ABSTRACT

In the airline industry, flight dispatchers are responsible for planning aircraft routes safely and economically. Training is essential to help dispatchers understand when and where icing may occur and what to do when it does. The goal of this project was to develop content for a web-based system devoted to flight dispatcher icing training. The content addresses basic meteorology and weather product interpretation so that flight dispatchers can learn how to determine where icing is and will form. It also includes scenarios to support the flight dispatcher decision making process. To develop the content, we collaborated with a regional airline and a major domestic airline. This paper describes the progress to date on the content development effort. For each content area, the lesson objectives and topic content are described. The paper also discusses the remaining effort required to complete the content development process.

1 INTRODUCTION

Icing remains one of aviation’s leading weather hazards (c.f., Boeing, 2003). Because aircraft are not certified for flight in all icing conditions, all aircraft are susceptible to icing – including those with anti-icing and de-icing equipment. Most aircraft involved in icing accidents are general aviation, but there have been commercial ones as well (NASA, 1998). The main problem is that weather conditions are never totally predictable and icing forecasts are not provided with the temporal and spatial accuracy and timeliness to help avoid all hazardous icing encounters. The density, frequency and resolution capability of today’s observation network is not compatible with the micro-scale nature of icing. The problem is made worse by missing data from reporting stations and areas that do not have the equipment necessary to forecast icing (i.e., the far North) (Ryerson, 2000). Also, there is a high dependency on icing pilot reports (PIREPs) (ASA, 2003), that are infrequently and subjectively reported (Kelsch & Wharton, 1996).

In addition to the safety concerns related to icing, aircraft operators are concerned about the unnecessary associated costs. Taking action to avoid icing that does not materialize, yields disruptions in planned altitudes and/or routing, significantly decreasing aircraft efficiency and therefore increasing operating costs. For airlines, many of the safety and cost related decisions with respect to icing are made by flight dispatchers who are licensed airmen certified by the Federal Aviation Administration (FAA). Dispatchers have joint responsibility with pilots-in-command for the safety and operations of the flights that they dispatch (FAA, n.d.). While pilots are the tactical decision-makers, flight dispatchers are the strategic decision-makers. This is true because while pilots fly the aircraft, flight dispatchers plan the flights. With respect to flight planning, dispatchers are responsible for decisions such as:

- Flight plan routing based on criteria such as aircraft equipment and forecast weather,
- Flight cancellation if the flight is deemed unsafe,
- Alternate airport selection when weather conditions require it,
- Fuel load planning, to deal with weather, traffic, and other contingencies,
- Weight restriction considerations, and
- Effects of inoperative equipment on the aircraft.

Icing is a complex subject, and flight dispatcher initial certification does not cover icing topics with the depth, breadth, and time required to assure mastery of the subject matter (Bass and Quil, 2003). Unfortunately, icing training for flight dispatchers is not freely available as the current icing resources are not focused on the flight dispatching profession. For example, NASA offers CD-ROMs, computer-based training, and videos (e.g. Icing for Regional and Corporate Pilots) that focus on how icing affects pilot decision making (Bond, n.d.). Likewise, COMET’s web-based icing training modules provide information targeted towards weather forecasters (COMET, n.d.).

In an effort sponsored by the Icing Branch at NASA Glenn Research Center, our team is developing the content for a flight dispatcher-centered web-based icing training system. Based on previous work (Quil, et al., 2003), the content must not only help flight dispatchers to identify current and forecast icing conditions but also to know what to do if icing conditions may be present. Thus the content of the training system focuses in three areas:

- Basic meteorology,
- Weather product interpretation, and
- Applied decision making through the use of scenarios.
Our team coordinated with one major air carrier and one regional airline to develop content for the training system. This paper describes the progress to date on the content development effort. For each content area, the lesson objectives and curriculum topics are described. The paper ends with a discussion of the future work required to complete the content development process.

2 BASIC METEOROLOGY

The purpose of the basic meteorology module is to teach the important meteorological concepts critical to the understanding and forecasting icing conditions. The lesson objectives for this module highlight that basic meteorology is critical to effective analysis of icing situations and that seasonal effects and geography play a vital role in the development of icing conditions. The objectives focus on the atmospheric conditions favorable to icing, the formation and properties of icing in clouds, the effects of frontal systems on icing conditions, the effects of seasonality on icing, and the effects of geography in the formation of icing.

