THE NATIONAL AVALANCHE FORECAST PLATFORM: A SYSTEM THAT HAS REDUCED COSTS, IMPROVED CONSISTENCY, AND PROMOTED COLLABORATION AMONG U.S. AVALANCHE CENTERS
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ABSTRACT: U.S. Avalanche Centers operate independently and may be federal, state, or NGO/nonprofit programs. Historically, each Avalanche Center (AC) built its own web-based interfaces for collecting and distributing avalanche safety information. This independent development leads to economic inefficiencies and inconsistency in the presentation of websites, avalanche forecasts, and observational data.

In 2019, the USDA Forest Service National Avalanche Center (NAC) assembled a working group to collaborate on web technology projects. This consortium led to the development of the National Avalanche Forecast Platform (AFP) in 2019. The AFP has expanded to include a suite of web-based modules that ACs can use according to their needs.

The internet is the single most powerful means of collecting and distributing avalanche safety information. Its use can be costly, technically complex, and maddeningly dynamic. In this paper, we highlight some of the key benefits of the AFP. Although the most obvious advantages of this system are cost-sharing, creating economies of scale, and consistent public messaging, other significant benefits include added efficiencies to forecaster workflow and training and a centralized database of U.S. avalanche forecast data.

This project reflects an unprecedented level of cooperation among the U.S. Avalanche Centers and suggests that we have entered a new and more collaborative phase in public avalanche forecasting in the U.S.

KEYWORDS: Avalanche Forecasting, Web Technology, Public Safety Messaging, Data Management

1. INTRODUCTION

U.S. Avalanche Centers (ACs) provide avalanche information and education to reduce the impacts of avalanches on the recreating public. They cover diverse mountain ranges stretching from the high latitudes of Alaska down to the low latitudes of California and from the west to the east coast. There are currently 22 Avalanche Centers in 12 states: 14 of these are operated by the USDA Forest Service (USDA-FS), one by the state of Colorado (the largest AC in the U.S.), and seven by private non-profit organizations. Even as government programs, each of the 14 USDA-FS ACs functions as a public-private partnership where community-based nonprofits provide funds, outreach, and education.

Public avalanche forecasting in the U.S. is largely decentralized and each operation is managed locally. This decentralized approach comes with both advantages and disadvantages. Advantages include the potential for nimble operations, rapid innovation, and close cooperation with local communities. A disadvantage is that each AC builds its own web-based interfaces for collecting and distributing avalanche safety information. This independent and redundant development leads to a lack of consistency in public safety products. It also creates economic inefficiencies and stressors for chronically underfunded programs.

One aim of the USDA-FS National Avalanche Center (NAC) is to facilitate systems that

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encourage and maintain local management while also promoting collaboration, consistency, and cost-effectiveness within the AC group. To this end, we have formed a public-private partnership with the American Avalanche Association (A3) to develop a series of information technology (IT) systems to enhance public avalanche safety within the U.S. The A3 provides the business administration for the project, and the NAC provides technical expertise and project management.

This initiative consists of two parts: The first is a national-level public website (Avalanche.org) that showcases danger maps, links to avalanche centers, accident information, and educational materials. The second—which is the focus of this paper—provides participating ACs with a centralized IT system for gathering, analyzing, and disseminating avalanche safety information. This system is called the National Avalanche Forecast Platform.

2. THE NATIONAL AVALANCHE FORECAST PLATFORM (AFP)

2.1. Background

Recognizing the need to promote collaboration, consistency, and cost-sharing within the U.S. AC community, the NAC assembled a working group in 2019 to build shared AC web technology (Figure 1). This group included members of the Sawtooth, Northwest, and Sierra Avalanche Centers. The Colorado Avalanche Information Center joined in an advisory capacity.

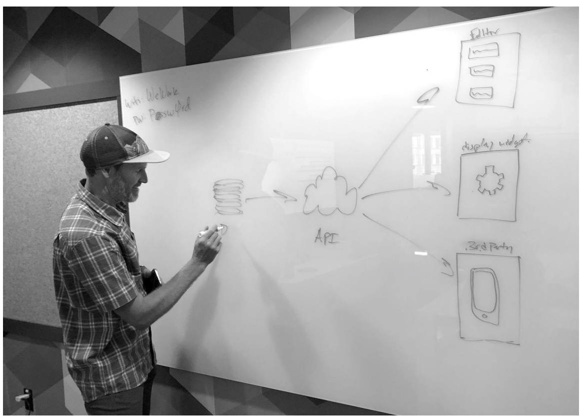

Figure 1: Andy Anderson at the original NAC IT working group meeting in 2019.

