packed with operational tasks. Operational recordkeeping is a necessary task, but the time allocated to it is often constrained. Many of the largest InfoEx subscribers (e.g., Canadian Mountain Holidays, British Columbia Ministry of Transportation and Infrastructure, Parks Canada) have developed sophisticated electronic systems for operational recordkeeping. However, the majority of the subscribers do not have the necessary financial and/or IT resources to build customized software solutions to fit their particular needs. While some programs exist (e.g., PowderCloud (powdercloud.com), AvTools (Ruttle, 2002), MechSki), many operations rely on self-made Excel templates or a paper/whiteboard system for operational recordkeeping.

In addition to the obvious limitations of paper and Excel systems regarding data analysis and presentation, most of the systems mentioned above cannot synchronize data with InfoEx, forcing many operations to enter their observations at least twice: once into their own operational system and once into InfoEx. In time-pressured work places, such procedures waste valuable time.

Requirement – InfoEx should provide data entry efficiencies

Requirement - InfoEx should integrate smoothly with operational recordkeeping.

3.6 Information overload

The time available for reading InfoEx reports is often quite limited and does not allow for detailed examination of all submissions—especially during times of significant avalanche activity when things

really matter. Many InfoEx users developed personal approaches to efficiently scan InfoEx reports for the information most relevant to their needs, but they always have to start from the complete report.

Requirement - InfoEx should allow users to a) quickly get an overview of the conditions across the entire InfoEx region and b) efficiently access more granular, locally relevant information.

3.7 Integration of recent development

The concepts of avalanche character (Atkins, 2004) and the later conceptual model of avalanche hazard (Statham *et al.*, 2010) have gained broad acceptance in the Canadian avalanche community. The conceptual model mimics the expert reasoning process, and offers a meaningful pathway from individual field observations to the final hazard assessment and treatment. Exchanging this type of data offers valuable insights about existing conditions. While these concepts had become *de facto* best practices for operational avalanche forecasting, they had not been integrated into InfoEx yet.

Requirement - InfoEx should support best practices in avalanche risk management.

3.8 Limited support resources at CAA

Computer skills among InfoEx subscriber community vary significantly, while the CAA has modest resources to provide IT support to subscribers.

Requirement - InfoEx installation and upgrades should be as user-friendly as possible.

3.9 Facilitating future developments

Best practices in avalanche hazard assessment and risk treatment will naturally evolve over time. The generous support from TECTERRA created a one-time opportunity for the Canadian avalanche community to rebuild its avalanche data systems, but future funding opportunities for software development projects will likely be much more limited and improvements to the system will be incremental.

Requirement - InfoEx should easily adapt to changes in best practices, facilitating incremental development of functionality.

4. SYSTEM CHARACTERISTICS

The development team was challenged by the extensive list of system requirements. Hard choices had to be made in support of the overall objective: rebuilding InfoEx to provide the biggest benefit to the largest number of subscribers while creating opportunities for future developments.

The main functionalities of InfoEx 3.0 include:

- Entering of field observations
- Assessing avalanche hazard
- Sharing observations and assessments
- Viewing of InfoEx data
- Managing of operational settings (users, location catalog, workflows and report templates, etc.)
- Managing of personal settings and preferences
- Managing of InfoEx service (CAA only)

In this section, we discuss key design choices of InfoEx 3.0, highlighting how each supports core requirements presented in the previous section.

4.1 Overall architecture

To support platform independence and user-friendly installation and upgrade, InfoEx 3.0 was developed as a web application consisting of a cloud-based service and a HTML5 browser-based client application. The application is downloaded and permanently stored in the application cache of the browser the first time a user visits the website. This supports base functionality of the application (e.g., data entry) without Internet connectivity. After the first visit, the application is automatically refreshed if a newer version has been posted.

The offline capabilities are further enhanced by the use of client-side storage using the Filesystem API. This API allows browser-based applications to read and write files to a sandboxed file system within the browser. This technology allows users to enter and store observations when offline and to permanently store local settings. Since Google Chrome and Opera are the only browsers supporting this API at this time, full InfoEx data entry functionality is currently limited to these browsers only.

The backend of InfoEx 3.0 is exposed as a HTTPS RESTful API that—in addition to the HTML5 client application—also supports direct submissions from third-party systems. The platform is based on the Java Spring Framework and PostgresSQL/ PostGIS, GeoJSON and KML are used to support the geospatial information.

Hosted by a cloud service, the system is easily scalable relative to fluctuating demand (e.g., winter vs. summer usage) and is designed to provide a high level of reliability and resiliency through the use of load balancing and hot standby clustered databases.

