Introduction

There are significant limitations in the current set of weather related decision support tools at major airports and terminal approach control facilities. Due to this situation air traffic managers must cognitively translate observed and forecast weather information into weather events that are then mentally translated to determine National Airspace System (NAS) resource capacities. The impact of this problem on the NAS is that cognitive-based capacity determinations can lead to inefficient or ineffective operational decisions. To address this issue, we consider two concepts, weather translation and weather threshold event, both contained in the Joint Planning and Development Office (JPDO) ATM-Weather Integration Plan Version 2.0 [1]. In this paper, we describe 1) the terminal weather translation and advisory concept that transforms raw weather into potentially actionable information and 2) the results of operational user evaluations of the terminal weather translation and advisory concept.

What is the Problem?

Multiple factors affect airport runway configuration, approach types including cloud ceiling, wind direction, wind speed, and visibility. Traffic Managers (TMs) in Air Traffic Control Towers (ATCTs) and Terminal Radar Approach Control (TRACON) facilities coordinate decisions on airport configuration and rate. Such decisions require access to and synthesis of information to determine how weather may evolve and affect airport operations and capacity measures such as Airport Arrival Rate (AAR) and Airport Departure Rate (ADR). Sources include Terminal Aerodrome Forecasts (TAFs), local area Meteorological Terminal Aviation Routine Weather Reports (METARs), guidance from Center Weather Service Unit (CWSU) and airline meteorologists, and local area commercial weather data.

The integration and translation of weather information by TMs to determine runway configurations and types of departure and approach procedures can be a subjective process [1]. Each check of forecasted weather during the day follows a similar pattern, with weather observations providing either a reason to change the airport operating state or confidence in the day’s forecasts. Figure 1 shows today’s process of translating cloud ceiling and visibilities to an airport operating state, and subsequently to the airport capacity measures. As can be surmised in Figure 1, because the translation of terminal weather to airport impacts has a human at the centre of the decision, each TM or Front-Line Manager (FLM) performs the translation based on his or her mental model, developed via operational experience. Thus, variability in operations managed in this largely subjective manner results in weather impact mitigation outcomes that are inconsistent. Moreover, decisions reached with the current approach can be both workload-intensive (which diverts time and attention away from other

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critical tasks) and inefficient with respect to minimizing avoidable impacts and delays when weather-induced airport state change are required [2].

Description of the Concept

The origin of the weather translation concept traces back to the ATM-Weather Integration Plan (AWIP) Version 2.0 [1], which introduced a key concept known as “weather translation”. This translation produces constraints or weather threshold events that can be integrated with automation systems or decision support tools. The AWIP introduced levels of integration as depicted in Figure 2. The degree of weather integration with ATC automation systems including decision support tools increases in complexity as the level of integration increases. The terminal weather translation concept is an example of Level 2 integration, where raw weather data is translated into weather threshold events.

Figure 1. Current Operation to Monitor and Translate Weather for Airport Operations [2]
With respect to the weather translation function, the term “weather threshold event” applies to observed or forecast weather parameters such as wind speed and direction, cloud heights and visibility that cross a regulatory or an operationally-relevant threshold which may result in an associated change in the state of the affected terminal element (airport or airspace).

The process of weather translation converts the weather threshold events, based on adapted, user-specified meteorological threshold values, to specific operating states for the affected airport or terminal airspace. Examples of state changes for an airport include runway configuration changes, approach procedure changes or landing minima changes, any of which can result in a change to the capacity of the airport, normally expressed as aircraft arrival or departure rates.