The beta version of the Avalanche Forecast module launched in 2019, and since then, the AFP has grown to include a full suite of web applications (Forecasts, Warnings, Observations, Media, and Weather Stations). Participation is optional, and ACs can pick and choose modules according to their needs. Put simply, the National Avalanche Forecast Platform provides web-based applications that ACs use to complete their missions.

2.2. System Architecture

The core architecture for each AFP module consists of server infrastructure, an underlying database, an application programming interface (API), and web applications that interact with the data (Figure 2). A login-protected, backend workspace (the Avalanche Center Dashboard, Figure 3) allows forecasters to interact with the data—such as creating avalanche forecasts, issuing warnings, or submitting or viewing observations. The Dashboard was developed by and for avalanche forecasters, resulting in an interface that prioritizes an efficient workflow.

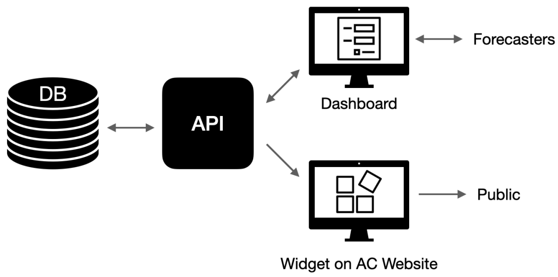

Figure 2: Simplified system architecture diagram of the National Avalanche Forecast Platform.

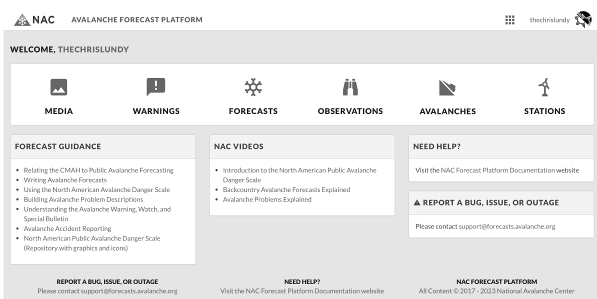

Figure 3: The Avalanche Center Dashboard, a password-protected backend workspace for forecasters.

While this system architecture is common for web applications, one unique aspect of the AFP is how data is displayed to the public. To visualize data on independent AC websites, we developed a suite of Javascript mini-applications that comprise the public-facing side of the AFP (Figure 4). These “widgets” are easily embedded on web pages and work with common web platforms. Updates to the widgets can be deployed without any action on the part of participating ACs. These widgets are notable in that they often comprise an entire web page except for the host website header and footer. The current suite of widgets includes the Home Page Danger Map, Avalanche Warning Banner, Avalanche Forecasts (Figure 4), Observation Viewer, and Weather Station Map.

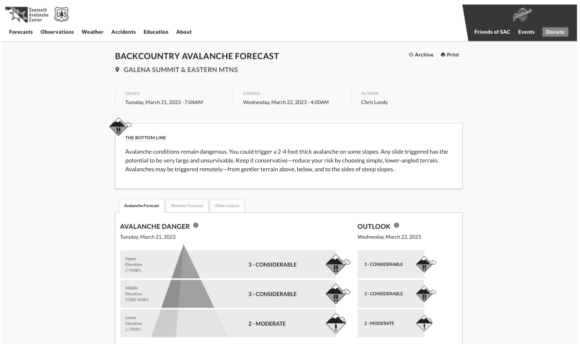

Figure 4: Avalanche Forecast Widget embedded within the Sawtooth Avalanche Center website.

2.3. Funding

While initial seed money was provided in 2019 by the Northwest, Sawtooth, and Sierra ACs, the development cost of the AFP has been primarily funded by the USDA-FS. Subscription fees paid by ACs using the AFP cover overhead costs such as infrastructure, servers, and maintenance.

The AFP has grown from its inception as a grassroots, shoe-string project to a stable and consistently funded program. In recognition of the AFP’s growing importance within the U.S. avalanche community, the USDA-FS added a new, full-time position within the NAC whose responsibilities include managing and supporting the AFP. It also continues to provide funds that support ongoing development work. The AFP annual project budget is approximately US$180,000, including NAC staff time, development contractors, and overhead costs. Approximately 75% of this budget is provided by the USDA-FS. The remainder is provided through AC subscription fees and A3 sponsor dollars. A future goal is to achieve a 50-50 split between public and private funding.

3. KEY BENEFITS

There are numerous advantages to moving from decentralized, individual IT development to a more centralized approach:

3.1. Cost

Centralized development is more cost-effective. Participating ACs share the financial burden with other centers and don’t spend limited resources on redundant work. Some small ACs simply cannot afford to build the web technology they need to achieve their missions.