4.2 Customization of data entry

Entry forms were developed for standard observations types (e.g., weather observations, avalanche observations, etc.). To streamline interactions with these forms while supporting large numbers of observation fields, the forms were designed to be completely customizable (Fig. 1).

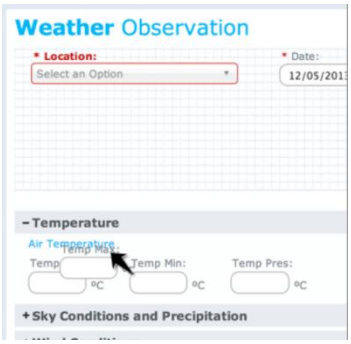

Fig. 1: Customizing of weather observation form.

Individual observation fields can be dragged from thematic sections at the bottom of forms to the 'favorite' section at the top, where they can be arranged freely. The thematic sections are collapsed by default, resulting in concise forms that focus on the observation elements collected in the subscriber's operation.

4.3 Workflow functionality

Some of the key tasks that avalanche safety operations perform on a regular basis are:

- Entering observations
- Viewing InfoEx reports
- Viewing websites
- Keeping track of current snowpack structure and relevant persistent weak layers
- Assessing avalanche hazard
- Making operational plans

While all avalanche safety operations perform these tasks in some fashion, the particular details and sequences in which they are executed vary from operation to operation. InfoEx 3.0 supports all of these activities with specifically designed customizable workflow modules, assisting users in performing the tasks efficiently and exchanging any associated information through InfoEx.

Workflow templates allow subscribers to create customized sequences of the available workflow modules tailored to their operational needs. Once a workflow template has been defined, users can execute workflow instances (Fig. 2) as part of their regular operational avalanche risk management routines. Any information entered is stored on the InfoEx server and appropriate parts are shared among the InfoEx community.

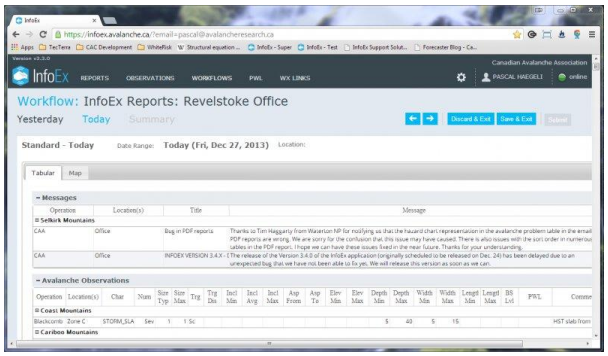

Fig. 2: Example of workflow instance with InfoEx report module.

A typical example of the application of this functionality is a workflow supporting the morning guides' meeting at a backcountry operation. This workflow would consist of the following steps:

- Intro to the meeting (i.e., attendance, time)
- Entering lodge weather
- Viewing InfoEx report
- Viewing favorite weather forecast sites
- Reviewing snowpack structure
- Assessing avalanche hazard for the day
- Submitting observations and assessments to InfoEx

The workflow functionality of InfoEx 3.0 allows an organic interaction with the system that seamlessly fits within existing operating practices. This integration has the potential to a) offer valuable structure for regular tasks (e.g., meetings, data analysis) and b) result in considerable operational timesaving while increasing the amount and/or quality of exchanged information.

Workflow functionality make InfoEx 3.0 infinitely adaptable to current and future subscriber needs. New avalanche risk management tools, such as the conceptual model of avalanche hazard, can easily be introduced into InfoEx 3.0 as new workflow modules.

4.4 *Enhanced tabular view of InfoEx reports*

The traditional tabular view has been enhanced with graphical representations of information (e.g., mountain icon for hazard ratings) and hyperlink pop-up balloons to provide easy access to more detailed information (Fig. 3).

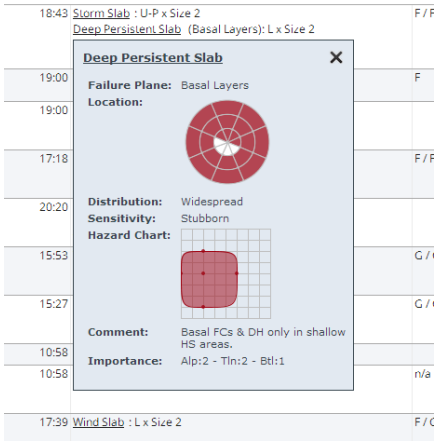

Fig. 3: Pop-up windows for detailed avalanche problem information.