Table 1. Basic Meteorology Module General Topic Outline (References)

<table>
<thead>
<tr>
<th>I. Brief Module Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. Atmospheric Conditions Favorable to Icing (2)</td>
</tr>
<tr>
<td>a. Freezing Temperatures (1,2)</td>
</tr>
<tr>
<td>b. Visible Moisture in Atmosphere (1,2)</td>
</tr>
<tr>
<td>i. Liquid Water Content Explanation (1,2)</td>
</tr>
<tr>
<td>ii. Droplet Size / Supercooled Liquid</td>
</tr>
<tr>
<td>iii. Droplet Formation (1,2)</td>
</tr>
<tr>
<td>iv. Types of Visible Moisture (1,2,4)</td>
</tr>
<tr>
<td>c. Location of Icing on the Vertical Scale (1,2)</td>
</tr>
<tr>
<td>i. Winter Time, Summer Time (2)</td>
</tr>
<tr>
<td>III. Icing and Clouds (1,2,3)</td>
</tr>
<tr>
<td>a. Icing in Stratiform Clouds (1,2,3,4,5)</td>
</tr>
<tr>
<td>b. Icing in Cumulus Clouds (1,2,3,4,5)</td>
</tr>
<tr>
<td>c. Orographic Clouds (2,3,4)</td>
</tr>
<tr>
<td>IV. Icing and Frontal Systems (2,3,4,5)</td>
</tr>
<tr>
<td>a. Warm Front (2,3,4,5)</td>
</tr>
<tr>
<td>b. Cold Front (2,3,5)</td>
</tr>
<tr>
<td>c. Occluded Front (2,4)</td>
</tr>
<tr>
<td>V. Icing and Seasonality (2,3)</td>
</tr>
<tr>
<td>a. Winter Season Icing (2,3,4)</td>
</tr>
<tr>
<td>b. Summer Season Icing (2,3,4)</td>
</tr>
<tr>
<td>VI. Icing and Geography (2,3)</td>
</tr>
<tr>
<td>a. Mountains (2,3)</td>
</tr>
<tr>
<td>b. Large Bodies of Water (2,4)</td>
</tr>
</tbody>
</table>

Various resources were consulted in order to develop the content included in the module. The references from which the information on the particular subject was gathered are identified via the numbers following the table entries:

1. Aircraft Icing (Lankford, 2000)
2. Aviation Weather (Lester, 2001)
3. Aviation Weather and Weather Services (Gleim, 2000)
4. NASA’s In-Flight Icing Training Module CD-ROM (NASA, 2002)

In the lessons for this module, first general meteorological information is presented. Then information specific to icing formation is presented. The following example concerning frontal systems highlights this structure. The general information on frontal systems and warm fronts are introduced (Figure 1 and Figure 2). Next, the information regarding warm fronts and how they relate to icing is presented (Figure 3 and Figure 4). In order to convey the essential information for the module, four representational forms were used and these are described next.

2.1 Text

As depicted in Figure 1, Figure 2 and Figure 4, definitions, key concepts and other important information are presented using text.

2.2 Links

In order to supplement the textual presentation of information, hypertext links can be inserted throughout the module. The use of hyperlinks allows a user to find content related to the topic being explained. Figure 1 demonstrates the use of hypertext links in an example related to frontal systems. Within the definition of a front, the terms “air masses” and “warm fronts” may not be understood by the dispatcher. For this reason, these key terms are hyperlinked to other module content. For example, when a user clicks on the “warm front” hyperlink, the module would jump to the information presented in Figure 2. At this point, the properties and specifics of warm fronts would be available.

2.3 Graphics and Illustrations

Graphics and illustrations are also important representation forms. As depicted in Figure 1 and Figure 2, graphics illustrate examples of fronts to enforce important information. Animations are also very helpful. Figure 3 shows the sequential illustrations (i.e., the animation) used to portray the movement of warm and cold air in the event of a warm front that appears on the right side of Figure 4.
**What is a Front?**

A front is the interface or transition zone between two air masses of different density (air masses with different temperatures, pressures, or relative humidity). Since the temperature distribution is the most important regulator of the atmosphere density, a front almost invariably separates air masses of different temperature. When warmer air replaces the colder, it is a warm front, and a front is a cold one when the opposite occurs.

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**Properties of Warm Fronts**

Warm fronts are characterized by the formation of stratus clouds:

- Develops uniform horizontal layers.
- Generally long exposure to icing conditions at a certain elevation.
- Short vertical icing extent.
- Precipitation falls from warmer air into cooler air, which results in a strong potential for icing conditions.