3.2. Consistency

A shared approach provides greater consistency in public-facing avalanche safety products and services. Users recreating in different avalanche forecast areas benefit from products that look similar. Avalanche educators can more effectively teach students how to read avalanche forecasts and submit observations.

3.3. Collaboration

While a small amount of individual innovation may be sacrificed, a collaborative approach helps build consensus and strengthens relationships among ACs. With a strong collaborative process in place, better results emerge from the efforts of many rather than a few.

3.4. Training

Shared training opportunities arise when forecasters from different ACs are using the same tools, technology, and workflow. Forecasters moving from one AC to another can spend time learning the geography and patterns of a new area rather than new IT systems.

3.5. Data

Collecting national-scale, avalanche-related data in a centralized location provides unique opportunities for research and data analysis. We discuss this further in Section 6.

4. ANALYSIS

Analyzing the effectiveness of the AFP—and that of any avalanche safety product—is challenging. We've received overwhelmingly positive feedback from both forecasters and the public. Still, we investigated several metrics that may quantify which aspects of the project have succeeded and those that need improvement.

4.1. Adoption By U.S. Avalanche Centers

The adoption of the AFP has been rapid among U.S. avalanche centers. When the AFP was launched in 2019, it was beta-tested by a single AC. By the 2022-23 winter, 17 of 22 ACs used the AFP covering approximately half of the forecasted area in the U.S. This is more impressive considering that 60% of the remaining half falls under the Colorado Avalanche Information Center, a large-scale, state-run program that uses proprietary systems.

4.2. Average User Time On Page - Avalanche Forecast Widget

Many web analytics such as unique visitors and pageviews are influenced by external factors. ACs report increased website traffic during snowy or particularly dangerous winters or after noteworthy avalanche accidents. One metric that may be less affected by these factors is the average time spent on a page. Particularly for the avalanche forecast, more user time spent on the page may be a proxy for user engagement.

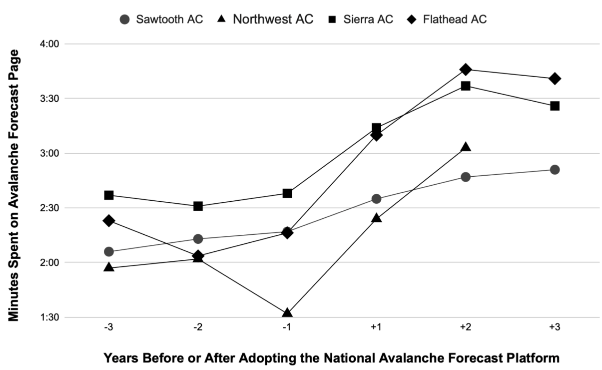

Figure 5: Graph illustrating the change in average time spent on the avalanche forecast for four ACs that switched to the AFP.

Using web analytics from the Sawtooth, Sierra, Northwest, and Flathead ACs, we compared the time spent on the avalanche forecast for the three years before and three years after adopting the AFP (the last year of data for the Northwest AC was absent). This comparison revealed a significant increase in the average time on page after adoption, ranging from 24% to 58% (Figure 5). Examining data from two large ACs that are not on the AFP showed a flat or decreasing trend over the same time period, suggesting that the increase observed upon AFP adoption is not following a more widespread trend. Perhaps this increased time-on-page is due to the emphasis the Avalanche Forecast Widget design places on photos and videos.

While this increased time spent on the avalanche forecast seems promising, we caution against drawing strong conclusions from this result. While we did our best to do an “apples-to-apples” comparison, web analytics can be finicky. Further, more work is needed to judge whether time-on-page analytics for the avalanche forecast is a useful measure.

4.3. User Engagement With The Widget Interface Elements

Our web analytics collect custom event data when the public interacts with user interface (UI) elements of the widgets. For example, we track when users click on a tab, hover over a highlighted glossary term, or click on a map interface. This data provides a novel way to investigate how avalanche safety products are used by the public on a national, multi-AC scale. These results can help guide design decisions that lead to a better user experience.

The Avalanche Forecast Widget displays the AC's most important avalanche safety product. On average, users interact with UI elements only .75 times per pageview (Table 1). The UI element that receives the greatest interaction is viewing and scrolling through enlarged media in a “lightbox” gallery. Since photos and videos are so important in public safety messaging, we're pleased to see that the public is engaging with the media. While the public commonly hovers over glossary terms to get a short definition snippet, they rarely click on the terms to receive more in-depth explanations. The avalanche forecast display utilizes a tabbed layout to separate the avalanche forecast from the weather forecast, recent observations, and other related information. We were disappointed to see that users rarely click on tabs. For example, during the 2021-22 season, we found that users only clicked on the weather forecast tab 5% of the time. This led us to move the weather section to the main avalanche forecast tab for the 2022-23 season.