4.5 *Map view of InfoEx reports*

Using the Google Earth plugin for browsers as the map engine, numerous observation parameters of InfoEx can now also be viewed in a map view (Fig. 4 & 5). While observation parameters, such as avalanche hazard, avalanche problems and weather observations are best viewed on overview maps to get a quick understanding of the large scale situation (Fig. 4), zooming into individual avalanche observations can also be useful to get a better understanding of the detailed terrain charac-

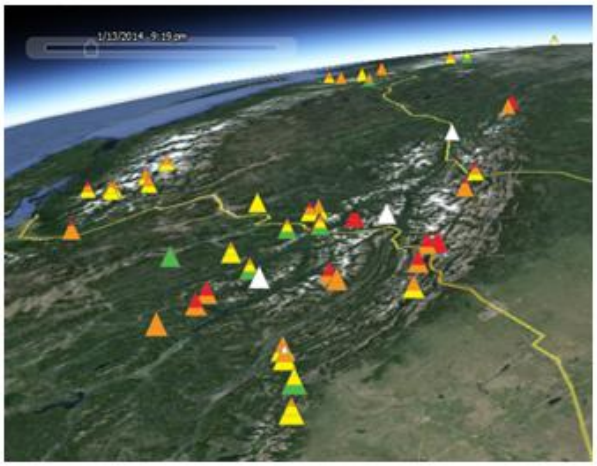

Fig. 4: Overview map of hazard ratings displayed with mountain icons.

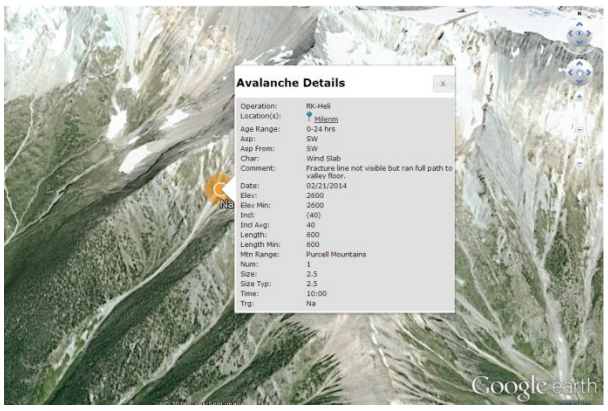

Fig. 5: Detailed map view of avalanche observation with pop-up balloon.

teristics of occurrences (Fig. 5). Avalanche observations are either shown at the precise location (if provided) or the centroid of the pre-defined location associated with the observation (e.g., ski run). Clicking on the avalanche icon opens a pop-up balloon with the available detail information including photos (Fig. 5).

Due to limitations in the Google Earth plugin, the map functionality is currently only available on certain platforms (e.g., not iOS) and only when connected to the Internet.

4.6 *Chart view of InfoEx reports*

Numerous observation parameters can also be displayed in predefined charts, which can provide a useful perspective on the temporal evolution of conditions at individual operations or summarized across an area (Fig. 6).

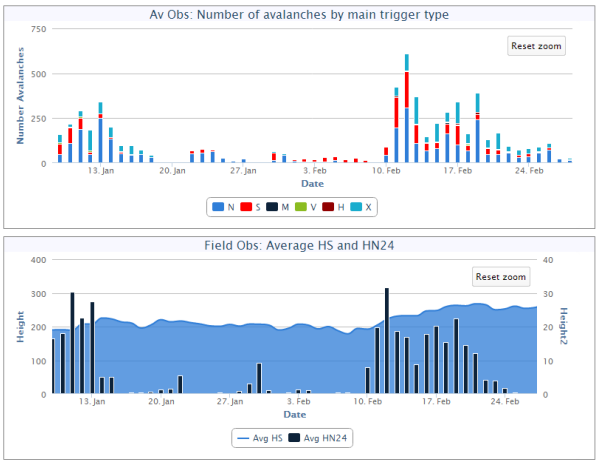

Fig. 6: Charts of number of avalanche by trigger type (top panel) and average HS and HN24 (bottom panel).

4.7 Customization of InfoEx reports

To make the processing of InfoEx report more efficient, users of the new InfoEx system can completely customize InfoEx report views and save the customizations as templates for future use. The customization abilities include:

- Specifying of date or date range (absolute and relative; e.g., last 3 days)
- Restricting of operations or locations shown in report
- Specifying observation types to be included
- Applying filters to individual observation types (e.g., only skier-trigger avalanches)

These customizations apply to all three InfoEx report views (tabular, map and chart), allowing users to switch back and forth between the different views and get different perspectives on the same data. In addition to the global customization options listed above, users may also select from several layout options for the tabular view, specify the point of view and the map layers shown in the map view, and select the charts to be shown and their order in the chart view.