As shown in Figure 3, Terminal Weather Translation and Advisory (TWTA) is an envisioned terminal area capability embedded within a surface and/or terminal decision support system, that evaluates specific atmospheric factors such as ceiling, visibility and wind conditions, and identifies weather events that may impact terminal flight operations and affect airport capacity. FLMs and TMs can use this translated information along with other airport operating considerations to determine the airport’s runway configuration and AAR/ADR values.
Application of Terminal Weather Translation to Atlanta Airport

After initial development, the translation concept needed to be applied to one of the NAS Core 30 airports for further exploration. The airport needed to be one that experiences a wide variety of weather types and has enough scheduled air traffic to produce situations with potentially challenging airport runway configuration changes and approach conditions. To simplify the initial exploration, the candidate airport should have a simple runway geometry. Thus, Atlanta (KATL) was selected as the first airport.

The MITRE team visited the Atlanta Tower and TRACON in June 2016, to interview traffic managers, supervisors and air traffic controllers to understand how they collectively use weather observations and forecasts to determine Atlanta’s airport configuration and AAR/ADR values. This information was used to define rule sets and threshold values that would be the basis for translated weather advisories.
Figure 4 depicts an encapsulated view of Atlanta’s arrival operations, airport runway geometry, the various cloud ceiling and visibility thresholds used to determine approach and departure procedures as well as the resulting AAR and ADR resulting from a given airport and arrival/departure configuration. The matrix in the lower right of Figure 4 summarizes the ceiling, visibility and winds data used as an input to a rules-based engine to produce the translated weather in terms of an airport configuration.

Because all three runways at KATL are parallel, and because terrain is not a significant factor on either side of the airport, the ceiling and visibility weather thresholds, and resultant allowable approach procedure types, are identical regardless of the airport runway configuration (i.e., direction of landing). The colour scheme shown in Figure 4 that delineate each of the configurations is the same as that used in the matrix. Information relevant to the wind-based runway configuration selection process was also included.

**Concept Evaluations**

After compiling the Atlanta weather thresholds, various methods of translating raw forecasts of ceiling, visibility and wind speed and direction into KATL-specific weather threshold events was explored. We developed a means to communicate the translated weather information to researchers and subject matter experts (SMEs). To explore the application and evaluation of the TWTA concept, the project team needed a means to visualize the translated weather. For the first evaluation, the most effective means of accomplishing this was to display the translated weather information graphically, as opposed to describing it textually and leaving it to users to cognitively visualize.

**Figure 4. Application of Terminal Weather Translation to Atlanta [2]**
Once the team agreed on notional translation concepts, the team generated PowerPoint weather translation mock-ups to be used by evaluators during the evaluations. For the second evaluation, the PowerPoint mock-ups were replaced by automated generation of the translated weather advisories. Examples of these translated weather concept visualizations are shown in Figure 5 and Figure 6. The details of these concept visualizations are documented in reference [2].

Figure 5. Notional Terminal Weather Translation mock-up used for 1st Evaluation [2]

Figure 6. Notional Terminal Weather Translation mock-up used for 2nd Evaluation [2]
The first evaluation was an eight-hour Tabletop Exercise (TTE) on November 17, 2016. The purpose of this first evaluation was to gain initial user feedback on the initial TWTA concept. TTE1 was conducted using scenarios based on actual conditions and operations at KATL. The scenarios had distinct types and sequences of weather conditions that occurred during the time frames of interest. Six MITRE SMEs, all former controllers and TMs with over 150 years of aggregated previous FAA experience, participated in TTE1 in the roles of TRACON and Tower TMs.

Evaluation observers included representatives from the FAA Aviation Weather Division, the FAA Aviation Weather Division New Weather Concept Development Branch, the FAA Operational Concepts, Validation & Requirements Division. To properly equip the participants with the kind of meteorological information they would have at a TRACON or ATCT, the study team produced paper copies of METARs and TAFs for all weather reporting stations within 60 Nautical Miles of KATL that spanned the scenario time frames (see Figure 7).

The second evaluation was also a TTE on April 5, 2017. The format for TTE2 was the same as TTE1, except for different SME participation. The same format as TTE1 was followed where scenarios were processed, discussed, and obtained objective SME feedback via evaluation surveys.