Total pageviews	4,125,798
Total events	3,105,049
Events per pageview	0.75
Media lightbox scrolled/swiped	1,303,792
Glossary term hovered	922,856
Media thumbnail expanded to lightbox	538,111
Tab changed	195,155
Help “i” button clicked	58,388
Glossary term clicked	23,434

Table 1: Table summarizing web analytics custom event tracking for the Avalanche Forecast Widget for the two years between September 2021 and August 2023.

The Observations Widget displays observations in a list or map-based interface. While a significant portion of our development budget went towards an effective and easy-to-use interface for filtering observations, analytics show these are seldom used. Anecdotally we believe the filter interface is critical to a minority of advanced users, but it's important to design these types of features with that in mind.

Info buttons, such as small “i”s, are often used in technical contexts to indicate that more information is available. We've found that they are rarely used (Table 1). While we wouldn't argue to remove them, our results may show that spending significant time writing the help content provides a low return on investment.

A conclusion that emerges from this preliminary analysis is that users seem to prefer getting information in a straightforward manner that requires minimal clicking. They also seem to consume a basic level of information and don't often interact with the more advanced “bells and whistles” that we (as professionals and/or designers) think are useful.

5. CASE STUDY - AFP OBSERVATION MODULE

To illustrate the points outlined in this paper, we'll take a closer look at the AFP Observation Module launched for the 2022-23 winter. It offers an example of how developing a centralized, shared system improved collaboration, reduced total costs, and resulted in a better-functioning system.

Crowd-sourcing observations related to the snowpack and avalanche activity are critical to forecasters issuing avalanche forecast products. Many established U.S. ACs with stable budgets have built proprietary systems to gather information from the public and document forecasters' observations. These systems are often complex and expensive; many smaller ACs with less robust funding have either limited observation systems or none at all.

5.1. Collaboration

While collaboration was certainly important during the design of the Avalanche Forecast Module, most existing avalanche forecast products had more in common than not. Unexpectedly, consensus building turned out to be more of a challenge during the design of the Observation Module. Most ACs involved with the design process had long-standing, but very disparate, observation systems. In the end, the NAC was struck by the willingness of participating ACs to compromise and prioritize finding common ground.

5.2. Cost Savings

The first phase of the Observation Module that went operational for the 2022-23 winter cost US$45,000 to develop. Two-thirds of that cost was paid to a contractor and the remaining third covered project management and development performed by NAC staff.

The estimated cost of an individual AC building an observation platform comparable to the first phase of the NAC Observation Module is ~US$20,000. Therefore, if the nine ACs that adopted the NAC observation platform built independent systems, the total cost would have been around US$180,000. This is four times the cost of building the shared system.

The second phase of the Observation Module launching for the 2023-24 winter is expected to cost a similar amount as the first. But we also expect 3-4 more ACs to subscribe to the observation system, continuing to build an economy of scale.

5.3. Integration With Other AFP Modules

The centralized architecture of the AFP allows modules to be interconnected, making forecasters' jobs easier and the public-facing products more effective.

Photos and videos can be incredibly effective in public safety messaging but are also time-consuming for forecasters to manage. The Avalanche Center Dashboard has been designed specifically to streamline this task. Whether submitted by a forecaster or the public, photos or video posted with an observation goes into a Media Manager shared by all of the AFP modules. When submitting an observation, the public explicitly chooses how their photos may be used by forecasters, eliminating the need to contact the observer. All of the photos and videos in the Media Manager are conveniently available to be used within avalanche forecast products.

When viewing the avalanche forecast product, tabbed sections contain recent field observations and avalanche activity within the selected forecast zone, providing a convenient "one-stop-shop" for users.

5.4. Results

When the Observation Module launched for the 2022-23 winter, nine ACs adopted it—more than initially expected. Over 2200 observations were collected through the system during its first season.

When we investigated the number of observations ACs received before and after adopting the NAC Observation Module, three stories emerged. Three participating ACs are small operations that lack the resources to build functional observation systems. They were able to add the NAC platform with minimal cost and successfully began receiving observations from the public. Four ACs had existing—but not particularly robust—obs platforms. This group saw 80-200% more observations submitted with the NAC system. Finally, two ACs that had pre-existing, well-functioning systems still received more observations than in prior years, but the gains were more modest (15-20%).