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**Figure 1.** Front Explanation (adapted from Weather World 2010, 2004)

**Figure 2.** Warm Front Explanation (adapted from Weather World 2010, 2004 and Windows to the Universe, 2004)

**Figure 3.** Sequential Illustration of Warm Front Movement (adapted from Athena, 2004)

**Figure 4.** Explanation of Warm Fronts and Icing (adapted from Athena, 2004 and Konrad, 2004)

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### 3 WEATHER PRODUCTS INTERPRETATION

The content of the weather products interpretation (WPI) module is intended to satisfy knowledge requirement 4 of Federal Aviation Regulation (FAR) 65.55: “Interpretation and use of weather charts, maps, forecasts, sequence reports, abbreviations, and symbols.” In addition, the interpretation lessons provide explanations missing from many of the available weather products.

The learning objectives in the WPI module concentrate on defining the components of each weather product and teaching the process of using them to identify icing conditions. In general, the objectives of each product lesson highlight the concepts flight dispatchers should understand about the weather product, the components of the product they should be able to interpret, and the skills needed to identify icing situations. In addition, the module explains the uses and limitations of the available products and how to use sets of products in combination.

#### 3.1 Module Content

The products in this module were selected based on recommendations from flight dispatchers at two airlines and NASA’s icing training material (NASA, 2002). The content of the WPI module is made up of separate lessons for each of the products shown in Table 2. There are several characteristics that differ among the weather products. First, they use several types of representation including codes, abbreviations, plain text, numerical graphing, numerical representation, shading, color coding, and symbols. The update rate is another differentiating characteristic. In addition, while some products provide data on current conditions, others are forecasts of future conditions, while others are both.
Table 2. Weather Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Methods of Communication</th>
<th>Update Rate</th>
<th>Format</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine Aviation Report (METAR): Airport weather</td>
<td>Code, abbreviation</td>
<td>Hourly</td>
<td>Text</td>
<td>Current</td>
</tr>
<tr>
<td>Terminal Aerodrome Forecast (TAF): Airport Weather</td>
<td>Code, abbreviation</td>
<td>Hourly</td>
<td>Text</td>
<td>Forecast</td>
</tr>
<tr>
<td>Pilot Report (PIREP)</td>
<td>Code, abbreviation</td>
<td>as needed</td>
<td>Text, air conditions</td>
<td>Current</td>
</tr>
<tr>
<td>AIRMETS/ SIGMETS: Regional weather conditions</td>
<td>Code, abbreviation</td>
<td>Every 6 hours or as necessary</td>
<td>Text</td>
<td>Current</td>
</tr>
<tr>
<td>Current Icing Potential (CIP)</td>
<td>Shading, symbols, code</td>
<td>Hourly</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Current</td>
</tr>
<tr>
<td>Freezing Level Charts</td>
<td>Shading, Numerical Represation</td>
<td>Every 3 hours</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Current and Forecast</td>
</tr>
<tr>
<td>Skewed-T plot</td>
<td>Numerical Graphing</td>
<td>Twice daily</td>
<td>Numerical Graph of Vertical Region</td>
<td>Current and Forecast</td>
</tr>
<tr>
<td>Forecast Icing Potential (FIP)</td>
<td>Shading, symbols, code</td>
<td>Hourly</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>forecast</td>
</tr>
<tr>
<td>RADAR</td>
<td>Shading, color coding</td>
<td>Every 2 hours</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Current</td>
</tr>
<tr>
<td>Satellite</td>
<td>Shading, color coding</td>
<td>Hourly</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Current</td>
</tr>
<tr>
<td>Winds/Temperatures Aloft</td>
<td>Code, Abbreviation</td>
<td>Twice a day</td>
<td>Text code of winds in a particular area</td>
<td>Current</td>
</tr>
<tr>
<td>Automated Terminal Information System (ATIS)</td>
<td>Code, Abbreviation</td>
<td>Hourly</td>
<td>Text code of conditions at airport</td>
<td>Current</td>
</tr>
<tr>
<td>Surface Weather Maps: surface conditions</td>
<td>Symbols, numerical represntation</td>
<td>varies</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Current</td>
</tr>
<tr>
<td>Meteograms</td>
<td>Numerical Graphing</td>
<td>Hourly</td>
<td>Time series of weather data</td>
<td>Current</td>
</tr>
<tr>
<td>Low-level significant weather prognostic charts</td>
<td>Shading, color coding, symbols</td>
<td>Every 6 hours</td>
<td>Graphical display of weather overlay on horizontal region</td>
<td>Forecast</td>
</tr>
</tbody>
</table>

Discussed next, there are three typical formats of weather products that will require different treatment in the training system: a) text products which cover a specific area, b) graphic products which cover a horizontal geographic area, and c) numerical graphs.