Figure 8 shows a summary of the six scenarios spanning the two tabletop evaluations.
Evaluation Results

For TTE1, surveys were completed after each of the three scenarios in which the TWTA concept was evaluated. Each survey consisted of five statements (S1 – S5), shown in Figure 9, concerning the usefulness or effectiveness of the TWTA concept. SMEs chose one of five Likert-scale responses for each statement. Each response (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree) had an assigned numerical value (1-5). Weighted average responses were calculated for each statement and in aggregate.

For TTE2, surveys were completed by each of the seven SMEs and the three observers at the completion of the third scenario. Each survey consisted of nine statements (S1 – S9) as shown in Figure 10. The SMEs used the same Likert-scale method as in TTE1. The survey statements were grouped into two categories: information content and expected value. Questions S1-S4 addressed the question: Does the information provided by terminal weather translation support airport and terminal airspace configuration decision-making?”. Questions S7-S9 addressed the following question: Is the information provided by terminal weather translation of value to the decision-making process?
<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1. Translated weather replaces the need to gather weather information from multiple sources</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S2. Translated weather replaces the need to mentally integrate information</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S3. Translated weather for local airports arranged in a situation display provides useful information</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S4. Translated weather arranged in decision support format provides useful information</td>
<td>16</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S5. Translated weather arranged in decision support format provides actionable information</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 9. Responses to TTE 1 Evaluation Survey

[source: MITRE]
Figure 10. Responses to TTE 2 Evaluation Survey
Conclusions
The evaluation results reflect strong, consistent support for the TWTA concept in general as exemplified first by the notional concept and then by an updated version of the TWTA concept. Supporting these evaluation results were the encouraging verbal comments offered by the SMEs during and after both evaluations.

Observations of the SMEs during TTE1, along with reviews of their survey results, their free text comments and the notes taken by TWTA team members, enabled the TWTA team to arrive at the following conclusions listed in Table 1.

Table 1. Summary of SME Comments during TWTA Evaluations

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>SME-Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE-1</td>
<td>Decision-makers will likely prefer translated weather information over text weather observations (METARs) and forecasts (TAFs).</td>
</tr>
<tr>
<td></td>
<td>TWTA will likely provide information that is useful and actionable.</td>
</tr>
<tr>
<td></td>
<td>TWTA will likely replace the need to gather weather information from multiple sources.</td>
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<tr>
<td></td>
<td>TWTA will likely reduce the need for operational users to cognitively integrate and translate weather information.</td>
</tr>
<tr>
<td></td>
<td>Decision-makers at area control centres should have access to terminal weather translated for airports in their area of responsibility.</td>
</tr>
<tr>
<td></td>
<td>Decision-makers at the command centres or control flow control should have access to terminal weather translated for airports.</td>
</tr>
<tr>
<td></td>
<td>TWTA will likely not replace the need for input and guidance from human meteorologists.</td>
</tr>
<tr>
<td>TTE-2</td>
<td>Splitting out the translation of ceiling and visibility information would be useful to see the individual components that lead to a given approach condition.</td>
</tr>
<tr>
<td></td>
<td>SMEs commented that having an accurate demand profile (i.e., “push,” projections) was important and would go a long way towards building “trust” in future projections of translated weather information.</td>
</tr>
<tr>
<td></td>
<td>If TWTA demonstrates a robust degree of reliability, this will reduce the need to “cross-reference” weather displays, meaning the user may not need to check a convective weather graphic like the local radar weather, TAFs, or commercial weather forecasting tools.</td>
</tr>
<tr>
<td></td>
<td>Consider adding the capability to see forecast decision support in the historical portion of the timeline. (Note: this comment refers to a capability which was included in the notional TWTA concept evaluated during TTE-1).</td>
</tr>
</tbody>
</table>

Parties interested in further details or additional explanation of the translated weather concept, methods or evaluations are encouraged to contact the author for additional details that were not provided in this extended abstract.

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