4.8 Integration with operational recordkeeping

Customization options for InfoEx reports allow subscribers to query the InfoEx database for their own data and use the existing functionality to display the information in a variety of formats (e.g., season charts of weather observations, map display of avalanche activity). For many small operators in the InfoEx community, this functionality is sufficient for internal operational recordkeeping. This approach eliminates the need for multiple data entry, saving considerable time. To further enhance the operational value, subscribers can download their own data in a tabular CSV format, allowing them to archive their observations locally and/or analyze them in ways currently not possible within the InfoEx 3.0.

Larger operations with existing electronic database systems do not need to use the InfoEx application for data entry. They can submit their observations directly from their systems to the InfoEx database via the HTTPS RESTful API. In the first year of operation, we also supported the legacy CAAML 3.0.3 API for operations that previously submitted their observations directly to the InfoEx backend to reduce the need for subscriber-side development.

5. OPERATIONAL EXPERIENCES

Overall, the first winter of InfoEx 3.0 was a success. Information was exchanged and the system only had a total of two hours of downtime. However, the transition from the old system was certainly not without growing pains.

Despite best efforts, neither the CAA nor InfoEx subscribers were completely prepared for the range of cultural, technological and operational changes presented by the new system. Many users lacked enough time to familiarize themselves with the new system before their operating season and consequently only scratched the surface of the available new capabilities. During time-pressured operations, many users quickly reverted to their old InfoEx ways and struggled along with a system that—in their perspective—seemed unreasonably complicated.

Numerous factors contributed to the challenging launch:

- The launch of the system on December 1 was too close to the operating season, not giving subscribers enough time to get set up properly.
- The hands-on workshops were useful introductions to the new system, but only provided limited help for getting subscribers properly set up for the season. Short one-on-one sessions with individual subscribers would have likely have resolved many of the frustrating challenges.
- The operational use of the system quickly highlighted designs choices that were not as intuitive as expected. The development team responded to these challenges quickly, but users' workloads prevented many from exploring improvements that were released in mid-season.

We learned that open communication, setting appropriate expectations and targeted training are essential to launch a system of this magnitude. Subscribers can only adapt to a modest amount of change once the season is in full swing.

The launch of the new system further revealed that introducing new geospatial technology and analysis tools demands considerable cultural adjustments from subscribers. To support the diversity within the Canadian avalanche community, InfoEx was designed to be highly customizable and allow subscribers to adjust their InfoEx experience to their needs. However, many users were overwhelmed by the system’s flexibility and the range of interpretations one might draw from di-

vergent InfoEx submissions. In the previous versions of InfoEx, technical limitations created *de facto* standards for data entry and reporting. InfoEx 3.0 freed subscribers from these technical limitations, but revealed the need for new standards for submissions and reporting. Now that these technical capabilities have been introduced, it is now up to the subscriber community to work with the CAA to decide how exactly they want to use this technology. These discussions are underway and form important next steps for ensuring the continuous success of InfoEx.

6. FUTURE

InfoEx 3.0 development was funded by TECTERRA up to March 31, 2014, after which the CAA assumed full responsibility for the system. The first operational year of InfoEx 3.0 represented a massive leap in the progression of the system. Yet, much development remains to make the application more functional and user-friendly. 2013-14 end-of-season meetings focused on InfoEx yielded much useful subscriber feedback to support required improvements. The CAA and InfoEx subscriber community are working to address these needs.

Additionally, the CAA is currently developing workflow extensions that address operational needs closely related to core InfoEx functionality, *but distinctly separate from information exchange*: a run list extension primarily aimed at backcountry skiing operations; and an avalanche control extension. These two extensions will cater to proprietary operational needs (i.e., this information is not shared with other subscriber), but seamlessly integrate into the workflow functionality and make InfoEx 3.0 a more complete avalanche risk management system. The run list and avalanche control extensions will be optional choices for the 2014/15 season, available to subscribers for additional fee.

These workflow extensions highlight the benefits of designing InfoEx 3.0 as a platform. Now that the foundation is in place, many opportunities exist for expanding the functionality of the system with moderate investments. We hope that the different segments of the community will recognize these opportunities and work collaboratively with the CAA and subscribers to expand InfoEx to address additional data management needs. These types of developments play an important role in supporting the long-term sustainability of InfoEx.

CONTRIBUTIONS

PH was the business analyst and overall project manager for this project. JO represented the interests of the Canadian Avalanche Association, the owner of InfoEx 3.0, during the development. BH represents the InfoEx subscriber community who contributed to this project in many ways. BM and JE were the developers who implemented the system as specified. JN is the Director of Commercialization Programs at TECTERRA and was responsible for the InfoEx project at TECTERRA.

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