3.2 Text-based Product Lessons

In order to understand a text-based product, a flight dispatcher must know what each part of the text represents including any codes or abbreviations that may appear. The training system must present and explain the meaning of each text component as it would appear in the product. The lessons to teach text-based products therefore have three segments: an example, an explanation of the components, and code definitions. Figure 5 shows the example and component definition sections of a METAR lesson. Not shown in the figure is the definition of the METAR codes, which would explain the other possible values for each component of the product.

Identifying icing using a text-based product requires identifying code values which help to diagnose where icing may be. There are text components which directly indicate the presence of icing conditions. In a METAR, for example, the weather phenomena component has code values for precipitation, such as freezing rain (FZRA), which may directly indicate the existence of icing. Also, there are text components which indicate precursors to icing. For example, in the METAR, the sky condition component will provide information about the cloud coverage and therefore where there is visible moisture. The training system must highlight the code values of these components in each text product which may correspond to potential icing conditions.
3.3 Geographic Graphical Weather Products

Geographic graphical weather products generally are horizontal geographic regions with weather information overlaid. They combine the use of codes and abbreviation with symbols, color coding and shading. The lessons to teach these products have two parts: 1) a declarative lesson, explaining the type and meaning of representations used in
the product; and 2) a process lesson detailing the steps used to identify icing conditions.

Teaching a dispatcher to use a geographical weather product to identify icing threats entails stressing the content that shows where icing conditions may exist. For example, the Current Icing Potential (CIP) product has a weather overlay that employs a color-coding scheme which goes from blue (low icing potential) to red (high icing potential). The training system will focus on explaining that the product shows the potential for icing but not severity.

3.4 Numerical Graphing Weather Products

The training system teaches lessons on numerical graphs in the same way it does other graphical products: a definition of the product and a process lesson on identifying icing conditions. However, the system must highlight the measurements given in the numerical graph, and explain each data component. The declarative section must clearly define each section of the graph, as the numerical graphing weather products are less intuitive than geographical weather products. Figure 6 illustrates a lesson for the skewed-t plot, in which the product’s axes and data components are defined.

Unlike geographical weather products, graphs are used to identify icing conditions by identifying specific numerical values which correspond to icing. For example, the skewed-t plot graphs the temperature and dew point at each altitude/pressure. The training system explains that to identify potential icing conditions, one must look for temperature/dew point spreads of less than 5 °C when the temperature is between 0 and -20 °C. This region of the graph is where there is potential for aircraft icing.

4 SCENARIOS

Scenarios can help reinforce the materials introduced in the basic meteorology and the weather product interpretation modules. They can also provide opportunities for flight dispatchers to apply their knowledge in order to refine their decision making processes. To develop the scenarios, the team first interviewed flight dispatchers, reviewed their decision support tools and documentation, and observed a training session to identify the general flight dispatcher decision support tools and documentation, and observed a training session to identify the general flight dispatcher decision-making process (Figure 7).

In the process of evaluating a flight, dispatchers must first review the computer generated flight plan. The information provided by this flight plan does not consider certain conditions such as weather, broken equipment, and scheduling issues; thus the dispatcher must make adjustments as necessary. Before adjustments are made, dispatchers must look at weather, crew, payload, alternates, and minimum equipment lists (MELs). Weather conditions at takeoff, along the flight route, and at the destination airport impact aircraft performance and alternate selection. Dispatchers must make sure that the flight will not fly into icing conditions beyond the aircraft’s capability including any performance decrements due to broken equipment. Dispatchers must also consider the payload of the flight, including the fuel, cargo, and passengers.

Dispatchers may need to add contingency taxi or holding fuel if weather delays are present or if anti- or de-icing equipment must be activated. Also, as mandated by the FARs, alternates may need to be added the flight plan depending on weather conditions. Finally, flight dispatchers may need to review the crew information because of issues with availability and timing. Based on these considerations, flight dispatchers may need to re-route the aircraft, change the payload, delay the flight for maintenance, or select an alternate. After the adjustments are made, flight dispatchers can then release the flight.

To develop the scenarios, first lesson objectives were created. Next, the materials a dispatcher would need to make decisions were defined. Our team developed two scenarios: a broken equipment scenario and a drift-down scenario.

4.1 Broken Equipment Scenario

This scenario highlights the MEL/CDL (minimum equipment list/configuration deviation list) and Alternates portions of the decision-making process. MEL procedures are developed to allow the continued operation of a flight with specific items of equipment inoperative under certain circumstances. With respect to icing, the flight dispatcher can determine if the aircraft should be considered an “Ice” or a “No Ice” release. If the aircraft has an MEL listing a malfunctioning part that is critical to the aircraft’s anti-icing or de-icing system, it is a “No Ice” aircraft. If this classification is made, the flight dispatcher can only dispatch this aircraft if the flight route contains no forecasted icing during the time frame and along the route for the flight. The flight dispatcher must also consider what future legs the aircraft will fly so it does not land at a destination and is unable to depart.