6. DATA CENTRALIZATION

Within the U.S., relatively small amounts of avalanche-related information have been databased at a national scale. In 1967 the U.S. Forest Service Avalanche Research Project established the Westwide Avalanche Network (WWAN) (Williams, 1994). This initiative gathered weather, snowpack, and avalanche information from a number of sites in the western U.S. The WWAN also started an avalanche accident database, which is now maintained by the Colorado Avalanche Information Center and contains U.S. accident reports dating back to the 1950s. Another database project termed Snowpilot has collected nearly 30,000 snow profiles since 2016 (Chabot, 2016).

Data	Source	Start
Avalanche Danger	All ACs	2013
Avalanche Warnings	All ACs	2017
Avalanche Forecasts	17 of 22 ACs in 2022	2019
Photos and Metadata	17 of 22 ACs in 2022	2019
Field Observations	13 of 22 ACs in 2023 (estimated)	2022
Avalanche Events	13 of 22 ACs in 2023 (estimated)	2023

Table 2: Types of data collected by the AFP, including their source and collection timeframe.

While these databases are noteworthy (especially the long-term accident record) the AFP is the first project to collect and store comprehensive avalanche-related data and analysis on a national level and in a central location. Table 2 outlines the type of data being stored, its source, and when collection began.

Having a multi-faceted, centralized data set—one that encompasses both field data and forecaster analysis—offers opportunities for impactful research. It also provides new ways to visualize and communicate avalanche information. For example, Birkeland and Trautman (2022) generated heat maps of avalanche danger over time and space to compare patterns between seasons. On the public-facing side, the NAC and A3 have worked together since 2015 to leverage this data by displaying avalanche danger on the Avalanche.org national map. We're just beginning to investigate other possibilities, such as gathering and displaying field observation data on a national scale (see section 8 below).

7. CHALLENGES

7.1. Sustainability

The development of the AFP has not been without challenges. The primary one has been achieving an appropriate level of sustainability, in terms of funding, in-house work capacity, and contractor time. The NAC, while "big in name", is a relatively small program with limited resources. Building a national-level, centralized IT system has opened the doors to many exciting possibilities, but we've had to carefully choose which to walk through in order to protect the viability of the program. The past five years have been a period of rapid growth and development. To remain sustainable going forward, we plan to slow the pace of development and focus on adequately supporting and maintaining our existing systems.

7.2. Data Management

Now that a significant portion of U.S. avalanche-related data is located in a centralized system, an unanticipated and growing challenge is managing the numerous third-party requests to consume this data. Sharing data with third parties (mapping app developers are a common example) brings up questions of the added financial burden to the NAC, loss of AC branding and identity if users can access the information elsewhere, and privacy concerns related to public observations. We've been working on a strategic approach to data sharing, but more work is needed.

8. FUTURE DIRECTION

In the near term, the second phase of the Observation Module will launch for the 2023-24 winter. This will add a robust avalanche event database to the platform, allowing forecasters to record and analyze avalanche activity.

As mentioned above, the centralized nature of the AFP has opened the doors to numerous unique opportunities to collect and disseminate avalanche safety information. One of the more exciting possibilities is implementing the Observation Module on a national scale. This concept may provide a way for users to exchange field observations in underserved portions of the U.S. where no AC provides forecasts. Yet another opportunity is building advanced data aggregation and visualization tools that draw from multiple data sources to help forecasters assess avalanche hazard and improve forecast accuracy.

As Fisher et al. (2021, 2022) have shown, evaluating the effectiveness of avalanche forecast products is challenging but possible. With so much of the forecasted area within the U.S. now served by a single forecast design, we believe the effort would be justified to assess its efficacy as a public safety messaging tool and to let those results drive improvements as needed.

9. CONCLUSION

The internet is the single most powerful means of collecting and distributing avalanche safety information. Its use can be costly, technically complex, and maddeningly dynamic. In the past, the decentralized nature of U.S. avalanche forecasting has required individual ACs to shoulder the financial and technical burden of designing and maintaining web technology.

In this paper, we highlight some of the key features and benefits of the centralized, collaborative National Avalanche Forecast Platform. Although the most obvious advantages of this system are cost-sharing, creating economies of scale, and consistent public messaging, other significant benefits include added efficiencies to forecaster workflow and training and a centralized database of U.S. avalanche forecast data.

We are in the early stages of investigating web analytics collected for our public-facing displays, but we believe this data will help drive design decisions moving forward, leading to more user-friendly and effective avalanche safety products.

This project reflects an unprecedented level of cooperation among the U.S. Avalanche Centers and suggests that we have entered a new and more collaborative phase in public avalanche forecasting in the U.S.

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