The learning objectives for this scenario were understanding how an MEL can affect a flight, the various alternatives available to a dispatcher when a flight cannot make the intended destination, how to interpret weather data, and how to evaluate an alternate. In this scenario an aircraft is scheduled to fly from Austin, TX (AUS) to Cincinnati, OH (CVG) at a cruise altitude of 33,000 feet. The departure time is 4:15 PM local and the arrival time is 8:40 PM local. After reviewing the flight plan and weather data, the dispatcher should notice that the engine anti-ice valve is not functioning (Figure 8) and there is significant precipitation along the flight path. The flight dispatcher would need to determine if the broken equipment and/or weather conditions would negatively affect the flight. To do so, the dispatcher would review the appropriate MEL documentation (Figure 9).
The lesson will help the flight dispatcher learn how to read the MEL. In this scenario, the flight dispatcher should know to avoid icing as the MEL states: “Flight is not made in known or forecast icing conditions.”

The dispatcher will be prompted to evaluate the weather conditions using the available materials and decide if potential icing may exist along the flight route. In this scenario, icing existed at both the origin and the destination. The system will help the flight dispatcher evaluate the alternatives such as delaying the flight until the conditions pass, canceling the flight, selecting an alternate route, having the aircraft repaired or swapping the aircraft. For example, to analyze the alternate option, dispatchers must evaluate the weather conditions at the available alternates. If icing is not present at the alternate, it should be selected and modifications should be made to the flight plan. If not, the other options should be considered. In this scenario, icing is very widespread around the destination airport, and therefore, no alternate could be selected.
4.2 Drift-down Scenario

Flight dispatchers at both the regional and major domestic airlines suggested using a drift-down scenario.

This scenario highlights the Payload portion in the general decision-making process. There are several lesson objectives for this scenario. Dispatchers should first understand that drift-down is an important flight issue, icing is a crucial factor in drift-down, and icing in drift-down affects the flight planning process. Next, flight dispatchers should know the process of determining if drift-down is a potential problem, how to determine if icing conditions exist, how icing affects the drift-down problem, and the information necessary to make a decision (i.e., flight plan, weather information, anti-icing and de-icing equipment availability). Finally, flight dispatchers should be able to appropriately plan a flight flying over drift-down zones and apply specific drift-down knowledge to situations as they arise.

In this scenario, an aircraft is scheduled to fly from San Jose, CA (SJC) to Atlanta, GA (ATL). The computer-generated flight plan route crosses several drift-down zones (Figure 11). In these areas, because of mountainous terrain, it is necessary to maintain the minimum drift-down altitude at these drift-down zones. If the aircraft cannot maintain that altitude with one engine out, an alternate must be named by the flight dispatcher. In this scenario, icing over the drift-down zones necessitates activating the anti-icing equipment. The anti-icing equipment reduces the power of the remaining engine causing the aircraft to drift to an even lower altitude. In this case, an alternate for the drift-down areas becomes mandatory.
The training system will help the flight dispatchers to review flight information. It will help dispatchers to recognize that the flight will be flying over drift-down zones (dotted areas in Figure 11). It will help them to determine that icing exists along the route. Based on the result of the weather analysis, the system will help flight dispatchers to determine that icing equipment will be activated and to perform an evaluation for each of the drift-down zones along the flight route to determine the level-off altitude. Using a level-off altitude chart similar to that in Figure 12, flight dispatchers should determine if the required altitude is maintainable and then add the appropriate remarks to the flight plan.

5 DISCUSSION AND RECOMMENDATIONS FOR FUTURE WORK

We have developed power point slides that provide a low fidelity demonstration of the training system concept and content. We recently met with flight dispatchers at a regional airline to present the results from this project. The flight dispatchers confirmed that the current content areas would be useful to them. It is important to note, however, that this was a brief session that did not allow the dispatchers to thoroughly review all of the content. It is essential that all of the information be validated to ensure its accuracy. As the authors are not certified flight dispatchers or meteorologists, subject matter experts are in the process of being recruited for this purpose.

In addition, it is recommended that the PowerPoint prototypes be used in a usability and content effectiveness study before the final web-based product is developed. Only if the prototype is deemed effective will airlines want to implement the final product in their training curriculum.

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